Introduction to cost-benefit analysis

INTRODUCTION TO COST-BENEFIT ANALYSIS

Theoretical foundations and rules of practice

PHILIPPE BARLA



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PRESENTATION OF THE AUTHOR

Presentation of the author

The author, Philippe Barla, is a full professor at Université Laval in Quebec City. His research interests include transportation and environmental economics, as well as industrial organization. He is a member of the Institut Environnement Développement et Société at Université Laval.

For more information : Google Scholar and CV

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THE COSTS AND ADVANTAGES OF LEARNING CBA

Before embarking on learning CBA, it is advisable to carefully evaluate the costs and benefits associated with this approach.

The costs

Learning CBA can be time and effort-intensive for several reasons:

1. **Foundation in Economics and Statistics**: It requires a solid understanding of fundamental microeconomic concepts and, in some cases, statistical analysis. This demands significant study and practice.
2. **Non-Standardized Approach**: CBA does not rely on a standardized model. Each project has unique characteristics, requiring a flexible and adaptable approach.
3. **Complexity of Projects**: Projects analyzed through CBA are often complex, requiring analysts to identify and evaluate primary social impacts amidst this complexity. This demands a deep understanding of CBA's theoretical and practical foundations.
4. **Navigating Uncertainty**: CBA involves working with simplifying assumptions, incomplete data, and various uncertainties. Analysts must be comfortable producing estimates and approximations rather than precise calculations.

The advantages

Despite these challenges, learning CBA offers significant benefits:

1. **A Powerful Decision-Making Tool**: CBA is widely recognized and recommended by international organizations such as the World Bank, OECD, and European Commission, as well as by governments and agencies worldwide. Mastery of this tool is a valuable asset for analysts evaluating projects and public policies.
2. **Enhanced Understanding of Microeconomics**: Applying microeconomic concepts to real-world projects through CBA deepens understanding and facilitates long-term retention of economic principles.

3. **Skill Development**: CBA hones the ability to apply economic principles to analyze real, complex situations. Learners develop simplified yet appropriate theoretical frameworks to evaluate social costs and benefits. This process engages advanced cognitive skills, including application, analysis, evaluation, and creation, as outlined in Bloom's taxonomy.
4. **Improved Analytical Thinking**: By providing a structured method for reasoning, CBA fosters essential analytical skills crucial for economic analysis.

Finally, with this manual, learning CBA is accessible through a free educational resource.

The role of CBA in academic research

CBA is often undervalued in academic circles, despite its widespread application in professional settings. The publication of complete CBAs in scholarly journals is rare, even though significant research focuses on evaluating the impacts of public policies—a fundamental aspect of CBA.

The **Journal of Benefit-Cost Analysis**, established in 2010, is the only academic journal dedicated entirely to CBA. As a relatively new publication, it primarily emphasizes methodological advancements in the field. The mixed reception of CBA within academia can be attributed to two key challenges: the inherent complexity of conducting a comprehensive CBA for a specific project and the difficulty of making original contributions that extend beyond the immediate scope of the analysis.

However, the limited interest in CBA within research circles should not diminish its importance in education. Most university students do not plan to pursue academic careers, and training competent analysts in CBA offers significant societal benefits. These skills are highly valued in evaluating public policies, infrastructure projects, and other areas of economic decision-making.

Furthermore, mastering CBA has immense formative value for students considering careers in research. The methodology fosters critical thinking, analytical rigor, and an applied understanding of economic principles—all essential competencies for high-quality academic work.

PREREQUISITES AND TARGET AUDIENCE

This textbook assumes a foundational understanding of basic microeconomic concepts and tools. For reference, Chapter 4 provides a concise review of these fundamentals. The approach used throughout the textbook is predominantly graphical, with minimal reliance on mathematical formulations. While certain sections reference econometrics, they can be covered in a simplified manner or omitted entirely, depending on the needs of the reader or course.

Primarily designed for undergraduate students, this textbook is also well-suited for graduate courses, particularly those focusing on applied economics or public policy analysis. Additionally, it serves as a practical resource for professionals in fields that require a deep understanding of cost-benefit analysis principles.

FOR EDUCATORS

This textbook is primarily designed for a course in cost-benefit analysis (CBA) for economics students. It may be somewaht too detailed and complex for an course intended for a general audience. However, certain sections, such as Parts I, III, and IV, may still be useful in such contexts.

The textbook also serves as an complementary resource for courses in microeconomics or public economics, illustrating the practical applications of various theoretical concepts. It may be valuable for environmental economics courses, especially Part III, which covers methods for evaluating non-market goods. Additionally, it may be relevant for courses focused on public policy analysis.

Given its depth, covering the entire textbook in a single semester may prove challenging. Strategic selection of chapters, aligned with the specific learning objectives of the course, is recommended. Part II, which explores the analytical framework of CBA, can be particularly demanding for learners, despite its reliance on fundamental microeconomic concepts. Nonetheless, this section is crucial for understanding the foundational principles of CBA and for developing the analytical skills necessary to construct coherent evaluation frameworks.

The textbook is designed for flexibility and can be used in both lecture-based teaching and flipped classroom formats. Each chapter opens with a scenario whose resolution is examined throughout the chapter, allowing students to apply the analytical tools presented. Concepts are presented using simplified yet realistic examples, supplemented by fictional but relevant exercises to reinforce understanding. Additionally, case studies in Part V illustrate the application of CBA tools to real-world projects.

The examples and case studies in this manual have been originally designed in the context of Quebec. Educators in other regions may wish to adapt these examples and cases to better align with their specific settings.

Access to solutions for some exercises is restricted to teaching staff. Educators may contact the author by email to request access.

If you use this manual in your courses or develop a derivative version, the author would appreciate being informed. Feedback on typos, errors, or suggestions for improvement is also welcome.

Contact the author: philippe.barla@ecn.ulaval.ca

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PART I
BASICS

In this section, we lay the foundations of cost-benefit analysis (CBA). Chapter 1 defines CBA, outlines its rationale, and positions it in relation to other approaches to project appraisal. Chapter 2 provides an overview of the steps involved in conducting a CBA, illustrating them with an analysis of replacing a ferry system with a bridge. The chapter also highlights the main pitfalls to avoid. Chapter 3 describes the main sources of divergence between the private and social returns of a project.

Chapter 4 introduces the basic concepts of microeconomics for assessing benefits and costs. In Chapter 5, we explore two approaches to designing a CBA framework and introduce some variations. Chapter 6 examines discounting techniques, which are also used to compare projects with different life spans, establish residual values, and account for the cost of durable assets. This chapter also looks at the CBA's decision rules in choosing projects.

1.

DEFINING AND CONTEXTUALIZING CBA

Motivation and learning objectives

Imagine that you are an analyst for an economic consulting firm and that as such you must provide recommendations on the relevance of various projects and public policies. As an example, here are some of your mandates:

- A municipality considers investing in a tramway system;
- A cement company wants to assess the profitability of a new plant project;
- A pharmaceutical company wants to convince the government to reimburse its new drug that reduces the risk of heart attacks;
- The Ministry of the Environment must evaluate a subsidy program for the purchase of electric vehicles;
- A political party wants to know the impacts of an election promise to reduce income taxes.

Is cost-benefit analysis (CBA) appropriate for all these mandates? If not, what other economic evaluation tools might be more appropriate?

By the end of this chapter, you will be able to:

1. Define CBA;
2. Determine the projects for which a CBA is appropriate;
3. Describe in general terms the foundations of this method;
4. Construct a table that presents the monetized impacts and the net present value of a project in the context of a CBA;
5. Understand the differences with other economic evaluation methods.

1.1 CBA: Definition and scope of application

> CBA constitutes a set of practices derived from economic theory which aims to evaluate the **social profitability** of a **project** either ***ex ante, ex post*** or ***in media res***.

The next subsections examine this definition in detail.

1.1.1 Social profitability

The objective of CBA is to assess the social profitability of a project. This involves measuring in monetary terms the favorable (benefits) and unfavorable (costs) impacts of a project for **all members of the relevant society**. In this respect, CBA differs from private profitability analysis, which only looks at the impacts for the project promoters. A project can therefore be profitable on a private level, but not on a social level, and vice versa.

Figure 1.1 illustrates the distinction between the private and social profitability of a project when the developer belongs to the relevant society. In this situation, the developer's costs and benefits form part of the social profitability analysis. Conversely, if the developer does not belong to the relevant society, its costs and benefits should be excluded from the CBA. For instance, a national CBA should not account for the profits earned by a foreign developer. Chapter 2 will discuss in greater detail how to define the relevant society.

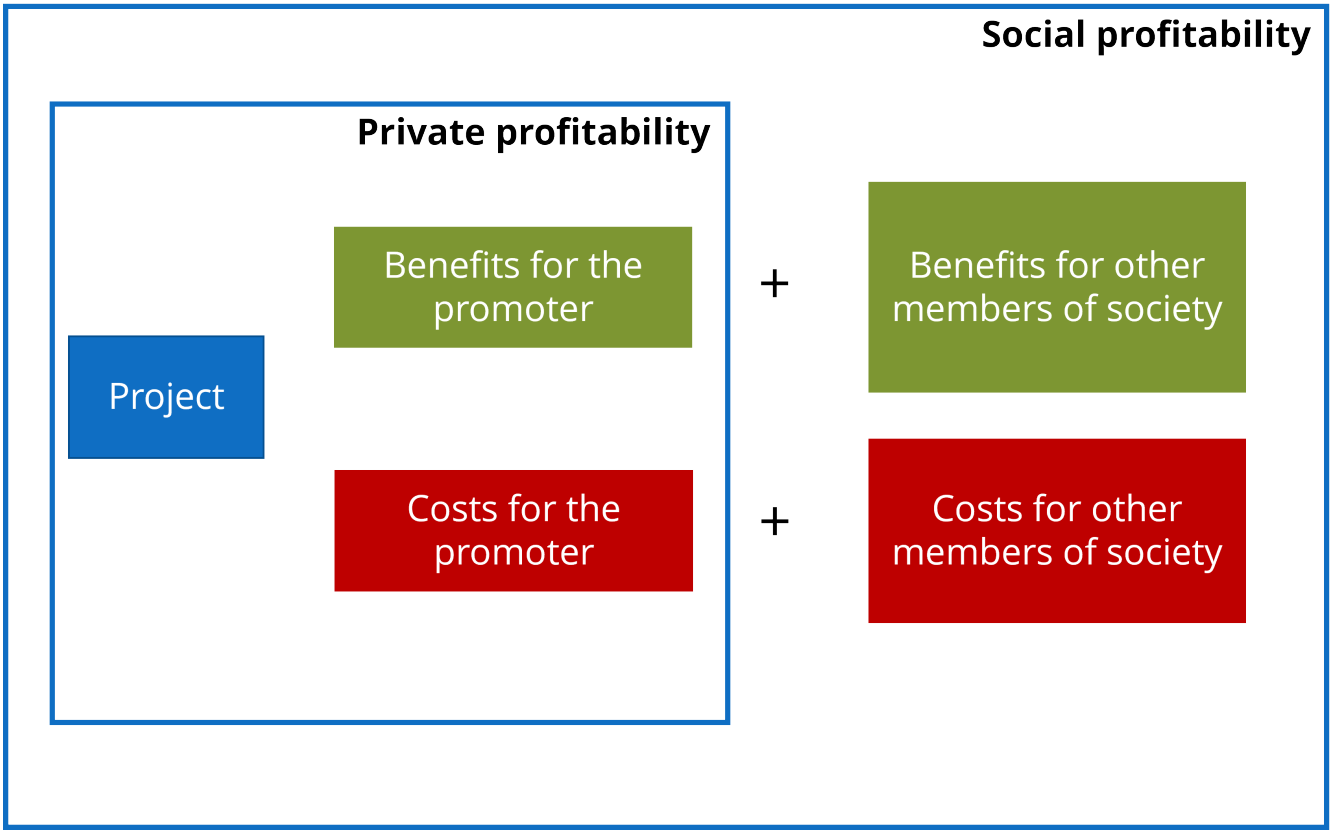


Figure 1.1 Difference between private and social profitability in the case where the promoter is part of the relevant society

The box below further illustrates the difference between social and private profitability with two examples.

Examples: differences between private and social profitability

Construction of an oil pipeline



- **Private profitability**: The project is profitable for its promoter if the expected operating revenues are greater than the construction and operating costs.
- **Social profitability** : The assessment of social profitability must take into account the impact of the pipeline on consumers and on the population, which may be affected by environmental damage.

The impacts on the promoter must also be taken into account if it is part of the reference company.

Buying an electric school bus instead of diesel



- **Private profitability** : The transport company assesses whether the reduction in fuel costs justifies the additional cost of purchasing the electric bus compared to the diesel bus.
- **Social profitability** : It takes into account the elements included to assess private profitability and adds the gains for the population from the reduction of air pollution, greenhouse gas emissions, and possibly certain impacts on the bus manufacturer, if it is part of the reference company.

1.1.2 The project

The notion of "project" is very general, since the CBA can apply to:

- **Public infrastructure**such as the construction of a bridge, a high-speed train line or an urban park;
- **Public policies**such as funding a vaccination campaign, granting tax credits to support an industry, making the wearing of bicycle helmets mandatory or protecting natural spaces;
- **Private projects**such as building a new chemical plant or a gas pipeline.

It is therefore not the identity of the promoter or the nature of the intervention that determines whether a CBA is relevant or not.

For the sake of brevity, we will often refer in this manual to the CBA of a project. It is important to keep in mind that the term "project" should be interpreted in a very broad sense and does not necessarily imply that it is a project that is initiated or supported by public authorities.

1.1.3 When to perform a CBA?

In general, CBAs are carried out ***ex ante***, that is, before the project starts, since the CBA aims precisely to determine the profitability of the project. However, it is possible to carry out a CBA ***in medias res,*** that is, during the project, to check whether it should be completed or whether it is necessary to modify its scope along the way. For example, should a social housing construction project that includes several phases be continued?

It is also possible to do ***ex post*** CBAs , that is, after the project is finished. They are useful to check whether the decision was the right one. In addition, by comparing the results of *ex ante* and *ex post* analyses , it is possible to improve CBAs, highlighting systematic biases and possible errors.

1.1.4 Scope of application

The use of a CBA is justified from the moment when it is suspected that **the social profitability of a project may be different from its private profitability**.

While the scope of CBA is broad, there are projects for which it is preferable to use other evaluation tools. Indeed, CBA is not the most appropriate tool for evaluating projects that have effects in a multitude of spheres of the economy or those that have a macroeconomic scope. For example, it would be unwise to conduct CBA on a proposed increase in sales tax or a reduction in business charges, since these policies will have consequences on the entire economy. A computable general equilibrium model is the preferred instrument for evaluating this type of intervention (see Decaluwé, Martens and Savard, 2001).

CBA is a **partial-equilibrium analysis** suited to evaluating projects whose impacts are concentrated on a limited set of markets.

For example, it is relevant to perform the CBA of a project to build a new hydroelectric dam if it has repercussions on the electricity market and perhaps also on the market for substitutes, such as the natural gas market. However, if the dam is of such a scale that it can trigger macroeconomic effects by reducing the price of energy in a country, then it is more appropriate to use a computable general equilibrium model.

1.2 Ten foundational principles of cost–benefit analysis

To understand the nature of CBA, it is useful to review its main foundations:

1. Impacts are assessed across relevant markets.
2. Impacts are expressed in monetary units.
3. Impacts refer to a common reference period.
4. Impacts are measured through willingness to pay or willingness to accept.
5. Opportunity costs are used as the valuation basis.
6. Changes are evaluated relative to a reference situation.
7. The goal is to inform decisions.
8. The efficiency test relies on the Kaldor-Hicks criterion (or potentially Pareto improvement).
9. The aim is to enhance overall well-being.
10. CBA improves efficiency, without necessarily reaching the optimum.

In this section, we present these ten principles in general terms and illustrate them with examples, including a new bike path project described in the box below. Some of these foundations will be examined in greater depth later in the manual.

Example: a new bike path

A municipality is considering the construction of a new bike path. This project generates positive impacts for cyclists, such as improved safety and reduced travel time, but it may also impose costs on other users and local residents, including the loss of on-street parking, increased congestion for motorists, or changes in access to nearby businesses. The project also entails construction and maintenance costs.

1.2.1 Impacts are assessed across relevant markets

As Figure 1.2 illustrates, the CBA aims to assess social profitability, which requires considering not only the effects that occur in **"markets,"**but also those that occur **"outside the market,"**also known as **intangible effects**. A subsidy program for the purchase of electric vehicles affects the market for electric and conventional vehicles, but also improves air quality, a "good" for which there is no explicit market. This is called a **"missing market,"**in the sense that it is impossible to buy or sell "air quality" directly. Similarly, the bike path project affects several markets, including the market for urban transportation by improving cycling conditions and potentially reducing car use. It may also affect local commercial activity by modifying access conditions and

parking availability. In addition, the project generates intangible effects, such as changes in road safety, noise levels, and the quality of life of nearby residents.

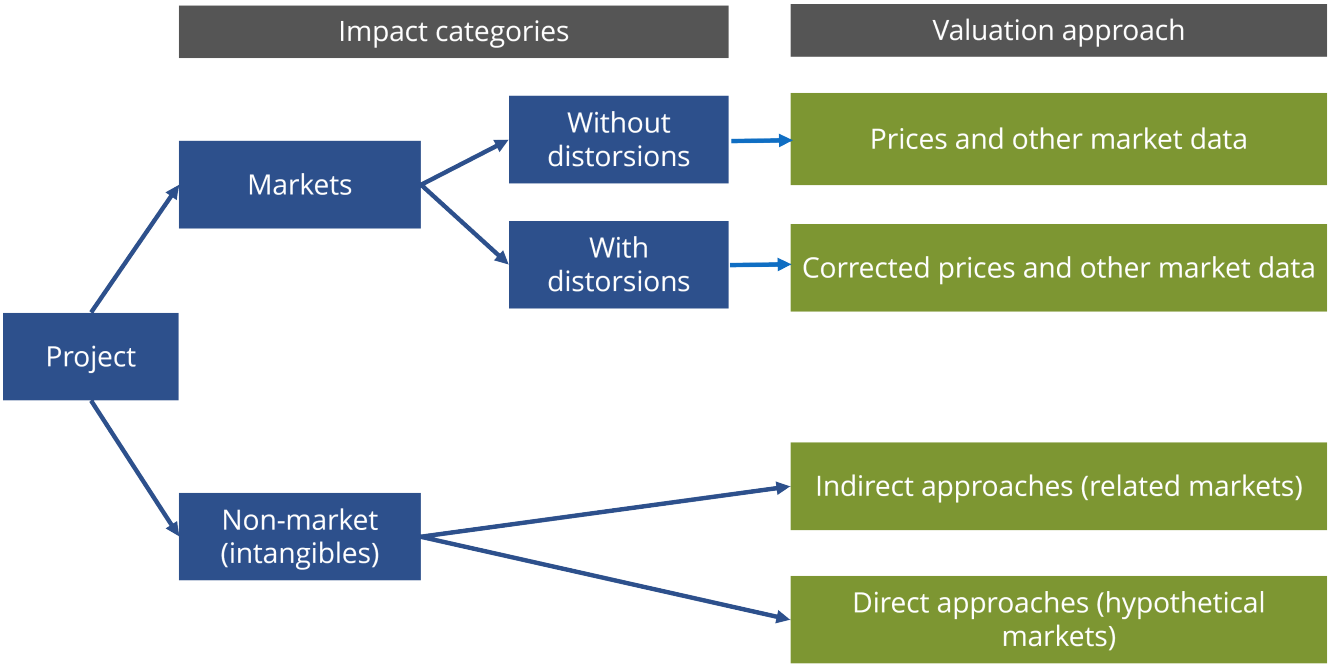


Figure 1.2 Typology of impacts and valorization approaches

The distinction between "market" and "intangible" effects is not always precise, universal, or stable over time. The ways in which production and trade are organized are varied and depend on the nature of the goods and services, the number and characteristics of the participants, and the degree of government involvement (see Chapter 3 for more details). They can change over time and space, and even coexist. In Brazil, university education is offered by private companies, non-profit organizations, and the state. There are also examples where governments are creating markets that were previously missing. This is the case with the carbon market that has been implemented in several jurisdictions.

The valuation of effects in markets relies on market data, in particular on prices and quantities exchanged, as we will see in more detail in Part 2 of this manual. However, market values do not always adequately reflect social benefits and costs. The price of gasoline at the pump poorly reflects the social cost of this resource, since it generates air pollution and greenhouse gas emissions. Schematically, we can distinguish between **markets without distortion**, in which the price reflects the social benefit and cost of the good fairly well, and **markets with distortions**, for which it is necessary to **correct the market price**, in order to better reflect the social benefit or cost.

For non-market effects, valuation can be done indirectly by assessing the traces of these effects on existing markets. For example, it is possible to estimate the value of improved road safety or reduced traffic noise associated with a bike path by examining their impact on nearby property values. It is also possible to use a direct approach, which consists of hypothetically creating a missing market and surveying individuals about

the value they place on the intangible effect. For instance, the benefits of a bike path can be assessed by asking potential users about the maximum amount they would be willing to pay to finance this infrastructure, which amounts to estimating the demand for the bike path. Non-market effects can therefore be conceived and analyzed using the same tools applied to market analysis, in particular the concepts of supply and demand. Part III of the manual is devoted to the valuation of intangible effects.

> In CBA, all impacts to be valued—even those occurring outside markets—should be conceptualized and analyzed using the same tools applied to market analysis, in particular the concepts of supply and demand.

In fact, economists refer to the notion of a "market" whenever there is a "supply" and a "demand." Accordingly, they study the "marriage market," the "political market," the "market for ideas," the "market for air quality," and even the "market for CBAs.[1]".

Over the past few decades, substantial progress has been made in developing methods to value a wide range of intangible effects. Nonetheless, some impacts remain extremely difficult to express credibly in monetary terms. This is particularly the case in the military sector, where benefits may involve intangible strategic or geopolitical effects, or in certain social programs, where outcomes concern complex human and societal dimensions that are hard to quantify financially. These challenges therefore limit the scope of CBA.

1.2.2 Impacts are expressed in monetary units

One of the key features of CBA is that project impacts are measured in monetary units. Using money as a common standard is a major strength, as it makes it possible to compare and aggregate effects of very different kinds. In the bike path example, CBA allows us to compare the benefits for cyclists—such as improved safety, time savings, and increased comfort—with the costs borne by other users and local residents, including the loss of parking spaces or reduced accessibility for motorists, by expressing all these effects in monetary terms.

However, this feature is also a source of difficulty, since monetizing certain intangible impacts can be challenging and sometimes controversial. No one disputes that transforming a road into a motorway generates monetary costs, such as the purchase of asphalt or workers' wages. Yet can we value the time savings as a

1. A regulation that would impose the realization of CBA for public projects would have the consequence of increasing the demand for CBA, which could eventually result in an increase in the "price" of these analyses, depending on the adjustment of the supply.

monetary benefit? And how do we account for the reduction in fatal accidents that a motorway might bring? Valuing such an impact requires establishing a value for human life, a controversial topic that we will examine more thoroughly in Chapter 16.

For now, it is enough to recognize that, in a world where resources are limited relative to needs, trade-offs are unavoidable. Even if we prefer to think of human life as priceless, it is impossible to devote all available resources to preventing a single case of cancer or a road accident. Moreover, it is not desirable for the amounts spent to prevent premature death to vary arbitrarily depending on the cause or the group affected. CBA helps clarify these choices and promote greater consistency in the resources we are collectively prepared to devote to saving a life or avoiding other undesirable intangible outcomes.

CBA seeks to assign a monetary value to the various impacts of a project, including intangible effects. Monetary valuation offers two major advantages:

1. It enables the comparison and aggregation of effects that differ widely in nature.
2. It defines the value attributed to intangible effects, thereby enhancing the consistency of public decisions and reducing arbitrariness.

1.2.3 Impacts refer to a common reference period

Projects often generate costs and benefits over several years. As illustrated in Figure 1.3, building a dam requires several years of construction before providing electricity for decades. The same is true for the bike path, which will be used for many years. Because a dollar received in the future does not have the same value as a dollar today, all values must be "converted" into dollars for a common reference period. In the dam example, if the CBA is conducted in 2023, the reference period will be the year 2023, and all costs and benefits will be expressed in 2023 dollars.

This conversion of future values into present ones is carried out through **discounting**, that is, the application of formulas whose main parameter is the **social discount rate**. The difference between discounted benefits and discounted costs for the reference year corresponds to the net present value (NPV), which indicates whether the project is socially profitable. Chapter 6 will examine in detail the principles of discounting and the decision rules used in CBA.

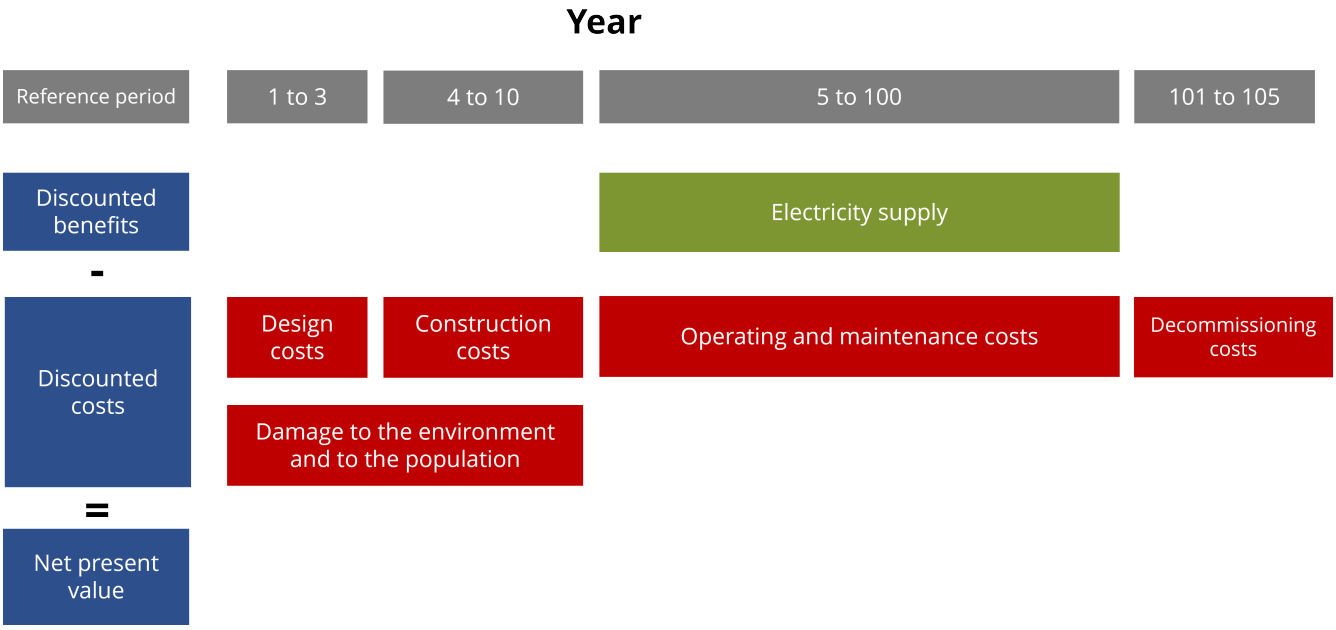


Figure 1.3 Time course of a hydroelectric dam project

Examples: the Three Gorges dam in China

The Three Gorges Dam in Hubei Province, China, required 17 years of construction. The project cost approximately $25 billion and resulted in the loss of more than one hundred lives, in addition to substantial environmental and human impacts. The dam now supplies about 3% of the country's electricity needs.



Le Grand Portage, adaptation: Rehman, CC BY 2.0 via Wikimedia Commons

1.2.4 Impacts are measured through willingness to pay or willingness to accept

As Figure 1.2 shows, the social impacts of a project can materialize either in markets (with or without distortions) or outside markets.

Regardless of the nature of the impact being assessed, CBA values impacts using the notions of **maximum willingness to pay** (WTP) and **minimum willingness to accept** (WTA).

WTP corresponds to the **maximum** amount that beneficiaries of a project are willing to pay to enjoy its benefits, or that victims of a nuisance are willing to pay to avoid it.

For instance, the benefit derived by bike path users can be measured by the maximum amount they are willing to pay to access and use the facility. Similarly, potential adverse effects of the bike path for nearby residents—such as the loss of on-street parking, changes in traffic patterns, or reduced accessibility for certain users—can be valued by the amount residents would be willing to pay to avoid these impacts.

WTA corresponds to the **minimum** amount that beneficiaries must receive to forgo an impact, or that victims of a nuisance require as compensation to tolerate it.

In our example, WTA would measure the minimum compensation required for cyclists to relinquish access to the bike path, or for local residents and other users to accept the inconveniences associated with the project.

In some situations, these values can be observed directly in markets through revealed purchasing or selling behaviors. In situations without markets, specific valuation techniques are required to estimate WTP or WTA. Parts 2 and 3 of this manual will explore these methods in detail.

In principle, WTP and WTA for a given impact should be similar. In practice, WTA is frequently much higher than WTP.[2]. Depending on the context, either WTP or WTA may be used to assess an impact.

2. See Chapter 4 of Atkinson *et al* ., (2019) for more details on this issue.

1.2.5 Opportunity costs are used as the valuation basis

In CBA, the goal is to measure the economic costs of a project for all members of the community.

> The economic cost of a project corresponds to the social value of all the resources used to carry it out. It is measured in terms of opportunity cost.

> The opportunity cost of an input or resource is the value it could have generated in its best alternative use.

For example, building a bike path requires workers, machinery, and potentially volunteer time. The economic cost of these inputs must be assessed based on their opportunity cost. Workers, for instance, could have contributed to another project and earned a similar salary. We will return to the implications of this reasoning in Chapter 4.

For now, it is useful to note that economic cost can differ considerably from monetary expenditure. Volunteers who help build or maintain the bike path may not generate a monetary expense, yet their contribution still represents an economic cost in a CBA, since they could have devoted their time to other valuable activities. There is therefore an opportunity cost.

1.2.6 Changes are evaluated relative to a reference situation

In CBA, only the benefits and costs **specifically generated** by the project should be taken into account. Impacts that would occur regardless of whether the project is implemented are not relevant. For example, if the municipality plans to resurface the road leading to the potential bike path and this work will take place regardless of the project's fate, its cost should not be included in the CBA.

To ensure that only project-specific impacts are considered, it is essential to define and specify a reference scenario.

CBA evaluates changes in social benefits and costs caused by a project relative to a baseline scenario—usually the status quo, meaning the situation without the project. The project's contribution is therefore measured by its net social benefit compared with this baseline.

The example below helps clarify this principle and illustrates how CBA results are typically presented.

Example: Replacing a ferry with a bridge

A municipality is considering replacing its river ferry system with a bridge. The analysis provides the following present values (expressed in base-year dollars):

- The benefits to current ferry users are estimated at $320 million (their willingness to pay for the service).
- A bridge reduces crossing time and improves service quality; the resulting user benefits are estimated at $650 million.
- If the ferry is maintained, it will need to be replaced in the coming years at a cost of $90 million.
- Operating the ferry would cost $100 million.
- Building the bridge is estimated to cost $400 million, with annual maintenance valued at $10 million.
- The access road to the bridge is the same as the road leading to the ferry. It has reached the end of its useful life and must be rebuilt at a cost of $3 million, regardless of which option is chosen.

Based on this data, is building the bridge socially profitable?

To answer this question, the data can be organized in different ways. Table 1.1 presents two common formats.

Separate presentation of the project and the baseline scenario

In Panel A, the benefits and costs of each scenario are presented separately. Maintaining the ferry generates an estimated net benefit of $127 million, whereas the bridge yields a net benefit of $237

million. The bridge should therefore be preferred, since it produces an additional net benefit of $110 million relative to maintaining the ferry.

Presentation in terms of variation

Panel B uses the format typically adopted in CBA. It shows the variation in benefits and costs of building the bridge relative to the baseline (keeping the ferry). The additional benefits generated by the bridge are $330 million, corresponding to the difference between $650 million and $320 million.

For costs, both the construction cost and maintenance cost of the bridge must be considered. However, the costs avoided by discontinuing the ferry must also be included—they are "negative costs," and therefore benefits.

Notice that the cost of rebuilding the road does not appear in Panel B, because it is incurred in both scenarios. Since it is identical across options, it cancels out when measuring the variation in costs.

Decision rule

The project should be adopted if the net effect—or, in CBA terminology, the **net present value (NPV)**—is positive, since this indicates that the project increases net social benefit compared with the reference scenario. The NPV is estimated at $110 million, identical to the difference between the two net benefits in Panel A.

One advantage of the Panel B format is that it can require less information. For instance, it is not necessary to estimate the full benefits of ferry use; only the additional benefit produced by the bridge needs to be evaluated. However, the Panel A presentation may be more intuitive for decision-makers because it makes the costs of the status quo explicit.

Table 1.1 Two formats for presenting the example data

Panel A: Benefits and costs of the two options (in millions of dollars)			
Maintaining the ferry (status quo)		**Construction of the bridge (the project)**	
User Benefits	320	User Benefits	650
Ferry replacement cost	-90	Construction cost	-400
Operating cost	-100	Maintenance cost	-10
Road reconstruction cost	-3	Road reconstruction cost	-3
Net benefit	127	**Net benefit**	237
Panel B: Benefits and costs of the bridge relative to the ferry			
Additional user benefits			330
Cost of building the bridge			-400
Bridge maintenance cost			-10
Avoided ferry replacement cost			90
Avoided ferry operation cost			100
Net present value			110

It is important to become familiar with the variation approach, as it is the method used throughout the remainder of this manual. In practical terms, this implies that:

- Only changes in benefits and costs relative to the baseline scenario are included;
- Avoided costs constitute benefits of the project, while foregone benefits constitute costs to the project;
- Any costs or benefits that occur in both scenarios are ignored.

1.2.7 The goal is to inform decisions

Public decisions can be analyzed from a **positive** perspective, which seeks to explain how decisions are made in practice. For example, some choices may be understood as reflecting the desire of elected officials to maximize their chances of re-election.

In contrast, CBA adopts a **normative** perspective, since its purpose is to recommend whether a project should be undertaken. CBA is therefore a tool intended to support public decision-making.

CBA provides recommendations to public authorities based on the project's impact on collective wealth.[3] For example, will the bike path generate greater social benefits than social costs? Like any normative analysis, CBA necessarily involves value judgments. Within CBA, the central criterion is improved economic efficiency, which is discussed in the next subsection.

The CBA provides a recommendation to public decision-makers based on the impact of the project on "collective wealth[4]". For example, will the bike path generate greater social benefits than its social costs? Like any normative analysis, the CBA relies on value judgments. In the CBA, the criterion of improved economic efficiency occupies a central place. This is described in more detail in the next subsection.

1.2.8 The Kaldor-Hicks or potentially Pareto improvement criterion of efficiency

The CBA recommends undertaking projects whose social benefits exceed their social costs. A project does not necessarily have to be unanimous, so the criterion used by the CBA is less demanding than the **Pareto criterion**[5]. In fact, the CBA is based on the **Kaldor-Hicks criterion**, also called the criterion of **potentially Pareto improvement**.

A project meets the Kaldor-Hicks criterion if the **sum of the gains received by the**

3. This term must be interpreted broadly, not only in a financial sense, since CBA also incorporates intangible effects such as losses in air quality.

4. This term must be interpreted in a broader sense than purely financial wealth, since the CBA takes into account intangible effects such as the degradation of air quality.

5. The Pareto criterion assumes unanimity. Indeed, according to this criterion, a project should be adopted if it does not harm anyone and improves the lot of at least one person. It is understandable that it would be difficult to make collective decisions based on such a demanding criterion.

beneficiaries of a project is greater than the sum of the costs assumed by the losers. The project thus constitutes a potentially Pareto improvement, since it is **theoretically** possible to set up a compensation system in which the winners compensate the losers. The project with the compensation system is unanimous since it improves the lot of all.

To illustrate this concept, let us assume that the impacts of the bike path have been valued in present value for the reference period:

Benefit for cyclists: $100,000;
Costs borne by residents and other users (e.g., loss of parking or reduced accessibility): $35,000;
Economic cost of construction and maintenance: $25,000.

In this case, the bike path should be developed, since its NPV is positive at $40,000 (i.e. $100,000 – $35,000 – $25,000). In other words, building the bike path increases collective wealth. The project therefore meets the Kaldor-Hicks improvement criterion, since cyclists could, in principle, compensate residents and other affected users for the inconveniences and cover the construction and maintenance costs, so that no one would be worse off. For example, cyclists could compensate residents $40,000 and pay for development and maintenance. They would be left with a net benefit of $35,000, residents would obtain a net gain of $5,000, and the resources mobilized for construction and maintenance would be compensated at their opportunity cost.

Please note that according to this criterion, the project must be adopted **even if the compensation system is not actually implemented**. It is only necessary that this possibility exists, which brings us to the next principle.

1.2.9 Assess impacts to, perhaps, increase well-being

In our example, the bike path project is socially profitable, since it increases collective wealth by $65,000 (i.e. $100,000 – $35,000). In the absence of a compensation system, the project creates losers, particularly residents, who must endure noise pollution. So, are we certain that the project will also increase collective well-being? The answer is no: a project can increase collective wealth while decreasing collective well-being, and the opposite is also possible. Let's explore how this is possible using an example.

Let us first clarify that the definition of "collective well-being" poses many challenges, the analysis of which goes beyond the objectives set out in this manual. We assume here that collective well-being is measured by

the sum of the levels of well-being of all members of the community[6]. Let us suppose that a project generates a gain estimated at $10,000 for individual 1 and a loss estimated at $10,000 for individual 2. In this case, this project does not change collective wealth, since the benefit is equal to the cost. But this project can still have an effect on collective well-being. Indeed, the $10,000 does not necessarily have the same impact on the level of well-being of the two individuals. Consider the case where individual 1 is rich and individual 2 is poor: it is then very likely that the gain in well-being of individual 1 is lower than the loss in well-being of individual 2. This is because the **marginal utility of income,**that is, the gain in well-being caused by an increase in income, decreases with the level of income.

Figure 1.4 illustrates our example: the curve shows the level of well-being (or "utility") that can be achieved as a function of income. We assume that this curve is the same for both individuals. This function is increasing, but concave, reflecting that well-being increases with income, but more and more slowly. In more technical terms, the marginal utility of income decreases with the level of income. Before the project, individual 1 has an income that allows him to reach point A, while individual 2, poorer, can only reach point C. The project amounts to decreasing individual 2's income by $10,000 and increasing individual 1's by the same amount. Thus, with the project, individual 1 reaches point B and individual 2 can only reach point D. Given the concavity of the curve, we see that the loss in well-being of individual 2 is greater than the gain in well-being of individual 1. Thus, even if the project keeps the level of collective wealth constant, it reduces collective well-being, since the sum of the utilities of the two individuals decreases.

6. This is Bentham's utilitarian approach.

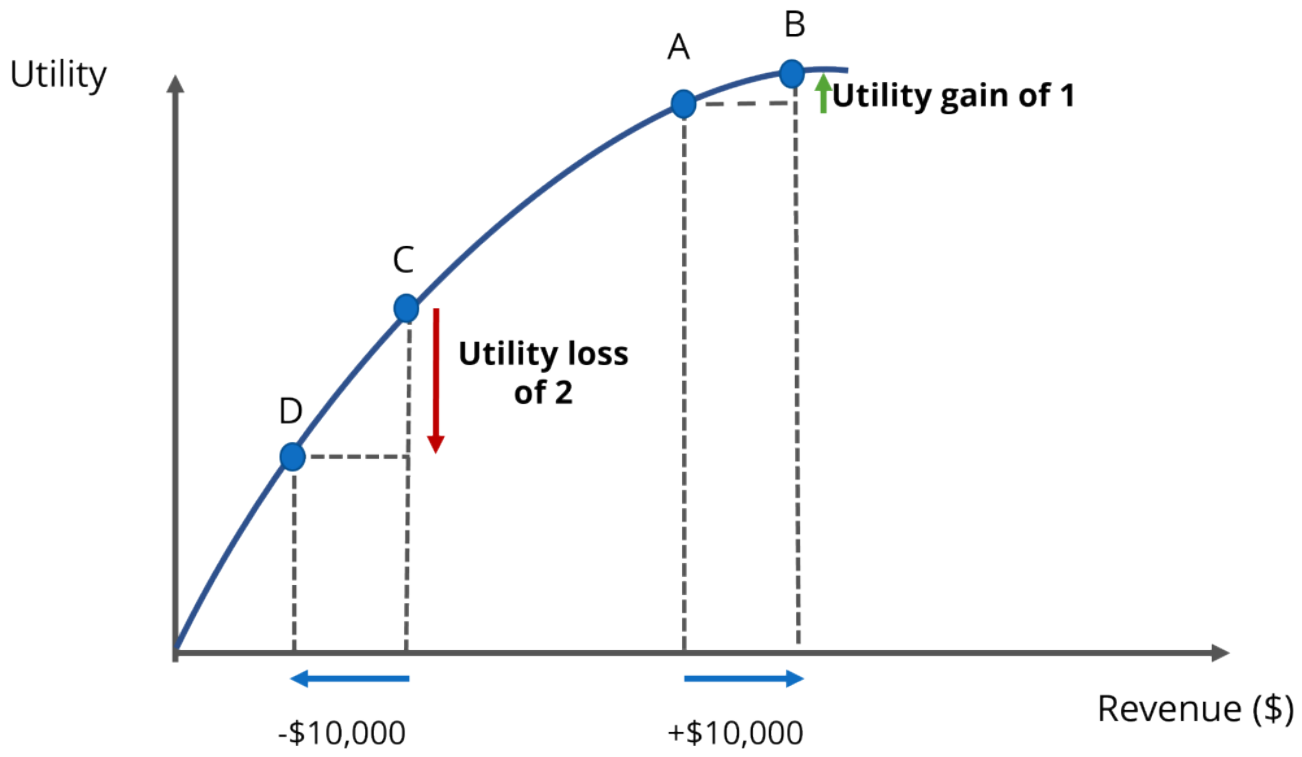


Figure 1.4 Impact on the utility of income redistribution

The marginal utility of income would have to be identical and constant for all individuals, in order to be certain that a project that passes the CBA test (Benefits > Costs) certainly improves collective well-being. If income were distributed equally, it would be reasonable to assume that the marginal utility of individuals would be the same. However, since this is not the case in reality, this leads us to formulate an important limitation of CBA:

> CBA focuses only on efficiency, that is, on increasing "collective wealth", without considering the equity consequences of the project. This approach can lead to the acceptance of projects that reduce collective well-being or the rejection of projects that could improve it.

The traditional response to this criticism is that other public policies should be mobilized to improve equity. In other words, we should adopt projects that increase collective wealth, without worrying about redistributive effects, and use appropriate instruments, such as the progressive tax system or transfers, to improve collective well-being through income redistribution.

This vision of a world where decisions about efficiency and equity can be made independently is somewhat

naive. However, adopting unprofitable projects solely for equity reasons risks making us all "equitly" poor. We will see in Chapter 5 how distributional aspects can be documented and taken into account in practice.

1.2.10 Evaluate impacts to improve efficiency, but without necessarily reaching the optimum

A CBA helps determine whether or not implementing a project improves efficiency compared to a baseline situation, but **does not necessarily lead to the most efficient solution**.

Consider again the example of building a dam on a river to produce hydroelectricity. Suppose that the social benefits and costs vary with the size of the infrastructure, as in Figure 1.5. If we knew these curves, it would be very easy to determine the optimal size of the dam Q^*. This is the size that provides the maximum net social benefit (i.e. the difference between A and C). Unfortunately, we do not know these curves and estimating them would probably be costly.

In a CBA, the costs and benefits of a limited number of options will be assessed, for example, a small dam (Q^S), a medium dam (Q^M), and a large dam (Q^L). On this basis, all three projects produce a positive net benefit, but project Q^M should be recommended since it provides the largest net benefit. However, given the limited number of options studied, the recommended project will not necessarily be the project that maximizes the net benefit. In our example, Q^M is too small relative to the optimum Q^*.

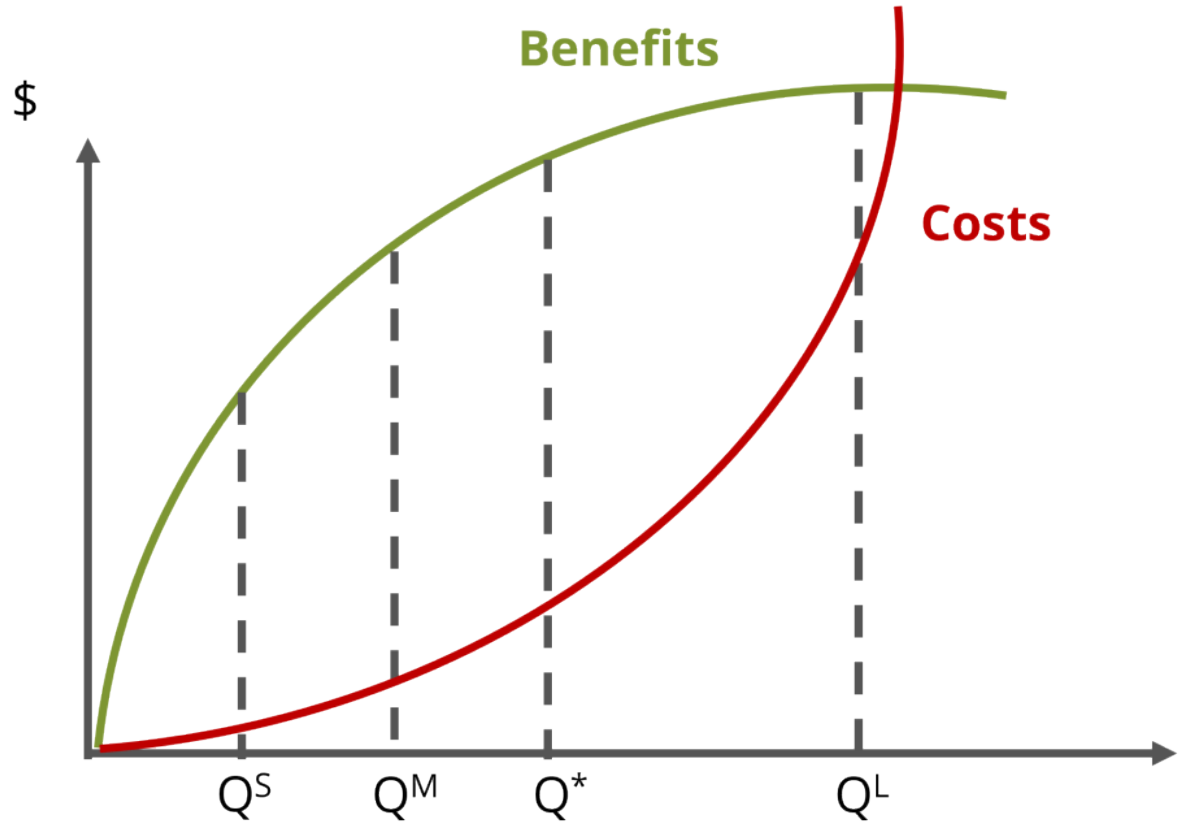


Figure 1.5 Project size, optimality and CBA

1.3 Other economic evaluation tools

In this section, we briefly describe other economic evaluation tools, in order to better understand the specificity of CBA. Some of these tools will be discussed in more detail in Chapter 20.

1.3.1 Financial analysis

The financial analysis of a project consists of establishing the inputs, outputs and financing needs during the duration of the project. It also involves determining the financing methods (loans, bond issues) and allocating responsibilities between the partners, i.e. the financial structure. It is therefore not an assessment of the social costs and benefits of the project, but rather the financial costs and benefits of the partners. This analysis is used in particular to assess the private profitability of the project for its partners. The data produced as part of a financial analysis are often very useful for carrying out the CBA. For more details on this approach, see, for example, Chapter 3 of Jenkins, Kuo and Harberger (2011).

1.3.2 Impact assessment

*Impact*evaluation is a set of quantitative techniques that aim to measure **the causal impact of a public intervention**. Compared to CBA, impact evaluation often focuses on a limited number of effects and generally does not monetize them. For example, an impact evaluation may seek to determine the extent to which reducing class sizes improves students' academic performance or the effect of a job-search training program on the unemployed. In the latter case, a simple comparison of the placement rate of unemployed people who have followed the training with that of those who have not followed it may be misleading if the group of trained unemployed people is different from the rest of the unemployed. For example, if participation in the program is voluntary, it is likely that individuals who follow it will be more motivated to find a job than the average unemployed. The effectiveness of the program is thus overestimated by comparing the average. This is the classic problem of selection bias.

Over the past decades, many statistical techniques have been developed to quantify the impacts, in physical terms, of public programs and interventions. We will not study these techniques here, since they are described in other textbooks such as Khandker *et al*., (2010) or Gertler *et al*., (2016). Of course, the results of impact evaluations are very useful inputs for conducting a CBA.

1.3.3 Analysis of impacts or economic repercussions

*Economic*Impact Analysis is a set of techniques based on input/output models that aim to assess the **economic effects or benefits**of a project. This technique is widely used, yet its interpretation is often problematic.[7].

The effects can be measured in terms of jobs, added value, tax revenues or imports. Input/output models take into account the interactions between different markets, but they assume that prices are not affected by a project, which means in particular the absence of any form of constraints on available resources. In other words, the economy can always produce more, without any opportunity cost. These are therefore models more suited to a context of generalized underemployment.

> Impact or benefit analyses **cannot be used to determine whether a project is socially profitable.**

7. See Chapter 20 for more details).

These analyses do not allow us to judge the social profitability of a project, for two main reasons:

1. The economic impacts and spinoffs measured by this approach **are generally not additional**. For example, a government subsidy program to help an industry grow will certainly create jobs, added value, and induced effects. However, these impacts are not additional, since the funds thus invested could be invested in another project that would also generate economic spinoffs. Alternatively, the funds could be left in the pockets of taxpayers, thus increasing their purchasing power and the economic spinoffs they generate[8] ;
2. Economic impacts, in this approach, **do not measure the net benefits**of the project, as is often wrongly suggested. Indeed, they include benefits, costs and even transfers. For example, the added value generated by a project is often presented as a positive element of the project. However, let us recall that added value measures the difference between the value of a sector's sales and the value of its intermediate consumption, i.e. its purchases of inputs, excluding the cost of capital and labor. In other words, it is the value generated by a sector to remunerate capital and labor. However, these two factors of production have opportunity costs that are not taken into account in the calculation of added value. Added value is therefore not a measure of net benefit.

Economic impact analysis describes how a project will affect different sectors of the economy, but impacts **cannot be used to justify a project.**In fact, any project, no matter how outlandish or harmful, will generate economic benefits (Stringer, 1993). Spending a billion dollars to dig a hole and then filling it in will generate economic impacts but will not create any benefits for the community. Worse, a hurricane will also generate economic benefits. We discuss the economic impact model in more detail in Chapter 20, but the example in the next box helps illustrate the fundamental difference between CBA and impact analysis.

Example: Economic impact of the apple industry in New York State

A common application of economic impact analysis is to estimate the contribution of a specific industry to the economy of a given region. An illustrative example is provided by an economic impact

8. Some projects do indeed create additional impacts, for example, foreign tourists attracted by a festival or foreign investment in a new factory (see Chapter 12).

study of the apple industry in New York State using the IMPLAN input–output modeling framework. Schmit et al. (2019) estimate that the direct effects of the apple industry amount to approximately $1,309 million per year in output, supporting about 8,033 direct jobs. These activities also generate indirect effects on upstream suppliers of roughly $441 million, corresponding to about 1,849 jobs, as well as induced effects of approximately $341 million resulting from household spending, supporting around 1,989 additional jobs. Taken together, these results highlight the scale of the apple industry's economic footprint within the regional economy. However, while this type of analysis is informative about the distribution and magnitude of economic activity linked to a sector, it does not provide precise information on the net benefits of that activity, since it does not explicitly compare the benefits generated by the industry with the opportunity costs and potential negative impacts associated with its existence.

It should be noted that computable general equilibrium models are also used to measure economic impacts. These models take into account resource constraints and price adjustments. They also allow for the consideration of opportunity costs. However, they are mainly used to analyze large-scale projects that have macroeconomic consequences.

1.3.4 Cost-effectiveness analysis and cost-utility analysis

Cost-effectiveness analysis differs from CBA mainly in two ways. First, this type of analysis generally focuses on one or a few impacts of the project. It is therefore not intended to be exhaustive like CBA. Second, if the costs of a project are monetized, the output(s) of the project are measured in natural units. There is therefore no monetary valuation of the benefits. Different types of treatment for a disease will, for example, be compared by calculating the ratio between the number of patients cured (measure of effectiveness) and the cost of each treatment, which is interpreted as the number of patients saved per million dollars invested. This tool is widely used in the health sector.

A special case of cost-effectiveness analysis is cost-utility analysis. This technique measures effectiveness based on a synthetic indicator called "utility", which measures the expected life span of a person weighted by the quality of life. A year of life in full health is equivalent to 1, while the same year in suffering would be worth, for example, only 0.5. The effectiveness of different drugs to treat a disease will thus be compared in terms of number of years of life, weighted by quality (in English, number of *Quality Adjusted Life Years* or QALYs). We detail these methods in Chapter 20.

1.4 A brief history of the CBA

Historically, the French engineer and economist Jules Dupuis (1804-1866) is probably one of the first to have conducted a CBA, in order to determine whether the construction of a bridge was socially justified. It is in this context that he proposed the concept of "**consumer surplus**", which is still used today as a measure of consumer benefits. The foundations of welfare theory and social choice were developed by Pareto (1848-1923), then by Hicks (1904-1989) and Kaldor (1908-1986). Later, several methods for evaluating intangible effects were developed, such as the **contingent valuation method**.

In practice, significant advances were made in the 1930s and 1950s in the United States in flood control policies. The Flood Control Act of 1936 provided that flood control measures (e.g., levee construction) should provide more benefits than costs.

Despite much progress on the subject, there are still many limitations, several unresolved questions and various controversies, both on the theoretical and practical levels. For example, the consideration of the structuring effects of transport infrastructures (*Wider Economic Benefits*) is still in its infancy today. Updating over a **time horizon** that extends to future generations also remains a subject of controversy and research today.

The reliability of CBAs remains a major challenge as shown by several studies. Based on the analysis of 2062 public projects in different countries and sectors, Flyvberg and Bester (2021) show the existence of systematic biases of underestimation of costs and overestimation of benefits. For costs, the average underestimation is of the order of 40% while the overestimation of benefits reaches 15%. In the transport sector, Flyvbjerg *et al*., (2002) analyze 258 infrastructure projects. They find that for 90% of the projects, the costs were underestimated, and that the average underestimation was close to 30%. Furthermore, Flyvbjerg (2005) evaluate the reliability of traffic forecasts of more than 2000 transport projects, an important determinant of benefits. For projects involving rail transport (trains and subways), 90% of projects overestimate traffic, with an average overestimation of 50%. We return to this issue in Chapters 3 and 18. Finally, even in cases where CBAs are carried out rigorously, their real impact on politicians' decision-making does not seem to be systematic[9].

9. See J. Eliasson, M. Borjesson, O. James and W. Morten (2015) on this subject. For a more positive view of the impact of CBAs on real decisions in the United States, see Sunstein (2018).

1.5 CBA in practice

1.5.1 In Canada

Since 1999, the federal government has required CBAs for all major federal regulatory proposals. In 2007, the Treasury Board of Canada Secretariat published the *Canadian Cost-Benefit Analysis Guide: Regulatory Proposals*. Since 2018, the federal regulatory assessment process has been governed by three texts:

- The *Cabinet Directive on Regulation*;
- The *Policy on Cost-Benefit Analysis (Treasury Board of Canada Secretariat, 2018b)*;
- The *Cost-Benefit Analysis Guide for Canada (Treasury Board of Canada Secretariat, 2018a)*.

A regulation is defined as "a statutory instrument made in the exercise of a legislative power conferred by an Act of Parliament and which carries with it legal sanctions if contravened" (see section 1.0 of the *Directive*).

The policy provides that any proposed regulation that is likely to result in an average annual cost of more than $1 million must be the subject of a CBA. This must be made public on the website of the department concerned, and a summary must be published in the *Canada Gazette* ,Part I. The *Guide*provides departments and agencies with guidelines for conducting "high-quality" CBAs (see the *Guide*,page 2).

1.5.2 In the United States

In the United States, the first law requiring a comparison of benefits and costs was the *Flood Control Act*of 1936. It required that flood control works (dams and levees) must provide more benefits than costs. The *US Army Corps of Engineers*therefore contributed to the practical application of the CBA. Later, Section 812 of the 1990 Amendment to the *US Clean Air Act required ex post*CBAs to be carried out on the impacts of this law. The results of these CBAs demonstrate that the benefits of improved air quality have significantly exceeded the costs.[10].

In 1981, President Reagan signed Executive Order 12291, which specified that regulatory action should not be taken unless the potential social benefits exceeded the social costs. In 1993, President Clinton confirmed this provision, but added the need to consider non-quantifiable effects such as effects on equity. In 2011, President Obama added the need to also consider impacts on human dignity and social justice (Posner, 2011). In January 2021, the Biden administration undertook a modernization of the provisions surrounding the evaluation of

10. Thus, the application of the law from 1970 to 1990 would have cost $523 billion, but would have generated benefits, particularly in terms of health and environmental quality, which were estimated at $22 trillion (US *Environmental Protection Agency* , 1997).

public policies. Although the process is still ongoing, the goal now seems to be to place more emphasis on qualitative assessments of impacts such as equity, human dignity, racial equality, or the interests of future generations (Nardinelli, 2021).

The practice of CBAs is governed by various guides such as the *Guidelines for Preparing Economic Analysis*of the *Environmental Protection Agency*or the *Benefit-Cost Analysis Guidance for Discretionary Grant Programs of*the *Department of Transportation.*

1.5.3 Elsewhere in the world

It is not possible to provide an exhaustive picture of CBA practices and practice guides in the rest of the world here. Table 1.2 provides only a few important leads and references in this area.

Table 1.2 Useful references for CBA

Countries or organizations	Reference
United Kingdom	HM Treasury (2022)
France	Gostner et Ni (2023) Baumstark et al. (2013)
OECD	Pearce, G. Atkinson et S. Mourato (2006) Atkinson et al. (2019)
European Commission	Sartori et al. (2014).
Society for Benefit-Cost Analysis	Organization dedicated to the advancement of CBA theory and practices.

1.6 Conclusions

This first chapter defines, situates and specifies the foundations of CBA. Several of the concepts discussed in this chapter will be re-examined in more depth later in the manual.

Key takeaways

- CBA is a set of methods based on microeconomic theory used to value the social costs and benefits of a project relative to a baseline scenario, with the objective of assessing its social profitability.
- A CBA can be conducted ex *ante* (before the project), *in media res* (during the project) or *ex post* (after the project).
- CBA is particularly relevant for projects where:
    - social profitability is expected to differ from private profitability;
    - impacts are concentrated in a limited number of markets.
- In a CBA, only the costs and benefits specifically generated by the project are included.
- Benefits are valued using willingness to pay (WTP) or willingness to receive (WR).
- Costs are measured as opportunity costs, that is, the value that society gives up by making a choice.
- Impacts are assessed in monetary units of a reference year through discounting.
- CBA is a normative decision-making tool. Its main criterion is efficiency, understood as an increase in collective wealth, and operationalized using the potentially Pareto improvement (Kaldor-Hicks) criterion.
- It is possible that projects that pass the CBA test reduce collective well-being due to distributional effects. Conversely, projects that fail the CBA test could improve collective well-being.

Back to motivation: Which economic evaluation method should be used?

Imagine that you are an analyst for an economic consulting firm and that as such you must provide recommendations on the relevance of various projects and public policies. As an example, here are some of your mandates:

- Municipality considers investing in tramway;
- A cement company wants to assess the profitability of a new plant project;
- A pharmaceutical company wants to convince the government to reimburse its new drug that reduces the risk of heart attacks;
- The Ministry of the Environment must evaluate a subsidy program for the purchase of electric vehicles;
- A political party wants to know the impacts of an election promise to reduce income taxes.

Is cost-benefit analysis appropriate for all these mandates? If not, what other economic evaluation tools might be more appropriate?

Answers

Tramway

The private (or financial) profitability of the project and its social profitability diverge. For example, the tramway may reduce congestion and pollution. The municipality therefore likely wants to assess the social profitability of the project.

In addition, although the investment is significant, the project is unlikely to generate large macroeconomic effects. It is therefore well suited to a CBA.

Cement plant

This mandate corresponds to a private profitability analysis. It may incorporate social impacts, such as pollution, but only insofar as these affect private profitability.

New medicine

A CBA might be relevant to convince the government, but a cost-effectiveness or cost-utility analysis would likely be more appropriate.

Electric car subsidy

This program can be evaluated using a CBA because the department wants to measure its social impact, not only its financial impact on the government budget. Furthermore, this program is expected to affect a limited number of markets.

Income tax reduction

This measure is likely to have macroeconomic consequences. A CBA is therefore not appropriate; a macroeconomic model would be preferable.

Exercises

(*) Indicates that a solution is available.

(**) Indicates that a solution is available in restricted mode.

1. A city plans to build a bike path along a commercial street, which would require eliminating parking spaces. Using the situation of cyclists and merchants, explain the concept of the "Kaldor-Hicks criterion."
2. (**) A municipality must decide whether to renovate its outdoor pool or build a new, larger one on the same site. In the current configuration, user benefits, assessed over the life of the infrastructure, are estimated at $1 million. The municipality expects to increase these benefits by 50% by building a larger pool. Renovating the existing pool would cost $350,000, while building a new pool would cost $1 million. Operating and maintenance costs for the renovated pool are estimated at $250,000, compared with $300,000 for the new pool. The municipality must also renovate the parking lot in front of the pool at a cost of $50,000.

   a) Using this information, perform a CBA of the decision to build a new pool rather than renovate the existing one. Present your results in terms of additional benefits and additional costs for the new pool compared with the renovation.

   b) How would your recommendation change if the provincial government agreed to cover 40% of the infrastructure costs (that is, the construction or renovation costs)?
3. (*) Using a graph and a project involving two individuals, construct an example of a project that would reduce collective wealth but increase collective well-being.

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2.

RECOMMENDED STEPS AND PITFALLS TO AVOID

Motivation and learning objectives

You work for a transportation authority and are tasked with carrying out a cost–benefit analysis (CBA) for a project involving the replacement of an existing ferry crossing that connects a peninsula to the mainland with a bridge. This project serves as the central illustrative example throughout this chapter and is inspired by a real infrastructure project submitted to a CBA concerning the crossing of the Saguenay River in Quebec.[1].

As illustrated in the image below, the current ferry crossing creates a discontinuity along a major transportation corridor between the peninsula and the mainland. This discontinuity generates travel time delays, reduces travel time reliability, and limits connectivity, contributing to a sense of isolation among residents. It also raises safety concerns for users, as scheduled crossings and limited capacity may encourage risky behavior, such as speeding to catch the ferry or unsafe maneuvers near boarding areas. The proposed project consists in replacing the ferry service with a fixed bridge, thereby restoring a continuous and reliable road connection across the river.

1. The technical and numerical elements of the example are drawn from that real-world study. See SNC-Lavalin/Genivar Consortium (2009).



How should you proceed to carry out the CBA for this project? What analytical steps should be followed to ensure a rigorous evaluation? If a higher level of government finances part of the project, does this affect its social profitability? How can the quality of an existing CBA be assessed?

At the end of this chapter, you will be able to:

1. Understand the main steps required to carry out a CBA;
2. Assess how the spatial horizon influences the results of a CBA;
3. Identify common errors frequently found in CBAs.

2.1 CBA in 7 steps

The approach to conducting a CBA can be summarized in seven steps. Table 2.1 provides an overview of these steps, the essential aspects to consider for each, and their links to the rest of the manual. A substantial portion of this manual focuses on constructing the analytical framework (step 2), which helps identify all relevant impacts.

Table 2.1 7-step process for carrying out a CBA

The steps	Elements to address	Relevant Chapters
1. Description of the context, the project and the state of knowledge	• Context ◦ Historical ◦ Problematic ◦ Legal framework ◦ Alternatives considered ◦ Project justifications • Project: ◦ Scenarios under study ◦ Temporal and spatial horizons • State of knowledge	Chapters 1 to 3
2. Establish the analysis framework to identify relevant impacts	• Potential impacts • Relevant stakeholders • Analytical framework • Cost and Benefit Table ◦ Part-by-part approach ◦ Social approach	Chapters 4,5 and 7 to 10
3. Quantification of impacts over the time horizon	• For each scenario, quantify in natural units the variables applicable over the analysis period. • Establish and justify the causal effects of the project on the variables of interest.	Not directly covered in this manual
4. Monetary valuation of impacts	• Determine and justify the choice of "prices" to proceed with the valuation of impacts.	Chapters 7 to 16
5. Updating impacts, calculating Net Present Value (NPV)	• Choice and justification of the discount rate	Chapters 6 and 17
6. Sensitivity analysis	• Analysis by parameter, by scenario or Monte Carlo analysis	Chapter 18
7. Drafting of the report and recommendations	• The report must contain the necessary information to reproduce the results. • Apply decision rules and issue recommendations.	Chapters 6 and 19

Before presenting these steps more fully, two clarifications are needed:

1. Although the seven proposed steps are presented in an approximate chronological order, real-world work is rarely linear. The analyst often works on several steps simultaneously, and progress at one stage may require revisiting earlier analyses. For instance, searching for available data for steps 3 and 4 may lead to adjustments in the analytical framework (step 2) or in reviewing the state of knowledge (step 1).
2. The steps are a work plan, not the structure of a CBA report. A report must present several elements described here, but not necessarily in the same order. The analytical process can include detours and false starts, which should not appear in the final written report

2.1.1. Description of the context, the project, the horizon and state of knowledge

The context

The context analysis should include:

- The history of the project and the stages leading to the decision to undertake a CBA;
- The issues or needs addressed by the project;
- The legal framework surrounding the project;
- Intervention alternatives that were considered but rejected;
- The economic justification for public sector involvement in the project (see Chapter 3).

The reference scenario

The baseline scenario usually represents the status quo in the absence of the project. However, it is important to emphasize that the status quo is not synonymous with inactivity or zero cost. In many cases, a "do nothing" option is not feasible over a long period.

In the ferry–bridge example, the baseline scenario consists of maintaining the existing ferry service. Because the analysis period spans forty years, the replacement of vessels during that period must be taken into account, generating significant costs. If the bridge is built, these replacement costs are avoided and therefore constitute a benefit of the project.

Establishing the baseline scenario can be just as complex as describing the project scenario. A CBA on greenhouse gas emission standards for cars, for example, must estimate how the vehicle fleet would evolve in the absence of standards. This task becomes increasingly complex over longer horizons.

Scenarios involving the project

It is essential to describe each scenario involving the project and its components in detail (see Table 2.2). Several project options may be assessed within a single CBA. For instance, bridge design alternatives could involve varying capacity (two, four or six lanes) or different implementation schedules. Some options may combine features, such as maintaining an improved ferry service.

Although the CBA client may specify the scenarios to be examined, a rigorous analyst should point out other potentially more socially profitable options.

Table 2.2 Baseline and project scenarios considered in the CBA for the bridge replacing the ferry

Baseline scenario	Scenario with the bridge
• Maintain the operation of the crossing according to the current three-ship schedule • Replacement of ships at the end of their useful life (one in 2025 and another in 2045)	• Four-lane suspension bridge (1350 m) • 9 years for the design and construction of the bridge and access roads • No toll • Shuttles for pedestrians and cyclists • Lifespan: 100 years for the bridge and 30 years for the road

The horizon of analysis

Two dimensions must be specified:

- The time horizon;
- The spatial horizon (identification of stakeholders).

The time horizon

The time horizon corresponds to the period over which costs and benefits are measured in the CBA.

Defining this horizon can be technically challenging, particularly for infrastructure projects with long service lives.

In the illustrative ferry–bridge example, the bridge is expected to remain structurally usable for several

decades, making very long-term forecasting highly uncertain. Predicting traffic volumes, user behavior, and economic conditions 50, 75, or 100 years into the future is inherently difficult.

For this reason, analysts may select a shorter analytical horizon, such as 40 years, based on more predictable elements, including the expected lifespan of the road surface and the construction period. At the end of this horizon, the bridge would still retain economic value, since it could continue to operate beyond the analysis period provided that resurfacing takes place. This remaining value must be captured through a residual value, which is treated as a benefit in the CBA. Estimating residual value, however, raises methodological challenges that are discussed in Chapter 6.

Choosing a shorter horizon improves the reliability of forecasts but may lead to an underestimation of long-term effects. For example, replacing the ferry with a bridge may initially reduce travel times and congestion, but over time it could induce additional traffic, partially offsetting these gains. An overly short horizon would therefore risk overstating the project's net benefits.

In practice

In Canada, federal guidelines require that cost–benefit analyses for regulatory interventions cover a minimum time horizon of 10 years, unless a different period is explicitly justified.

The space horizon

The spatial horizon defines the boundaries of the community whose welfare is considered in the CBA.

A municipal CBA considers only local stakeholders. A provincial, national or universal CBA includes increasingly broader communities. Ideally, the spatial horizon should be universal from a social welfare perspective. In the bridge example, time savings for foreign tourists should be included.

In practice, the chosen horizon is often narrower and influenced by the CBA sponsor. Results can vary significantly depending on the spatial horizon (see Exercise 1). The analyst must clearly present and justify the choice of the spatial horizon used in the CBA, explaining why it is appropriate given the nature of the project and the objectives of the analysis.

In practice

When using a national horizon, the OECD recommends also considering impacts on non-nationals when an international treaty governs these impacts or when ethical considerations justify doing so. For example, Canada has international commitments to reduce its greenhouse gas emissions, so any project that emits must account for this cost using the social cost of a tonne of carbon, which reflects the additional damage to the planet caused by one more tonne released into the atmosphere (see Chapter 16). Similarly, a project that reduces human trafficking should, for ethical reasons, include the benefits for all affected individuals, regardless of where they reside.

The Canadian Benefit-Cost Analysis Guide provides additional guidelines, notably for determining whether a business entity is genuinely Canadian. The Guide also specifies that impacts resulting from **illegal acts** that affect the welfare of the party breaking the law should not be considered in a CBA. For example, a theft-control program should not account for the welfare loss of thieves, but it should include the benefit for victims.

The state of knowledge

Before carrying out a CBA, analysts should review existing studies on similar projects. These may include feasibility studies, financial analyses, ex post evaluations, or CBAs conducted for comparable interventions. A review of the academic and grey literature helps identify relevant impacts, methodological challenges, and appropriate valuation parameters, and it also provides a basis for external validation of results. Analysts must nevertheless remain critical, as prior studies may contain biases or errors that should not be mechanically replicated. When available, meta-analyses published in peer-reviewed journals are generally preferred.

In the case of bridge projects replacing ferry services, the literature commonly finds that improved connectivity leads to a substantial increase in crossings, often on the order of 18 to 25 percent.

2.1.2. Establish the framework of the analysis to identify relevant impacts

The list of impacts

The analyst must compile a comprehensive list of positive and negative impacts. These must reflect:

- Arguments from supporters and opponents;
- Findings from the literature review;
- Insights from experts.

The list must be exhaustive but should exclude impacts known to be negligible. For instance, the bridge may require cutting trees, but the quantity involved is too small to be relevant. The CBA is a partial equilibrium analysis focusing on a limited number of markets, so diffuse impacts should generally be excluded.

Not all listed impacts must ultimately be included in the CBA. The analytical framework determines which ones are relevant. But the initial list is useful for two reasons. First, it helps ensure that no relevant effects are overlooked. Second, it supports the formulation of clear justifications for omitting certain impacts highlighted by supporters or opponents of the project. For example, supporters of the bridge may emphasize the economic activity generated during construction, but as noted in Chapter 1, these benefits are not additional, since the funds devoted to the bridge could just as well finance another project that would generate similar benefits.

Stakeholders

It is also necessary to identify the relevant stakeholders, that is, the groups or categories of agents that are part of the spatial horizon and that will be impacted if the project is carried out. In the case of the bridge, the stakeholders are:

- Users who have to cross the river;
- The state that pays for the infrastructure;
- The ferry operator will see its operations reduced;
- People who experience negative environmental impacts, often referred to as " **third parties**" when it is difficult to identify them precisely.

The CBA should focus on stakeholders who are seriously impacted. In other words, the analyst should use judgment and avoid including parties who suffer negligible consequences.

Moreover, it is not necessary to include parties whose gains are entirely offset by their costs. In our example, the firm selected to build the bridge is not treated as a stakeholder because it is assumed that the contract will be awarded through competitive bidding. In such a context, the revenue the firm receives for building the bridge

exactly matches its economic costs.[2] Since the net effect of the project on this party is zero, it does not need to be included in the CBA.

The analytical framework

The analytical framework uses microeconomic tools to:

- Identify affected markets;
- Analyze how they differ between the baseline and project scenarios;
- Establish valuation strategies using available data.

The framework must distinguish relevant impacts from **those already captured elsewhere** or **from non-additional impacts**.

Effects already taken into account

We will see in Chapter 5 that impacts can be classified as **primary**, **secondary** and **induced**. We will also show that a CBA should focus primarily on primary effects, and that secondary effects are often only a reflection of primary effects. There is therefore **a risk of double counting**if the analyst uncritically includes in the CBA both the primary effect and the associated secondary effect.

In the case of the bridge, there would be double counting if the CBA added together the time savings of truckers and the reduction in costs of trucking companies. There is also a risk of double counting if the CBA includes the time savings of tourists and the increase in tourism spending in the region. We will return to these aspects in more detail in Chapter 12.

Effects that are not additional

As we indicated in Chapter 1, a CBA only considers impacts that are specifically caused by the project. In other words, effects that are not additional must be excluded. This is often the case for induced effects or spin-offs.

For some projects, the analytical framework is straightforward to establish because the impacts are self-

2. The economic cost is the opportunity cost of all the resources used to build the bridge, including a "normal" compensation for its developer (see Chapter 4 for more details).

evident or because numerous CBAs have already examined similar situations. In addition, procedural guides and specialized software are available for common applications, particularly in the transport and health sectors[3]. However, for other types of projects, the relevant impacts are much less apparent and existing studies are scarce. In such cases, designing the analytical framework becomes a delicate and critical stage.

A substantial portion of this manual is therefore devoted to explaining analytical frameworks for different kinds of projects, including our example of replacing ferries with a bridge. These examples help interpret the procedures proposed by existing guides and software, while also developing sound analytical reflexes for CBAs in more complex contexts.

The quality of the analytical framework is often decisive for the validity of the CBA. Too often, CBAs are carried out without a solid conceptual foundation or with an inappropriate framework, which can lead to significant errors.

Cost and benefit table

Ultimately, the analytical framework must make it possible to establish a table of relevant costs and benefits. As we will see in Chapter 5, both the framework and the table can be constructed using two approaches:

1. **The social or collective approach**, which only identifies the costs and benefits for the reference community;
2. **The stakeholder approach**, which lists the costs and benefits for each of the categories of agents within that community.

Both approaches should lead to the same NPV. The difference lies in how they treat transfers and financial flows between parties.

- A **transfer** corresponds to a payment made by one stakeholder and received as income by another, **without** any counterpart in the form of an economic good or service for the payer.
- **Financial flows** between parties also involve a payment for one party and income for the other, but in this case the exchange corresponds to a good or service. The value of these

3. See, for example, Rojas et al. (2023).

goods and services must be captured through their **real impacts**: that is, the underlying benefits and costs associated with the input used or the output produced. These real impacts are what matter in the CBA.

In the social approach, transfers and financial flows are not included because they merely redistribute benefits and costs among stakeholders without affecting the Net Present Value (NPV). A payment made by one party is received by another, so the cost for the payer is exactly matched by an equivalent benefit for the recipient. When these amounts are aggregated from a social perspective, they cancel each other out and therefore have no effect on overall profitability. However, financial flows may sometimes be useful to estimate real impacts when market conditions allow them to approximate the social cost or social value of the inputs or outputs involved. Once the real benefits and costs have been identified and valued, the financial flows themselves should not be counted again, as they do not change social welfare and therefore do not influence the NPV.

Table 2.3 presents the impacts of the bridge according to the social approach, while Table 2.4 illustrates the stakeholder approach.

Table 2.3 Benefits and costs of the bridge project (social approach)

Social benefits	Social costs
Value of travel time savings	Construction costs
Reduction of vehicle operating costs	Land acquisition costs
Reduction of costs related to pollutant emissions	Transition costs
Reduction of costs associated with accidents	Shuttle maintenance and operating costs
Elimination of ferry capital and operating costs	Environmental damage caused by the bridge
Residual value of the bridge at the end of the period	
Reduction in the sense of isolation among peninsula residents	
In italics, relevant impacts, but which are not valued, because they are too diffuse and difficult to evaluate.	

The social approach simply ignores transfers and financial flows, while the parts approach documents them. In Table 2.4, we observe a reduction in government subsidies to the Ferry Corporation following the construction of the bridge, which constitutes a financial flow. This reduction in the subsidy generates a benefit for the government and an equivalent cost for the Ferry Corporation. It is important to note that these financial flows offset each other, but they are intrinsically linked to a real impact, namely the reduction in ferry service, the

consequences of which are taken into account by the reduction in capital and operating costs. We will return to these two approaches in Chapter 5.

Table 2.4 Benefitsand costs of the Saguenay bridge project (stakeholder approach)

Benefits	Costs
Users: • Value of travel time savings • Reduction of vehicle operating costs • Reduction of accident costs (partly)	**State :** • Construction and land costs • Shuttle maintenance and operating costs
State : • Government ferry company subsidies cut following service elimination • Residual value • Reduction of accident costs (partly)	**Nearby residents:** • Transition costs
Third party : • Reducing the costs of polluting emissions • *Reduction in the sense of isolation among peninsula residents*	**Third party :** • Negative environmental impacts
Ferry company: • Elimination of ferry capital and operating costs	**Ferry company:** • Reduction in subsidies to the government ferry company, following the elimination of the ferry service
In red, financial flows between parties. *In italics, relevant impacts, but which are not valued, because they are too diffuse or difficult to evaluate.*	

Finally, note that some impacts relevant to a project's CBA may not be monetized because they are diffuse, difficult to quantify, or lack reliable data. In the illustrative example, this is the case for the benefit associated with reducing residents' sense of isolation resulting from limited connectivity to the mainland. Such impacts should nevertheless be identified and included in the cost–benefit tables, even if no monetary value is assigned to them, and they must be taken into account when interpreting the results of the analysis.

2.1.3. Quantify in natural units the impacts on the project horizon

Conceptually, valuing an impact amounts to multiplying:

Impact in $ = Impact (in natural units) x Price or Value (in $ per natural unit)

For example, a dam project produces a quantity of hydroelectricity Q. The benefit of this production corresponds to the product of this quantity (in kWh) and the social value of an additional unit of electricity, i.e., an appropriate "price" ($/kWh). The choice of this price will be examined in the next subsection. At this stage, the task consists of projecting the quantities of impacts in natural or physical units. In the same way, estimating the construction costs of a new dam requires information on the quantities of concrete, labor and other inputs needed. In many projects, technical or financial documents already provide direct cost data. However, these amounts may have to be corrected, because financial costs (expenses) do not necessarily reflect social costs.

Each application relies on a specific set of variables, which makes it difficult to provide more detailed guidance at a general level. In the bridge case study, analysts should project the number of crossings over the analysis horizon under both the reference scenario and the bridge scenario (see Figure 2.2 for an illustration). These projections should be based on historical traffic patterns and explicit assumptions regarding economic and demographic development. The impact of the bridge on traffic volumes is then estimated by comparing these projections with observed outcomes from comparable real-world projects.

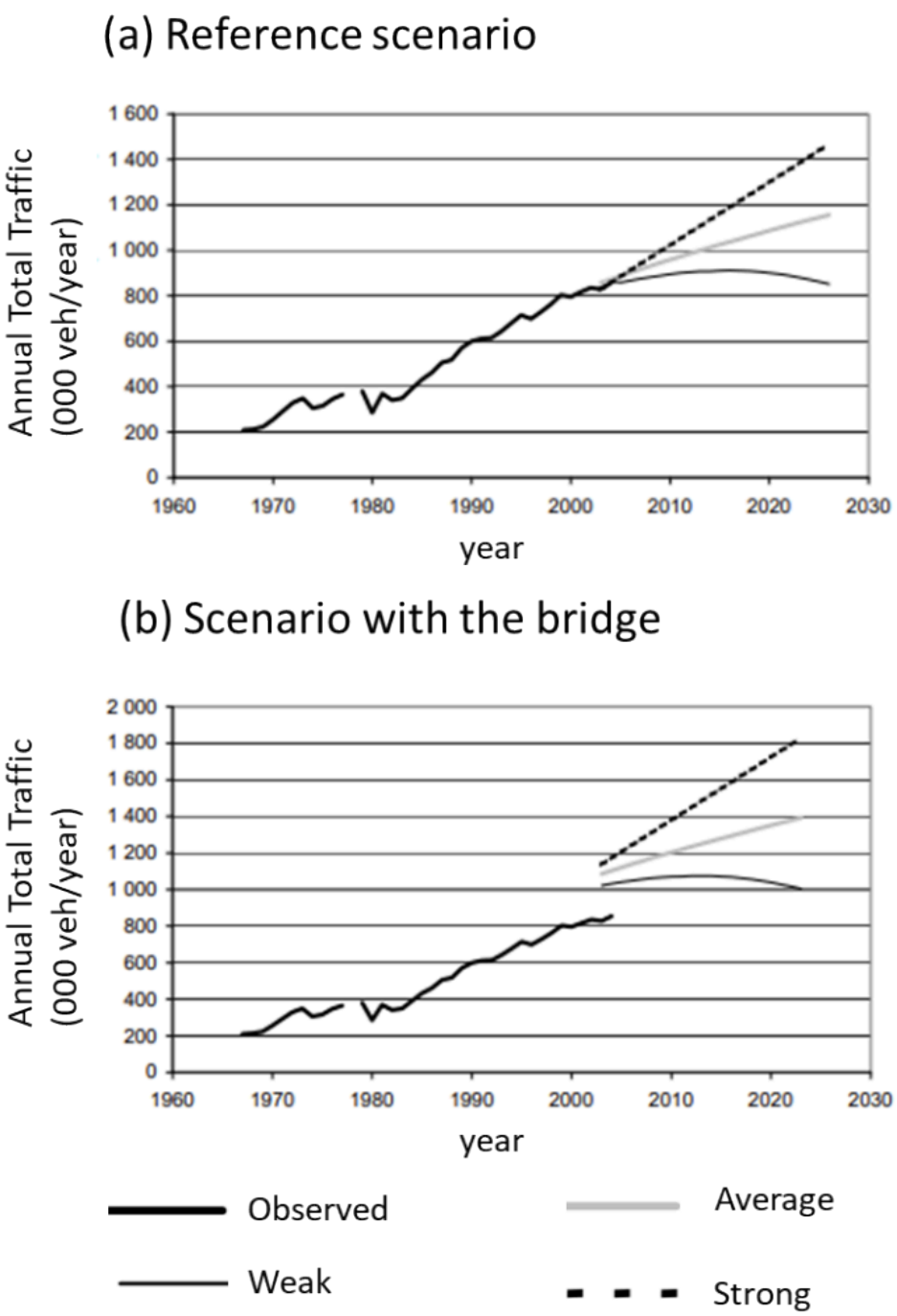


Figure 2.2 Projections of the number of crossings over the Saguenay River in the reference scenario and the scenario with the bridge (source: SNC-Lavalin/Genivar Consortium, 2009, p. 4-62, reproduced with the kind permission of the Ministère des Transports et de la Mobilité durable du Québec, all rights reserved)

Time savings, expressed in hours per year, are obtained by multiplying the average time saved per crossing (30 minutes) by projected annual traffic volume. The monetary valuation of these time savings will be examined in the next subsection.

2.1.4. Valorization of impacts

Once impacts have been quantified in physical terms, the next step is to determine the prices used for monetary valuation. This manual devotes several chapters to this issue. The selected "price" must reflect the **social value** of the output produced or the input used. Under certain conditions, valuation can rely on competitive market prices. In such situations, the calculation is straightforward: multiplying the quantity by the market price is sufficient. For example, valuing the fill stones required to build a new dam could consist of multiplying the market price per ton by the quantity used, which corresponds to the observed expense for that input.

As indicated in Chapter 1, markets are sometimes distorted, and market prices may not accurately reflect social costs or benefits. In these cases, reference or "**shadow**" prices must be used. These consist of correcting market prices to better represent social value. For example, valuing the cement used in dam construction should incorporate the environmental costs associated with its production. Likewise, if the engineering services market is not competitive, the price paid may exceed the social cost of this input, and adjustments must be made accordingly.

Some effects are also intangible or non-market, and therefore lack explicit prices. If a dam disrupts ecosystems, this generates environmental costs, but there is no "market" for ecosystems that indicates the value of a hectare. Part 3 of this manual presents several techniques to establish the social value of non-market goods.

In the bridge case study, time savings for truck travel are directly valued at the gross wage of the drivers, reflecting a market-based measure of opportunity cost. For private car drivers, the value of time depends on the purpose of the trip, since the opportunity cost varies across activities. Travel time to work is valued at the net wage, while leisure travel is valued at a lower amount (see Chapter 16 for more details on time valuation). The benefits of reducing fatal accidents require determining the value of a statistical life.

2.1.5. Discounting impacts

Chapter 6 examines in detail the techniques and formulas involved in discounting. The purpose of discounting is to express impacts that occur at different points in time in a common temporal unit. An impact valued in 2020 dollars cannot be compared directly with one valued in 2040 dollars. Part of this adjustment reflects inflation, i.e., the general rise in prices: ten dollars today does not buy what it did ten years ago. However, discounting primarily incorporates another essential consideration: opportunity cost.

> Discounting accounts for the foregone return associated with allocating resources to a given project rather than to alternative uses.

A discount rate of 3% means that funds invested in the project could earn a 3% return if deployed elsewhere. Discounting formulas therefore imply that a project will yield a positive Net Present Value (NPV) only if its internal rate of return exceeds 3%.

Table 2.5 reports the CBA results for the replacement of a ferry system with a bridge across the Saguenay River. When a 5% discount rate is applied, the project yields a negative net present value (NPV). This indicates that the social benefits generated by the project are insufficient to cover its social opportunity cost, that is, the average return that society forgoes by allocating resources to this project rather than to alternative uses.

Table 2.5 Results of the cost–benefit analysis of replacing the ferry system with a bridge across the Saguenay River

	Current value (2006 $ millions)
Benefits	
Time savings	277.6
Reduced usage costs	5.4
Reduction of pollutant emissions	1.4
Improving road safety	106.3
Avoidance of crossing immobilization and operating costs	148.3
Residual value	75.6
Total benefits	**614.6**
Costs	
Cost of immobilization	637.9
Other costs	66.1
Total costs	**704**
Net present value	**-89.4**

Source: *Adapted from SNC-Lavalin/Genivar Consortium, (2009), pp. 5-14 and pp. 5-15, reproduced with the kind permission of the Ministère des Transports et de la Mobilité durable du Québec, all rights reserved.*

2.1.6 Sensitivity analysis

The parameter values and forecasts required to perform a CBA inevitably involve uncertainty. For example, projecting the number of crossings over a 40-year horizon is inherently uncertain. It is therefore essential to

analyze these risks and assess how the NPV varies with changes in the parameters and forecasts. Three types of sensitivity analysis can be used:

- **Parameter analysis:** NPV is examined by modifying one parameter at a time. The results can be displayed using a tornado diagram, as illustrated in Figure 2.3.
- **Scenario analysis:** Several parameters are modified simultaneously to construct alternative scenarios, such as base, optimistic and pessimistic cases[4].
- **Monte Carlo simulation:** This more sophisticated approach assumes that parameters are random variables drawn from known statistical distributions. By generating a large number of random draws for all parameters, it becomes possible to obtain a statistical distribution for the NPV, including estimates of the probability that the NPV is positive.

In the Saguenay bridge case study, sensitivity analysis was conducted using the parameter approach. It shows, among other results, that the NPV becomes positive if the discount rate is set at 4% or if the projected crossing demand is higher than in the original scenario.

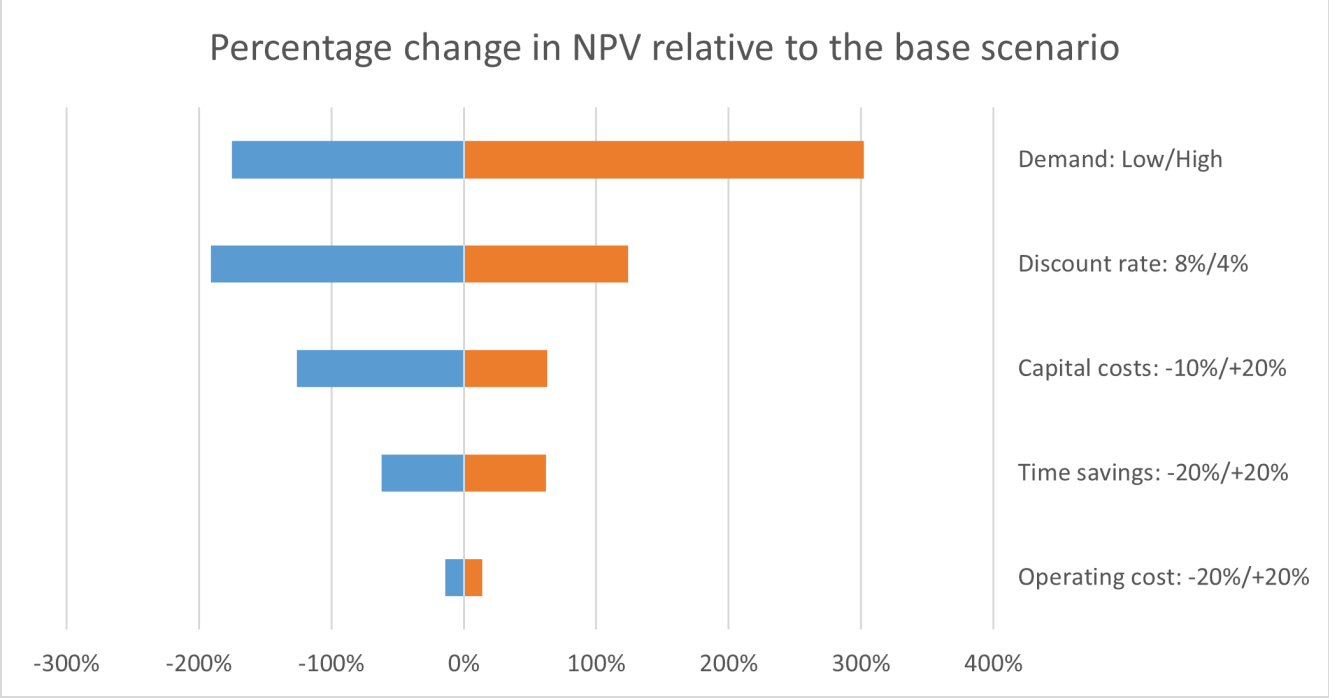


Figure 2.3. Tornado diagram for the sensitivity analysis of the CBA of the Saguenay bridge project (based on Table 5.5, page 5-16 of the SNC-Lavalin/Genivar Consortium, 2009)

4. Note that the notion of "scenario" here differs from that used previously in step 1. Here, scenarios are defined by alternative values of analysis parameters (e.g., different discount rates or different assumptions for the residual value of the project).

2.1.7. Drafting of the report and recommendation

As emphasized earlier, the seven steps described above are intended to guide the analytical process rather than to prescribe the structure of the final CBA report. In practice, the report should present the problem, scenarios, impacts, methods, and results in a clear and coherent manner, with technical details included in appendices when appropriate.

> The report should provide a sufficient level of detail to allow readers to assess the validity of the approach and to reproduce the results.

It must also conclude with a recommendation on the project's social profitability. This recommendation must obviously be consistent with the analytical results[5]. The decision rule depends on the context. When only one option is being assessed, the rule is simple: the project should be recommended if the NPV is positive, meaning that it generates more benefits than costs relative to the reference scenario. When several mutually exclusive options are being compared, or when budget constraints apply, the decision rule is more complex, as explained in Chapter 6.

2.2. Evaluating the quality of a CBA

Evaluating the quality of a CBA begins by identifying who funded the analysis and assessing the credibility of its authors. These elements should be explicitly stated in the report, as they help detect potential conflicts of interest. As in any evaluative process, there is a risk of instrumentalization: the client may expect or request conclusions that justify a decision already made.[6]

The quality of a CBA also depends on the resources devoted to its production. Analysts are sometimes required to produce CBAs rapidly and with limited means. This is not necessarily problematic, since preparing a CBA itself generates costs. When a project is relatively small or when its profitability is clearly established, a concise analysis may be entirely appropriate. Conversely, when a project requires substantial resources and its

5. Although this may seem obvious, it is not always the case in existing studies. For instance, the CBA for the Saguenay Bridge recommends building the bridge even though the NPV is negative in most evaluated scenarios!

6. In the case of the Saguenay Bridge study, the consortium responsible for the analysis was composed of engineering firms that could potentially have played a role in the bridge's construction.

profitability is uncertain, it is preferable to allocate more time and expertise to produce a robust and detailed CBA.

Conducting a CBA can be conceptually and operationally demanding. Unfortunately, there are no binding professional standards, and anyone can undertake a CBA. As a result, the quality of existing studies varies widely. Three types of recurring errors are particularly noteworthy:

1. **Confusion between costs and benefits.** A CBA must adopt a social perspective, meaning that it evaluates impacts on society as a whole. Some studies restrict the definition of society so narrowly that they cease to be CBAs, even though they are presented as such. Worse, these analyses do not always make explicit the spatial horizon they use, adding to the confusion. Some "CBAs" are in fact disguised financial analyses for the organization that commissioned them. In such cases, benefits correspond to revenues and costs to expenditures in the organization's budget. For instance, an analyst working for a finance ministry might estimate the effects of increasing taxes on alcohol and consider only the additional revenue for the ministry as a benefit, ignoring health impacts and the welfare loss for consumers associated with higher prices. The tax is, in fact, a transfer from consumers to the State. Another common mistake is to consider only the impacts on the "customer base" of the organization. For example, a Ministry of Social Affairs evaluating a home-care program for seniors might treat program expenses as benefits and user contributions as costs[7]. In a proper CBA, operating expenses are a cost, and user contributions represent part of the beneficiaries' willingness to pay, i.e., part of the benefits (see Exercise 6).
2. **Double counting** : A common mistake, even among experienced analysts, is counting the same impact twice when it appears in different forms.
3. **Jobs = benefit.** It is often assumed that jobs created by a project are a benefit and job losses are a cost. In the bridge example, this reasoning would imply that jobs created during construction are a benefit, while those eliminated by discontinuing the ferry service are a cost. This reasoning is incorrect because it ignores opportunity cost. The funds invested in building the bridge could have been used elsewhere, thereby generating employment in another sector. Workers mobilized on the project are therefore unavailable for other productive activities. Likewise, workers freed up from the ferry operation can be reallocated to other productive uses in the economy. Jobs created by construction should therefore be treated as a cost of the project, and job reductions from closing the ferry service should be treated as a benefit.

7. See Boardman, Vining and Waters (1993) for a discussion of these two typical erroneous views of CBA.

CBA and macroeconomic conditions

Although jobs associated with a project do not constitute a benefit in a CBA, the project's NPV may still be influenced by prevailing macroeconomic conditions. When unemployment is widespread, the opportunity cost of labor mobilized by the project is lower than when the economy is at full employment. Without the project, some workers might remain unemployed and therefore significantly less productive. In such a context, allocating labor to the project implies a smaller sacrifice of alternative output. We will return to the concept of the "social cost of labor" in Chapter 11.

2.3 Conclusions

This chapter presents a seven-step approach to conducting a CBA. It offers an initial overview of several elements that will be examined in greater detail throughout the manual. The chapter also highlights common errors frequently encountered in CBAs.

Key takeaways

- It is important to clearly define the reference scenario and the scenario comprising the project.
- The CBA time horizon specifies the length of time over which benefits and costs are accounted for. Too short a horizon may result in ignoring long-term effects, but a longer horizon involves more uncertainty.
- If a project asset has a longer life than the analysis horizon, its residual value should be considered as a benefit of the project.
- The spatial horizon determines the boundaries of the reference community. Ideally, the perspective should be universal. At the very least, it should be broader than that used in a private profitability study.
- The CBA must account for impacts on relevant stakeholders, i.e. those who experience

significant impacts.

- A CBA should focus on the most important primary effects. Some secondary effects may need to be included, but it is important to ensure that this does not lead to double counting. Induced effects should most often be ignored.
- Discounting allows us to take into account the opportunity cost of resources invested in a project.
- Common mistakes in CBAs are:
    - Double counting;
    - Too limited a definition of stakeholders which leads to confusion between benefits and costs;
    - Associating jobs created with a benefit and job losses with a cost.

Exercises

(*) Indicates that the solution is available.

(**) Indicates that the solution is available with restricted access

1. (**) A municipality is considering building a biomethanization plant to treat its residents' organic waste. The construction cost is estimated at $100 million. The municipality will pay for the work, but will receive a federal government grant equal to 25% of the construction cost and an equivalent grant from the provincial government. The present value of the plant's operating costs, including the costs of collecting organic matter, is estimated at $80 million. The plant will produce natural gas that will be sold on the renewable natural gas market, generating expected revenues of $37 million. Redirecting organic waste to the biomethanization plant will save the municipality $13 million on its landfill bill. The plant will also help reduce greenhouse gas emissions, which represents a benefit estimated at $3 million. The inconvenience associated with sorting household waste for citizens has been estimated at $1.5 million. All values presented are discounted data over the duration of the project. For simplicity, it is assumed that there are no other impacts. Based on these data, perform a CBA of this project using the part-by-part approach and successively adopting the following spatial horizons:
    1. Universal;
    2. Provincial;
    3. Municipal.
2. The project under consideration involves the renovation and expansion of an airport. For the implementation of a national CBA, who do you consider to be the relevant stakeholders?

3. (*) A project aims to improve the public transit offering in a transportation corridor, which would result in time savings for users. These time savings are taken into account in the project's CBA. The project would also increase property values along the corridor. Should this impact be included in the project's CBA? Justify your answer.
4. (*) A project involves moving all of a city's citizen support services to a new building. The city will have to pay one million dollars to a local company that will be responsible for constructing the building. You are tasked with performing a CBA of this project with a colleague. She suggests ignoring this million-dollar amount in the CBA, since it is a transfer between stakeholders: the municipality bears a cost of one million dollars, while the contractor receives a benefit of one million dollars. What do you think of your colleague's argument?
5. (*) The bridge project to replace the ferry system will result in job losses for employees of the Ferry operator. Using Table 2.3, examine how this impact should be taken into account if we add "ferry workers" as a stakeholder.
6. (*) A regional health organization is considering setting up a home care service for seniors. The organization will receive a government grant of $2 million per year for this service. Personnel costs are estimated at $3 million per year. In addition, there are $200,000 per year in expenses for supplies and equipment. Beneficiaries will have to pay part of the cost of the services, their contributions being estimated at $300,000 per year. The remainder is covered by the organization's budget. The gross benefits for users, or their maximum willingness to pay (MWP), are estimated at $4 million per year. Complete:
    1. A financial analysis from the perspective of the regional health organization;
    2. An analysis that adopts solely the point of view of the interests of the elderly;
    3. A CBA with a regional perspective;
    4. A CBA with a national perspective.

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3.

PRIVATE PROFITABILITY AND SOCIAL PROFITABILITY

Motivation and learning objectives

You are an analyst at the Ministry of Health and have been asked to conduct a CBA of a tax on sugary drinks (carbonated beverages, energy drinks, and colas). Before carrying out the analysis, it is essential to identify the economic rationale that could justify such a measure. In other words, you must first understand why the status quo – a free market without taxation – does not naturally lead to a socially optimal situation. Which market imperfections imply that a tax would increase collective welfare? Why is there a gap between private and social choices?

These questions should be examined early in the CBA process to establish an appropriate analytical framework. In some cases, the underlying economic issues may already have been analyzed as part of a regulatory impact assessment or an opportunity study.

This chapter presents an overview of the main economic reasons that create a divergence between the private profitability and the social profitability of a project. [1] Such divergences frequently justify government intervention, which may take various forms. The authorities may authorize or prohibit a project, subsidize it, or take full responsibility for it. In other contexts, they may introduce incentives to modify private behavior, as in the case of a tax on sugary drinks.

The chapter briefly outlines the main roles of the state and its shortcomings. However, it does not examine in detail the different types of government intervention or their respective advantages and disadvantages. For an in-depth discussion, see Weimer and Vining (2017).

1. The technical analysis of these issues will be addressed in Part 2.

To conclude, we introduce the distinction between commercial and non-commercial sectors, as well as the classic typology of goods and services. These classifications help the analyst identify the sources of divergences between private and social profitability.

By the end of this chapter, you will be able to:

1. Analyze the economic reasons behind divergences between private and social profitability
2. Understand the roles of the state and its potential failures
3. Identify the nature of the goods and markets affected by a project

3.1 Sources of divergence between private profitability and social profitability

Two broad categories of factors can explain a gap between private choices and socially optimal choices:

- Classic market failures
- Failures in private decision-making arising from agents' limited rationality

3.1.1 Classic market failures

In the neoclassical framework, a **perfectly competitive market** is characterized by [2] :

- Minimal state participation : the role of the state is limited to sovereign functions (e.g., protection of rights and security). Private agents therefore enjoy a high degree of freedom in market transactions.
- Pursuit of individual interest : agents are rational. Consumers maximize their well-being (or utility) subject to their budget constraint, while firms optimize profits given their technological constraints.
- Competition : it keeps prices at competitive levels, promotes efficiency by pushing less productive firms out of the market, and encourages the entry of new, more efficient players.
- Competitive prices : they act as a coordination signal, aligning supply and demand.

The key advantage of perfect competition is that, under certain conditions, it ensures **an efficient allocation**

2. Chapter 4 presents the functioning of a competitive market in more detail.

of resources. All socially desirable gains from exchange are realized, and the **social welfare** generated by a given good or service is maximized.

Several imperfections can lead to **market failures** and result in a suboptimal allocation of resources. The main classic failures are the following:

- **External costs**, or negative externalities, arise when the actions of an agent generate costs for other agents without full compensation. For example, gasoline-powered cars produce air pollution that adversely affects people living near busy roads. Motorists do not bear the full costs they create, which leads to excessive traffic. In such a situation, the private cost associated with automobile use is lower than the social cost.
- **External benefits**, or positive externalities, occur when an agent generates a benefit for others without receiving full compensation. For instance, a firm investing in research and development may discover a more efficient technology, but faces the risk that other firms will imitate it, limiting its ability to fully benefit from the innovation. In this case, the private benefit is lower than the social benefit.
- **Public goods** and services are goods that are consumed collectively, such as street lighting. Markets alone generally cannot provide them adequately in terms of quantity or quality, because it is difficult to charge users based on the individual benefits they receive (see Section 3.3). For this reason, the private profitability of providing a public good is lower than its social profitability.
- **Market power** arises when the number of suppliers of a good or service is limited. Reduced competition decreases the volume of trade and maintains prices at high levels, as in monopoly or oligopoly markets. In these settings, the social profitability of expanding trade is greater than the private profitability. In other cases, it is the number of buyers that is limited (monopsony or oligopsony). A dominant buyer can impose prices that are socially too low. For example, when a single firm is the main employer in a region, it may pay wages below the competitive level.
- **Information problems** occur when essential information about a good or service is not accessible to all market participants, which prevents the market from functioning efficiently. For example, without regulation, consumers may struggle to obtain reliable information about the composition of food products. This uncertainty can reduce trade. In other situations, such as certain insurance markets, the absence of credible information can even prevent a market from emerging altogether.

In the presence of market failures, governments may intervene to increase collective welfare. Table 3.1 illustrates various types of interventions aimed at correcting market distortions. From the perspective of a CBA, the existence of failures has two main implications:

- The project may consist directly in evaluating the benefits and costs of an intervention designed to correct a market failure. For example, a CBA may assess the efficiency of an eco-tax on automobiles.
- The project may pursue different objectives, but the analysis must still account for existing distortions

when estimating benefits and costs. For instance, the widening of a motorway must take into account the external costs associated with additional traffic that the project may induce.

These analytical issues will be discussed in more detail in Part 2.

Table 3.1 Classic market failures, possible interventions and examples

Failures	Interventions	Examples
External costs	• Objective: internalization of external costs • Measures: taxes, exchangeable permit system, standards	• Ecotaxation (carbon tax, waste pricing) • Cap-and-trade system for emissions rights (Carbon market)
External benefits	• Objective: internalize external benefits • Measures: subsidies, legal protection of the benefits generated	• R&D Grants • Free vaccination • Patent Law
Public goods	• Objective: to ensure funding to achieve the optimum level and quality • Measure: funding by public authorities	• Support for national defense, public lighting, parks • Ecosystem Protection Non-Profit Grant
Market power	• Objective: to prevent the exercise of market power • Measure: Competition Law	• Refusal of the anti-competitive merger • Measures to promote competition in mobile telephony
Information problems	• Purpose: To provide verifiable information or limit the possibilities of exploiting an information advantage • Measure: obligation to participate, information to be provided, monitoring of professional practices	• Universal health insurance • Obligation to display nutritional values • Professional Order of Dentists

3.1.2 Intrapersonal externalities

A project can also increase collective welfare by correcting individual decisions that are not fully rational.

Neoclassical analysis assumes that economic agents (individuals and organizations) are perfectly rational: they seek to maximize their well-being and are able to process information in a purely logical manner. In other words, they do not behave in a systematically irrational way or against their own interests.

Recent developments in behavioral economics have shown that systematic and predictable deviations from this rationality hypothesis exist [3]. Psychological, cognitive, emotional, cultural, and social factors influence economic decisions, beyond a simple comparison of private costs and benefits. Rationality is therefore limited, notably due to three types of biases or reasoning defects:

- Cognitive biases, which are systematic errors in the perception and processing of information
- Emotional biases, which stem from emotional reactions
- Moral biases, which lead individuals to make decisions that are personally non-optimal for ethical or moral reasons

Behavioral economics has mainly focused on the effects of cognitive biases.

Intrapersonal externalities, or **internalities**, refer to situations where an agent makes a decision today that generates a future cost or benefit without taking it fully into account, due to cognitive limitations.

Cognitive biases can create a gap between the subjective (or biased) profitability of a decision and its objective profitability. For example, a young person who drops out of school may underestimate the long-term costs of this choice because of **present bias**, meaning a tendency to overvalue short-term benefits (earning a salary immediately by leaving school) compared to long-term gains (earning a higher salary in the future thanks to a degree). This bias partly explains why many individuals tend not to save sufficiently for retirement.

These divergences between subjective profitability and real profitability create opportunities for interventions aimed at correcting agents' "irrational" choices, thereby improving their individual well-being and, by extension, collective welfare. For instance, governments may require compulsory schooling until age 18. In such cases, the State intervenes to protect individuals from decisions that may harm themselves, with the inherent risk of introducing paternalistic policies that restrict personal freedom and reduce individual responsibility.

3. For an introduction to these developments, see, for example, Cartwright (2024).

A very large number of cognitive biases (more than 200) have been identified and classified into different typologies [4]. Table 3.2 presents a few illustrative examples.

Table 3.2 Some examples of cognitive biases

Bias	Meaning
Optimism bias	Tendency to underestimate risks and overestimate favorable contingencies.
Present bias	Tendency to overweight immediate benefits over benefits that are more distant in time. See also the section on hyperbolic discounting below.
Status quo	Tendency to prefer the status quo.
Loss aversion	Tendency to overweight losses relative to benefits, even if they are comparable.
Planning fallacy	Tendency to systematically underestimate the time needed to complete a task.
Salience bias	Tendency to give more weight to certain aspects that are more visible and to ignore others, even if they are of comparable importance.

Rational or irrational dependencies?

Although it is now universally acknowledged that tobacco is deadly, many young people still begin smoking. According to the theory of rational addiction (Becker and Murphy, 1988), the consumption of an addictive substance can be interpreted as a fully rational decision. Individuals anticipate that their current consumption will alter their future preferences in favor of greater consumption. Under this



4. For a list of cognitive biases, see https://fr.wikipedia.org/wiki/Biais_cognitif

interpretation, there is no reason to intervene to protect the individual, since the decision is consistent with his or her expected utility.

However, it is also possible that the individual lacks key information when deciding to smoke, which justifies informational or educational campaigns (a classic market failure related to information). It is also possible that the person is subject to present bias and gives insufficient weight to the long-term consequences of smoking relative to its immediate benefits. In that case, the initial decision is irrational in the sense that the individual will ultimately regret it. A preventive intervention may therefore improve the individual's own well-being.

Beyond cognitive biases, behavioral economics more broadly questions the stability of preferences and the mechanisms underlying decision-making, as illustrated by the topics briefly discussed below.

Endogenous preferences

Traditional economic analysis assumes that preferences are stable and independent of context. However, many public interventions explicitly or implicitly aim to influence preferences through awareness campaigns, ethics education, or rehabilitation programs for offenders. An unresolved issue is whether these interventions truly redefine preferences or simply alter the costs and benefits associated with certain choices. For example, how do awareness campaigns against violence toward women operate? Do they modify the preferences of violent men or of victimized women? Do they make perpetrators more aware of the costs of their actions? Do they act by reinforcing social norms?

Cognitive shortcuts

It appears that many decisions are made using cognitive shortcuts or judgment heuristics, rather than through a systematic comparison of costs and benefits. In practice, individuals rely on two decision-making systems (Kahneman, 2012). System 1 operates quickly, automatically, and intuitively, and requires little effort. It is typically used for routine or simple decisions (e.g., which route to take to go to the grocery store). While System 1 often leads to acceptable decisions, these may not be optimal and are more susceptible to cognitive biases. System 2 operates more slowly and analytically, requiring greater cognitive effort. It is mobilized for more complex or unusual decisions (e.g., purchasing a house). Although System 2 is more deliberate, it is not immune to biases.

Decision making under uncertainty

Risk perception and decision-making under uncertainty have been widely studied. According to classical expected utility theory, individuals facing uncertain outcomes are assumed to apply sufficiently complex statistical reasoning to arrive at a rational decision. Experimental evidence, however, shows that this framework does not always accurately explain observed choices. Individuals tend to overestimate small or unusual risks and

underestimate larger but more familiar ones [5]. They also tend to be loss averse, meaning that the impact of a loss exceeds that of an equivalent gain. Losing 100 dollars has a greater effect on well-being than gaining 100 dollars (loss aversion bias). Kahneman and Tversky's (1979) prospect theory provides a framework for explaining these patterns.

Intertemporal choices[6]

When a decision involves benefits and costs occurring at different points in time, individuals must weigh the present against the future. In CBA, this weighting is done through discounting, using a constant discount rate, such that depreciation per unit of time is constant. Experimental studies, however, indicate that individuals do not necessarily apply a constant rate. They tend to apply a very high discount rate for periods close to the present and lower rates for longer horizons. For example, an individual who prefers receiving 90 000 dollars today rather than 100 000 dollars in one year may still prefer 100 000 dollars in two years to 90 000 dollars in one year. This implies a discount rate of roughly 11 percent for the present decision, but a lower implicit rate for the longer horizon.

One explanation is that individuals use hyperbolic discounting, meaning the discount rate decreases with the length of the period considered. This produces a bias in favor of the present and generates inconsistent choices. After one year, the same individual may regret choosing to wait another year to receive 100 000 dollars instead of accepting 90 000 dollars immediately. Certain corrective interventions may therefore be justified. The discounting mechanism may also vary depending on the magnitude of the amounts involved or differ between losses and gains. Hyperbolic discounting may, for example, explain procrastination among students preparing an end-of-semester project.

School dropout

5. See, for example, Prelec (1998).

6. See Weimer (2017) for more details on these aspects.



A large body of empirical research shows that education generates substantial private and social returns. Individuals with higher levels of education tend to earn higher incomes, face lower unemployment risks, and enjoy better health outcomes, while societies benefit from higher productivity, lower crime rates, and reduced reliance on public assistance. Despite these well-documented benefits, a significant share of students in many countries leave school before completing upper secondary education.

Is the decision to drop out of school rational? Should governments intervene, and if so, how?

For some individuals, dropping out may be a rational choice if the effort, time, and costs required to complete a degree exceed the perceived value of future benefits, such as higher earnings. However, several mechanisms can also lead individuals to underinvest in education relative to what would be socially desirable:

- Incomplete information about the long-term consequences of dropping out
- Present bias: education requires current effort for uncertain or distant gains
- Lack of self-control (e.g., procrastination detrimental to academic performance)
- Imperfect optimization: settling for a minimum-wage job

If the level of dropout is indeed excessive, several interventions are possible, including:

- Compulsory schooling up to a specified age
- Reducing the cost of education
- Information sessions about the long-term benefits of graduation
- Activities encouraging young people to reflect on their future plans
- Immediate rewards (financial or non-financial), such as providing compensation when students undertake specific learning tasks or paying them to remain in school

Evidence suggests that some of these interventions have clear positive impacts (e.g., compulsory schooling), whereas the effectiveness of others remains uncertain (e.g., monetary incentives [7]).

7. See Levitt et al. (2016), Lavecchia, Liu, and Oreopoulos (2016).

Other elements can make preferences more complex than those used in classical models of decision making. For example, individuals may have interdependent preferences, meaning that an individual's well-being depends, positively or negatively, on the well-being of others. Preferences may also depend not only on outcomes but on the process through which these outcomes are achieved. Laboratory experiments show that individuals exhibit aversion to inequity: an efficient solution may be rejected solely because it results from a process perceived as unfair [8].

Bounded rationality also raises questions about the use of the **maximum willingness to pay (WTP)** or the **minimum willingness to receive (RTR)** as measures of impacts in CBA. For instance, can we legitimately use the WTP of a person struggling with alcohol addiction to assess the benefits of their consumption? These issues are examined again in Chapter 10.

3.2 The roles of the State and its failures

As mentioned in Chapter 1, CBA can be applied to projects that are entirely undertaken by private actors. However, when there is a gap between private and social profitability, government intervention often becomes necessary. As illustrated in Figure 3.1, Musgrave (1959) distinguishes three broad economic functions of the State.



Figure *3.1 The three economic functions of the State*

CBA is particularly relevant when the goal is to improve economic efficiency, especially when markets fail or when individual decisions are biased.

8. See, for example, the dictator game or the ultimatum game.

Nevertheless, CBA can also be used to evaluate projects whose primary objective is to modify the distribution of income or access to essential goods. For instance, a CBA may be useful to compare different measures designed to improve housing access for vulnerable populations. In such cases, however, the evaluation criteria remain centered on economic efficiency.

State intervention can enhance social efficiency by using the State's coercive power. This enables the financing of public goods through mandatory contributions, a function that markets cannot effectively ensure. In addition, the State can internalize external costs through taxation or subsidize activities generating external benefits.

The State may also intervene to counter cognitive biases that harm individuals. Insights from behavioral economics make it possible to improve public policy design by explicitly accounting for decision-making biases. The **theory of nudges**, or "libertarian paternalism," developed by Thaler and Sunstein, seeks to influence individual behavior without coercion or sanctions, simply by modifying the architecture, context, or information surrounding a decision [9]. In practice, this approach uses cognitive biases to guide individual choices. For example, rather than requiring an individual to check a box to consent to organ donation, the default rule can require individuals to uncheck the box to refuse. The policy exploits inertia to promote socially beneficial outcomes.

However, it is essential to recognize that **the State is also subject to failures**. It does not necessarily behave like a benevolent social planner maximizing collective welfare. **Public choice theory** suggests that public interventions may be motivated by politicians' desire for re-election, by individual interests within the civil service, or by the influence of pressure groups (clientelism, corruption, or influence peddling). The State is therefore not a unitary actor pursuing a collective objective, but rather a set of agents with heterogeneous interests. State action can therefore be diverted (**regulatory capture**) to serve particular or sectoral interests.

Clientelism often arises because certain interventions generate concentrated benefits for a small group (for example, a specific industry or profession), while imposing diffuse costs on a large number of individuals (consumers or taxpayers). This asymmetry explains the lobbying efforts made by small groups of beneficiaries and the weak reaction of the many dispersed losers.

Like any large organization, the public administration faces coordination challenges, incentive problems, and information frictions. Moreover, public officials and analysts are themselves subject to cognitive biases. CBA practitioners are not immune to these effects, as illustrated in the box on optimism bias and CBA.

9. For more details, see Thaler and Sunstein (2021).

Clientelism often arises when a public intervention generates **concentrated benefits** for a small group (for example, a specific industry or professional association), while spreading the associated costs across a very large number of agents (consumers or taxpayers), who therefore bear **diffuse costs**. This asymmetry explains why the small group of beneficiaries has strong incentives to lobby in favor of the intervention, whereas the numerous dispersed losers have little motivation or capacity to mobilize collectively.

Like any large organization, the public administration faces coordination problems, incentive challenges, and information frictions. Its members are also subject to cognitive biases. Analysts conducting a CBA are not immune to these limitations, as illustrated in the box on optimism bias and CBA.

State failures have two implications:

- The first is normative: it may be preferable not to intervene to correct a **market failure** when state imperfections risk worsening the situation. In such cases, the cure may be worse than the disease.
- The second is positive: public authorities may intervene in the economy without a solid economic justification. For example, a government may invest in a project to satisfy a pressure group or for electoral reasons.

Even when a public intervention is subject to a CBA, there remains a risk — as mentioned in Chapter 1 — that the analysis will be instrumentalized. To ensure that a project passes the CBA test, benefits may be consciously or unconsciously overstated, costs understated, and risks minimized or ignored. Ensuring neutrality in the evaluation process and adhering to best practices are therefore critical for maintaining the credibility of a CBA.

CBA and optimism bias

The reliability of cost and benefit assessments is often problematic. Based on an analysis of 2,062 public projects across different countries and sectors, Flyvbjerg and Bester (2021) demonstrate the existence of systematic biases: costs tend to be underestimated and benefits overestimated. On average, cost underestimation is approximately 40 percent, while benefit overestimation is about

15 percent. According to these authors, these patterns can be explained by optimism or overconfidence bias, which leads analysts to ignore or underestimate risks. In practice, project planning frequently reflects a form of "magical thinking," assuming that the project will unfold smoothly even though most comparable initiatives encounter unforeseen complications. This phenomenon is also known as the "planning fallacy," referring to a systematic tendency to underestimate the time required to complete a task.

To mitigate these biases, Flyvbjerg and Bester (2021) propose adjusting estimated costs and benefits using a correction factor based on empirical data from comparable projects, a method known as Reference Class Forecasting. In the United Kingdom, such adjustments are applied systematically, particularly during the early stages of planning. For example, it is recommended that estimated rail project costs be increased by 66 percent during initial planning (De Reyck et al., 2015). These issues are discussed again in Chapter 19.

3.3 Characterize the markets and goods affected by a project

In practice, it is often useful to characterize the markets affected by a project and to understand the nature of the goods and services impacted.

3.3.1 Commercial sector and non-commercial sector

Modern economies encompass a wide diversity of ways to produce and exchange goods and services. Within this diversity, we can schematically distinguish two broad sectors:

- **The market sector**: includes economic activities involving goods and services exchanged for remuneration. In this sector, prices are relevant signals that shape the decisions of buyers and sellers. Supply is generally provided by for-profit firms, although other organizational forms may also participate (such as state-owned enterprises or non-profit entities).
- T**he non-market sector**: concerns goods, but especially services, that are provided free of charge or at prices that are not economically significant. These activities are delivered by public administrations or non-profit organizations, and sometimes also by for-profit firms. Their financing relies on donations, voluntary work, subsidies, or taxation.

The boundary between these two sectors is often blurred and evolves across societies and historical periods. Each sector contains a multitude of "markets" in which individuals, for-profit firms, non-profit organizations, and different incarnations of the State participate to varying degrees. The boundary between the market and non-market sectors, and the relative importance of different types of organizations in any given market, can be explained by:

- Historical factors
- Political choices
- The specific advantages and disadvantages of each organizational method
- The nature of the goods and services involved

For example, alcohol sales belong to the commercial sector, yet in many jurisdictions they are subject to significant state involvement, sometimes through public monopolies, often for historical or political reasons. More recently, some governments have chosen to legalize and distribute cannabis through state-controlled monopolies, while others have opted for privately operated but regulated distribution systems. These institutional differences reflect contrasting assessments of the relative merits of market-based organization versus direct state control.

Instead of using a descriptive typology such as the distinction between the market and non-market sectors, it is also possible to classify modes of economic organization according to their degree of centralization or decentralization. The free market is an example of a decentralized organizational model in which agents operate with a high degree of autonomy and respond to price signals. By contrast, the State often relies on centralized organizational models based on hierarchy and authority, as illustrated by the education or health care sectors.

3.3.2 The Ostrom and Ostrom classification

Belonging to the market or non-market sector depends partly on the nature of the goods and services, since their characteristics influence the failures of private markets. Ostrom and Ostrom (1977) propose a classification based on two dimensions:

> **Rivalry in consumption**: to what extent does the consumption of a good or service by one agent prevent its consumption by another agent?

An apple is a fully rival good: my neighbor cannot consume the apple that I have eaten. Radio waves, air

quality, or knowledge display weak or no rivalry: one person's use does not diminish another person's ability to enjoy the same resource.

> **Excludability**: to what extent is it possible to exclude an agent from using or consuming the good or service?

For an apple, exclusion is achieved through the payment of a price for ownership. In normal conditions, exclusivity is easy to enforce. In contrast, some goods make exclusion costly or difficult. The owner of a large forest estate must incur significant costs to prevent intrusions. Likewise, protecting an innovation from imitation may be expensive and imperfect. In extreme cases, exclusion is practically impossible: once produced, everyone may benefit from the good. For example, a country that reduces its greenhouse gas emissions generates benefits for the entire planet, without being able to monetize this positive externality. The degree of excludability therefore depends on a combination of technical, legal, and political factors.

Figure 3.2 presents four categories of goods based on these two dimensions. Private goods or services combine high excludability and high rivalry. At the opposite end, pure public goods display low excludability and low rivalry. Between these two poles, impure public goods have either:

- high rivalry and low excludability, or
- low rivalry and high excludability.

It is important to emphasize that rivalry and excludability lie on continua, meaning that many goods occupy intermediate positions. Highways are an illustrative example: they provide a service with low rivalry when traffic is light but become rival during periods of congestion. Such goods are known as "congestible services." User exclusion is technically possible through toll systems, but may be costly to implement.

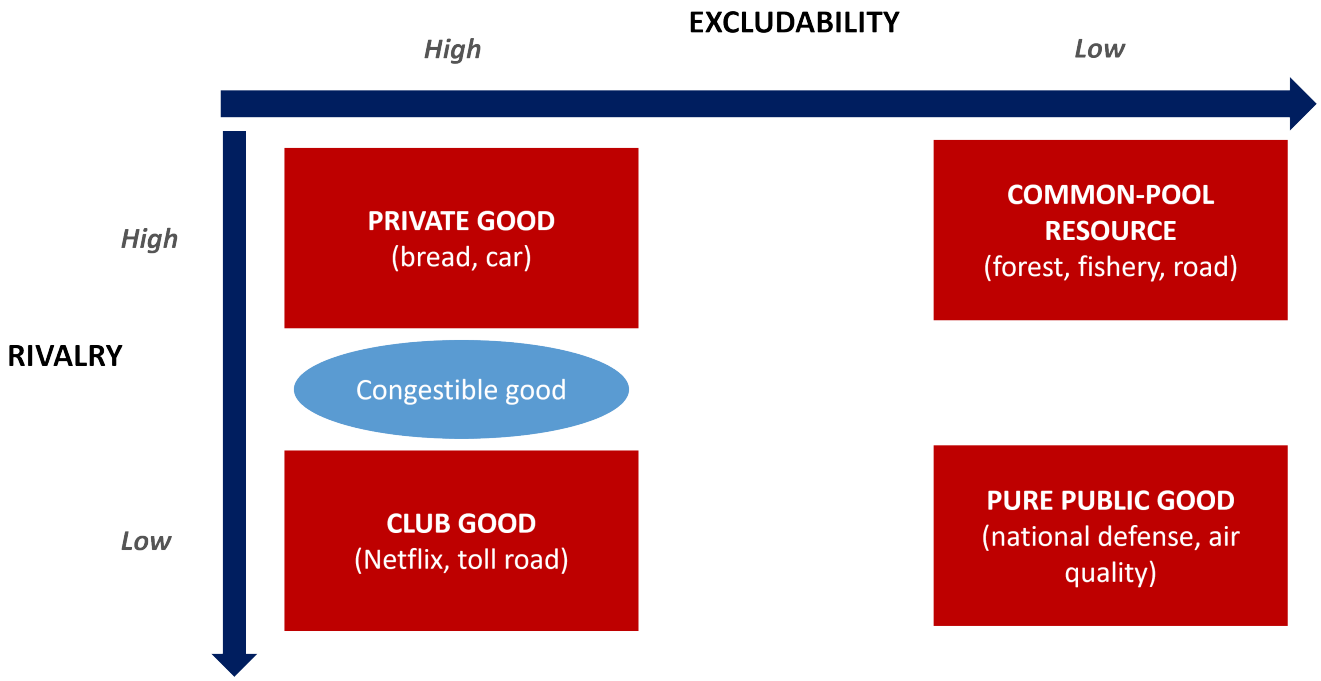


Figure 3.2 Classification of goods and services

The nature of a good, particularly its degree of excludability, helps determine the extent to which market mechanisms can adequately produce it. A pure public good generates substantial external benefits because no one can be excluded from enjoying it and everyone has access to the same quantity and quality. A for-profit firm therefore has little incentive to supply such a good, since users cannot be charged for access. In these situations, government provision or financing is often required.

Similarly, common goods are associated with external costs that may require government intervention to limit access to the resource. **The tragedy of the commons** (Hardin, 1968) illustrates the risks of overexploitation when access is uncontrolled. For example, a fishing boat considers only its private costs but ignores the costs it imposes on others. By reducing the quantity of fish available, it increases the operating costs of other boats. As a result, the social cost of its fishing activity exceeds its private cost. Without regulation, the outcome is excessive entry into the market, excessive fishing effort, and a risk of resource depletion or extinction.

Impure public goods may be supplied either by the market sector or the non-market sector, depending on the circumstances. Likewise, some private goods may fall within the non-market sector. Education is often organized as a non-market service, even though it can be described as a private good: excludability is technically possible and there is some rivalry in consumption. However, education generates significant external benefits that may justify a non-market mode of provision. In addition, education is frequently considered an essential service that should be accessible on a universal basis.

3.4 Conclusions

Key takeaways

- Divergences between private profitability and social profitability may arise from market dysfunctions or from the limited rationality of economic agents.
- Classic market failures include: (i) external costs and benefits; (ii) public goods; (iii) market power; and (iv) information asymmetry among market participants.
- Intrapersonal externalities refer to situations in which cognitive biases lead individuals to make decisions that are contrary to their own long-term interests, possibly justifying intervention by public authorities.
- The State has three main economic functions: (i) promoting economic efficiency; (ii) improving equity; and (iii) stabilizing economic fluctuations. CBA primarily contributes to the function of improving economic efficiency.
- The State is able to finance activities through mechanisms other than market prices, which gives it an advantage in the provision of public goods. It also has the power to internalize externalities, limit market power, or influence individual choices.
- The State is not exempt from failures, which may result from information asymmetries, the influence of pressure groups, electoral constraints on politicians, or the cognitive biases of its members.
- Economic activities can be organized in diverse ways, which can be grouped into the market and non-market sectors.
- The commercial sector operates according to a commercial logic in which prices generally cover costs. In the non-commercial sector, goods and services are provided free of charge or at prices that reflect only a portion of their cost.
- The nature of goods and services helps determine how activities are organized and whether market failures are likely. Two key dimensions matter: (i) rivalry in consumption and (ii)

excludability. The lower the rivalry and excludability of a good or service, the harder it is for a free market to provide it efficiently.

Exercises

(*) Indicates that the solution is available.

1. (*) For each of the projects below, discuss the economic justifications for government intervention:

    - Smoking prohibited in public places;
    - Investment in new combat helicopters;
    - Grants for R&D activities;
    - Construction of a bridge;
    - Public transport subsidy;
    - Ban on non-tobacco flavors in vaping products;
    - Provide social housing;
    - Certification of organic products;
    - Obligation to wear a helmet when cycling;
    - Tax on sugary drinks.

2. (*) For each of the following goods and services, discuss its nature according to the Ostrom and Ostrom classification, the organization of its production (market, non-market) and any possible distortions.

    - Motor vehicles;
    - A dose of flu vaccine;
    - Oil;
    - The information;
    - Internet services;
    - Film production;
    - Pesticides;
    - Medical care;
    - Dental care.

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4.

THE TOOLS OF MICROECONOMICS

Motivation and learning objectives



A museum is planning a temporary exhibition with a total cost of 2 million dollars. The organizers anticipate 300,000 visitors and plan to charge an admission fee of 5 dollars per person. To finance the project, the museum is applying for a government grant. As an analyst at a public funding authority, you are tasked with reviewing the CBA of this project, prepared by an intern under your supervision. Here is the summary of the intern's analysis:

Table 4.1 Benefits and costs of exhibition

Impact	Value in millions of dollars
The advantage for visitors	1.5
Intangible benefits (positive external effects, tourism, etc.)	0.1
Total cost of the exhibition	2
VAN	-0.4

The intern concludes that this project is not socially profitable.
What is your assessment of this conclusion?

The tools presented in this chapter will help you evaluate your intern's analysis.

Conducting a CBA requires an appropriate analytical framework in order to avoid major errors. This framework is built using basic tools from microeconomics. At the end of this chapter, you will be able to:

1. Understand and use the supply and demand model
2. Calculate the gross and net benefits to consumers from the demand curve
3. Calculate the gross and net benefits to producers from the supply curve
4. Predict changes in the equilibrium of a competitive market following a demand or supply shock

This chapter reviews several basic concepts of microeconomics [1] that are directly relevant to CBA. We begin with demand, which allows us to measure the gross and net benefits derived from consuming a good or service. We then present several foundational notions of cost, followed by the concept of supply, which determines the operating profit generated by a good or service. Next, we consider the case in which a good or service is exchanged in a market operating under pure and perfect competition. The interaction between supply and demand determines both the equilibrium price and the equilibrium quantity. This framework will enable us to assess the gains from exchange and the way they are shared between buyers and sellers. Although simple, this model already provides a useful way to conceptualize the impacts of certain projects. It will also serve as a foundation for the analysis of more complex situations, which we develop in Chapters 7 to 12.

4.1 Consumer demand and surplus

A key tool for valuing the impacts of a project is the demand curve, since it allows us to measure the value or benefit derived from the consumption of a good or service by consumers, as we will demonstrate later. The term "good" refers to both material goods and services.

1. Introductory microeconomics textbooks provide a detailed presentation of these concepts. Greenlaw and Shapiro (2017) and Hutchinson and Taylor (2017) are available in open access.

The demand for a given good expresses the relationship between the quantity purchased by a consumer and several determinants, including the price of the good, the consumer's disposable income, the price of other goods, and a set of variables affecting preferences.

Formally, demand can be represented by the following mathematical function:

$$Q^D = Q^D(P, R, P_a, X)$$

Q^D is the quantity demanded, P the price of this good, R is disposable income, P_a is the price of other goods (substitutes or complements in consumption) and X refers to other variables that influence preferences.

Quantity demanded Q^D is a flow that is expressed in physical units per unit of time (for example, tons per year). Price is expressed in value per physical unit (for example, dollars per ton).

In practice, demand results from the trade-offs a consumer makes between meeting needs and respecting a budget constraint. A consumer seeks to maximize a utility function that reflects his preferences, subject to limits given by disposable income and the prices of goods.

The demand curve refers specifically to the relationship between the quantity demanded and the price of a good, all other things being equal. It therefore describes the relationship between Q^D and P, assuming all other variables remain constant.

The law of demand states that, with some exceptions, the quantity demanded decreases when the price increases. This relationship reflects the fact that the additional utility obtained from consuming an extra unit of a good tends to diminish as the quantity consumed increases, a phenomenon known as the effect of satiety.

An increase in the price of a good leads to a reduction in the quantity demanded, through two effects:

- The substitution effect, which encourages the consumer to replace the good with substitute goods;
- The income effect, which leads the consumer to reconsider all of their expenditures, because the price increase reduces purchasing power.

Figure 4.1 represents an individual's monthly demand curve for gasoline (D). When the price is 1.50 dollars per litre, he consumes 70 litres per month. If the price increases to 1.75 dollars per litre, the quantity demanded decreases to approximately 60 litres per month. In response to the price increase, the consumer reduces

consumption in several ways: adopting more energy-efficient driving, limiting certain trips, using substitutes such as the bus or bicycle, or potentially purchasing a more fuel-efficient vehicle. The observed decrease in quantity demanded corresponds to the combination of all these adjustments.

Note that the demand curve in Figure 4.1 assumes that quantity is perfectly divisible. In practice, this assumption is an approximation, but it is generally acceptable for analytical purposes.

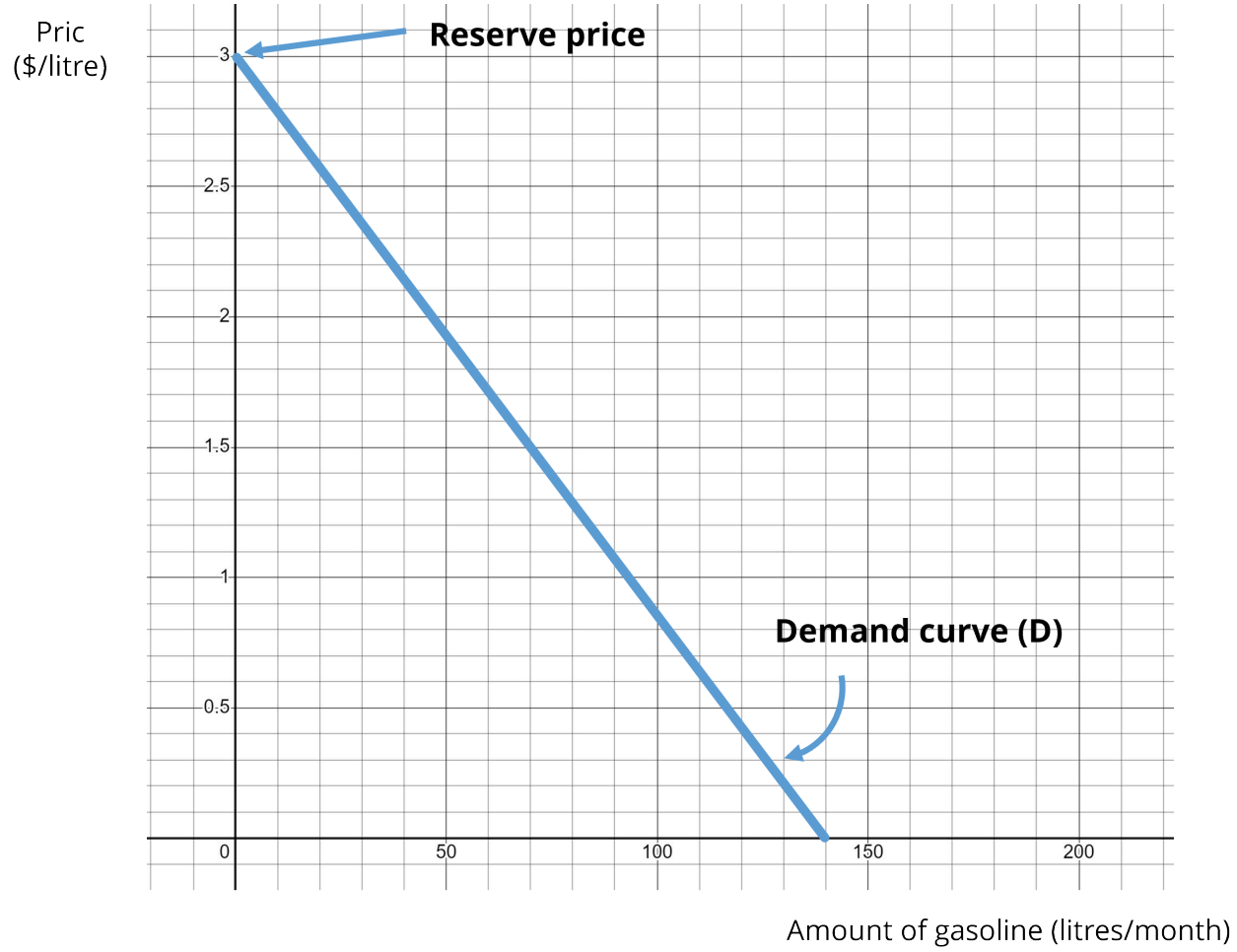


Figure 4.1 Individual demand

The **reserve price** is the price at which the quantity demanded becomes zero.

In our example, demand for gasoline falls to zero when the price reaches 3 dollars per liter, meaning that at this price the individual abandons the car in favor of other modes of transportation.

However, some goods are purchased in a single unit or in a limited number of units (for example, a car or a

refrigerator). This is called **unitary or discrete demand**. In such cases, demand is characterized solely by the reserve price: the maximum amount a consumer is willing to pay for the good. If the market price is lower than the reserve price, the consumer buys the good; if it is higher, demand is zero. The reserve price varies among individuals depending on preferences and income.

An alternative interpretation of the demand curve is particularly relevant for CBA.

> The demand curve can be viewed as measuring the **marginal benefit** (or value) that the consumer derives from each additional unit consumed. It therefore expresses the **maximum willingness to pay at the margin** for each additional unit, that is, the maximum amount the consumer is willing to sacrifice to obtain that unit.

This monetary sacrifice represents an **opportunity cost**, since the amount could be used to purchase other goods and services. For example, Figure 4.2 shows that the consumer is willing to pay a maximum of 1.50 dollars per liter for the 70th liter of gasoline. Alternatively, the same amount can be interpreted as the minimum compensation that would need to be offered for the consumer to give up the 70th liter. It is therefore also a measure of the **minimum willingness to receive at the margin**, in the form of compensation for foregoing consumption.

4.1.1 Gross benefit, expenditure and net benefit to the consumer

By extension, it is possible to measure the benefit associated with consuming a certain quantity of a good (or with a change in quantity). In Figure 4.2, with a gasoline price of 1.50 dollars per liter:

- The **gross benefit** from gasoline consumption is measured by t**he area *abcd* under the demand curve**, up to the consumed quantity of 70 liters.
- This area represents the individual's **maximum willingness to pay (WTP)** to consume 70 liters, that is, the maximum monetary amount the individual is prepared to sacrifice to obtain this consumption level. It is a monetary measure of the gross gain in well-being generated by consuming this good.

- Alternatively, the same area can be interpreted as the **minimum willingness to accept (WTA)** for

giving up consumption: it is the minimum gross compensation that would need to be paid to induce the individual to stop consuming 70 liters of gasoline. [2]

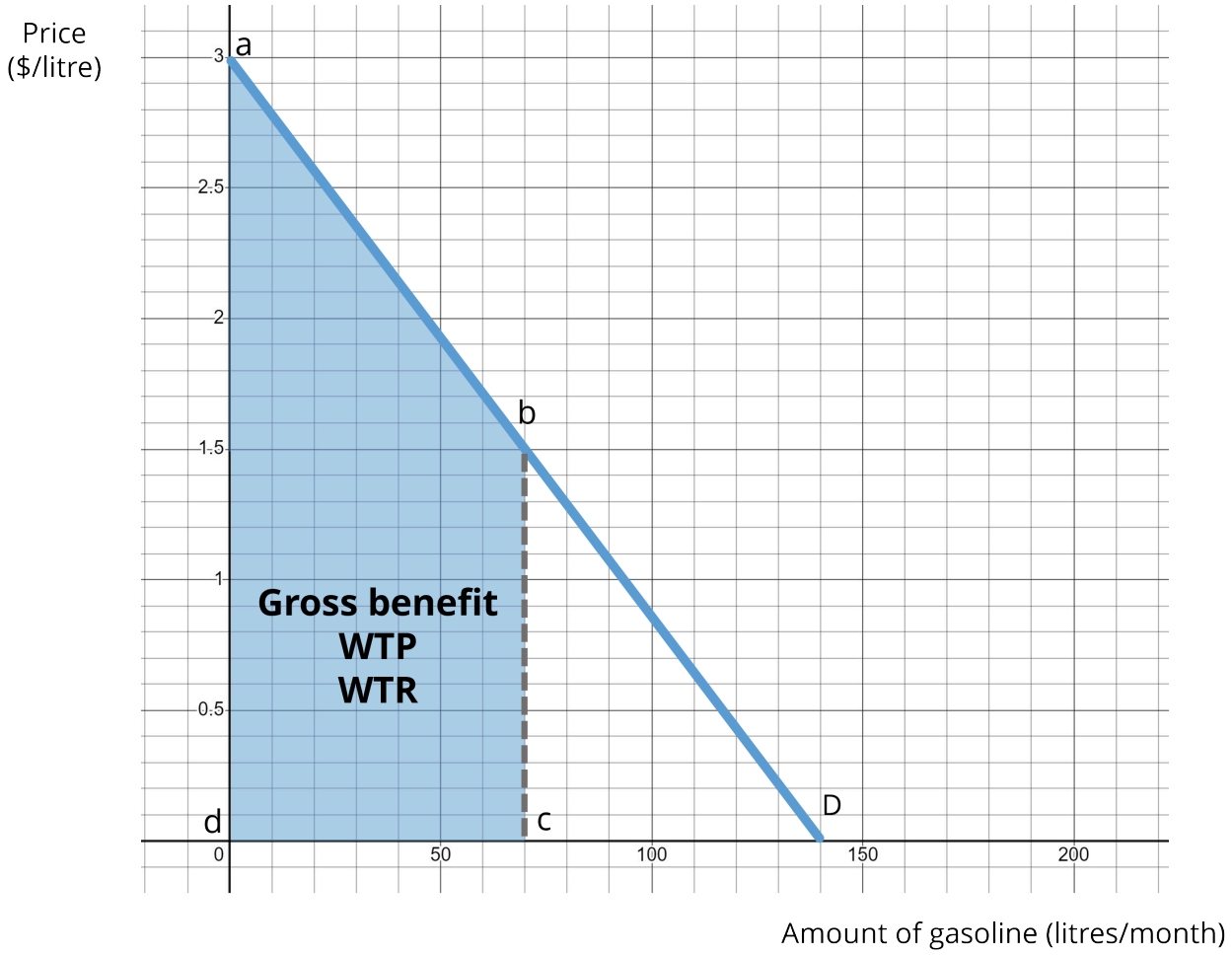


Figure 4.2 Gross benefit, willingness to pay and willingness to receive from consumption of 70 litres/month

The WTP or WTA represents the gross benefit associated with consumption. To obtain the net benefit, it is necessary to take into account the payment required to obtain the good. At a price of 1.50 dollars per liter of gasoline, the consumer must spend 105 dollars to acquire 70 liters. In Figure 4.3, this **expenditure**, which represents the cost from the consumer's point of view, is measured by the area *bcde*. The difference between

2. Note that the area located under the demand curve represents an approximation that overestimates the true WTP and underestimates the true WTA. The degree of approximation depends on the magnitude of the income effect, that is, the effect of a change in the price of the good on purchasing power. This depends on the share of the good in the consumer's budget. An increase in the price of salt will have a negligible impact on purchasing power because salt represents a very small share of total spending. In contrast, an increase in rents will have a substantial impact on income. In such cases, using the demand curve to measure WTP and WTA becomes questionable.

the gross benefit and the expenditure corresponds to the consumer's net benefit, represented by the area abe. In microeconomics, this net benefit is known as **consumer surplus** (CS).

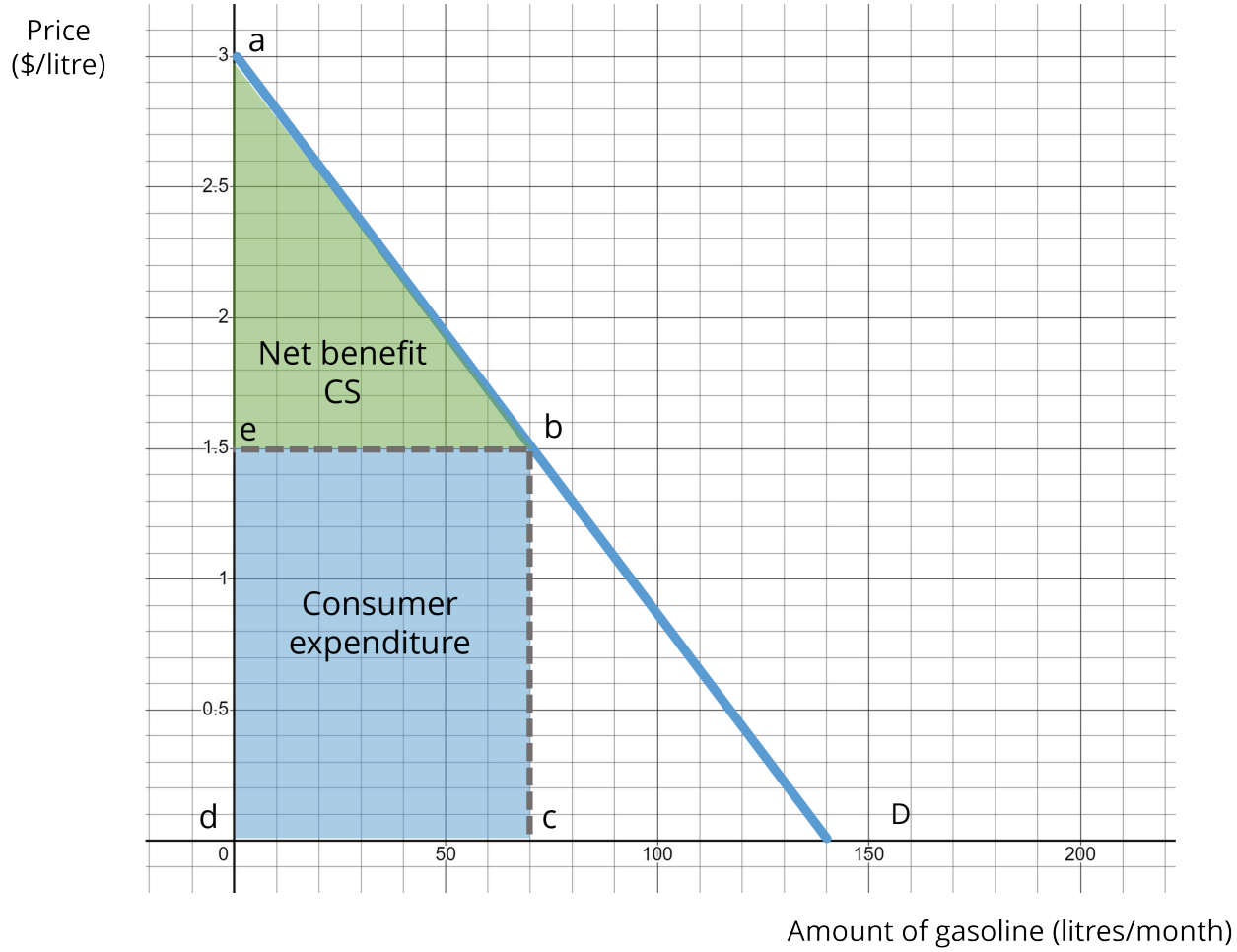


Figure 4.3. Net benefit, consumer surplus and expenditure

Note that we have just performed a CBA of the "project to buy 70 liters of gasoline," adopting exclusively the consumer's perspective. With a linear demand curve, calculating the areas is straightforward and requires relatively little information. As explained earlier, expenditure is calculated as the area of a rectangle corresponding to the price multiplied by the quantity purchased (1.50 dollars × 70 = 105 dollars). Consumer surplus (CS) additionally requires knowledge of the reserve price. It is measured by the area of a triangle, calculated as follows:

$$\text{SC} = \frac{1}{2} \times (\text{reserve price} - \text{price paid}) \times \text{quantity at price paid}$$

In practice, CS represents the average surplus on the units purchased multiplied by the quantity consumed. In our example, the average surplus is ½ × (3 dollars – 1.50 dollars), or 0.75 dollars. The CS is therefore 0.75 × 70 = 52.50 dollars.

In summary:

- The individual assigns a monetary value of 157.50 dollars to the consumption of 70 liters of gasoline per month.
- He must pay 105 dollars to obtain these 70 liters.
- The net benefit associated with purchasing and consuming these 70 liters of gasoline is therefore 52.50 dollars.

Finally, note that the consumer has no interest in consuming more than 70 liters: an additional unit would generate a marginal benefit lower than its cost. Conversely, consuming less than 70 liters would reduce his CS, because he would no longer consume all units whose value is greater than or equal to the price.

4.1.2 Market demand

Market demand is obtained by summing the individual demands of all consumers. For a **private good** such as gasoline, this summation is carried out **in quantities**: for a given price, the quantities demanded by each consumer are added to obtain the total quantity demanded in the market at that price. Graphically, this corresponds to a **horizontal addition** of individual demand curves.

Figure 4.4 illustrates the procedure for two consumers whose individual demands are D1 and D2. When the price exceeds 1.75 dollars per liter, consumer 1 no longer demands gasoline, so market demand coincides with consumer 2's demand curve (D2). At lower prices, both demand curves must be added horizontally. If the price is zero, consumer 1 demands 40 liters and consumer 2 demands 70 liters; the market quantity demanded is therefore 110 liters.

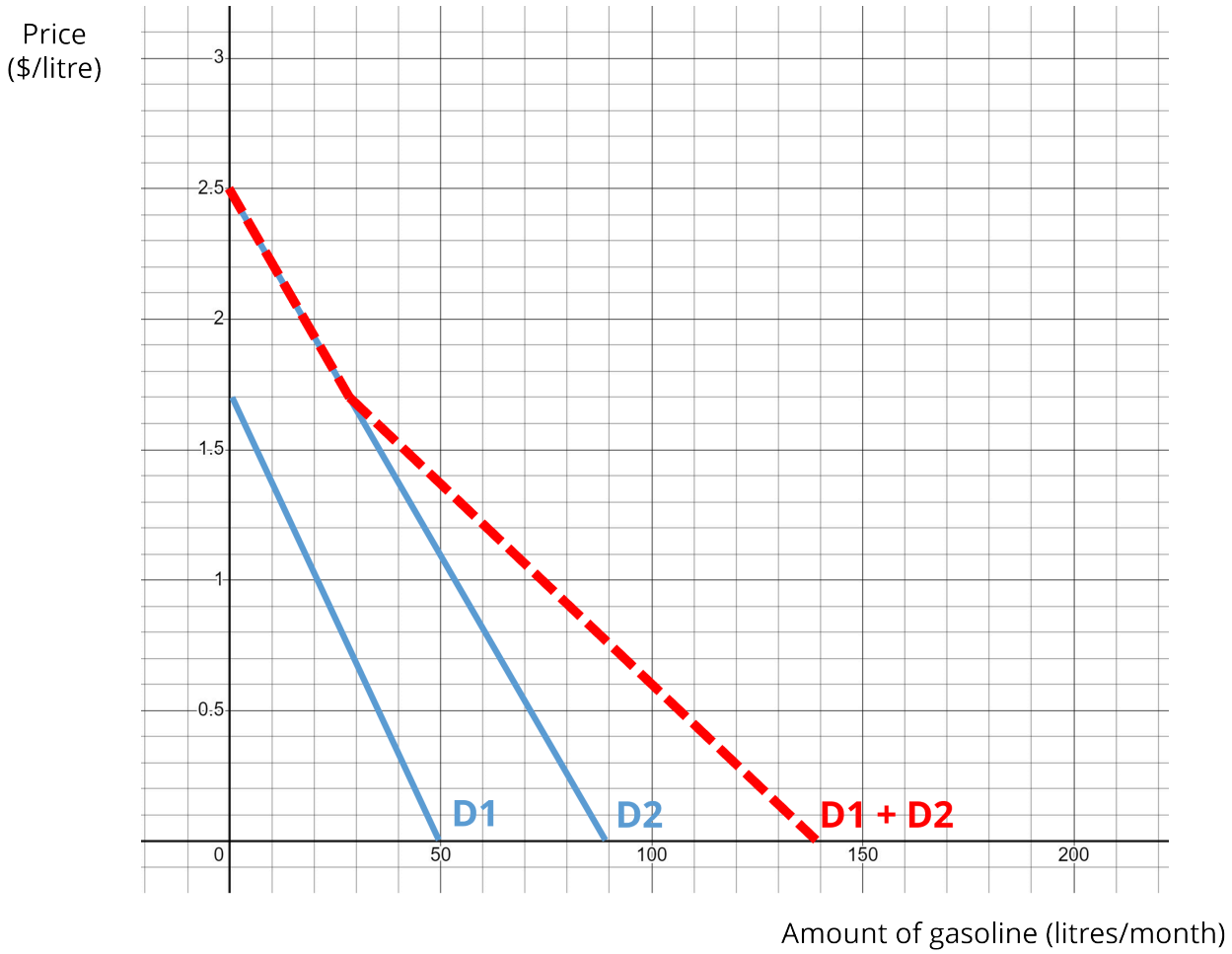


Figure 4.4 Illustration of the construction of market demand (private goods)

The interpretation of market demand is similar to that presented for an individual consumer. In particular, the gains from trade for consumers are measured by consumer surplus.

Consumer surplus (CS) corresponds to the sum of the differences between the maximum willingness to pay, as indicated by the demand curve, and the price actually paid for a good or service. In other words, it measures the difference between the total amount that consumers would be willing to pay (WTP) and what they actually spend (expenditure). CS therefore reflects the gains obtained from exchange in the market, that is, the net benefit accruing to consumers.

In summary:

- Market demand for a private good corresponds to the summation in quantity (horizontal addition) of individual demands.
- Market demand measures the maximum willingness to pay at the margin for consumers.
- The area under the market demand curve for a given quantity measures WTP or WTA. This corresponds to the gross benefit associated with consumption in that market.
- The net benefit to consumers is given by consumer surplus, which is the difference between the gross benefit and the total expenditure.

Furthermore, if consumption of the good does not generate **positive externalities** and if consumers correctly assess the benefits of its consumption, then the benefit quantified by market demand also represents the **social benefit** of consuming that good. We will return to this point later.

Warning: ignore the CS!

A common mistake in CBA conducted without a theoretical framework is to equate consumer spending with the benefit generated by a project, thereby ignoring consumer surplus. For example, an analyst who evaluates the benefit of a program promoting broadband Internet deployment in rural areas solely on the basis of subscription revenues would underestimate the true benefit, because they would fail to include CS.

However, under certain conditions, consumer spending may reasonably approximate the benefit. In those specific situations, CS is sufficiently small that its omission leads to only limited error. We will specify these conditions later in the chapter.

4.1.3 Collective demand for a public good

It is appropriate to use the concept of a demand curve for a **public good** such as air quality. However, recall that in the case of a public good, consumption is collective: everyone enjoys the same quantity and quality of the good. We will see in Chapter 8 that this characteristic modifies the way in which collective demand is obtained from individual demands. We will also note that estimating individual demands for a public good raises particular challenges.

Beyond these specific difficulties, the collective demand curve for a public good still reflects WTP or WTA. Suppose that Figure 4.5 represents the collective demand for air quality by the citizens of a city. The collective

WTP for improving air quality from Q0 to Q1 is given by the area under this demand curve. Conversely, this same area represents the WTA—that is, the level of compensation that would have to be paid to citizens if air quality were to deteriorate from Q1 to Q0.

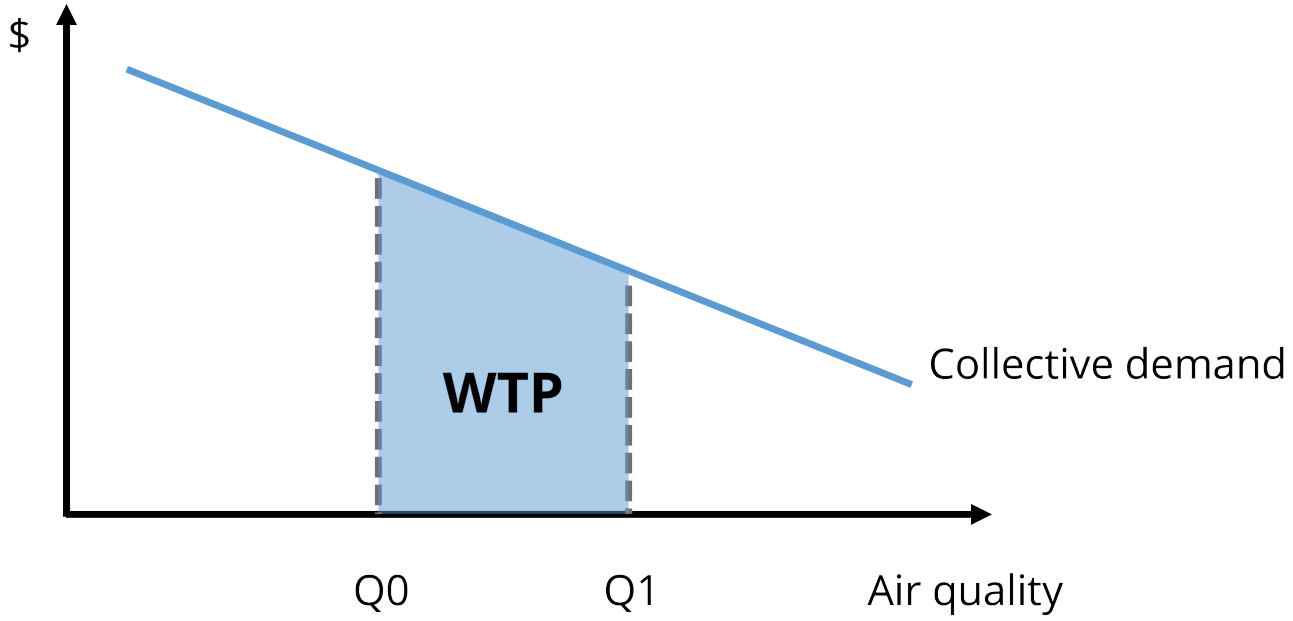


Figure 4.5 Collective demand for a public good

4.1.4 Price elasticity of demand

To predict the magnitude of changes in quantity demanded following a price change, an important parameter is used: t**he price elasticity of demand**. This concept applies to both individual consumer demand and market demand.

The price elasticity of demand measures the percentage change in quantity demanded (QD) caused by a 1% change in price (P). It is often expressed as an absolute value, without the negative sign. More formally, it is defined as:

$$n_d = \left| \frac{\Delta Q^D(\%)}{\Delta P(\%)} \right|$$

For example, if a project increases the market price by 10% and the price elasticity of market demand is

estimated at 3, we can predict a decrease in quantity demanded of about 3 × 10% = 30%. [3] In a similar way, elasticity is also useful for predicting the change in price following a change in the quantity traded. For instance, if the traded quantity increases by 20% and demand has an elasticity of 3, we can expect a price decrease of approximately 6.7%, that is, 20% ÷ 3.

Figure 4.6 illustrates two extreme cases:

- Perfectly elastic demand: any change in price generates an extremely large change in quantity demanded.
- Perfectly inelastic demand: the quantity demanded is completely insensitive to price.

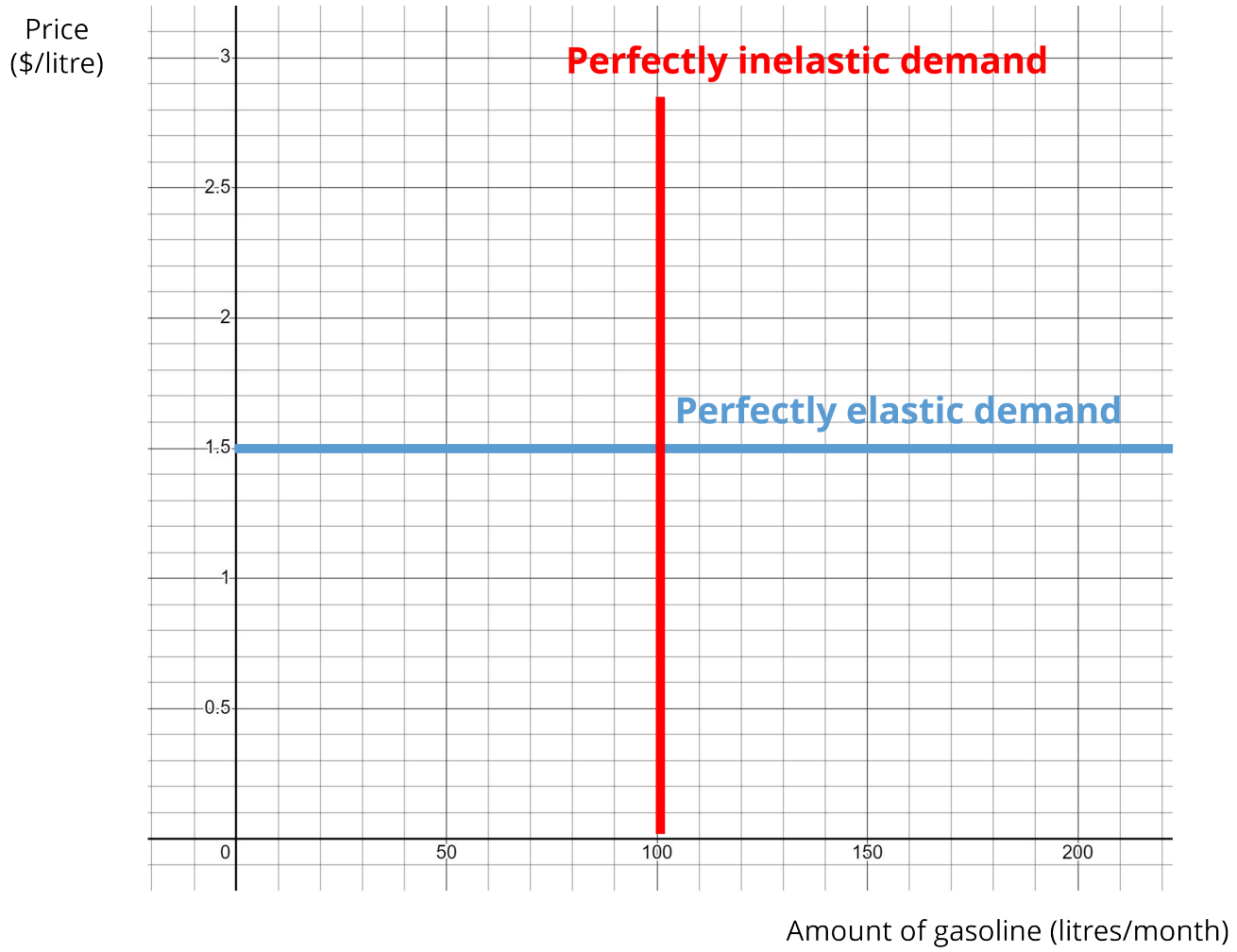


Figure 4.6 Two extreme cases of price elasticity of demand

3. Note that this is an approximation, because price elasticity may vary with the price level. The smaller the price change, the more accurate the approximation will be.

Figure 4.7 illustrates how price elasticity varies along a standard linear demand curve. Elasticity is unitary (n_d = 1) when evaluated at a price equal to half of the reserve price. For prices above this level, demand is elastic (n_d > 1), whereas for prices below this level, demand is inelastic (n_d < 1).

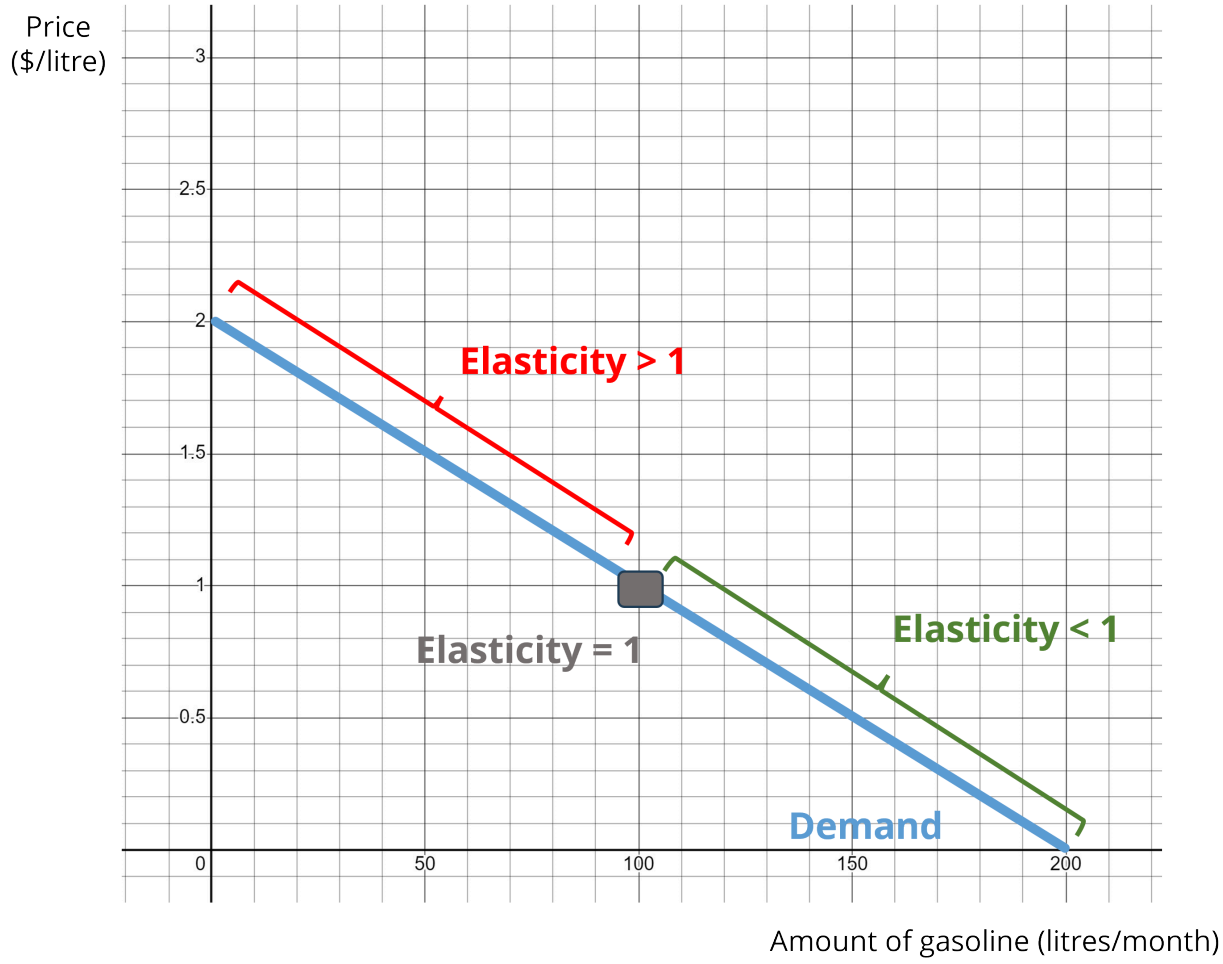


Figure 4.7 Evolution of price elasticity along a decreasing linear demand

4.1.5 Shifts in the demand curve

The demand curve illustrates the relationship between quantity demanded and price, all other things being equal. If a variable other than price changes, the effect is a shift in the entire demand curve rather than a movement along it. For example, Figure 4.8 shows the impact of an increase in an individual's disposable income on their demand for gasoline. Since gasoline is a normal good, the demand curve shifts to the right (from D0 to D1) as income rises, indicating a higher quantity demanded at every price level. This type of shift also applies to aggregate market demand.

Conversely, if the good were inferior, an increase in income would reduce the quantity demanded at each price level, causing the demand curve to shift in the opposite direction.

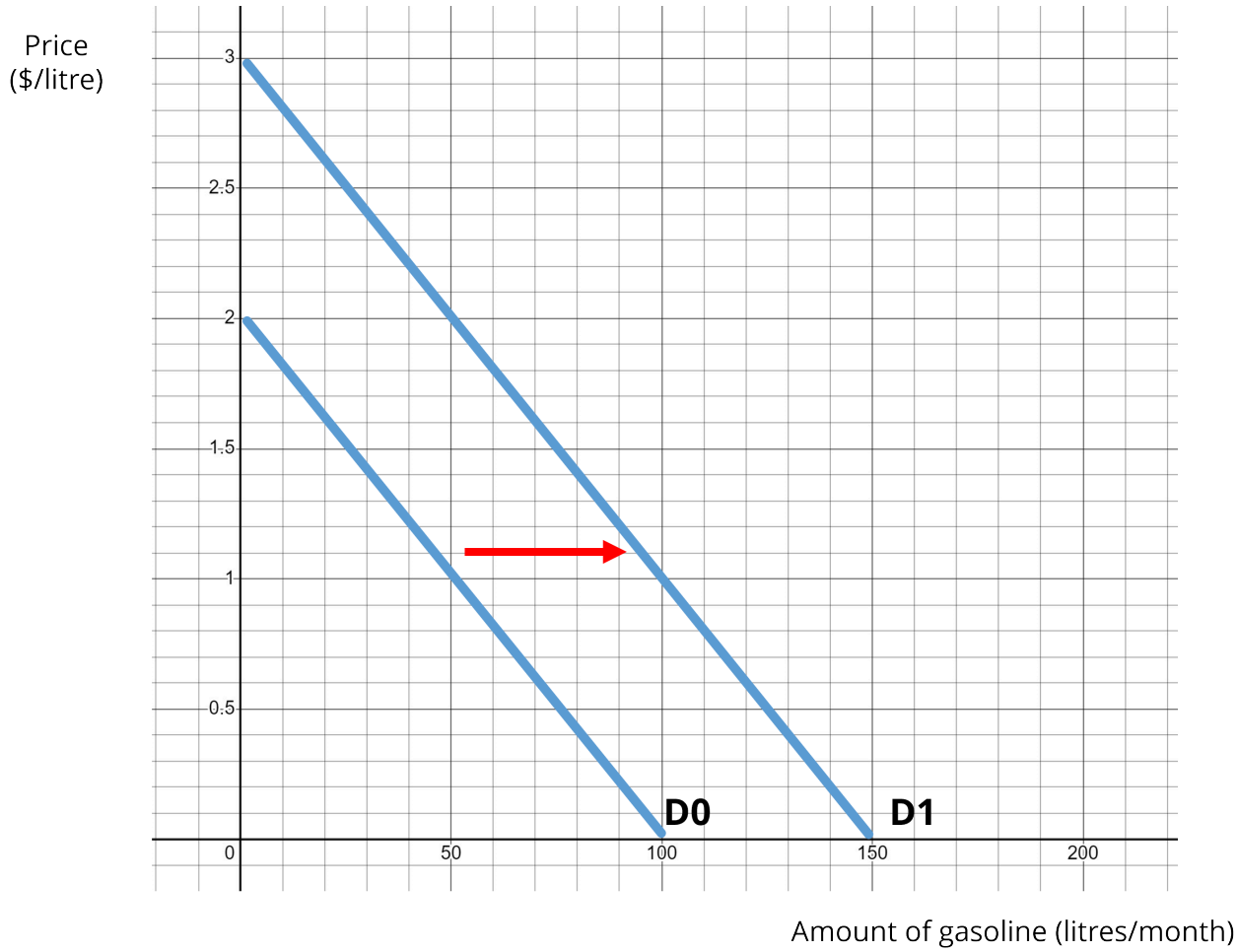


Figure 4.8 Shift of the demand curve

Exercise: Increase in the price of sodas

The government is considering imposing a nutritional tax on sugary drinks such as soda. The current average price is 1 dollar per liter, and annual consumption is 820 million liters. The new tax is expected to increase the average price by about 15 percent. The price elasticity of demand for soda is estimated at 0.8.

- Determine the WTP associated with the units that are no longer consumed because of the tax.

- Also determine the impact of this measure on consumer surplus in the soda market.

Resolution

First, we must determine the state of the market in the scenario without the tax, then in the one with the tax. The scenario without the tax is directly given by current observations. The scenario with the tax is determined by taking into account the anticipated price increase of 15% and the price elasticity of demand, which allows us to anticipate a 12% decrease in the quantity consumed.

No-tax scenario:

- Average observed price = 1 dollar per liter
- Observed quantity = 820 million liters

Scenario with tax:

- Average expected price with tax = 1 x (1 + 0.15) = 1.15 dollar per liter
- Quantity expected with tax = 820 x (1- 0.8 x 0.15) million = 721.6 million liters

We have two points on the demand curve, namely (820; 1) and (721.6; 1.15), as illustrated in Figure 4.9. Assuming that the demand curve is linear between these two points, we can approximate the impacts.

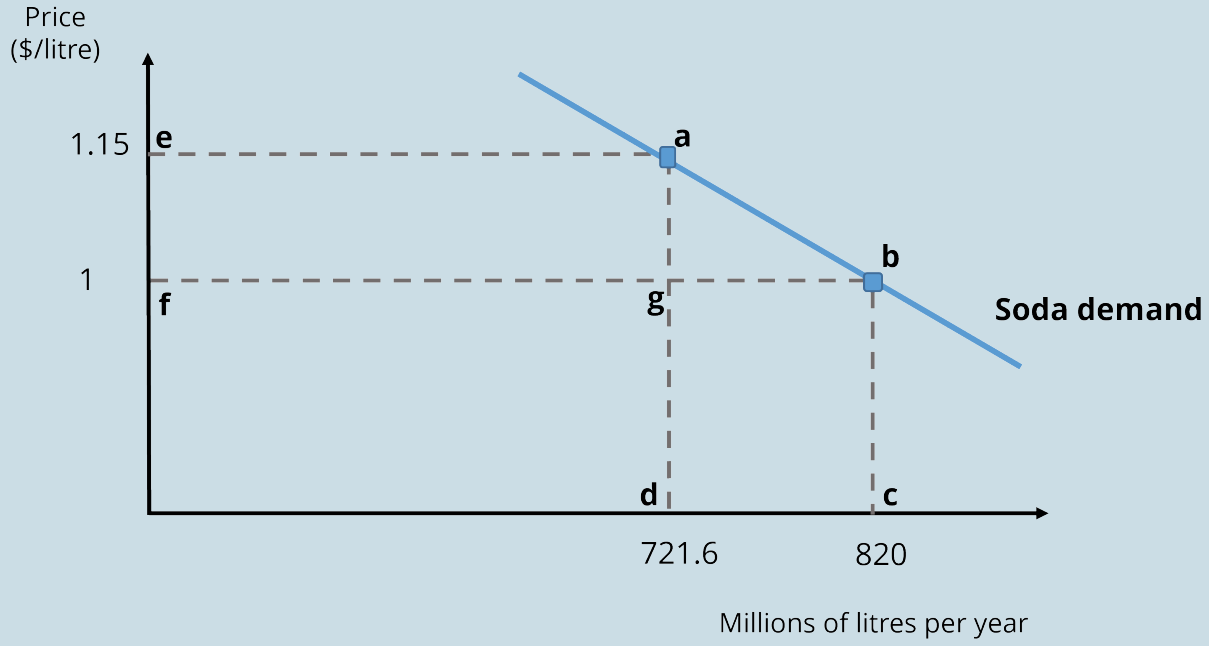


Figure 4.9 Impact of a nutritional tax on soda drink consumers

- The units that are no longer consumed because of the tax have a value for consumers that is evaluated by the area of the surface under the demand curve between 721.6 million and 820 million liters, or the surface *abcd* whose value is ½ x (1.15 + 1) x (820 – 721.6) = 105.78 million dollars.
- The net impact on consumers must take into account both the reduction in expenditure due to the decrease in the quantity purchased and the increase in price on the quantities that continue to be consumed. This net effect is measured by the reduction in the CS, which is broken down into two components: the rectangle *eagf*, which quantifies the increase in expenditure on the units that continue to be purchased, and the triangle *abg*, which measures the decrease in the CS resulting from the reduction in the quantity consumed.
- In sum, this tax reduces the CS by $115.62 million per year. This value can be interpreted as the maximum amount that consumers would be willing to pay (WTP) to prevent the implementation of the project, or as the minimum compensation (WTA) that would have to be paid to them to maintain their initial level of utility before the imposition of the tax.

Of course, a full CBA must also take into account other effects of this measure (for example, reductions in obesity and diabetes, impacts on producers and on government revenues, etc.). It should also be noted that the tax revenue collected by the government is in fact a transfer, rather than a net loss of collective resources.

4.2 Costs, supply and producer surplus

4.2.1 The economic cost of production

To produce a good, producers mobilize resources called inputs, such as labor or natural resources. Capital, or more precisely **physical capital** [4], is another essential input in most production processes. It includes all durable goods created by humans and used in production, such as buildings, machinery, and tools. These durable goods can be used repeatedly, unlike other inputs that are "consumed" during the production process. For example, the kiln used to heat wood chips and extract woody material in papermaking is capital. By contrast, the chemicals added during the process are classified as equipment and supplies.

Inputs also include entrepreneurship, which organizes other inputs and assumes risks. The time, energy,

4. Not to be confused with financial capital, which is not an input but rather a means of financing physical capital.

and creativity that an entrepreneur devotes to her business involve an opportunity cost, defined as the compensation she could obtain in a better alternative. Normal profit can be interpreted as the compensation required to cover this opportunity cost.

The economic cost of production is defined as the sum of the opportunity costs of all the factors of production mobilized. It measures t**he economic value that could be generated if those inputs were allocated to a better alternative**. This interpretation of the notion of economic cost is particularly important in CBA.

To illustrate, imagine a project with only one employee as an input, whose wage is competitive at 75,000 dollars per year. This implies that if the project does not proceed, the employee will find another job paying the same wage. Moreover, the social value of what she would produce in this alternative job is also 75,000 dollars, since a competitive wage measures marginal productivity in value terms; that is, the value of the additional production generated by the employee. Thus, the social cost of mobilizing this employee for the project is 75,000 dollars per year.

For producers, some inputs involve direct outlays, such as wages paid to workers. Capital, however, involves a purchase outlay when acquired, but this cost is typically spread over the useful life of the durable good, for example through mortgage payments for a building or through **depreciation** of a mechanical device (see Chapter 6 for more details).

Some inputs do not require current monetary outlays, such as entrepreneurship or the use of a building already owned. However, mobilizing these inputs still implies an economic cost in terms of opportunity cost. For example, a building could be rented to another firm instead of being used for the company's operations; the forgone rental income then measures its economic cost.

For inputs that generate current expenditures, the expenditure may measure the opportunity cost. For instance, wages paid in a competitive labor market reflect what the employee could earn in an alternative job, as noted earlier. However, in some cases, the expenditure is not a good proxy for opportunity cost. Similarly, accounting or financial costs do not necessarily measure economic cost. These issues are examined in more detail in Chapter 11.

4.2.2 Cost categories

Production costs can be divided into two broad categories: **fixed costs**, which do not vary with the level of production, and **variable costs**, which depend on the level of production. Formally,

$$CT(Q) = CF + CV(Q)$$

With

$CT\,(Q)$: the total cost which increases with the production level Q,

CF: the fixed cost component, that is, costs that do not vary with the quantity produced;

$CV\,(Q)$: the variable cost component, which changes with the level of production Q.

The costs of research and development of a new vaccine are fixed costs, while the costs of producing doses of the vaccine are variable.

The distinction between fixed and variable costs can sometimes be complex to establish and apply. Some inputs cannot be perfectly subdivided, creating discontinuities (for example, it is impossible to add half a truck). The distinction also depends on the time period in question, whether it is the short run or the long run.

- The **short run**is defined as a period during which some factors of production, usually capital, cannot be adjusted. The length of this period varies from industry to industry. For example, it may take several years to build a new oil pipeline, while it may take only a few weeks to expand a restaurant. Factors that remain fixed in the short run are known as fixed costs.
- The **long run** is a period during which all factors of production can be adjusted.

For CBA purposes, the most useful distinction is whether a cost is **avoidable** or not given the execution of the project. Avoidable costs must be included in the analysis, because they arise only if the project is implemented. Unavoidable costs are irrelevant for CBA, since they also occur in the baseline (no-project) scenario and therefore do not represent a real incremental cost attributable to the project.

Quasi-fixed costs

In most introductory microeconomics textbooks, the capital factor is treated as fixed in the short run, which generates fixed costs. In the long run, all factors are variable; therefore, there is no longer any **fixed cost**. In addition, fixed costs are often implicitly assumed to be unavoidable: they must be borne even if production stops in the short run. In the long run, since all costs are variable,

all costs are assumed to be avoidable. This creates an implicit confusion between the distinction fixed cost vs. **variable cost** and the distinction avoidable vs. non-avoidable cost.

In reality, the situation is more nuanced. In the short run, some fixed costs are avoidable; these are called quasi-fixed costs. For example, consider an entrepreneur who rents premises on a monthly basis. The rent is a cost that does not vary with the level of production (fixed cost), but it is avoidable if operations are suspended, even temporarily.

Similarly, in the long run, certain costs may be fixed in nature but are nonetheless avoidable. The cost of developing a new product is generally a fixed cost, yet in a long-run perspective, the firm may decide not to undertake the project at all; this cost is therefore avoidable.

It is very rare for a company to know with precision the entire total cost function CT(Q). In practice, a firm typically has a good approximation of its **average cost** (AC) of production and of its **marginal cost** (MC) of production, rather than detailed knowledge of total cost at every output level.

The average cost is defined as $AC(Q) = \frac{CT(Q)}{Q}$ that is, the total cost divided by the quantity produced.

Marginal cost MC(Q) measures the change in total cost associated with producing one additional unit. Formally, it corresponds to the increment in total cost when output increases from Q to Q+1, or, in a continuous formulation, to the derivative of total cost with respect to output.

In theory, marginal cost is measured by the increase in total cost resulting from the production of one additional unit. In practice, however, entrepreneurs often evaluate marginal cost on the basis of more substantial changes in output, such as the cost associated with accepting an additional order or the extra cost of increasing production by, for example, 20 percent.

In many industries, the evolution of total cost as output increases follows a pattern similar to that illustrated in Panel A of Figure 4.10. The corresponding average cost and marginal cost curves are shown in Panel B. Other cost configurations are possible, and simpler functional forms will often be used later in this chapter for analytical clarity.

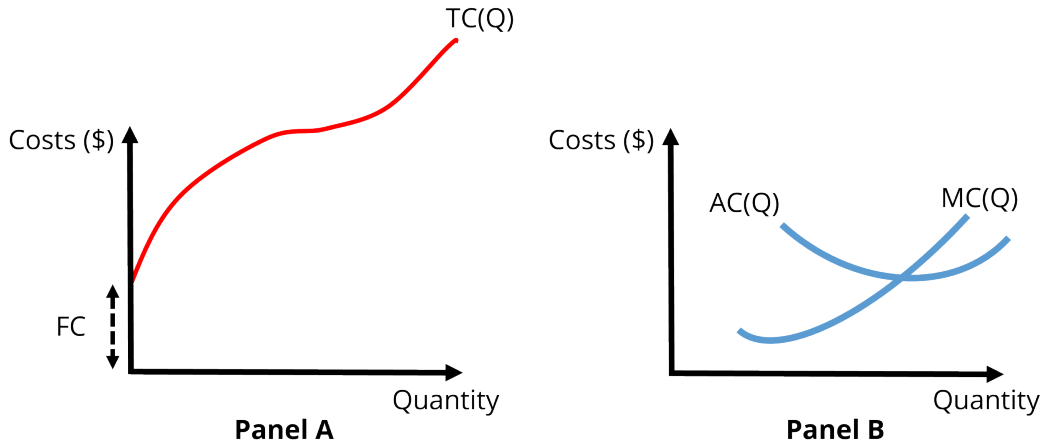


Figure 4.10 Example of total cost, average cost and marginal cost curve

4.2.3 Supply

Supply represents the relationship between the quantity produced and its determinants, such as the price of the good, the prices of inputs, the prices of substitute or complementary goods in production, and technology.

The supply curve shows the relationship between the quantity supplied and the price of the good, all other things being equal.

Supply results from a profit-maximization process subject to technological and market constraints. In a perfectly competitive market, producers are price takers. They maximize profit at the point where the market price intersects their marginal cost curve. A producer will increase output as long as the marginal cost of the last unit produced does not exceed the selling price. Figure 4.11 illustrates the supply curve of a gasoline refinery. If

the price of gasoline is 1.25 dollar per liter, the quantity supplied is 40,000 liters per month. At a price of 1.70 dollar per liter, the quantity supplied increases to 70,000 liters.

In a competitive market, a producer's supply curve coincides with its **marginal cost curve**.

The law of supply states that, in a competitive market, the quantity supplied generally increases with price, because marginal cost tends to rise as output expands.

The supply curve can also be interpreted as the **minimum amount required by the producer to supply an additional unit**, that is, the producer's minimum willingness to accept at the margin. If the cost of producing the 40 thousandth liter is 1.25 dollar, this is the minimum amount required for it to be brought to market.

By extension, the area under the supply curve between two quantity levels measures the cost of the resources mobilized to produce the units between these two levels. For example, the area under the supply curve between 0 and 40,000 units (ebcd) measures the variable costs associated with increasing production from 0 to 40,000 liters. Note, however, that **this area does not measure total cost**, but only variable cost—that is, the part of cost that varies with output. Fixed costs are not included in this area. [5]

5. Fixed costs are also not measured by the y-intercept. This point corresponds to the marginal cost when output is initially zero.

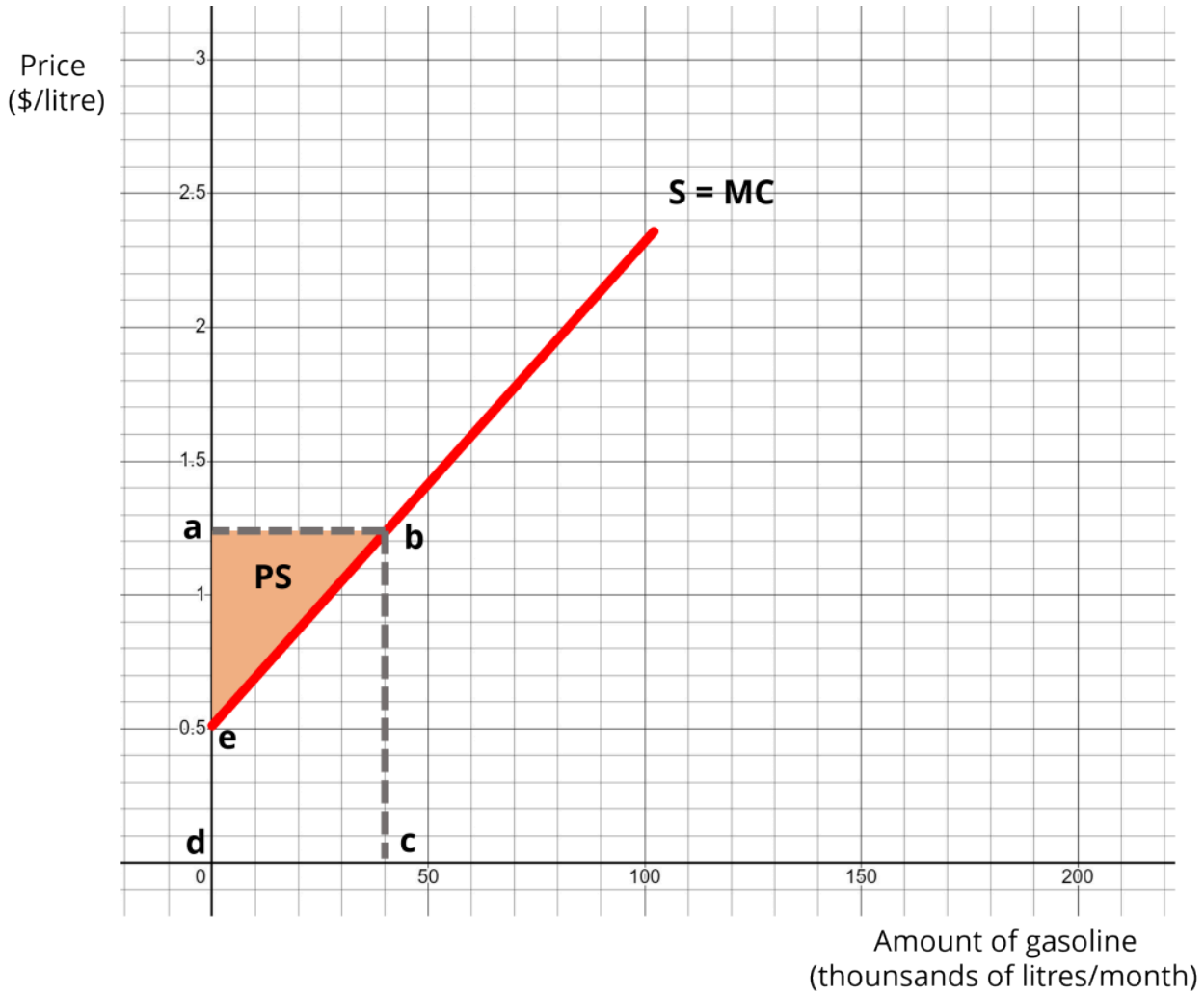


Figure 4.11 The curve of a firm in perfect competition

Producer surplus (PS) measures the sum of the differences between the selling price and marginal cost for all units sold. It can also be interpreted as the difference between total revenue (area *abcd*) and variable costs (area *ebcd*).

PS therefore does not generally measure profit (π), unless fixed costs (FC) are zero. In fact, we have:

$$\text{SP} = \pi + \text{CF} \text{ or } \pi = \text{SP} - \text{CF}$$

In Figure 13, when the price is 1.25 dollar per liter, the producer supplies 40,000 liters per month and obtains a surplus of 15,000 dollars, which corresponds to the area of triangle *abe*.

Operationally, PS is close to the concept of **operating profit**, commonly used in business accounting. Operating profit is the difference between operating revenues and operating costs.

However, accounting and tax rules used to compute operating profit do not necessarily rely on the notion of opportunity cost. Nonetheless, reported operating profit, revenue, and cost data constitute a useful starting point for estimating PS in practice.

As with demand, **market supply** is obtained by summing individual supply curves in quantity (horizontal summation).

To characterize the sensitivity of the quantity supplied (*QO*) to the price (*P*), we use the concept of elasticity of supply,

$$n_o = \left| \frac{\Delta Q_o(\%)}{\Delta P(\%)} \right|$$

This elasticity measures the percentage change in the quantity supplied following a 1 percent increase in price.

Two limiting cases help illustrate the concept:

- **Perfectly elastic supply:** supply is infinitely sensitive to price (horizontal supply curve);
- **Perfectly inelastic supply:** supply is completely insensitive to price (vertical supply curve).

The supply curve shifts when a determinant of supply other than price changes. For example:

- An increase in the price of a variable input raises marginal cost, thereby increasing the minimum willingness to accept at the margin. This results in an **upward (or leftward) shift** in supply.
- A technological innovation that raises productivity reduces marginal cost and leads to a **downward (or rightward) shift** in supply.

Two extreme cases are to be considered: the case of a perfectly elastic supply (a horizontal line) and the case of a perfectly inelastic supply (a vertical line).

In the context of the CBA:

- The area under the supply curve measures the incremental economic cost associated with increasing the level of production.
- The variation in producer surplus (PS) measures the impact of a project on producers.

Note that in certain situations involving market imperfections (for example, monopoly, markets for public goods, or markets in the non-market sector), the notion of a supply curve is not truly operational. However, identifying economic costs and analyzing how they evolve with the level of production remain essential components of a CBA.

Exercise: Increasing a quota

A project proposes to increase the authorized production quota in a market from 4,000 to 7,000 tonnes per day. Using Figure 4.12:

- Determine the **additional economic cost** resulting from this increase in production.
- Calculate the **net impact on producers**, measured by the variation in producer surplus (PS).

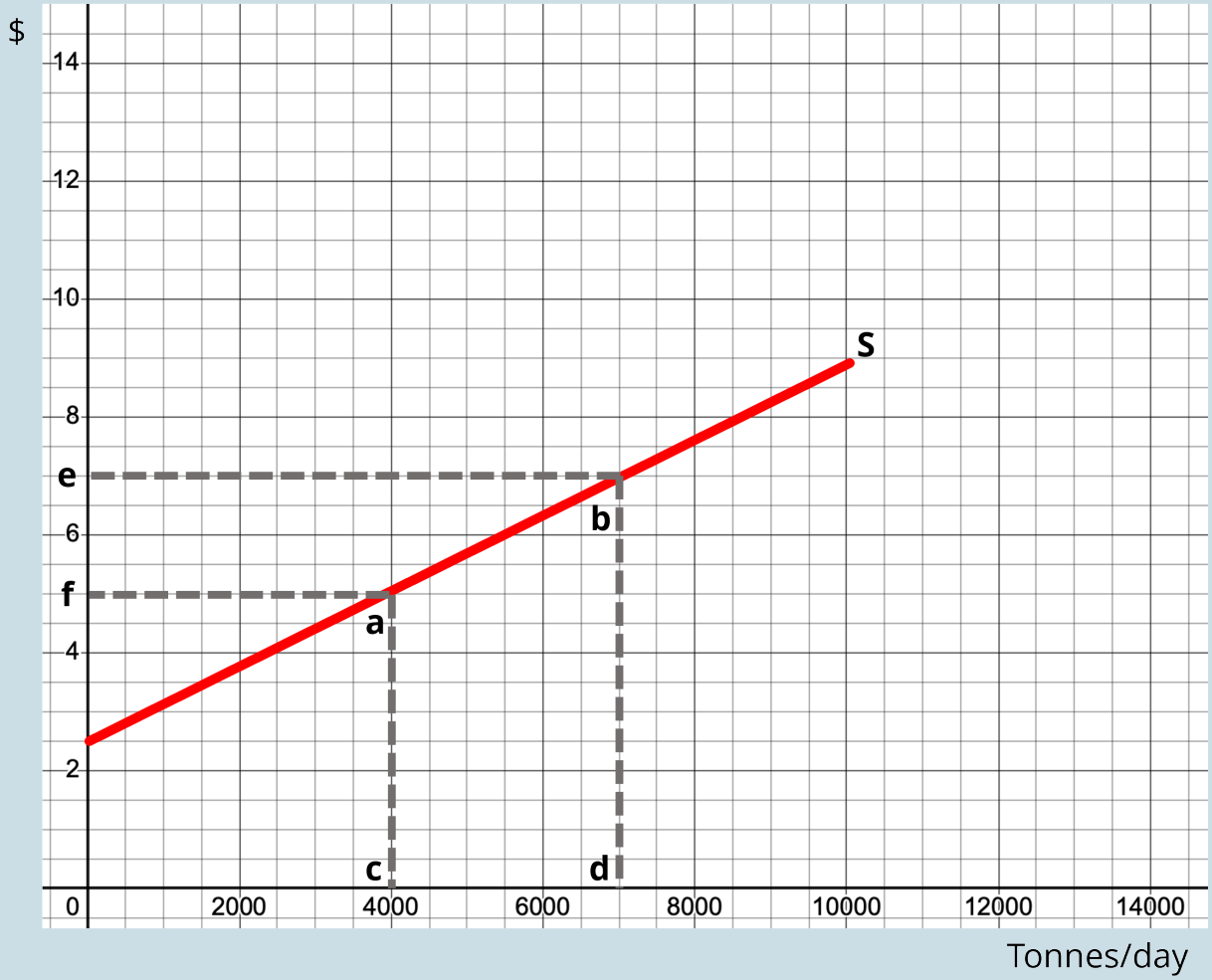


Figure 4.12 The impact of increasing production quotas

Resolution

- The additional cost generated by the quota increase is measured by the area under the supply curve between 4,000 and 7,000 tonnes (area abdc). Numerically: 5 x (7000 – 4000) + ½ x (7 – 5) x (7000 – 4000) = $18,000/day.
- This value represents the minimum compensation (WTA) required for producers to expand production from 4,000 to 7,000 tonnes. It reflects the additional economic cost of mobilizing the necessary resources.
- The net impact on producers must consider both the additional cost and the additional revenue generated by selling the extra output (area *ebdcaf*).
- The variation in producer surplus (PS) is therefore measured by area *ebaf*, that is: (7 – 5) x 4000 + ½ x (7 – 5) x (7000 – 4000) = $11,000/day.

The change in PS represents the net effect on producers. In this example, the impact is positive. The increase in PS can be interpreted as producers' willingness to pay (WTP) for the project to be implemented.

If the project instead consisted in reducing the quota from 7,000 to 4,000 tonnes, the change in PS would be –11,000 dollars/day. This amount would represent the minimum compensation (WTA) required so that producers agree to the quota reduction.

4.3 Competitive equilibrium

A market for a private good is in perfect competition when:

- The good sold is standardized;
- There is no **information asymmetry**;
- All market participants (consumers and producers) are small relative to the market as a whole. They therefore have no influence on the price and are "price takers";
- Entry and exit of firms in the long run are unrestricted;
- Production and consumption of the good do not generate external costs or benefits.

Market equilibrium occurs at the intersection of market supply and demand, at price P* and quantity Q* in Figure 4.13. If the price is below P*, the quantity demanded exceeds the quantity supplied, which drives the price upward. A price above P* implies that the quantity supplied exceeds the quantity demanded, pushing the price downward. At P*, the quantity demanded equals the quantity supplied and the market is in equilibrium.

Of course, the other determinants of supply and demand change continuously, so supply and demand curves shift over time, and the equilibrium price adjusts accordingly.

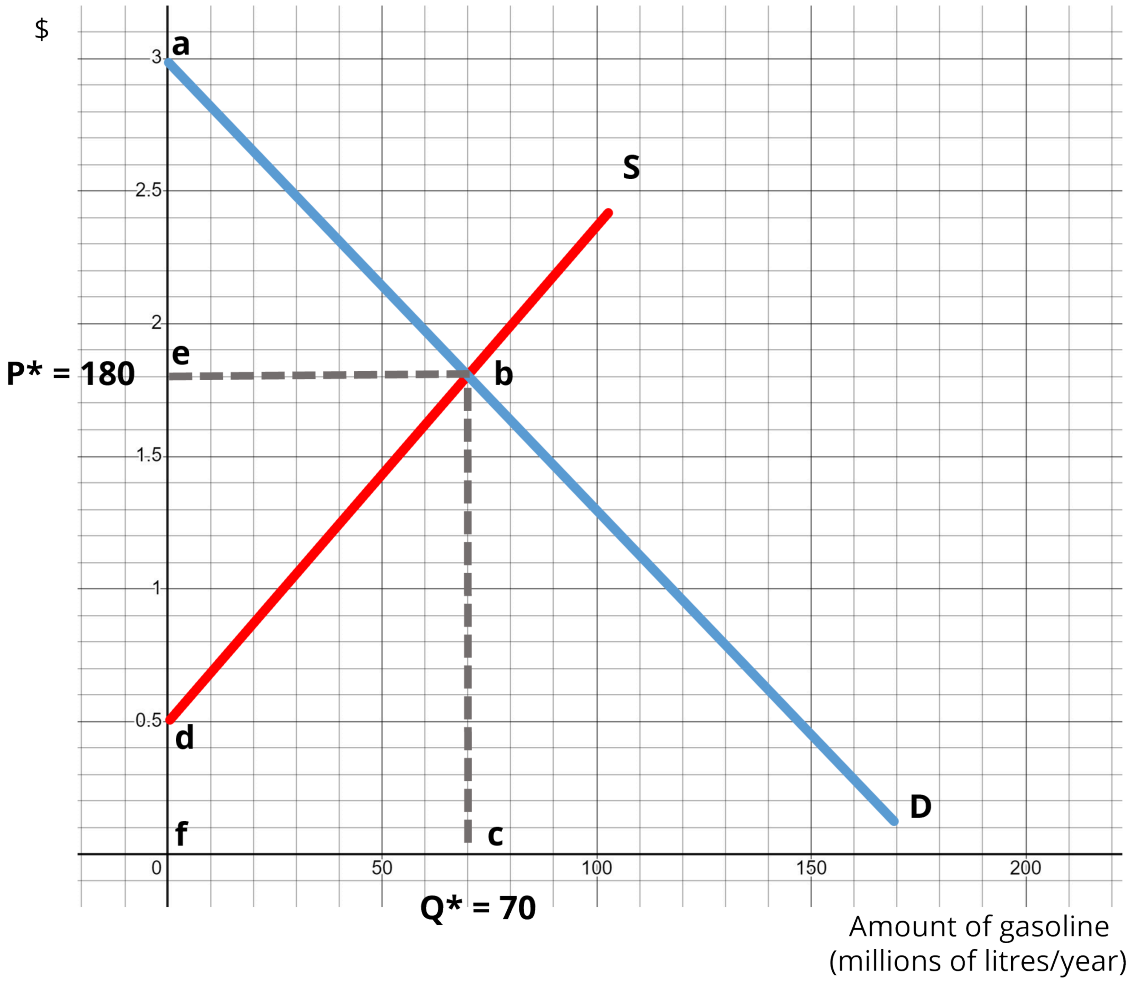


Figure 4.13 Equilibrium in a competitive market

In perfect competition equilibrium:

1. The last unit supplied Q* costs to produce what it is worth to consumers. At Q*, curve, which reflects marginal cost, equals the demand curve, which measures the willingness to pay for the unit Q*;
2. All units whose value to consumers exceeds their production cost are traded. The net social benefit generated by exchange is maximized at Q*. It correspond to the area *abd*, which is the difference between the WTP (*abcf*) and the production costs (*dbcf*);
3. The gains from trade are shared between consumers and producers. Consumer surplus is given by area *abe,*and producer surplus by area *ebd* ;
4. By realizing all gains from exchange, competitive equilibrium leads to a socially efficient allocation of resources.

However, these results rely on two key assumptions:

- The marginal cost curve of producers incorporates all social costs of production;
- Consumer demand captures all social benefits associated with consumption.

If these assumptions do not hold, the market outcome will not be socially optimal. There is a **market failure or distortion**, as explained in Chapter 3. The classic example is a good that generates pollution: production imposes private costs on producers and external costs on others. In that case, the supply curve reflects private marginal cost rather than social marginal cost. The consequences for CBA will be examined in greater detail in Chapters 8 to 10.

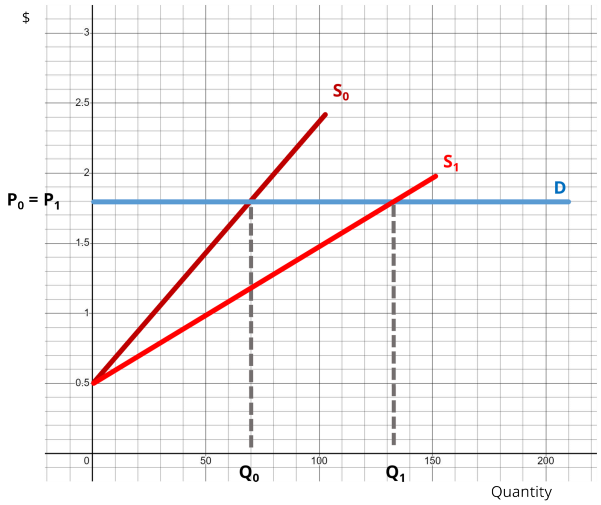
4.4 Predicting the impacts of a shock on supply or demand

Some projects affect a competitive market by shifting the demand or supply curve. For example, a road maintenance program may increase the demand for asphalt. A subsidy for the construction of a new cement plant will shift the supply curve to the right. An awareness campaign on the harmful effects of tobacco will reduce demand for that product. A tightening of a health standard may increase the production costs of a food item and therefore reduce supply.

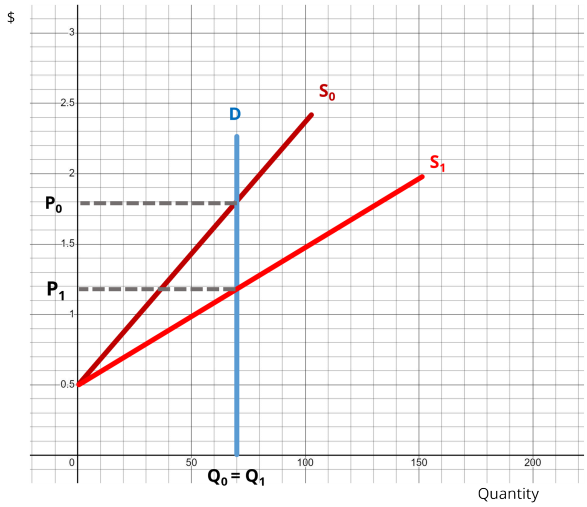
In these situations, the analyst usually has information on the price and quantity traded before the implementation of the project. These observations make it possible to establish the baseline scenario. The analyst must then predict how the project will affect market equilibrium through shocks to the demand or supply curve.

If the analyst has a reliable estimate of the supply and demand curves in both the reference and project scenarios, determining the equilibrium in each case is straightforward. In practice, however, such detailed curve estimation is rarely available. Fortunately, it is possible to predict the consequences for market equilibrium using **price elasticities of supply and demand**. These elasticities are key parameters for anticipating how price and quantity adjust.

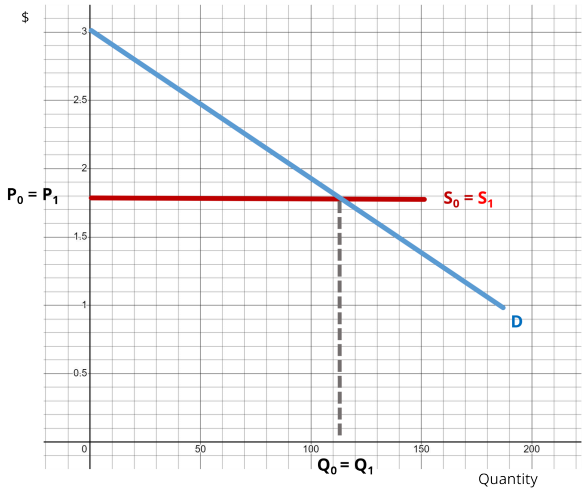
Figure 4.14 illustrates this point in the case of a rightward shift in supply. If demand is perfectly elastic (Panel A), the equilibrium price remains unchanged, and the additional supply increases the quantity traded. If demand is perfectly inelastic (Panel B), the increase in supply primarily reduces the equilibrium price. With perfectly elastic supply (Panel C), the increase in supply has no effect on price or quantity. Finally, if supply is perfectly inelastic (Panel D), the entire shock translates into an adjustment in quantity traded, with price moving accordingly.



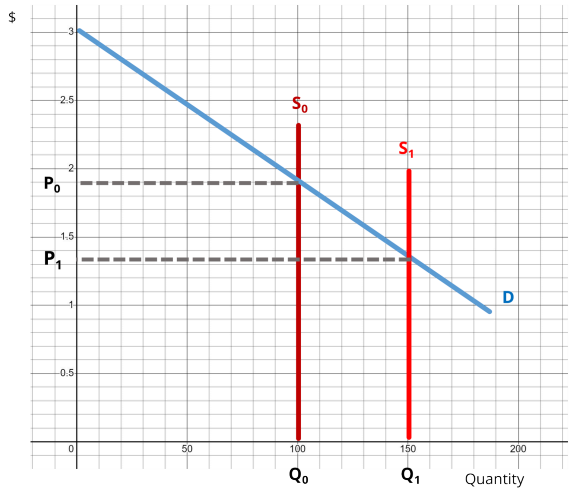
Pannel A : Perfectly elastic demand



Pannel B : Perfectly inelastic demand



Pannel C : Perfectly elastic supply



Pannel D : Perfectly inelastic supply

Figure 4.14. The impact of an increase in supply on the equilibrium, depending on the values of the price elasticities of supply and demand

In general, a project can generate either a **quantity (horizontal)** shock or a **value (vertical)** shock to the demand or supply curve. Table 4.2 provides formulas that allow the analyst to predict the impact on equilibrium price and quantity using comparative statics in a competitive market. These formulas follow directly from the basic model of competitive equilibrium and are discussed in more detail in Nicholson and Snyder (2012, p. 422) as well as in the explanatory video referenced at the end of this chapter.

Table 4.2 An approximation of the impact of the shock on the equilibrium of a competitive market

Nature of the shock	Impact on the equilibrium price	Impact on equilibrium quantity
Quantity shock (horizontal): The project causes a shift in supply or demand of k units to the right		
Supply	$\Delta p\ \% = -\left(\frac{k}{Q_0}\right) \times \left(\frac{1}{\eta_D + \eta_O}\right)$	$\Delta Q\ \% = +\left(\frac{k}{Q_0}\right) \times \left(\frac{\eta_D}{\eta_D + \eta_O}\right)$
Demand	$\Delta p\ \% = +\left(\frac{k}{Q_0}\right) \times \left(\frac{1}{\eta_D + \eta_O}\right)$	$\Delta Q\ \% = +\left(\frac{k}{Q_0}\right) \times \left(\frac{\eta_O}{\eta_D + \eta_O}\right)$
Value shock (vertical): The project causes a vertical upward shift of c$ in supply or demand		
Supply	$\Delta p\ \% = +\left(\frac{c}{P_0}\right) \times \left(\frac{\eta_O}{\eta_D + \eta_O}\right)$	$\Delta Q\ \% = -\left(\frac{c}{P_0}\right) \times \left(\frac{\eta_D \times \eta_O}{\eta_D + \eta_O}\right)$
Demand	$\Delta p\ \% = +\left(\frac{c}{P_0}\right) \times \left(\frac{\eta_D}{\eta_D + \eta_O}\right)$	$\Delta Q\ \% = +\left(\frac{c}{P_0}\right) \times \left(\frac{\eta_D \times \eta_O}{\eta_D + \eta_O}\right)$
(Q_0, P_0): The quantity traded and the price on the market in the reference scenario.		

These formulas will be used repeatedly in the remainder of this manual, notably to analyze the effects of taxes or subsidies (Chapter 8) and to predict the impact of projects that alter production costs (Chapter 8).

An example

Suppose that, in the baseline scenario, the competitive market price is 128 dollars per tonne and the quantity traded is 360,000 tonnes per year. The price elasticity of demand is 1.77 and the price elasticity of supply is 0.64.

Case 1 — Quantity shock to supply

A project that adds a fixed quantity of 125,000 tonnes to supply will reduce the equilibrium price by 14.4 percent, that is:

$(125,000/360,000) \times (1/2.41)$and will increase the equilibrium quantity by 25.48 percent. The new equilibrium price is therefore approximately 109.5 dollars, and the new equilibrium quantity is 451,728 tonnes.

Case 2 — Quantity shock to demand

A project that adds a fixed quantity of 125,000 tonnes to demand will increase the equilibrium price by 14.4 percent and the equilibrium quantity by 9.22 percent. The new equilibrium price becomes approximately 146 dollars and the new equilibrium quantity 393,195 tonnes.

Case 3 — Vertical shock to supply (increase in marginal cost)

A project that increases marginal cost by 15 dollars will raise the equilibrium price by 3.31 percent and lower the equilibrium quantity by 5.85 percent. The new equilibrium price is therefore approximately 131 dollars and the new equilibrium quantity 338,940 tonnes.

Case 4 — Vertical shock to demand (increase in marginal willingness to pay)

A project that increases buyers' marginal willingness to pay by 15 dollars will increase the equilibrium price by 8.6 percent and the equilibrium quantity by 5.5 percent. The new equilibrium price is therefore approximately 139 dollars and the new equilibrium quantity 379,800 tonnes.

4.5 The WTP and its distribution

In general, it is important to remember that the WTP, or the gross benefit generated in a market, is distributed among different stakeholders. Figure 4.15 illustrates a possible distribution:

- Consumers receive consumer surplus (CS), which represents their net benefit;
- Producers obtain producer surplus (PS), or operating surplus. The PS is used to cover fixed costs and economic profit (or loss);
- Production factors receive payments equal to the avoidable costs associated with producing the good.

Other types of distribution are possible, as will be examined later. For example, the State may appropriate part of the WTP through a purchase tax. If a production factor is paid more than its opportunity cost, it receives a **rent** (factor surplus). In addition, some pricing structures may reduce consumer surplus partly or entirely in favor of producers.

It is essential to understand the different possible components of WTP and to be able to

reassemble them, like pieces of a puzzle, using available data. This skill makes it possible to deduce the WTP itself or one of its components, depending on the information at hand.

4.6 Conclusions

Key takeaways

- The area under the demand curve between two quantity levels measures the WTP for an increase in quantity and therefore the gross benefit to consumers. If demand correctly reflects social benefits and no external benefits exist, this area also measures the **social benefit** of the change in quantity.
- The **economic cost of production** corresponds to the sum of the opportunity costs of all resources mobilized to produce a good or service. This cost represents the economic value that could have been generated if these resources had been allocated to their best alternative use.
- **Financial or accounting costs** do not always measure economic cost adequately because they may ignore the opportunity cost of using resources that do not entail monetary outlays.
- The **average cost (AC)** and **marginal cost (MC)** curves summarize the cost function. The area under the marginal cost curve between two quantity levels measures the resources that must be mobilized to produce the additional output. This is an opportunity cost, and—if no external costs exist—also a measure of the **social cost** of production.
- The variation in **consumer surplus** measures the net benefit to consumers (gross benefit minus expenditure). The variation in **producer surplus** measures the net benefit to producers (operating profit, equal to revenue minus operating costs).

- When a project shifts the demand or supply curve of a competitive market, its effects on price and quantity can be predicted using **price elasticities of demand and supply**.
- The WTP generated in a market is shared among market participants, including consumer surplus, producer surplus, and the cost of the resources mobilized. Other components may also arise in some contexts (factor rents, taxes, etc.).

Back to motivation: The CBA of the temporary exhibition

A museum is planning a temporary exhibition with a total cost of 2 million dollars. The organizers anticipate 300,000 visitors and plan to charge an admission fee of 5 dollars per person. To finance the project, the museum is applying for a government grant. As an analyst at a public funding authority, you are tasked with reviewing the CBA of this project, prepared by an intern under your supervision. Here is the summary of the intern's analysis:

Table 4.1 Benefits and costs of exposure (in millions of dollars)

Impact	Value in millions of dollars
The advantage for visitors	1.5
Intangible benefits (positive external effects, tourism, etc.)	0.1
Total cost of the exhibition	2
VAN	-0.4 million

The intern concludes that this project is not socially profitable.
What is your assessment of this conclusion?

Answer

The intern's mistake is to ignore the possibility that visitors' willingness to pay may exceed the admission price actually paid. In other words, the analysis neglects consumer surplus and implicitly assumes it to be zero—a restrictive and generally unrealistic assumption.

To incorporate consumer surplus properly, additional information would be required about the demand for the exhibition (for example, the level of attendance at different prices or an estimate of the price elasticity of demand).

Given the current information, the project becomes socially profitable if the average consumer surplus is at least $1.33 per visitor, that is, $0.4 million divided by 300,000 visitors. Under the additional assumption of linear demand, this corresponds to a minimum reserve price of approximately $7.66. This threshold is not particularly high, suggesting that the project could very plausibly be socially profitable once consumer surplus is taken into account.

Exercises

1. (*) Canada applies a supply management system in the dairy and poultry sectors. This system combines domestic production quotas with customs tariffs that limit imports. It stabilizes prices and keeps them at higher levels than in the United States, where there is no supply management. You are asked to assess the impact of this system on Canadian butter consumers. An initial knowledge inventory has provided the following information on this market (2012 data):

    - The price of butter is on average 30% more expensive in Canada than in the United States;
    - The price elasticity of demand for butter was estimated at 0.9.

    Based on this information, can you determine the impact of the supply management system on consumers? What assumptions would you need to make? What additional information would you need? Find this additional information and calculate the impact. Clearly indicate the sources used to gather this information.
2. How would market equilibrium be affected by a project that reduces production costs by 10 dollars per tonne in a competitive industry, for example by simplifying regulatory procedures? In the baseline scenario, the market price is 150 dollars per tonne and the quantity traded is 525,000 tonnes per year. The price elasticity of demand is estimated at 3.2 and that of supply at 1.5. Using this information, determine the new market equilibrium if the project is implemented.
3. (*) Additional electricity needs are estimated at 50 TWh. The figure below shows the marginal cost curve for this additional production. An energy efficiency program would reduce these additional needs by 10%.
    1. Determine the maximum amount that it would be justified to invest in the energy-efficiency program.

2. How would your answer change if you learned that the electricity production avoided by the energy-efficiency program would have created 200 jobs with an average annual remuneration of $55,000 per job?
3. Can you think of any other potential benefits that this program might generate?

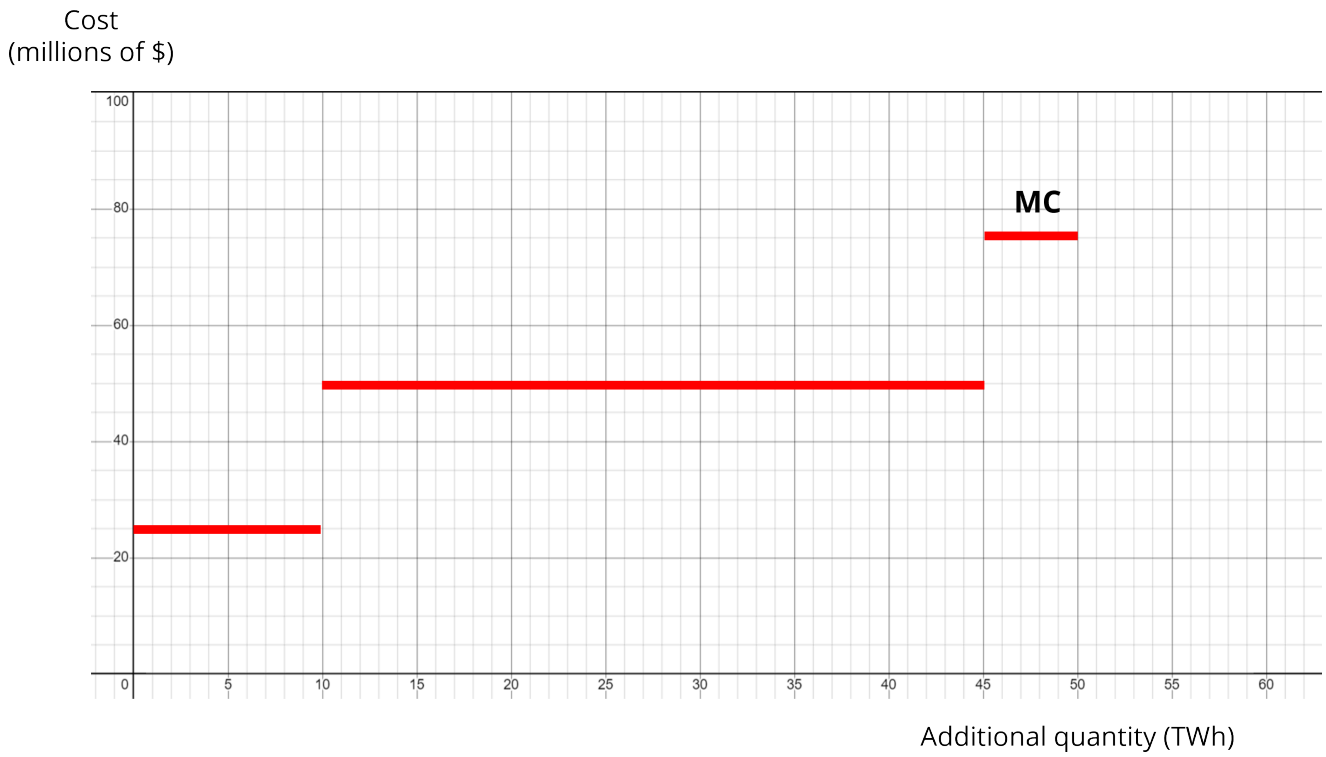


Figure 4.16 Cost structure of electricity production

Appendix 1: Demand with constant elasticity

Apart from the linear demand curve, there are other functional forms, such as the constant elasticity demand. This demand has the following form:

$$Q_D = Ap^{-\eta_d}$$

with A, a constant that determines the magnitude of demand[6].

The inverse function of this demand is given by:

$$p = \left(\frac{A}{Q^D}\right)^{\eta_d}$$

6. This is a functional form often used in empirical assessments of demand, since it is log linear, that is, it can be linearized by taking the log of this function.

And the consumer surplus when the price is p is equal to:

$$\mathrm{SC}(p) = \int_{p}^{+\infty} Ap^{-\eta_d}\,\mathrm{d}p = \frac{Ap^{1-\eta_d}}{\eta_d - 1}$$

It is possible to use this functional form in the example presented in the chapter on the impact of a 15% nutritional tax on sodas. Indeed, a constant-elasticity demand function can be calibrated using the observed market outcome: when the average price is $1 per liter, annual consumption is 820 million liters. From this observation, it follows directly that A=820 million liters. The demand curve can therefore be written as:

$$Q = 820p^{-0.8}$$

Thus, the price increase to $1.15 reduces the quantity from 820 million to 733.25 million liters, which is slightly different from the linear valuation. The exact calculation of the change in surplus ($\Delta\mathrm{SC}$) is given by:

$$\Delta\mathrm{SC} = -\int_{1}^{1.15} 820p^{-0.8}\mathrm{d}p = -\left[\left(\frac{820}{0.2}\right)p^{0.2}\right]_{1}^{1.15} = -116.2 \text{ million \$.}$$

Appendix 2: Demonstration of the formulas in Table 4.2

Let us demonstrate the validity of the following formula: $\frac{\Delta P}{P}\% = -\frac{(k/Q_0)\%}{\eta_o + \eta_d}$ (1)

Consider the impact on the equilibrium price of an exogenous change in the quantity supplied in a market. The market equilibrium condition requires:

$$D\left(p\left(Q+k\right)\right) = O\left(p\left(Q+k\right)\right) + k \quad (2)$$

With the quantity put on the market by the project, $O\left(p\left(Q+k\right)\right)$ represents the supply of existing firms, which depends on the equilibrium price in the market $p\left(Q+k\right)$. This itself depends on the total quantity exchanged in the market, i.e. $Q+k$. Let us examine the impact of a change in k by completely differentiating the relation (2) with respect to k:

$$\frac{\Delta D}{\Delta p} \times \frac{\Delta p}{\Delta k} = \frac{\Delta O}{\Delta p}\frac{\Delta p}{\Delta k} + 1$$

After manipulation, we obtain:

$$\frac{\Delta p}{\Delta k} = -\frac{1}{\frac{\Delta O}{\Delta p} - \frac{\Delta D}{\Delta p}}\ quad(3)$$

We multiply the numerator and denominator of the term on the right by $\frac{\Delta Q}{\Delta p}$, so that we obtain, after some manipulations:

$$\frac{\Delta p}{p} = \frac{k/Q}{\eta_o + \eta_d} \quad (4)$$

It is possible to demonstrate the other formulas using the same type of reasoning.

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One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.pbuq.ca/introduction-cost-benefit-analysis/?p=73#oembed-1

5.

THE ANALYSIS FRAMEWORK

Motivation and learning objectives



The government is considering strengthening safety standards to reduce workplace accidents in a competitive industry. These new standards are expected to increase production costs by $5 per ton. Inspection and enforcement costs are estimated at $25,000 per year and will be borne by the government. The annual benefits of improved safety are estimated at $525,000. Based on a review of the literature and consultations with experts, you have determined that:

- The industry's **average cost** is constant at $50 per ton.
- Current output is 50,000 tonnes per year.
- The **price elasticity of demand** is equal to 1.

Based on this information, a CBA can be conducted. How should you proceed? Which analytical framework is most appropriate? Does government spending accurately reflect the social cost of public funds? How should equity considerations be incorporated? If the good produced by this industry is used as an input in other industries, should the resulting cost increases in those industries be taken into account in the CBA?

At the end of this chapter, you will be able to:

1. Understand and apply the two approaches used to structure a CBA, namely the social approach and the stakeholder approach.
2. Interpret the concept of the marginal cost of public funds.
3. Understand how equity considerations are incorporated into a weighted CBA.
4. Apply the classification of impacts by type (primary, secondary, and induced).

5.1 The two approaches to designing the analysis framework

Two approaches can be used to design the analytical framework of a CBA: the social approach and the stakeholder approach. Both approaches must ultimately lead to the same result. Some situations are easier to analyze using the social approach, while others are more naturally addressed using the stakeholder approach. In practice, it is often useful to apply both approaches, as this allows the analysis to be cross-checked and validated.

5.1.1 The social approach

In the social approach:

1. The reasoning is conducted with respect to the entire reference community;
2. The objective is to determine the project's gross social benefits and costs;
3. Transfers and flows between individual parties are not taken into account;
4. The analysis is typically carried out in terms of quantities (or horizontally), that is, by examining the project as a change in the quantity exchanged.

We now discuss each of these elements in greater detail. Under this approach, the objective is not to identify the impact on each individual stakeholder. Instead, the reasoning applies directly to the reference community as a whole, by asking the following question:

Is the gross social value generated by the project greater than the social cost of the project?

In simple settings, it is straightforward to determine the net social value of a project directly [1]. In other cases, however, the net social value is obtained by answering the following three questions:

1. What is the gross social value generated or destroyed by the project?
2. What is the social value of the resources saved by the project?
3. What is the social cost of the resources mobilized by the project?

To illustrate this approach, consider a simple project: the creation of a competitive market with supply and demand curves shown in Figure 5.1 [2]. The project consists of authorizing trade in this market. It can be

1. The net social benefit of a project can also be called "net social value" or "change in social surplus." Sometimes, for simplicity, the term "social" is omitted. In a CBA, the preferred terminology is Net Present Value (NPV), which we will use when discounting is introduced in the next chapter.

2. We assume that fixed costs are zero.

described as an increase in the quantity traded from $Q = 0$ to $Q = Q^*$, which corresponds to quantity-based reasoning (or horizontal reasoning in Figure 5.1). The scenarios under consideration are as follows:

- ***Baseline scenario*** : Trading in the market is not allowed, so $Q = 0$.
- ***Scenario with the project***: Trading is allowed, so that $Q = Q^*$.

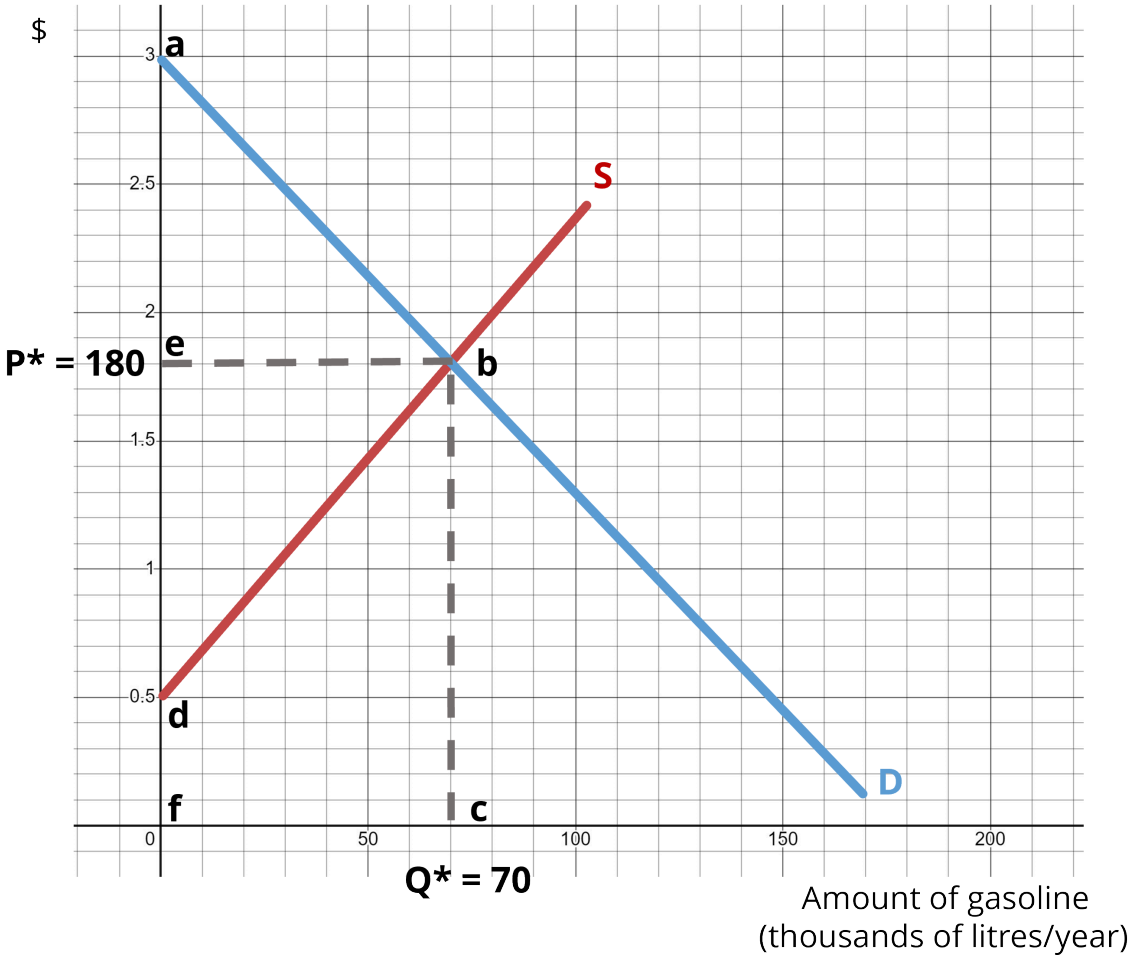


Figure 5.1 CBA of the project to authorize trading in the market

Note that this is the same market as in Chapter 4, so the net benefit corresponds to the area *abd*, that is, the gains from the exchange. Let us nevertheless verify that the social approach can indeed allows us to recover this area.

1) What is the gross social value generated by the project?

As shown in Chapter 4, the social benefit is measured by willingness to pay (WTP), which corresponds to the area under the **demand curve** between $Q = 0$ and $Q = Q^*$. The gross social benefit is therefore equal to $16,625, which corresponds to area *abcf*.

2) What is the social value of the resources saved?

In this context, no resource is saved. This component is therefore equal to zero.

3) What is the social cost of the resources mobilized by the project ?

This component is measured by the area under the supply curve between $Q = 0$ and $Q = Q^*$, that is, area *dbcf*, which is estimated at \$7,875.

The net social value of the project is therefore \$8,750, corresponding to area abd.

Finally, note that the payment from consumers to sellers is not taken into account, as it represents a financial transfer between two stakeholders rather than a social cost or benefit.

5.1.2 The stakeholder approach

In the stakeholder approach:

1. The analysis is carried out at the level of individual stakeholders;
2. The net impact on each stakeholder must be assessed;
   transfers and **financial flows** between stakeholders must be explicitly taken into account;
3. The reasoning is usually conducted in terms of prices (or vertically), that is, by analyzing the project as a change in price.

We now examine the different elements of this approach in greater detail. Under the stakeholder approach, the analysis is performed separately for each stakeholder. As the number of identified stakeholders increases and their roles become more detailed, tracking all the flows between them becomes more complex. For this reason, it is generally advisable to begin by grouping stakeholders into broad categories and to refine this classification progressively as the analysis requires.

A key feature of the stakeholder approach is that it explicitly accounts for transfers and financial flows between stakeholders. When the analysis is conducted consistently, these flows offset one another, so that the resulting net social value is identical to that obtained using the social approach.

Let us apply this approach to the market authorization project illustrated in Figure 5.1.

- The stakeholders are producers and consumers;
- The project can be interpreted as a reduction in price from \$300 (the reservation price at which no trade occurs) to \$175 (the competitive market equilibrium price). The analysis therefore proceeds in terms of price, or vertically in the figure;

- As shown in Chapter 4, the net impact of this price reduction on consumers corresponds to the **consumer surplus**, while the net impact on producers corresponds to the **producer surplus**.

Table 5.1 presents the detailed calculation of the net impacts on each stakeholder, including the payment of $12,250 made by consumers to producers, which represents a financial flow between stakeholders. When computing the social value of the project, this flow cancels out, yielding a net social value of $8,750.

Table 5.1 CBA by stakeholder of the project to authorize trade

Part	Gross benefits	Costs	Net impact
Consumers	*abcf* = $16,625	*ebcf* = $12,250	*abe* = $4,375 CS increase
Producers	*ebcf* = $12,250	*dbcf* = $7,875	*ebd* = $4,375 Increase in SP
Net social value = abd = $8,750 (Increase in social surplus)			

For projects that affect a market, the main stakeholders are typically consumers and producers. In such cases, the change in social surplus generated by a project is evaluated as:

Change in social surplus caused by the project =

Change in CS (consumer surplus)

+ Change in PS (producer surplus)

Accordingly, the change in social surplus induced by the project—also referred to as the project's net social value—is equal to the sum of the changes in consumer surplus and producer surplus. The latter includes both the change in producers' economic profit (that is, the change in π) and any change in fixed costs, as measured by comparing the reference scenario with the project scenario.

Other stakeholders

The **State** is often a key actor in a CBA. As a result, changes in government surplus (GS) must also be taken into account. The change in government surplus is defined as follows:

Change in GS =

Change in government revenues caused by the project

– Change in government spending caused by the project

With three actors, the change in social surplus generated by the project is therefore given by:

Change in social surplus caused by the project =

Change in the CS

+ Change in PS

+ Change in the GS

Additional stakeholders may also be relevant, depending on the nature of the project. For example, if a project generates diffuse environmental impacts, it may be appropriate to introduce a stakeholder such as "Third Parties" to account for environmental costs. In this case, the analysis requires evaluating the reduction in the surplus of this stakeholder.

As discussed earlier, it is generally unnecessary to account for impacts on factors of production when their remuneration is competitive. For instance, if workers are laid off as a result of the project, their loss of wages is offset by the income they can earn in their best available alternative employment. In such cases, there is no net effect to include in the analysis.

By contrast, when the remuneration of a factor of production is not competitive, it may be necessary to include **the change in the rent** earned by that factor in the CBA[3].

The **rent of a factor of production** is the additional remuneration that the factor receives from

3. We speak of "rent" rather than "surplus" in the case of factors of production.

a particular use relative to what it could earn in its best alternative use.

For example, suppose that workers in a given industry receive an annual rent of $10,000 due to the bargaining power of their union. If a project leads to a reduction in employment in that industry, the displaced workers will find jobs elsewhere at a competitive wage, that is, without this rent. In the project's CBA, using the part-by-part approach, this loss of workers' rent must be taken into account (that is, $10,000 multiplied by the reduction in the number of workers). Note, however, that this rent typically corresponds to a cost borne by another stakeholder, such as the government or consumers.

Thus, in its most general form, the part-by-part approach can be expressed as follows:

Change in social surplus caused by the project =

Change in the SC

+ Change in SP

+ Change in the GS

+ Change in third party surplus

+ Change in the rent of production factors

5.2 The marginal cost of public funds

Building on this general framework, several extensions are possible. A first extension consists of incorporating the **Marginal Cost of Public Funds** (MCFP). This concept reflects the fact that the social cost of a project financed with public funds is likely to exceed the amount of public expenditure itself. The reason is that raising taxes generates distortions in the economy.

It is important to note that this is not the **opportunity cost**, which is already taken into account through discounting. Rather, the issue is that raising one dollar of public revenue typically costs the economy more than one dollar. This additional cost reflects, first, the administrative costs associated with tax collection, and second—and more importantly—the efficiency losses resulting from the behavioral responses of economic agents to taxes. For example, income taxes tend to reduce labor supply; taxes on goods distort consumption

choices; capital taxes discourage investment; and taxes can encourage participation in the underground economy. As a result, increases in the tax burden may lead to a contraction of the tax base.

Figure 5.2 illustrates this idea using a simple example. Initially, a 20% tax is levied on a tax base of $100 million, yielding tax revenues of $20 million. Suppose now that the tax rate increases by 10%, so that it rises from 20% to 22%. If economic agents do not adjust their behavior, the tax base remains at $100 million and tax revenues increase by 10%, reaching $22 million. The marginal cost of public funds is then calculated as:

MCFP = \frac{\text{Change in tax rate in %}}{\text{Change in tax revenue in %}} - 1

In this case, where there is no effect on the tax base, MCFP = 0, since (10% / 10% – 1) = 0.

Now suppose instead that the 10% increase in the tax rate induces behavioral responses, causing the tax base to shrink to $98 million. Tax revenues then increase by only 7.8%, reaching $21.56 million. In this case, MCFP = 0.28 (that is, 10% / 7.8% – 1). In other words, each additional dollar of public revenue collected entails a social cost of $1.28.

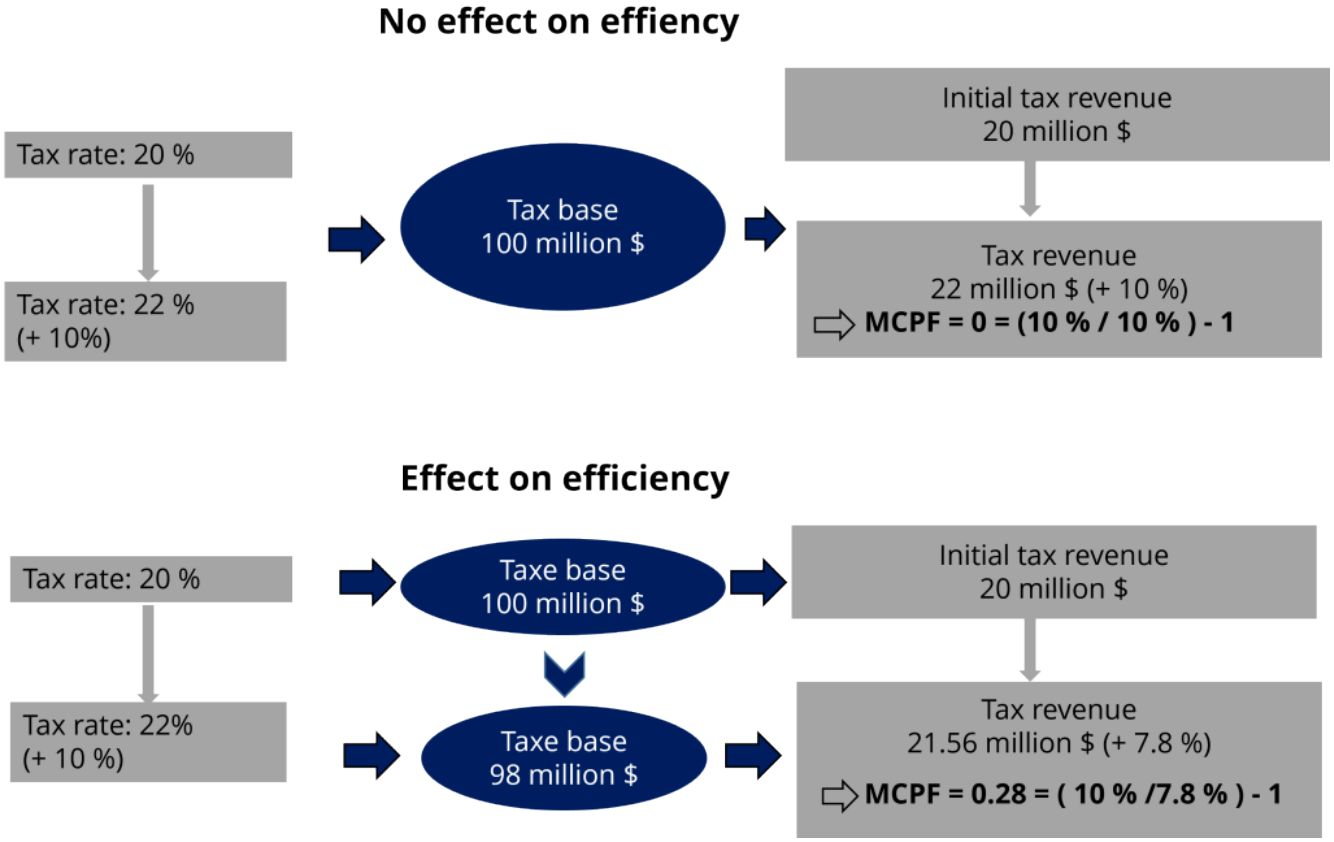


Figure 5.2 Determining the marginal cost of public funds

This variable can be incorporated into a CBA by multiplying the net amount of public funds invested in the project by (1 + MCFP). For example, consider a project in which the government invests $24 million. If MCFP = 0.28, the analysis must account for a social cost of $30.72 million (that is, 1.28 × $24 million).

Under the stakeholder approach, the general accounting identity therefore becomes:

Change in net social value caused by the project =

Change in the SC

+ Change in SP

+ (1 + MCFP) x Change in GS

+ Change in third party surplus

+ Change in the rent of production factors

Under the social approach, the excess cost of public funds must be added directly to the social cost of the project. In the example above, an amount equal to 0.28 × $24 million must be added to the cost of the resources mobilized by the project. The $24 million itself will already have been accounted for elsewhere in the analysis.

The MCFP depends on the tax instruments used to raise public funds and on the existing tax structure. The analyst must therefore identify the most plausible source of project financing when incorporating the MCFP into a CBA.

If the project is financed through a reallocation of existing government expenditures, no additional taxation is required and the MCFP can be set to zero. If the source of financing is uncertain, or if it involves borrowing that will ultimately be repaid through future taxation, the analyst may use a weighted average of MCFP values associated with different tax instruments. In this case, the weights should reflect the relative importance of each instrument in overall government revenues or in the expected financing mix.

This approach emphasizes that the choice of the MCFP is context-dependent and should be guided by the most credible information available on how public funds are actually raised.

5.3 The weighted CBA

Another extension consists of weighting the impacts on different categories of agents in order to account for equity considerations. This approach relies on the part-by-part framework. Considering the three standard categories of agents, the formulation becomes:

Change in social surplus caused by the project =

$$\alpha_c \times \text{CS change} + \alpha_p \times \text{PS change} + \alpha_g \times \text{GS change}$$

where α_c, α_p, and α_g denote the weights assigned to consumers, producers, and the State, respectively. The larger the weight, the greater the influence of the corresponding group's impact on the decision-making process. It is also possible to disaggregate household impacts by income level (for example, by disposable-income quartile) and to assign higher weights to lower-income households.

The choice of weights, however, necessarily involves value judgments. For this reason, it may sometimes be preferable not to apply weighted CBA directly, but instead to present unweighted efficiency results and allow decision-makers to explicitly arbitrate between efficiency and equity considerations[4].

5.4 Primary, secondary and induced effects

As noted earlier, a project will generally affect several different "markets." Figure 5.3 presents a classification of project impacts according to whether they are **primary**, **secondary**, or **induced**.

4. See Chapter 19 of Boardman et al. (2018) for more details.

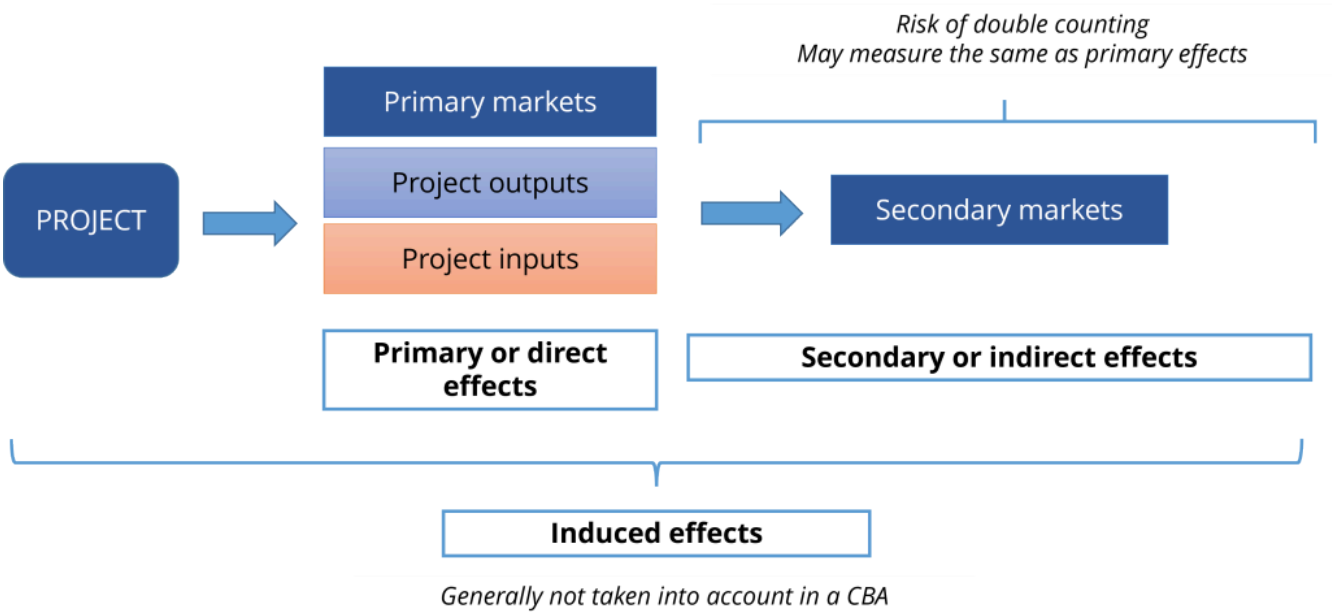


Figure 5.3 Classification of project impacts

A project has a **primary** (or **direct**) effect when it directly causes a change in the quantity or quality of a good supplied (project outputs) or when it alters the quantity of resources used (project inputs).

For example, the construction of a new hydroelectric dam directly increases the supply of electricity in the electricity market (an output of the project) and increases the demand for concrete (an input of the project). If the project also generates additional outputs, such as recreational activities made possible by the creation of the reservoir, these effects must likewise be included in the CBA.

A project generates a **secondary** (or **indirect**) effect when it influences a market indirectly. In this case, the effect arises because of interactions between a primary market and another market, referred to as a secondary market. In other words, the project has a direct impact on one market, which then leads to an indirect impact on a related market.

Several types of interactions can link markets.

1. Goods may be **substitutes or complements in consumption or production**. For instance, the construction of a mega-dam directly affects the electricity market, but indirectly affects the natural gas market, which is a substitute in consumption. Similarly, a health regulation that increases the cost of slaughtering cattle may have consequences for pig slaughtering, which is a substitute in production.
2. Markets may also be connected through **a value chain**. In this case, the secondary market may be upstream or downstream relative to the primary market. For example, an environmental regulation that directly affects oil refineries may generate secondary effects in the upstream oil extraction market or in the downstream gasoline market.

In practice, however, the distinction between primary and secondary effects is not always clear. We return to the treatment of secondary effects in CBA in Chapter 12. At this stage, it is sufficient to note that there is a risk of **double counting**, since secondary effects often represent an alternative expression of primary effects.

A project may also generate induced effects (sometimes referred to as spillover effects or multiplier effects). These effects occur in markets that are not directly connected to the project's primary markets. They arise because the project generates income for certain economic agents, who then spend this income on a wide range of goods and services.

For example, the construction of a dam provides income to workers employed on the project. These workers spend their earnings on various goods and services, thereby generating income for other workers, and so on. The resulting effects are spread throughout the economy, without any specific link to the primary market. As noted earlier, such effects are often excluded from the CBA because they do not represent additional income [5]. Indeed, in the reference scenario, the alternative use of the resources mobilized by the project would also generate induced effects.

In the CBA:

- Primary effects must be taken into consideration;
- Secondary effects may often be ignored, as they frequently represent alternative

5. See Chapter 12 for exceptions.

manifestations of primary effects and therefore risk double counting;
- Except in exceptional cases, induced effects should be excluded from the analysis.

5.5 Conclusions

Key takeaways

- A project's analytical framework can be developed using the social approach, which relies on horizontal reasoning (changes in quantities). Under this approach, the objective is to assess the project's social impacts without considering transfers or financial flows between stakeholders. Three key questions guide the analysis: i) What value is created or destroyed for the reference community? ii) What is the social value of the resources potentially released by the project? iii) What are the social costs associated with the mobilization of resources?
- In **undistorted markets**, the value created or destroyed corresponds to the area under the demand curve, while the social value of resources mobilized or saved corresponds to the area under the supply curve.
- The analytical framework can also be developed using the stakeholder approach. In this case, reasoning is conducted vertically (in terms of price changes). The objective is to assess the net impact on each stakeholder, including changes in consumer surplus, producer surplus, government surplus, third-party surplus, and factor rents.
- Although transfers and financial flows between stakeholders are explicitly accounted for under the stakeholder approach, they offset one another when computing the net present value (NPV).
- The stakeholder approach also makes it possible to document distributional impacts across

different categories of agents and, if desired, to apply weights to reflect equity considerations (weighted CBA).

- In addition, the analyst must assess whether it is appropriate to incorporate the marginal cost of public funds into the CBA.
- Finally, the analyst must distinguish between primary, secondary, and induced effects. In general, CBA focuses primarily on primary effects. In some contexts, secondary effects should be excluded to avoid double counting, while in others certain secondary effects may need to be included. Induced effects should most often be excluded from the analysis.

Back to motivation: CBA for strengthening safety standards

The government is considering strengthening safety standards to reduce workplace accidents in a competitive industry. These new standards are expected to increase production costs by $5 per ton. Inspection and enforcement costs are estimated at $25,000 per year and will be borne by the government. The annual benefits of improved safety are estimated at $525,000. Based on a review of the literature and consultations with experts, you have determined that:

- The industry's **average cost** is constant at $50 per ton.
- Current output is 50,000 tonnes per year.
- The **price elasticity of demand** is equal to 1.

Based on this information, a CBA can be conducted. How should you proceed? Which analytical framework is most appropriate? Does government spending accurately reflect the social cost of public funds? How should equity considerations be incorporated? If the good produced by this industry is used as an input in other industries, should the resulting cost increases in those industries be taken into account in the CBA?

Answer

The industry operates in a competitive environment, which makes it appropriate to use the supply-and-demand framework to analyze the market impact of the project. The analysis begins by

defining the initial market conditions, that is, the reference (baseline) scenario. We then predict the new market equilibrium following the implementation of the strengthened safety standards, that is, the project scenario.

The baseline scenario

In the baseline scenario, the quantity traded, denoted Q_0, is 50,000 tonnes per year. Since average cost is constant at $50 per tonne, marginal cost is also constant at $50. The initial equilibrium price, denoted P_0, is therefore $50. This initial equilibrium is illustrated in Figure 5.4 at point *b*.

The project scenario

With the introduction of the new standards, both average and marginal costs increase to $55 per tonne. This increase in production costs is fully passed on to consumers, resulting in a new equilibrium price, denoted P_1, of $55. The next step is to determine the quantity traded at this new price. Using the price elasticity of demand, which is equal to 1, a 10% increase in price leads to a 10% decrease in quantity demanded. The new equilibrium quantity is therefore $Q_1 = 45{,}000$ tonnes. This new equilibrium is also shown in Figure 5.4, at point *a*.

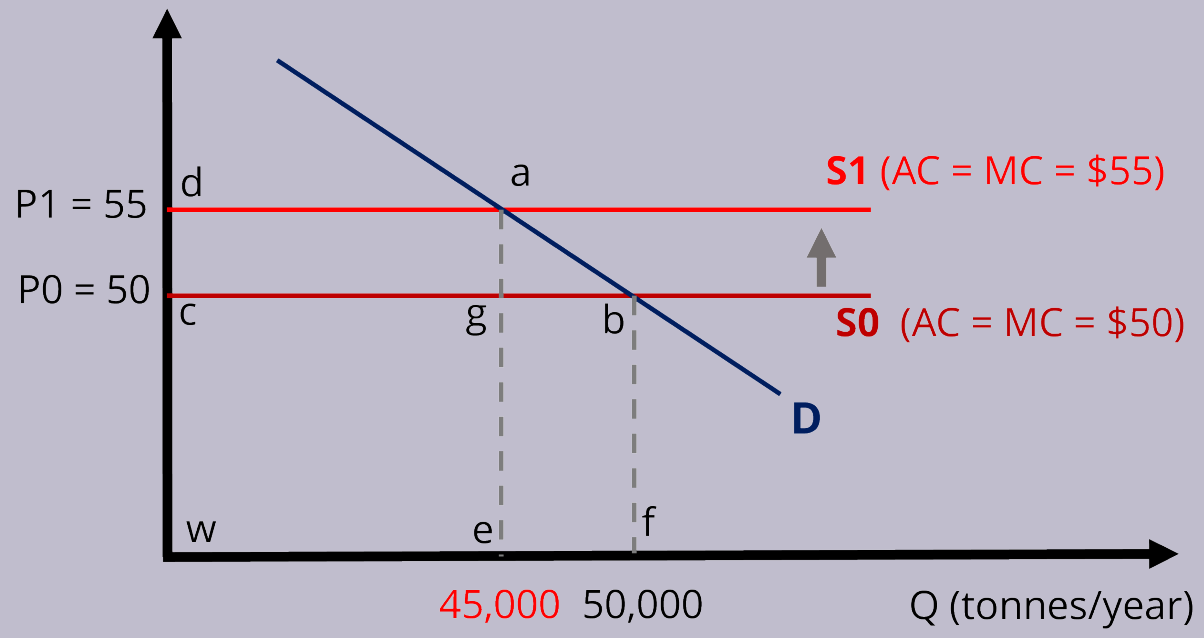


Figure 5.4 Impact of strengthening safety standards in the market

We can now evaluate the project using both the social approach and the part-by-part approach.

The social approach

1. The social value lost due to the reduction in production from Q_0 to Q_1 is measured by area abfe, which amounts to $262,500 (a cost).

2. The social value of the resources released as a result of the decrease in production is measured by area gbfe, equal to $250,000 (a benefit).

3. The social cost of the resources mobilized by the project is given by area dagc, which amounts to $225,000 (a cost).

   To these market effects must be added the $525,000 benefit associated with improved worker health and the $25,000 in inspection and enforcement costs.

   The annual net social value of the project is therefore estimated at $262,500.

The stakeholder approach

Stakeholders include industry customers, producers, workers and government. The table below assesses the impacts on each of these parties.

Table 5.3 CBA of strengthening security standards

Stakeholder	Impact	Annual value
Customers	Decline in surplus — *dabc surface*	– $237,500
Producers	No impact (no surplus)	0$
Workers	Safety Gains[6]	$525,000
Government	GS decrease linked to monitoring costs	– $25,000
	Annual net worth	$262,500

The answers to the remaining questions can be found directly in the chapter text.

6. We attribute all of the safety benefits to workers, but in reality some of the gains should perhaps accrue to the government in the form of lower health care costs, for example.

Does government spending adequately reflect the social cost of public funds?	Section 5.2
How should equity be taken into account?	Section 5.3
If the good produced by this industry is used as an input in other industries, should the resulting increase in production costs in those industries be included in the CBA?	This constitutes a secondary effect that is already captured in the valuation of primary effects, through the decrease in consumer surplus. See Section 5.4.

Exercises

(*) Indicates that the solution is available

(**) Indicates that the solution is available with restricted access

1. (**) Annual production of greenhouse tomatoes in a region is 25,000 tonnes, generating revenues of $75 million for producers. This corresponds to an average price of $3,000 per tonne. Assume that Figure 5.5 illustrates the supply and demand curves in the wholesale market for greenhouse tomatoes.

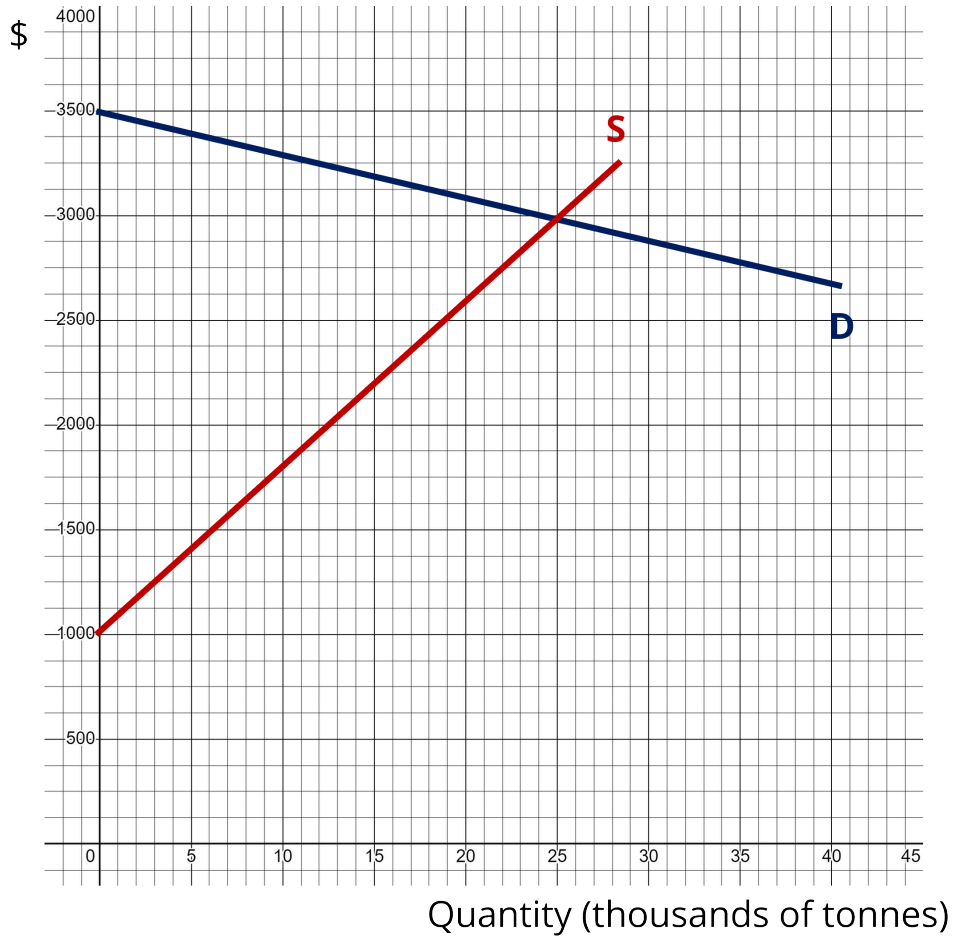


Figure 5.5 The greenhouse tomato market

- Determine the value of the price elasticity of demand at market equilibrium?
- Does this value seem realistic?

To promote food self-sufficiency, the government is considering granting greenhouse tomato producers access to a preferential electricity rate of 3 cents per kilowatt-hour (kWh) instead of the standard rate of 5.8 cents per kWh. Assume that this reduction in electricity prices leads to a cost reduction of $500 per tonne produced. Analyze the impact of this project on the wholesale market for greenhouse tomatoes using both the social and stakeholder approaches.

If you were to conduct a more comprehensive CBA of this project, what other important impacts should be taken into account?

2. (*) A project aims to modernize a railway line between Region A, which is remote and isolated, and the urban Region B. For each of the following effects, identify the nature of the impact; that is, determine whether it is a direct (primary), indirect (secondary), or induced effect.

E1. The project increases mining production in Region A by reducing transportation costs.

E2. The price of imported food in Region A decreases.

E3. Time savings for passengers travelling by train between Regions A and B.

E4. A decline in the revenues of air carriers operating between the two regions.

E5. A reduction in maintenance costs for the road linking the two regions, due to lower truck traffic.

E6. An increase in tourism activities in Region A.

E7. An increase in the average wage of railway personnel.

E8. An increase in the price of railway tracks.

E9.Higher sales in bars in Region A, resulting from spending by workers employed by the project.

3. (*) (**Advanced**) The government has decided to produce 5,000 units of a good. Production requires only one input: low-skilled labor. With the existing technology, 6 units of labor are needed to produce one unit of output, and there are no **fixed costs**. The wage rate is $w = \$10$ per unit of labor, as determined by an undistorted competitive labor market. Alternatively, the government can make a one-time investment of $130,000 to adopt a new technology that doubles productivity.
    1. Using the stakeholder approach, perform a CBA of the decision to invest in the new technology or not. Complete the table below. Then verify your results using the social approach.
    2. How would your answers change if the wage paid included a $2 rent? In other words, workers are paid $10 per unit of labor, but their wage in the best alternative job is $8 per unit.

Table 5.4 CBA of new technology adoption

Stakeholder	Advantage	Cost	Net effect	Description of impacts
State				
Workers				
			NPV =	

Table 5.5 CBA of new technology adoption with a labor rent

Stakeholder	Advantage	Cost	Net effect	Description of impacts
State				
Workers				
			NPV =	

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6.

DISCOUNTING AND DECISION RULES

Motivation and learning objectives

In your role, you must choose between two mutually exclusive projects. Project A provides an annual benefit of $30,000 and an annual cost of $12,000 for five years. Project B incurs a cost of $25,000 in year 1 and an annual cost of $5,000 from year 2 through year 10. It also generates an annual benefit of $30,000 for ten years. Which project would you select, assuming a 5% discount rate?

Although both projects generate the same annual benefit of $30,000, their cost profiles differ: Project A is less costly in the first year, but relatively more costly thereafter. In addition, the projects have different lifespans—five years for Project A and ten years for Project B. Finally, it is possible that neither project is socially worthwhile. The discounting techniques presented in this chapter will help you make this choice.

1. Understand the mechanics and interpretation of discounting;
2. Compare projects with different time horizons;
3. Understand the challenges involved in estimating a project's residual value;
4. Neutralize the effects of inflation;
5. Apply the appropriate project selection rules;
6. Avoid double counting costs associated with durable goods.

This chapter does not address the choice of the social discount rate. That issue is discussed in Chapter 17.

6.1 Why discounting?

CBAs typically evaluate projects that unfold over several years. These projects often involve investments in

infrastructure (durable goods), so that most of the costs are incurred at the beginning of the project, while the benefits accrue gradually over time.[1] These impacts are initially expressed in monetary terms that vary over time, since a dollar today does not have the same value as a dollar received ten years from now. But why is this the case?

Why is $1,000 today worth more than the same amount in ten years? There are two main reasons:

1. Inflation;
2. The opportunity cost of invested resources.

Inflation refers to a general increase in prices over time, which reduces the purchasing power of money. As a result, the real value of $1,000 declines over time. Discounting eliminates the effects of inflation. However, this effect can also be neutralized by working with data expressed in real terms, that is, in constant dollars of a given base year. Inflation is therefore not the fundamental reason for using discounting techniques.

The primary purpose of discounting is instead to account for the **opportunity cost** of the resources invested in a project. These resources could alternatively be:

Invested in another project that yields a certain rate of return;
Used for current consumption, generating immediate benefits.

For a project to be considered worthwhile, it must therefore generate a rate of return that exceeds what could be obtained in its best alternative use. The discount rate is the parameter that captures this opportunity cost. Moreover, because CBA adopts a social perspective, a social discount rate must be used.

> The **social discount rate** represents the return forgone by society when resources are committed to a particular project.

For example, if the social discount rate is 7%, a project will have a positive net present value only if its internal rate of return exceeds 7%, as we will illustrate in the next section.

6.2 Discounting formulas

We begin with the simplest case of a project that spans a single period. In most CBAs, a period corresponds to

1. The opposite situation can also occur. For example, operating a nuclear power plant may generate benefits today while giving rise to environmental and waste management costs that are deferred to the future.

one year. Consider a project that requires an investment of $1 million today, at $t = 0$, and generates a benefit of $1.07 million one year later, at $t = 1$. The base year for the CBA is therefore $t = 0$. Figure 6.1 illustrates the project's timeline.

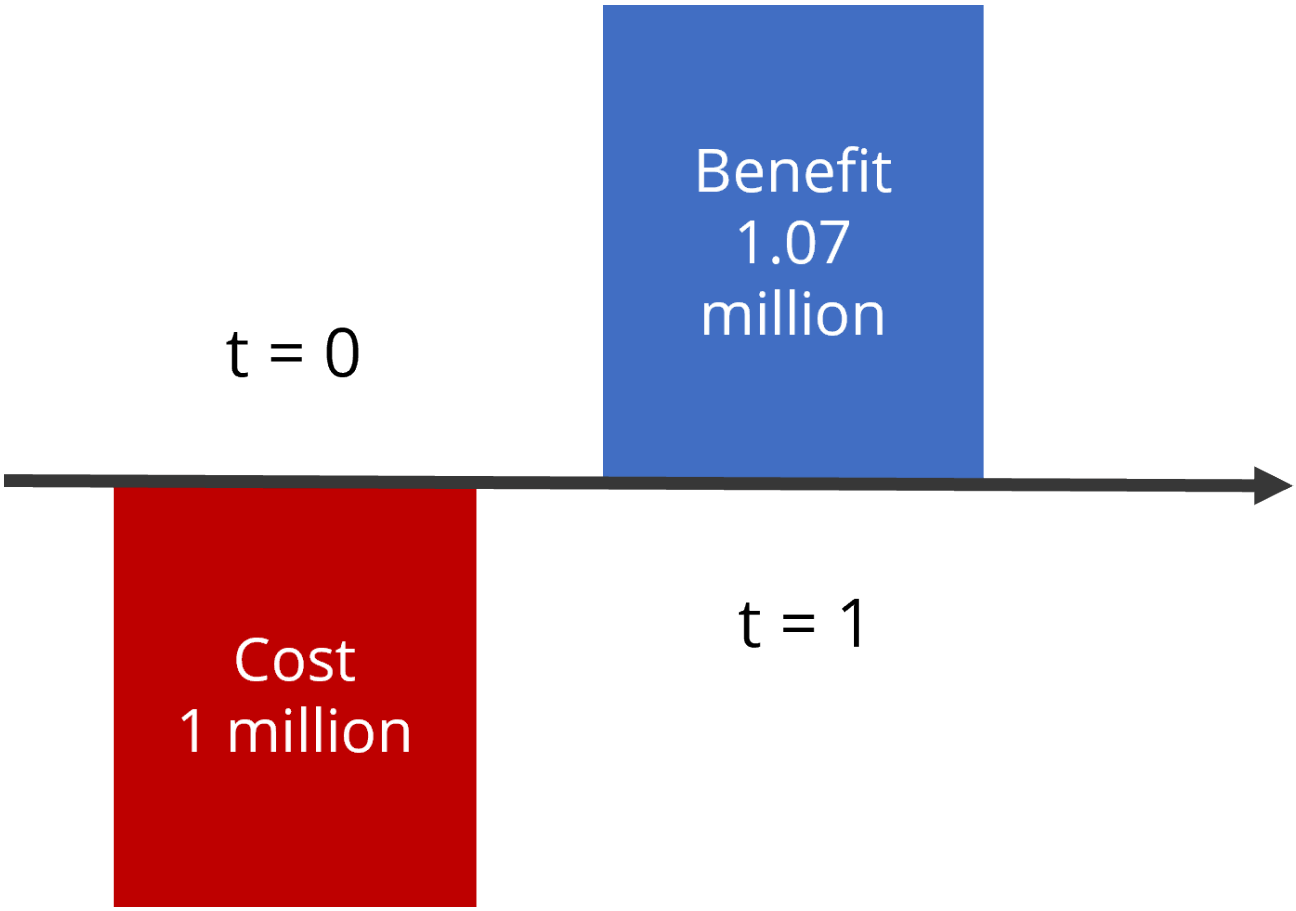


Figure 6.1 Project timeline

As explained in Chapter 1, this project must be evaluated relative to a **baseline scenario**. We must therefore ask what the best alternative use of the $1 million invested in the project would be. As discussed in the previous section, this amount could be invested in another project or used for current consumption. Rather than identifying the precise best alternative use, it is sufficient to determine the expected social rate of return if the funds were allocated elsewhere. This rate is the social discount rate, denoted by the letter s.

In our example, let s = 5%, or 0.05. In the baseline scenario, the $1 million would then generate a return of $1.05 million at $t = 1$ if invested in an alternative project. This follows directly from the interest formula:

$$V_1 = V_0 \times (1 + s)$$

where V_1 denotes the future value at $t = 1$ and V_0 denotes the current value, or present value, at $t = 0$.

Table 6.1 illustrates the costs and benefits under the baseline and project scenarios. Here, we adopt a presentation format in which the two options are displayed side by side for comparison.

Table 6.1 Comparison of the project with the best alternative use of funds (in millions of $)

Invest in the project		**Invest in your best alternative**	
Cost (t = 0)	1	Cost (t = 0)	1
Advantage (t = 1)	1.07	Advantage (t = 1)	1.05

The initial cost is the same in both scenarios; however, the project generates an additional benefit of $0.2 million at $t = 1$. Table 6.2 presents the results using an alternative format that highlights the project's opportunity cost, namely the foregone benefit of $1.05 million, as implied by the social discount rate.

Table 6.2 CBA results in terms of net future value

CBA of the project	Future value (in millions of $)
Project benefit (t = 1)	1.07
Opportunity cost (t = 1)	1.05
Net future value (NFV) (t = 1)	0.02

Note that in Table 6.2, all values are expressed in future value terms, that is, at $t = 1$. In CBA, results are instead expressed in present value terms, that is, at $t = 0$. To do so, we simply invert the previous formula:

$$V_0 = \frac{V_1}{1 + s}$$

Table 6.3 applies this formula to the values reported in Table 6.2. As expected, the opportunity cost expressed at $t = 0$ is simply the initial cost of the project. The discounted benefits amount to $1.019 million, yielding an NPV of $0.019 million. This corresponds to the present value of the net future value, that is, $0.02/(1 + 0.05) = \$0.019$ million.

Table 6.3 Results of the project CBA in present value

CBA of the project	Present value (in millions of $)
Project benefit in present value (t = 1)	1,019
Opportunity cost in present value (t = 1)	1
Net Present Value (NPV) (t = 1)	0.019

In summary:

In CBA, all values are converted to present value, or base-year value, using the social discount rate. This process reflects the opportunity cost of the resources invested in a project, that is, the return that society could have obtained by allocating those resources to their best alternative use, whether through an alternative investment or immediate consumption.

The formulas can be generalized to multiple periods. In this case, it is necessary to account for the fact that interest is compounded: accumulated interest itself earns interest. Thus, an amount V_0 invested for N years at a rate of s will be worth, at $t = N$:

$$V_N = V_0 \times (1+s)^N$$

By inverting this formula, we obtain the present value (V_0) of an amount received in N periods (V_N), given a discount rate s:

$$V_0 = \frac{V_N}{(1+s)^N}$$

This formula can be applied to either a future benefit or a future cost. Accordingly, the NPV of a project with a **time horizon** of N periods is given by:

$$VAN = \frac{A_0}{(1+s)^0} + \frac{A_1}{(1+s)^1} + \cdots + \frac{A_N}{(1+s)^N} - \left(\frac{C_0}{(1+s)^0} + \frac{C_1}{(1+s)^1} + \cdots + \frac{C_N}{(1+s)^N} \right)$$

or, in a more compact form:

$$NPV = \sum_{t=0}^{N} \frac{A_t}{(1+s)^t} - \sum_{t=0}^{N} \frac{C_t}{(1+s)^t} = \sum_{t=0}^{N} \frac{A_t - C_t}{(1+s)^t} \quad (6.1)$$

where A_t denotes the benefit generated by the project at the end of period t, and C_t denotes the cost incurred at the end of period t.

The NPV can be computed either by discounting benefits and costs separately or by first calculating the net benefit in each period and then discounting those net benefits. Discounting is generally performed on an annual basis[2].

It is important to describe the timing of costs and benefits precisely. Equation (6.1) assumes that the project generates costs and benefits starting at the beginning of the project, that is, at $t = 0$. In practice, however, many projects involve substantial upfront costs, followed by operating costs in later periods, while benefits may only materialize after several periods.

2. The impact of the discounting frequency on results is relatively small, especially compared with the level of precision typically achievable in a CBA. For example, one million dollars received in ten years is worth $613,913 today when discounted annually at a rate of 5%. If discounting is continuous (that is, if interest is compounded continuously), the present value is $606,530—a difference of less than 3%.

Beyond specifying how costs and benefits are distributed over time, it is also necessary to indicate when within a given year they occur. Three cases can be distinguished (see also Figure 6.2):

1. The impact occurs at the end of each year. In this case, A_{10}, for example, is received at the end of year 10 and must therefore be discounted over 10 years, yielding a present value of $A_{10}/(1+s)^{10}$. This is the convention adopted in equation (6.1).
2. The impact occurs at the beginning of each year. In this case, A_{10} is assumed to be received at the beginning of the tenth year, that is, after 9 years. Its present value is therefore $A_{10}/(1+s)^{9}$.
3. The impact occurs continuously throughout the year. If A_{10} is received gradually over the course of year 10, this is equivalent to assuming that it is received at $t = 9.5$, that is, at the midpoint of the year. Its present value is then $A_{10}/(1+s)^{9.5}$.

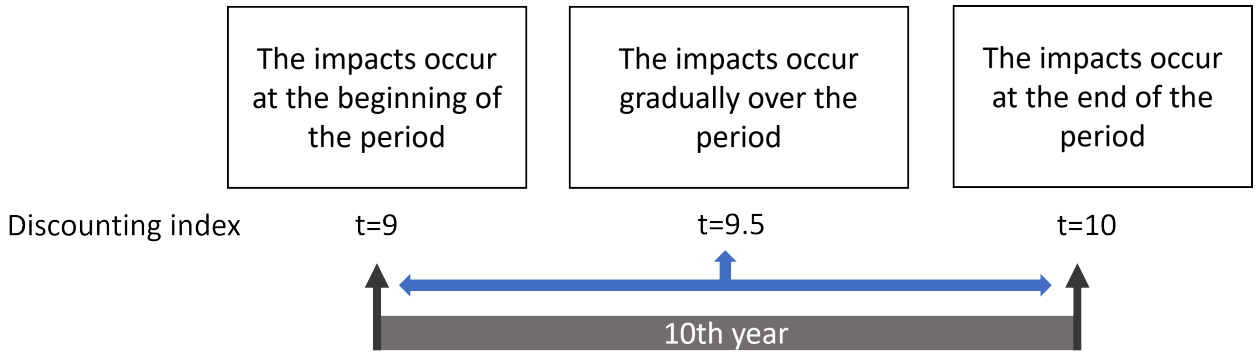


Figure 6.2 Different hypotheses regarding the course of impacts over a period

6.3 Annuity, perpetuity and annualization

6.3.1 The annuity

In some cases, project benefits or costs take the form of constant annual amounts over time, such that $A_t = A$ or $C_t = C$. These streams of constant payments are referred to as annuities. Although formula (6.1) can be applied in this case, a more convenient closed-form expression is available. The present value of an annuity A received at the end of each period for N periods, using a discount rate s, is given by:

$$VA\,(A) = A \times a_s^N \quad (6.2)$$

where $a_s^N = \dfrac{1-(1+s)^{-N}}{s}$ is the annuity factor.

If the annuity is received at the beginning of each period rather than at the end, the present value is calculated as:

$$VA\,(A) = A \times a_s^N \times (1+i) \quad (6.3)$$

Finally, if the annuity is received continuously throughout each period, the present value is given by:

$$VA(A) = A \times a_s^N \times (1+i)^{0.5} \quad (6.4)$$

Example: Present value of operating costs

The annual operating costs of a project are estimated at $100,000 for five years. These costs are incurred at the end of each period. Calculate their present value using a discount rate of 7%.

Answer

The annuity factor is $a_{7\%}^5 = 4.1$. The present value of operating costs is therefore $410,000.

In some cases, the annual amount of an annuity is not constant but instead grows (or declines) at a constant rate g. For example, suppose a benefit is received at the end of the first period and then increases each year at rate g. The amount received at the end of period t is then given by:

$$A_t = A_{t-1}(1+g) = A_{t-2}(1+g)^2 = \cdots = A_1(1+g)^{t-1}$$

In this case, the present value can still be computed using the constant-annuity formula, that is, equation (6.2), provided it is applied to the following adjusted annual amount:

$$A = \frac{A_1}{1+g}$$

and using the following effective discount rate:

$$i = \frac{s-g}{1+g}$$

Note that this procedure is valid only if $s > g$.

Moreover, when g is relatively small, the present value can be approximated using equation (6.2) with the following simplifications:

$A = A_1$ and $i = s - g$.

Example: Benefits that increase with population

The benefits of a project are valued at $200,000 at the end of the first year. Thereafter, they are

assumed to grow at the same rate as the population, namely 1% per year. The project has a duration of 10 years, and the social discount rate is 5%. Calculate the present value of these benefits.

Answer

The present value of this growing annuity can be estimated using formula (6.2), applied to an equivalent annuity with

$A = 200{,}000/(1 + 0.01) = \$198{,}020$

and an effective discount rate of

i = 0.04 / 1.01 = 3.96%.

With these parameters, the annuity factor is 8.13, yielding a present value of $1,609,903.

Using the approximation, we instead take

$A = 200{,}000$ and i = 4%.

The corresponding annuity factor is 8.11, which gives a present value of $1,622,000.

6.3.2 Perpetuity

A **perpetuity**is defined as a constant amount received (or paid) each period for an **infinite duration**.

The present value of $1,000 received at the end of each year in perpetuity, discounted at a rate of 5%, is:

$$VA = 1000\$ \times a_{5\%}^{\infty} = \frac{1000\$}{0.05} = 20\ 000\$$$

Indeed, the annuity factor over an infinite time horizon is equal to $1/s$. This formula is particularly useful as an approximation when the project's time horizon is very long.

6.3.3 Annualization

In some applications, it may be useful to **annualize** a cost or a benefit, that is, to express it as an equivalent constant annual amount over the life of the project.

This can be done by inverting formula (6.2). For example, suppose a project requires an initial investment of \$20,000 at $t = 0$ and has a lifespan of five years. Annualizing this cost at a discount rate of 6% yields:

$$A = \frac{20\ 000\$}{a^{5}_{6\%}} = 4\ 747.9\$$$

In other words, an annuity of \$4,747.9 per year, discounted at 6%, has a present value equal to \$20,000.

6.4 Comparing projects with different time horizons

In some cases, it is necessary to compare projects with different durations. Consider the case of controlling the spread of a contagious disease for which two vaccines are available. Vaccine 1 costs \$15 per dose and provides immunity for one year, while Vaccine 2 costs \$70 per dose and provides the same level of immunity for five years. For simplicity, assume that the cost per dose includes both the vaccine itself and its administration.

Because the two vaccines are equally effective, the choice between them can be based solely on costs. However, the relevant time horizons differ: Vaccine 1 provides protection for one year, whereas Vaccine 2 provides protection for five years. There are three methods for comparing projects with different time horizons.

6.4.1 The rollovermethod

To compare the cost of Vaccine 1 over the same time horizon as Vaccine 2, Vaccine 1 can simply be administered once per year for five years, that is, the project is replicated five times. It is important to note, however, that this is not equivalent to multiplying the cost of Vaccine 1 by five, since discounting must be taken into account.

For example, with a discount rate of 5%, the total cost of administering Vaccine 1 annually for five years is equal to:

VA (Vaccine 1 administered annually for 5 years) = $15\$ \times a^{5}_{5\%} = 64.95\$$

Vaccine 1 therefore appears to be the less expensive option.

6.4.2 The average annual equivalent method

This method consists of calculating, for each option, the Average Annual Equivalent (AAE), that is, the annualized net present value. In this example, the average annual cost of Vaccine 1 is, by definition, $15.

To compute the average annual cost of Vaccine 2, we apply the annualization formula introduced in Section 6.3.3:

$$\text{Average annual cost of Vaccine 2} = \frac{70\$}{a^{5}_{5\%}} = 16.16\$$$

As expected, both methods lead to the same recommendation.

6.4.3 Inclusion of residual value in the longest project

In some cases, replicating a project is not realistic. In such situations, the NPV of the longer project can be calculated using the time horizon of the shorter project, as if the longer project were terminated prematurely. The residual value of the longer project must then be included among the project's benefits (see Section 5.7 for further details).

6.5 Taking inflation into account

Inflation refers to a general increase in prices over time, while deflation to the opposite phenomenon. In **cost-benefit analysis (CBA)**, the objective is to neutralize the effects of inflation (or deflation). The standard approach for doing so is to work with data expressed in constant, or real, dollars rather than in current, or nominal, dollars. Converting a nominal series into real terms requirefers res adjusting for inflation using a price index.

Several price indices are available, but the two most commonly used are the following:

1. The Consumer Price Index (CPI) measures changes in the prices of a representative basket of goods and services consumed by households. In the base or reference year, the CPI is set equal to 100, and price changes are expressed relative to that year. For example, in 2009, the CPI (2002 = 100) was 119.1, indicating that prices increased by 19.1% between 2002 and 2009.
2. The gross domestic product (GDP) price index is broader than the CPI, as it captures price changes across the entire economy. It includes not only consumer goods and services, but also prices in other sectors.

The choice of price index depends on the type of series being adjusted. For a consumer good price series (for example, the price of cell phones), the CPI is generally appropriate. By contrast, when the series concerns the price of an input (for example, lumber), the GDP price index is more suitable.

The conversion of a nominal series into a real series is straightforward, as illustrated in Table 6.4. Line (1) reports the observed price of gasoline. Line (2) shows the evolution of the CPI, with 2002 as the reference year. Using these two series, line (3) can be calculated to represent the evolution of real gasoline prices expressed in 2002 dollars. This is obtained by dividing line (1) by line (2) and multiplying by 100.

It may happen that the base year of the CPI reported by official statistical agencies does not correspond to the desired reference year. In such cases, the CPI can easily be rebased, as shown in line (4), using a simple proportional adjustment. Specifically, CPI values are divided by the CPI value of the new reference year and then multiplied by 100. In this example, to express the CPI in 2023 dollars, line (1) is divided by 171.6. Using this rebased index, line (5) is then computed to represent the real price of gasoline expressed in 2023 dollars.

Table 6.4 Nominal and real price of a litre of gasoline (cents/litre)

	2000	2010	2020	2023
(1) Current price	73.2	106.3	103.7	171.6
(2) CPI (2002 = 100)	95.8	114.8	131.6	151.7
(3) Real prices in 2002 $	76.4	92.6	78.8	113.1
(4) CPI (2023 = 100)	63.2	75.7	86.8	100
(5) Actual prices in 2023 $	115.8	140.4	119.5	171.6

Accordingly, all value series used in a CBA—including projections and forecasts—should be expressed in constant, base-year dollars. When this is the case, discounting is performed using a real social discount rate, that is, a rate that excludes inflation.

It is also possible, however, to work with forecast series expressed in current (nominal) dollars. In that case, discounting must be carried out using a nominal social discount rate, which incorporates inflation so that its effect is neutralized.

The difference between the real and nominal discount rates reflects expected inflation over the analysis horizon. The exact relationship between the two rates is given by:

$$s^r = \frac{s^n - m}{1 + m}$$

where s^r denotes the real social discount rate, s^n the nominal social discount rate, and m the average expected inflation rate over the analysis period.

When m is small, this relationship can be approximated as:

$$s^r = s^n - m$$

In a CBA, the effects of inflation must be eliminated. This can be achieved either by working with forecasts expressed in real terms and discounting them using a real social discount rate, or by working with forecasts expressed in nominal terms and discounting them using a nominal social discount rate.

6.6 Residual value

Ideally, the analysis horizon should coincide with the project's life span. However, for long-lived infrastructure projects, making reliable long-term forecasts can be difficult. In addition, some projects involve multiple infrastructures with different life spans. As a result, the analysis horizon (denoted by T) may be shorter than the project life span (denoted by F).

For example, consider a bridge project for which the analysis horizon is 40 years ($T = 40$), while the technical life span of the infrastructure is 100 years ($F = 100$). Figure 6.3 illustrates another situation in which the project life span is 10 years and the analysis horizon is 6 years. In such cases, the CBA must incorporate the residual value of the project corresponding to the remaining 4 years that are not explicitly included in the analysis.

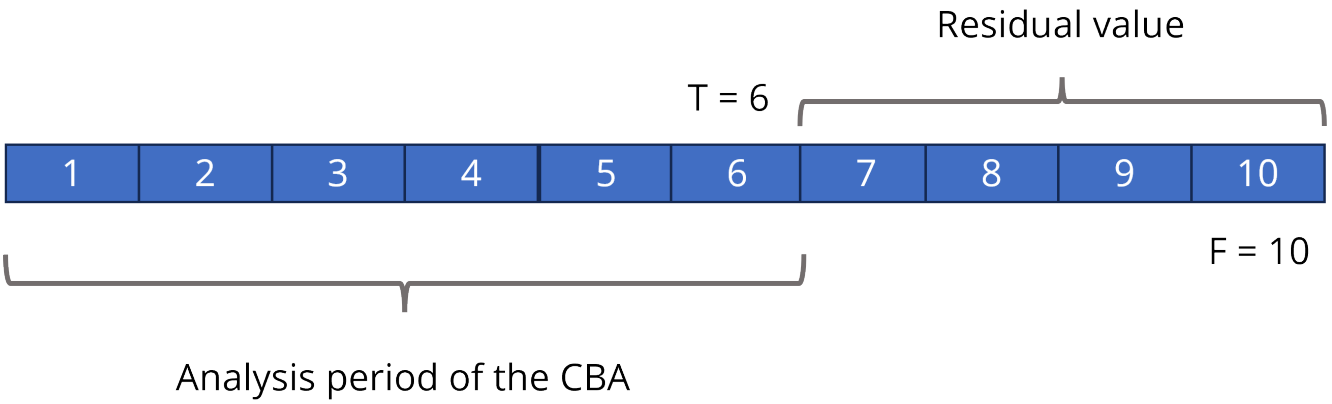


Figure 6.3 Example of including a residual value

Residual value is often a benefit of the project (RV > 0), as it reflects the project's resale or remaining economic value at the end of the analysis horizon. In some cases, however, residual value may be negative (RV < 0), when end-of-life costs exceed remaining benefits. This can occur, for example, in mining projects, where declining ore quality and site closure require costly decontamination and restoration activities.

Estimating a project's residual value is a delicate task, particularly because it can have a decisive influence on the project's NPV. Several valuation methods are available (see Boardman et al., 2018).

6.6.1 Evaluation by extrapolation

Conceptually, the residual value (RV) of a project corresponds to the present value of the project's net benefits accruing between the end of the analysis horizon (T) and the end of the project's life (F). It can therefore be expressed as:

$$VR_T = \frac{B_{T+1} - C_{T+1}}{(1+i)^{T+1}} + \frac{B_{T+2} - C_{T+2}}{(1+i)^{T+2}} + \cdots + \frac{B_{T+F} - C_{T+F}}{(1+i)^{T+F}}$$

Note that VR_T measures the residual value evaluated at time T. It must therefore be discounted once more to express it in base-year value (see Figure 6.4). The residual value to be included in the CBA is thus given by:

$$VR_0 = \frac{VR_T}{(1+i)^T}$$

If the values of B_t and C_t between $T+1$ and F were known with certainty, the project could simply be evaluated over its entire life span. In practice, however, the difficulty lies precisely in estimating B_t and C_t beyond the analysis horizon.

> The extrapolation method consists of projecting the benefits and costs observed at the end of the analysis period (A_t and C_t) over the remainder of the project's life.

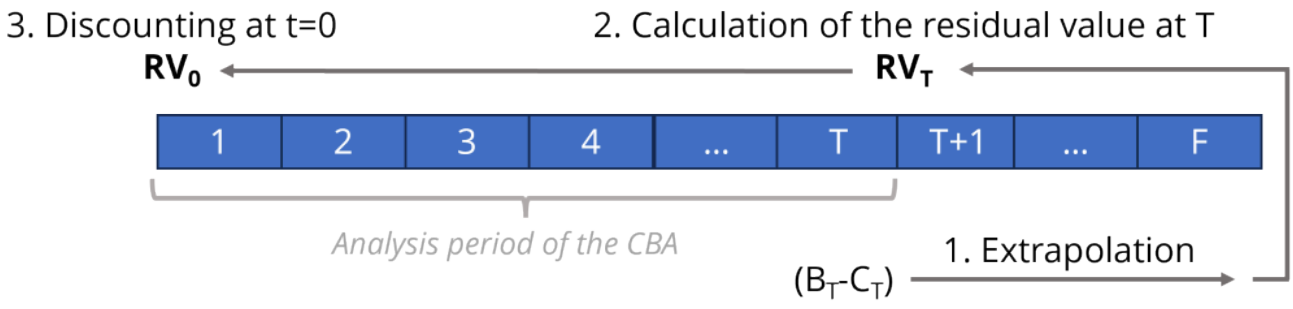


Figure 6.4 Determination of RV by extrapolation

The simplest form of extrapolation assumes that the benefits and costs observed at the end of the analysis period remain constant until the end of the project. In other words, $A_t = A_T$ and $C_t = C_T$ for all t between $T+1$ and F.

An alternative approach is to treat A_T and C_T as annuities that either grow or decline at a constant rate between $T+1$ and F. In that case, the residual value at time T can be computed using the formulas presented in Section 6.3.1, and then discounted to base-year value.

In all cases, the analyst must justify the realism of the chosen extrapolation method and clearly discuss its implications for the results.

6.6.2 Assessment based on resale value

The residual value of a durable good used in a project can be assessed using its resale value on a secondary market.

Indeed, the resale price observed on a secondary market reflects the expected net benefits associated with the remaining useful life of the durable good. For example, the residual value of a truck can be estimated by its resale value at the end of the analysis horizon T. However, it is essential to remember that this resale value must be discounted back to time T and then expressed in base-year dollars before being included in the CBA.

6.6.3 Assessment based on economic depreciation

The residual value of certain assets can be estimated using an annual depreciation rate obtained from external sources[3] and applying the depreciation formulas that correspond to the chosen depreciation profile.

Straight-line depreciation is the simplest and most commonly used method, particularly in a tax context. Under this approach, the depreciation rate is simply the inverse of the asset's useful life $(1/F)$. For example, a computer purchased for \$4,000 with a useful life of four years has a straight-line depreciation rate of 25%. After three years, its remaining value is therefore equal to

$$(1 - 3 \times 0.25) \times \$4{,}000 = \$1{,}000.$$

3. For the United States, see Fraumeni (1997) and Sliker (2018). For Canada, see Baldwin, J., H. Liu, and M. Tanguay (2015).

Another common method is geometric depreciation, under which the asset depreciates at a constant rate over time.[4] The exercise below illustrates the geometric depreciation formula.

Other depreciation profiles are also possible, such as gradual depreciation, which involves an acceleration in the asset's loss of value over time (for example, hyperbolic depreciation).

Example: The residual value of a truck

A truck is purchased for $1 million at the beginning of a project. The geometric depreciation rate for this class of assets is 21.2% per year. Determine the residual value of the truck to be included in the project's CBA, given an analysis horizon of five years and a discount rate of 7%.



Answer

Because depreciation is geometric, the residual value of the truck at $T = 5$ is calculated as follows:

$$VR\,(t = T) = 1 \text{ million} \times (1 - 0.212)^5 = 303\ 830\$$$

In other words, the truck loses 21.2% of its value at the beginning of each year.

The residual value to be included in the CBA must be expressed in base-year value, that is, at $t = 0$:

$$VR\,(t = 0) = \frac{303\ 830\$}{(1 + 0.07)^5} = 216\ 627\$$$

4. The U.S. Bureau of Economic Analysis determines the geometric depreciation rate δ as the ratio of the declining-balance rate (DBR) to the asset's service life (T), that is, $\delta = \mathrm{DBR}/T$. The agency typically uses a value of 1.65, except for government assets, for which a value of 0.91 is applied.

6.6.4 Zero residual value

If the analysis period is long relative to the project's life span, it may be reasonable to assume a zero residual value (RV). In such cases, the residual value at the end of the analysis period is likely to be small, particularly once expressed in base-year dollars. Moreover, this assumption is conservative, as it tends to err on the side of caution.

Finally, two important points should be emphasized:

1. The analyst should justify, as thoroughly as possible, the choice of the depreciation profile used.
2. Regardless of the method chosen to estimate the residual value, it is essential to conduct a **sensitivity analysis** of the NPV with respect to this value. If the project's profitability depends critically on the assumed residual value, this dependence should be clearly highlighted, and decision-makers should be urged to exercise caution.

Finally, it is important to draw attention to an approach sometimes used to estimate residual value that raises significant conceptual concerns.

An approach to avoid: residual value based on straight-line depreciation

In some evaluations of long-lived infrastructure projects, analysts assess impacts over a relatively short analysis horizon, even though the infrastructure itself is expected to remain in service for many decades. To account for the value of the asset beyond the analysis horizon, a simple method is sometimes used: the infrastructure is assumed to lose a fixed proportion of its initial construction cost each year through straight-line depreciation. At the end of the analysis horizon, the remaining share of the initial construction cost is treated as the project's residual value (for example, a project with a service life of 100 years that is analyzed over 40 years would be assigned a residual value of 60%). This amount is then discounted to present value and included in the CBA.

However, this method raises an important conceptual concern. By deriving the residual value

directly from the initial construction cost, the analysis implicitly assumes that benefits equal costs beyond the analysis horizon.

As a result, this approach may bias the analysis in favor of the project. Analysts should therefore conduct sensitivity analyses with respect to the residual value and, more appropriately, rely on alternative methods—such as extrapolating net benefits observed near the end of the analysis horizon—that are consistent with the logic of cost–benefit analysis.

6.7 Decision criteria and rules

6.7.1 Decisions based on NPV

The decision to recommend or reject a project must be based on its net present value (NPV). Three types of decision contexts may arise, each requiring a specific decision rule.

Situation 1: Deciding whether to undertake a project

When the choice is simply **whether or not to undertake a project**, the decision rule is straightforward: the project should be recommended if its NPV is positive. A positive NPV indicates that the project generates net social value beyond what could be achieved by allocating the same resources to their best alternative use.

Situation 2: Choosing between mutually exclusive projects

Consider, for example, a situation in which authorities must choose between a bus rapid transit system (BRT), a tramway, or a metro to improve urban transportation. In this case, the projects are mutually exclusive, meaning that only one option can be implemented. The decision rule is therefore as follows:

When comparing mutually exclusive projects, the project with the highest positive NPV should be recommended.

In the example above, suppose the NPV of the BRT is estimated at $120 million, that of the tramway at $35

million, and that of the metro at −$46 million. The BRT should then be recommended. Note that the NPV of each option is always evaluated relative to the reference scenario (for example, maintaining the current bus system). However, in this context, the opportunity cost of choosing the BRT is the best alternative project that is forgone, namely the tramway. Relative to the tramway, the BRT therefore generates an additional NPV of $85 million.

Situation 3: Choosing between projects under a budget constraint

In this case, the projects are not mutually exclusive, but it is not possible to implement all of them because of a budget constraint. For example, a Department of Transportation may have a budget of $3 million for road safety improvement projects. Table 6.5 presents the present value of costs and benefits, as well as the NPV, for four possible interventions. An additional option is to implement interventions 3 and 4 jointly. These two projects exhibit positive synergies, in the sense that the combined benefits of implementing them together exceed the sum of the benefits obtained if each project were implemented separately.[5]

Table 6.5 Project selection with budget constraint ($ millions)

Intervention	Present value of benefits	Present value of costs	Net Present Value (NPV)
1	1.9	0.7	1.2
2	2.7	2	0.7
3	2	1	1
4	1.5	1	0.5
3 and 4	4	2	2

In this type of situation, the appropriate decision rule is as follows:

> When projects are subject to a budget constraint and cannot all be implemented, the analyst should select the combination of projects that maximizes the sum of NPVs while respecting the budget constraint.

In the example, the combination of projects 1 and 3+4 yields the highest net benefits, with a total NPV of $3.2

5. Synergies could also be negative and may arise on the cost side as well.

million, while remaining within the budget limit. The total cost of these projects is less than $3 million. By contrast, the other feasible combinations (projects 2+3 and 2+4) generate lower net present values.

6.7.2 The benefit cost ratio

Some studies present results using the benefit–cost ratio (B/C), defined as the present value of benefits divided by the present value of costs. This ratio is often appealing to policymakers; for example, a benefit–cost ratio of 3 allows one to argue that every dollar invested generates three dollars in benefits.

The B/C ratio can be used to assess whether a single project should be recommended. A ratio greater than 1 indicates that the project has a positive NPV. However, when choosing among mutually exclusive projects or when a budget constraint is present, reliance on the B/C ratio can lead to incorrect decisions.

Table 6.6 illustrates this issue by presenting the evaluation of three mutually exclusive projects. Project 1 should be recommended because it generates the highest positive NPV. If the decision were based on the B/C ratio instead, Project 3 would be selected, since it has the highest ratio. This example highlights a key limitation of the B/C ratio: it does not allow for meaningful comparisons across projects of different scales.

Table 6.6 Comparison of three projects according to NPV and B/C ratio (millions of $)

Project	Present value of benefits	Present value of costs	Net Present Value (NPV)	Cost Benefit Ratio (C/B)
1	120	100	20	1.2
2	60	45	15	1.3
3	25	15	10	1.6

The selection of mutually exclusive projects or projects subject to a budget constraint should not be based on the benefit–cost ratio.

6.7.3 The internal rate of return criterion

The internal rate of return (IRR) is the discount rate that makes the net present value (NPV) equal to zero. Formally, the internal rate of return, denoted ρ, is obtained by solving the following equation:

$$VAN = \sum_{t=0}^{n} \frac{A_t - C_t}{(1+\rho)^t} = 0$$

The decision rule is therefore to recommend the project if its internal rate of return (ρ) exceeds the social discount rate (s).

For example, suppose a project entails an initial cost of \$100 million at $t = 0$ and generates a perpetuity of \$15 million per year starting at $t = 1$. The social discount rate is 10%. In this case, ρ is obtained by solving:

$$-100 + \frac{15}{\rho} = 0$$

The internal rate of return is therefore 15%, which exceeds the social discount rate of 10%. The project should thus be recommended. The corresponding NPV of the project is \$50 million.

The internal rate of return is an indicator frequently used to assess the profitability of private investments. However, it has several important limitations:

1. Except in special cases, determining ρ requires solving non-linear equations that may admit multiple solutions, raising the problem of selecting the appropriate rate;
2. As with the benefit–cost ratio criterion, selecting projects solely on the basis of the highest internal rate of return does not maximize NPV when projects are mutually exclusive or when a budget constraint is present (see Exercise 3 for an illustration).

The selection of mutually exclusive projects or projects subject to a budget constraint should not be based on the internal rate of return.

In conclusion, project selection criteria should be based on net present value. The benefit–cost ratio and the internal rate of return may be reported as supplementary indicators, but they should not be used as the primary basis for selecting a project.

6.8 The break-even analysis

In many cases, it is easier to obtain reliable information on a project's costs than on its benefits. In such situations, a simple and effective approach is to determine the break-even point. This point corresponds to the minimum level of benefits required for the project's NPV to be equal to zero. The break-even approach was already used in the cost-benefit analysis of the temporary exhibition presented in Chapter 4.

The discounting formulas introduced above make it possible to compute break-even thresholds in more complex settings, as illustrated in the exercise below.

Exercise: The break-even point of a newbridge

In order to reduce congestion, a city is considering building a third bridge between the two banks of the river that runs through it. The project is estimated to cost $4 billion. The analysis horizon is 50 years, and the discount rate is 5%.

1. Determine the minimum average annual benefit required for this project to be justified.
2. Given that there are, on average, 152,000 crossings per day between the two banks, and that this number is expected to increase by approximately 25% with the new link, determine the minimum average benefit per crossing required to justify the bridge.
3. Given that total gasoline sales in the region are 787 million liters per year, and assuming that the new bridge does not affect this quantity, calculate the additional tax per liter of gasoline that would need to be imposed in the region to finance the infrastructure.

What can you conclude about the likely **social profitability** of this project?

Answer

1. This requires annualizing the $4 billion cost at a discount rate of 5%, as explained in Section 6.3.3. Assuming that benefits accrue gradually over each year, the annuity factor with $T = 50$ and i = 5% is 18.7. The minimum annual benefit required is therefore approximately $214 million per year (that is, $4 billion divided by 18.7).

2. To put this figure into perspective, it is useful to compare it with the expected annual number of crossings if the new infrastructure is built, namely 69,350,000 ($152{,}000 \times 1.25 \times 365$). The implied break-even condition is that the average **maximum willingness to pay** per crossing must be at least $3.

3. If the project were financed through a surcharge on gasoline sold in the region, the required surcharge would be at least 27 cents per litre.

These break-even calculations provide a quick first assessment of the project's likely profitability. In this case, the required minimum benefits are particularly high because the project is costly relative to the number of users. The social profitability of the project therefore appears, at best, doubtful.

6.9 Taking into account the cost of a durable good

Many projects rely on inputs that are durable goods, that is, assets that can be used over several years. How should the costs of these durable goods be treated in a CBA? Several accounting approaches are possible, which creates a risk of counting the same cost more than once if the analysis is not handled carefully. To illustrate these approaches and their equivalence, consider the example of a hospital project involving the purchase of a new magnetic resonance imaging (MRI) machine.

Example: A new MRI machine

A hospital is considering purchasing a state-of-the-art magnetic resonance imaging (MRI) machine that would improve the detection of abnormalities in patients. The machine has a purchase price of $1.5 million and an estimated service life of 10 years. The project's financial report assumes straight-line depreciation of $150,000 per year. The purchase is financed through borrowing at an interest rate of 5%, with equal annual repayments made at the end of each year. Annual operating costs are estimated at $150,000 and are also paid at the end of each year. The present value of the project's benefits is estimated at $3 million. The social discount rate is 5%.

6.9.1 Annual usage cost

In some types of analysis, such as **financial analysis** or tax analysis, the cost of an investment is allocated over its useful life. This involves calculating the **annual usage cost** of the asset, which can be interpreted as the annual consumption of the capital embodied in the asset. The annual usage cost of a durable good has two components:

1. Depreciation, or **economic depreciation**, that is, the loss in the asset's value over the course of a year due to wear and tear and obsolescence[6];
2. The **opportunity cost of capital**, that is, the return forgone by keeping capital tied up in the asset for one additional year.

6. Accounting depreciation does not necessarily correspond to the true economic depreciation of an asset.

In the MRI example, suppose that economic depreciation is indeed linear over a 10-year period, implying an annual loss in value of $150,000. The residual value of the equipment—its resale value at the end of each year—is reported in Table 6.7. It is obtained by subtracting annual depreciation from the residual value at the end of the previous period.

Using a social discount rate of 5%, Table 6.7 also reports the annual opportunity cost of capital. For each year, this cost is equal to the residual value at the end of the previous period multiplied by the 5% discount rate. It represents the return forgone by continuing to use the equipment during the year rather than selling it and reallocating the funds to another project. For example, at the end of the second year, the MRI could be resold for $1.2 million. If this amount were invested elsewhere, it would yield a return of $60,000. This amount therefore represents the opportunity cost of keeping the MRI in operation during the third year.

The sum of economic depreciation and the opportunity cost of capital constitutes the annual usage cost of the durable good.

More formally, the cost of using an asset in period t is given by:

$$\text{Usage cost}_t = (\text{Asset value}_{t-1} - \text{Asset value}_t) + \text{i}\% \times \text{Asset value}_t$$

This expression captures both components of the user cost: the loss in asset value between periods $t-1$ and t (economic depreciation) and the opportunity cost of capital tied up in the asset during period t.

Table 6.7 Calculation of the cost of using MRI (in millions of $)

Year	Residual value	Economic depreciation	Opportunity cost	Annual usage cost
0	1.5	–	–	
1	1.35	0.15	0.075	0.225
2	1.2	0.15	0.0675	0.2175
3	1.05	0.15	0.06	0.21
4	0.9	0.15	0.0525	0.2025
5	0.75	0.15	0.045	0.195
6	0.6	0.15	0.0375	0.1875
7	0.45	0.15	0.03	0.18
8	0.3	0.15	0.0225	0.1725

6.9.2 The implicit rent

Alternatively, the hospital could rent the MRI by paying a fixed annual fee or finance its purchase through a loan with constant annual repayments. Using the social discount rate, this rent or annual repayment can be determined by annualizing the investment cost, that is:

$$\text{Rent} = \text{Reimbursement} = \text{A} = \frac{1.5m}{a_{5\%}^{10}} = 194\ 256\$ \text{ per year}$$

The cost of the MRI can therefore be incorporated into the analysis as a constant annual amount, corresponding to an implicit rental cost.

6.9.3 Accounting for the investment when it is incurred

In CBA, the standard approach is to account for the full investment cost at the time it is incurred. In the present example, this means including the \$1.5 million expenditure at $t = 0$. As discussed earlier, discounting future benefits and costs already captures the opportunity cost of capital.

As shown in Table 6.8, the three approaches described above are equivalent in the sense that they yield the same NPV. A direct implication of this equivalence is that it would be incorrect to both record the investment cost when it is incurred and also include depreciation, opportunity cost, interest payments, or rental costs. Doing so would result in double counting the same cost.

Table 6.8 Three equivalent approaches to accounting for the cost of a durable good (in millions of $)

Year	Approach 1	Approach 2	Approach 3
0	–	–	1.5
1	0.225	0.1942	
2	0.2175	0.1942	
3	0.21	0.1942	
4	0.2025	0.1942	
5	0.195	0.1942	
6	0.1875	0.1942	
7	0.18	0.1942	
8	0.1725	0.1942	

In CBA, the third approach is generally preferred. It should also be noted that under this approach, if the analysis period is shorter than the asset's useful life (for example, five years in the case of the MRI), the asset's residual value must be treated as a benefit (see Section 6.6)[7].

In summary

In a CBA, the investment cost of an asset should generally be recorded in full at the time it is incurred. Discounting, together with the choice of the analysis horizon and the treatment of residual value, already accounts for depreciation and the opportunity cost of capital. As a result, depreciation charges, interest expenses, or rental payments should not be added separately to the CBA, as doing so would lead to double counting.

Table 6.9 presents the complete CBA results of the MRI project.

7. Under approach 1, the cost of use must be included over the five-year analysis period. By contrast, approach 2 would underestimate the asset's cost if only the rent for the first five years were taken into account.

Table 6.9 CBA of the MRI project

Impact	Annual value	Present value
Benefits		$3,000,000
Purchase cost	$1,500,000 at t = 0	$1,500,000
Operating costs	$150,000 from t = 1 to t = 10	$1,158,300
	NPV =	**$341,700**

6.10 Conclusions

Key takeaways

- Discounting allows impacts that occur at different points in time to be expressed on a common temporal basis.
- Discounting makes it possible to account for the opportunity cost of the funds invested in a project. A project's NPV will be positive only if its internal rate of return exceeds the social discount rate.
- The social discount rate measures the opportunity cost of resources invested in a project, that is, the return those resources could generate in their best alternative use.
- When the analysis horizon is shorter than the useful life of some project assets, the residual value of those assets must be included in the CBA. Residual values can be estimated by extrapolating benefits and costs, by using resale values, or by applying estimates of economic depreciation.
- To compare projects with different time horizons, analysts may use the replication method, the average annual equivalent method, or evaluate the longer project over the shorter horizon while including a residual value.
- The appropriate project selection rule depends on whether the projects under consideration are mutually exclusive and whether a budget constraint is present.

- Project selection should be based on NPV, as the benefit–cost ratio and the internal rate of return do not always lead to the correct choice.
- When data are insufficient to calculate the NPV precisely, or when a rapid appraisal is required, it is useful to determine the project's break-even point. This corresponds to the minimum average annual benefit required for the NPV to equal zero.
- In a CBA, the cost of a durable good is generally recorded in full at the time it is incurred. Depreciation, the opportunity cost of capital, and implicit rent are alternative ways of accounting for the cost of a durable good. Care must be taken to ensure that the cost of a durable good is not counted more than once.

Back to motivation

In your role, you must choose between two mutually exclusive projects. Project A provides an annual benefit of $30,000 and an annual cost of $12,000 for five years. Project B incurs a cost of $25,000 in year 1 and an annual cost of $5,000 from year 2 through year 10. It also generates an annual benefit of $30,000 for ten years. Which project would you select, assuming a 5% discount rate?

Answer

We now know that the decision must be based on NPV. The statement does not specify when impacts occur within each year, so we assume that costs and benefits accrue continuously over the year.

Project A

The NPV of Project A is straightforward to compute because it involves discounting an annuity. The annual net benefit is $8,000 (that is, $30,000 − $12,000) for five years. With $T = 5$ and s = 5%, the annuity factor is 4.44, so the NPV is $35,520.

Project B

The present value of benefits is computed as an annuity with $T = 10$ and s = 5%. The annuity factor is 7.9, so the present value of benefits is $237,000.

The present value of the cost incurred in year 1 is \$24,398, that is, $25{,}000/(1.05)^{0.5}$. The present value of costs in subsequent years is computed as an annuity, while accounting for the fact that this cost stream begins in year 2. The present value of these costs is therefore \$35,523, that is, $(7.28 \times 5{,}000)/(1.05)^{0.5}$.

The NPV of Project B is therefore \$177,079.

Because the two projects have different time horizons, their NPVs should not be compared directly. We therefore use the average annual equivalent method.

The average annual equivalent of Project A is \$8,000.

The average annual equivalent of Project B is \$22,387, that is, $177{,}079/7.91$ (where the denominator is the annuity factor with $T = 10$ and s = 5%).

Project B should therefore be recommended.

Exercises

(*) Indicates that the solution is available

1. (*) To implement a kindergarten program for four-year-olds, new buildings would need to be constructed. The **average cost** of these buildings is estimated at \$800,000 per classroom. Assuming a 40-year service life and a social discount rate of 3%, calculate the equivalent annual cost of one classroom.
2. (*) A project's net benefits are estimated at \$450,000 at the end of the first year. These net benefits are expected to decline at a rate of 2% per year thereafter. The project lasts 20 years, and the social discount rate is s = 7%. Calculate the NPV of this project.

3. Consider the following two mutually exclusive projects:

   Project A incurs a cost of \$10 million at $t = 0$ and provides a benefit of \$13.5 million at $t = 1$. Project B also incurs a cost of \$10 million at $t = 0$ but provides a perpetuity of \$1.08 million starting at $t = 1$.

   Assume the discount rate is 5%. Show that using the internal rate of return as a decision criterion does not lead to the selection of the project that generates the greatest social value.
4. (*) A project has a useful life of 50 years, but the CBA evaluates its costs and benefits over a horizon of only 20 years. In the final year of the analysis, the project's current net benefit (that is, undiscounted $A - C$) is estimated at \$1.5 million. This net benefit is positively related to the size of the affected population. It is expected that, from $T = 21$ to $T = 50$, population will grow at 1% per year.

Calculate the residual value to be included in the CBA as a benefit. The social discount rate is 7%.

5. (*) A municipality currently sends all of its waste to a neighbouring municipality's landfill for a fee. It could continue with this option, but a CBA has shown that building its own landfill would generate an NPV of $3 million relative to maintaining the current arrangement. The new landfill would have a service life of 15 years. Alternatively, the municipality could build both a landfill and a composting facility. The NPV of this option is estimated at $4 million, and it would allow waste disposal for 30 years. Based on the information provided, and assuming a social discount rate of 5%, which option would you recommend?

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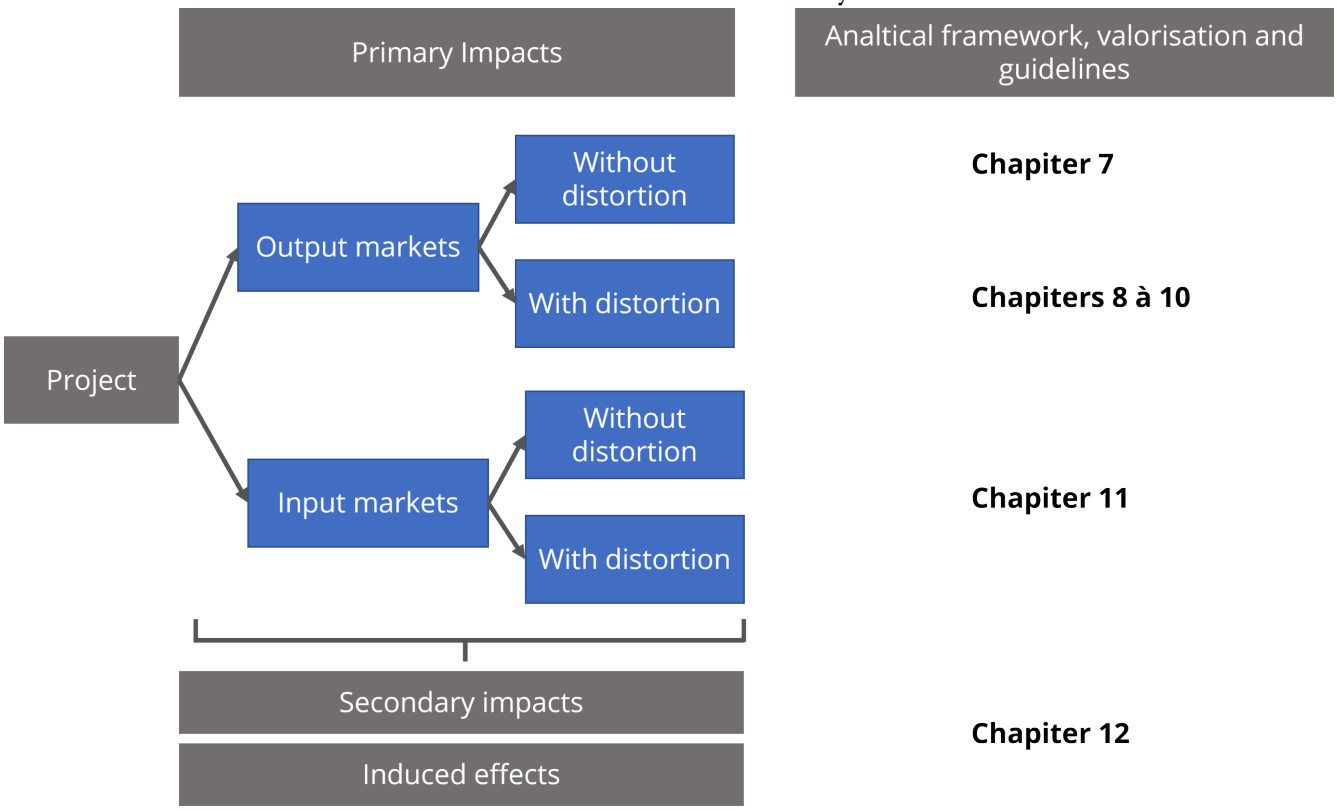
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PART II
VALUING MARKET EFFECTS

As illustrated in Figure below, Chapters 7 to 10 focus more specifically on the analytical framework, valuation methods, and practical guidelines for assessing project outputs in a **primary market**. Chapter 7 examines these issues in the context of an undistorted competitive market. Chapter 8 analyzes the valuation of outputs in the presence of taxes or subsidies and presents the analytical framework required to assess the impacts of projects that alter production costs within an industry. Chapter 9 addresses the treatment of externalities in the valuation of project outcomes, while Chapter 10 explores the implications of other sources of market distortions, such as market power, information asymmetry, and cognitive biases.

Chapter 11 returns to the concepts developed in Chapters 7 to 10, but shifts the focus to the valuation of project inputs. It therefore examines the analytical framework, valuation issues, and practical guidelines applicable to both competitive and imperfect markets. Finally, Chapter 12 considers whether impacts on **secondary markets** should be included in a CBA or instead excluded to avoid double counting. This chapter also discusses the circumstances under which certain induced effects may be relevant.



7.

VALUING OUTPUTS IN UNDISTORTED MARKETS

Motivation and learning objectives

A medium-sized city is considering replacing a high-frequency express bus corridor with a more modern and efficient light rail transit (LRT) system. The proposed line would be approximately 14 km long and include 17 stations. The main expected benefits of the LRT project are as follows:



Source: Pliny, CC BY-SA 3.0 via Wikimedia Common

- Higher operating speed (about 34 km/h instead of 21 km/h), leading to shorter travel times;
- Increased passenger capacity to accommodate future population growth;
- Improved comfort and service reliability.

What analytical framework should be used to value these outputs in a cost–benefit analysis (CBA)?

In this chapter, we build on tools introduced earlier to develop an analytical framework for evaluating projects that directly affect the supply of a good or service. The focus is on valuing outputs in primary markets, while temporarily setting aside market distortions and issues related to the valuation of inputs. Given the wide range of possible contexts, we examine a set of representative situations designed to build the analytical intuition needed to assess other cases.

By the end of this chapter, you will be able to design an analytical framework for a project that:

1. Introduces a new good or service;

2. Improves the quality of an existing good or service;
3. Increases supply in a competitive market.

7.1 The project introduces a new service

Many projects evaluated through a CBA involve the construction of infrastructure that enables users to access a new service. Examples include the construction of a bridge, a museum, a performance hall, or a sports facility. While each project has its own specific features, these initiatives often share common patterns in terms of costs and benefits, as illustrated in Figure 7.1.

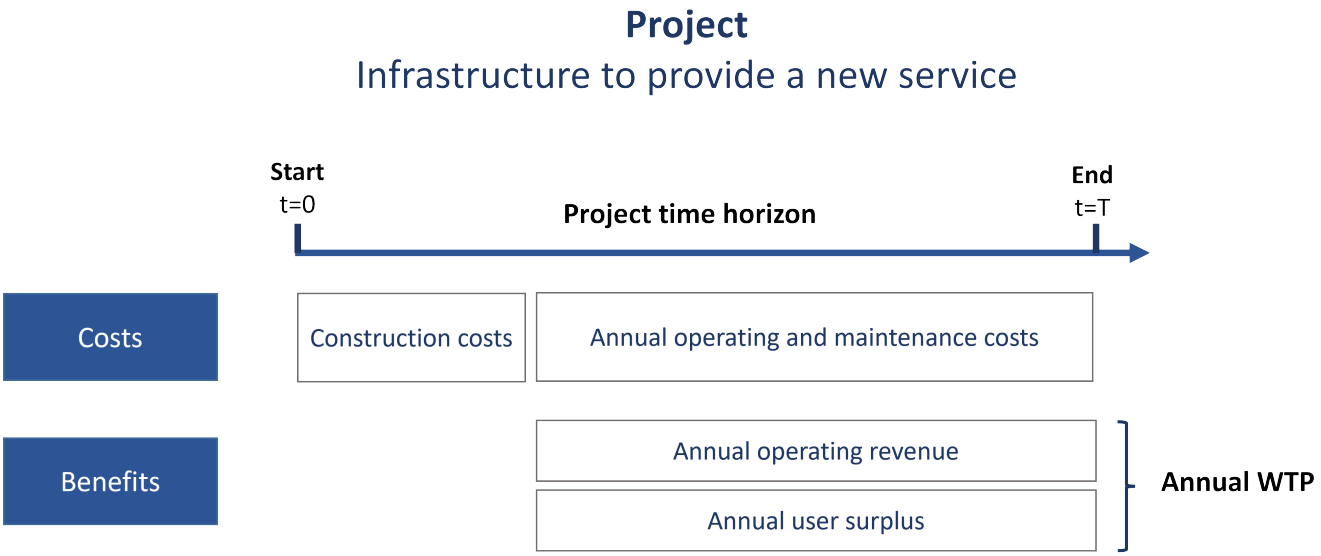


Figure 7.1 The impacts of new infrastructure

The costs

Construction-related expenditures are usually one of the main components of total project costs. These costs are incurred primarily at the beginning of the project and, once the infrastructure is in place, become unavoidable fixed costs.

At the other end of the cost spectrum are **operating and maintenance costs**. These expenses typically vary very little with the number of users. Whether a theatre is full or nearly empty, operating costs change only marginally. While additional front-of-house staff may be required on particularly busy days, expenses related

to the building, insurance, and performers generally remain constant. Moreover, these costs can usually be avoided if the facility is closed. As a result, operating costs are quasi-fixed in nature.

Overall, the cost structure of this type of project is generally characterized by the following features:

- A predominance of fixed and quasi-fixed costs;
- A very low, and often negligible, marginal cost of serving an additional user;
- A decline in average cost per user as the utilization rate of the infrastructure increases (**an economy-of-scale effect**).

The Advantages

As discussed in Chapter 4, the gross benefit to users of a new service is measured by their willingness to pay (WTP), that is, the area under the **demand curve** between zero and the quantity consumed. This willingness to pay is distributed among different stakeholders: users retain the consumer surplus (CS), while the infrastructure operator captures operating revenues[1]. These revenues are used in particular to cover all or part of the operating costs and the costs of the infrastructure.

The relative importance of operating revenues and consumer surplus depends on the pricing scheme adopted. If access is free for users, consumer surplus corresponds to total WTP, and operating revenues are zero. When a positive price is charged, the operator captures part of the consumer surplus. The role of pricing and its implications will be discussed in Chapter 10.

In practice, the main challenge lies in estimating demand for the new service. This can be done using qualitative approaches, such as market studies or the Delphi method, or quantitative approaches, such as time-series analysis and other econometric techniques. A detailed discussion of these methods is beyond the scope of this manual (see Bourbonnais and Usunier, 2017). However, some of the tools introduced in Part 3 may prove useful for estimating demand for a new service.

The exercise below allows you to apply the concepts covered in this section and in the previous chapters.

Exercise: A water amusement park

1. Other stakeholders, such as the State, may also appropriate part of the WTP, for example through a tax on the access price.

A remote town is considering subsidizing the construction of a water amusement park. The project is estimated to cost $3 million and will take one year to build. The town would contribute $1 million, with the remaining $2 million financed by a local private investor, who would also be responsible for operating the facility. According to the project's business plan, the admission fee would be $15 and annual attendance would be 20,000 admissions. Annual operating costs are estimated at $100,000. Once operational, the park is expected to have a useful life of 20 years. Perform a CBA of this project using a 5% discount rate.

Solution

Let us apply the first two steps of the approach presented in Chapter 2 in order to assess the **social profitability** of the project.

Step 1: Context, project description, and state of knowledge

Because this is a fictitious example, there is little to add regarding the context, beyond the economic arguments that could justify municipal participation. This infrastructure could promote physical activity among residents, as in the swimming pool example in Chapter 4.[2] A review of the literature and relevant evidence could help document these effects more carefully and improve the estimation of demand for this type of facility.

The scenarios under consideration are:

1. The **reference scenario**: no park is built;
   The project scenario: the water amusement park is constructed and operated.
2. The **time horizon** is 21 years, including one year of construction, and the **spatial horizon** is assumed to be universal.

Step 2: Analytical framework

To build the analytical framework, it is useful to identify the output market directly affected by the project (the primary output market). Using the North American Industry Classification System (NAICS), a water amusement park falls under industry 71311 (Amusement Parks and Theme Parks), within sector 71 (Arts, Entertainment and Recreation). For the purposes of the analysis, the relevant market can be defined more narrowly as the market for water amusement parks. The service is

2. Additional arguments may also support municipal intervention. The municipality may seek to attract a new source of property tax revenue, or view the project as a way to increase its attractiveness to new residents, thereby expanding its tax base.

sufficiently differentiated to justify treating it as a distinct market. Moreover, because the town is remote, competition from similar facilities in neighbouring municipalities is unlikely to be a major concern. The availability of other local recreational activities (for example, a playground or a movie theatre) will nonetheless influence demand for the park and the price elasticity of demand.

In terms of the nature of the service, a water amusement park provides a commercial service for which exclusion is relatively inexpensive. The service is also non-rival in consumption up to capacity; rivalry may arise if the park becomes congested (i.e., it is a congestible club good).

The stakeholders are users, the private investor, and the municipality. Other local recreational services may experience reduced demand following the opening of the park, but these are indirect effects that will not be considered at this stage (see Chapter 12).

We can now establish the analytical framework in order to identify the project's primary effects. On the demand side, we have a single observation: $(Q = 20{,}000, , p = \$15)$. The analyst would need to assess the plausibility of this estimate, for example by comparing it with data from similar parks or by conducting an independent market study. Figure 7.2 illustrates demand for the park. The representation is necessarily imprecise, since only one point is available.

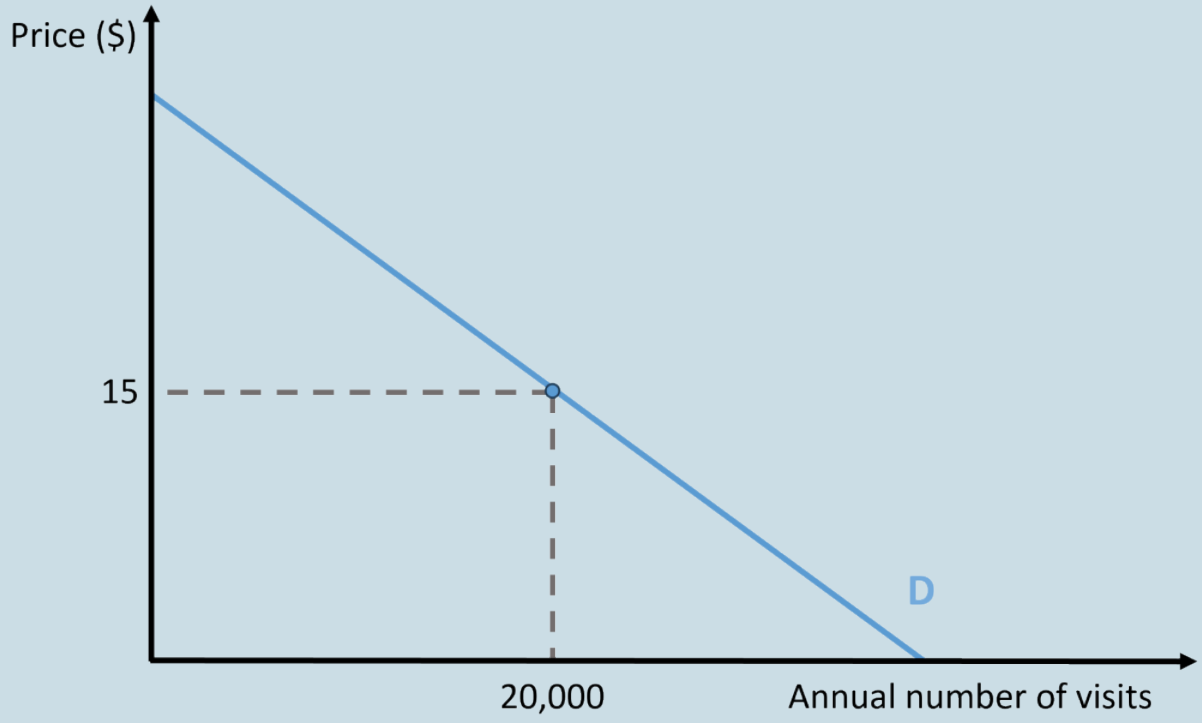
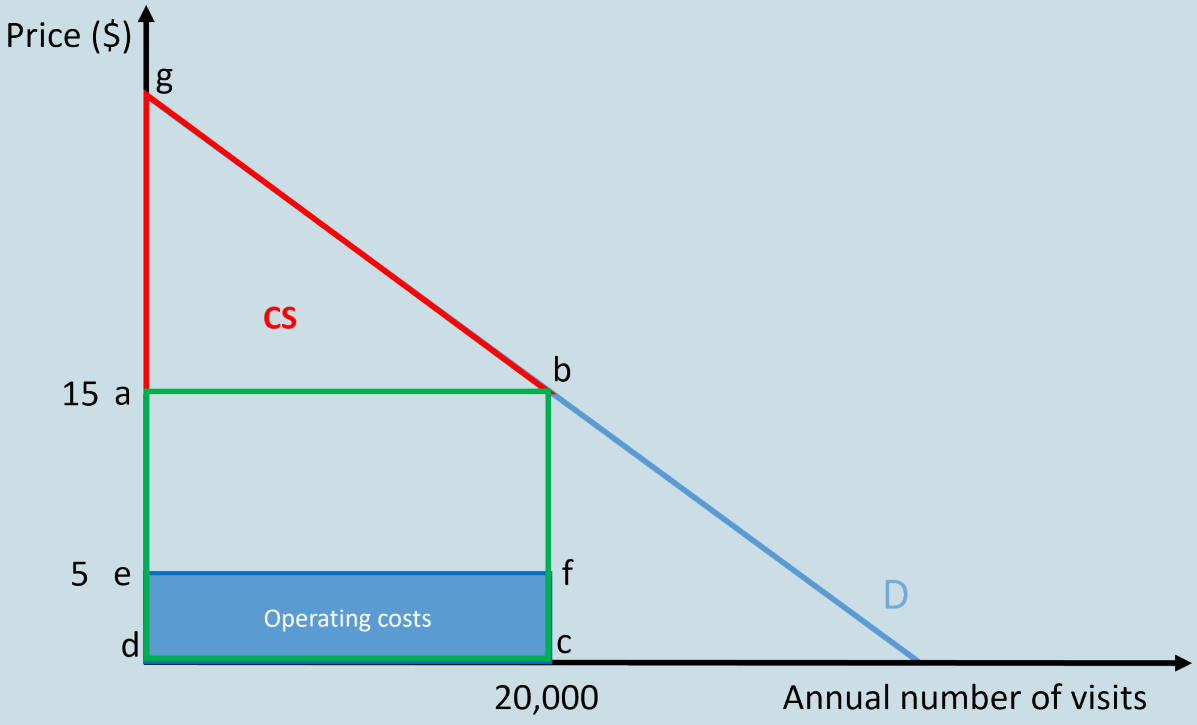


Figure 7.2 Demand for the amusement park

On the supply side, there is only one firm, so the setting is not one of perfect competition, in which the supply curve coincides with marginal cost. As we will see in Chapter 10, there is no supply curve in a monopoly context. However, we do have information on the proposed pricing and on the project's cost structure, which includes a substantial **fixed cost** for construction as well as annual operating costs.

Although we cannot identify a supply curve, we can still represent the operator's situation graphically. The business plan anticipates 20,000 visits per year at an admission fee of $15. We can therefore compute operating revenues and average operating costs. Operating revenues are equal to $15 × 20,000 and correspond to area abcd in Figure 7.3. Operating costs can also be represented, since the average operating cost is $5 ($100,000 divided by 20,000 visits). Area *efdc* therefore represents operating costs.[3]



3. Note that line *ef* in Figure 7.2 does not represent an average variable cost curve of the type introduced in Chapter 4. Figure 7.2 provides no information on how average operating costs vary with the number of admissions. It would therefore be inappropriate to infer (without further evidence) that operating costs would be $50,000 if admissions fell to 10,000. As noted earlier, a substantial share of operating costs is likely to be quasi-fixed, in which case average operating cost would probably exceed $5 at lower attendance levels.

From Figure 7.3, the relevant impacts can be identified using either the **social approach** or the **party approach**.

The social approach

The project increases the quantity of services provided from $Q = 0$ to $Q = 20{,}000$ admissions per year.

1. The social value of the project's output is measured by users' willingness to pay (WTP), that is, the area under the demand curve between $Q = 0$ and $Q = 20{,}000$, corresponding to area gbcd.
2. The social value of the resources mobilized by the project is measured by the construction cost and the annual operating costs (area efcd).
3. This project does not release any resources; therefore, there are no resources saved.

The stakeholder approach

Conceptually, the project can be interpreted as a reduction in price from a level greater than or equal to the reserve price to the planned admission fee of $15.

The impact on users is measured by the consumer surplus, corresponding to area gba. This benefit can be treated as an annuity received throughout the year, starting in the second year of the project. However, given the information available, consumer surplus cannot be quantified. Doing so would require knowledge of the reserve price or information on the price elasticity of demand.

The impact on the operator is measured by producer surplus, which can be approximated by annual operating profit of $200,000, corresponding to area abef. This amount represents an annuity received each year, beginning in the second year of the project. The analyst must nonetheless ensure that operating costs are properly evaluated using the concept of **economic cost** (or **opportunity cost**), rather than relying solely on accounting expenditures. For instance, it is important to verify whether operating costs include compensation for the owner's time spent managing the park.

The impact on the municipality is reflected in a reduction in its surplus due to the $1 million investment.[4].

4. It may also be appropriate to account for the marginal cost of public funds. That said, a substantial share of municipal revenues comes from property taxes, which generally generate relatively limited economic distortions.

The break-even point

Even in the absence of sufficient information to estimate consumer surplus, it is still possible to determine a **break-even point**. Table 7.1 presents the present values of the impacts on the operator and the municipality. For the project's NPV to be equal to zero, the present value of consumer surplus must be at least $X = \$543{,}520$, which corresponds to the net value of the impacts on the other two stakeholders.

Annualizing this amount implies that consumer surplus must reach at least $x = \$44{,}690$ per year, starting in the second year of the project. Relative to the number of users, this corresponds to an average surplus of at least $2.25 per user.

This threshold provides a simple way to assess whether the project appears promising. Specifically, one must ask whether it is realistic to assume that the average user would be willing to pay $2.25 more—namely, $17.25 instead of $15—to access the water amusement park.

Table 7.1 CBA by Stakeholder

Stakeholder	Advantage	Cost	Present value
Users	CS = x $/year (from t = 1.5 to t = 20.5)		X $
Private investor	Operating profit = $200,000 (from t = 1.5 to t = 20.5)	Investment 2m (t = 0.5)	$432,380
Municipality		Investment 1m (t = 0.5)	
		Break-even if NPV = $0	

Notes on Table 7.1

Recall that the first period corresponds to the construction phase. Because construction costs accrue continuously over the first period, ***discounting*** *is carried out using* $t = 0.5$ *(see Chapter 6). Operations begin in the second period and continue for twenty years, so the final period corresponds to year 21.*

Benefits and operating costs take the form of annuities over the 20 years of operation. Since these impacts occur throughout each year, discounting is performed using the annuity factor $a_{s=5\%}^{T=20} \times (1+s)^{0.5} = 12.77$.

This factor must then be multiplied by $1/(1+s)$*, because the impacts begin only in the second period. This adjustment brings the present value of the annuities from* $t = 1$ *back to the base year,* $t = 0$.

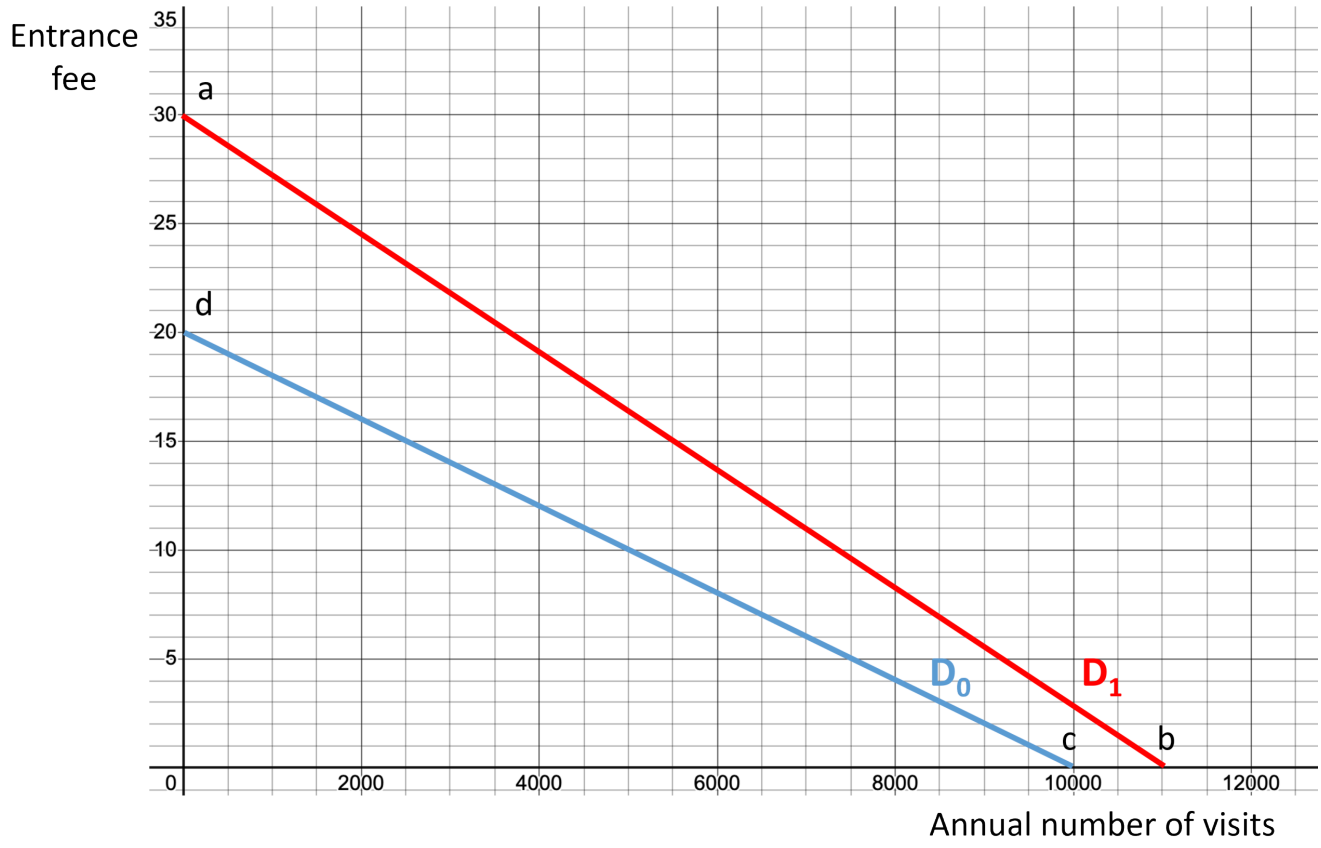
7.2 The project improves the quality of a service

Some projects aim to improve the quality of an existing service, such as replacing buses to enhance user comfort or installing a heating system in a public swimming pool. In the transportation sector, quality improvements often take the form of reduced travel time, achieved by increasing service speed or frequency. We examine both types of situations using simple examples.

7.2.1 Improving the quality of a service

In general, an improvement in service quality leads to an increase in users' **willingness to pay**, which is reflected by an upward shift in the demand curve. To illustrate this effect, consider a project involving the installation of a water-heating system in an outdoor municipal swimming pool. Figure 7.4 shows the initial demand without heating, denoted D_0. Based on a population survey and an analysis of comparable projects, demand is expected to increase to D_1 once the water is heated.

Assuming that access to the pool remains free (that is, no entry fee is charged), the project's impact on users is measured by the change in willingness to pay. In the reference scenario, total WTP is \$100,000 per year, whereas under the project scenario it increases to \$165,000 per year. The project therefore generates an annual benefit of \$65,000 for users, corresponding to the area abcd.



7.2.2 Reducing travel time

A second example illustrates how to design an analytical framework for transportation projects that affect travel time, which is a key dimension of service quality in this sector.

The project

A commuter rail line carries an average of 100,000 passengers per year between the suburbs and the city centre. The fare is $15 per trip, which covers the average operating cost. A proposed project would upgrade the line, reducing travel time from 45 minutes to 30 minutes. This improvement is expected to increase ridership by 20%, while the fare remains unchanged at $15.

Assume the following:

- There are no other impacts;
- Construction lasts one year and does not disrupt current service;
- The improvement has a useful life of 20 years (excluding the construction year), and the social discount rate is 3%;
- Average operating costs remain at $15 per trip;
- Users are willing to pay an average of $10 to save one hour of travel time.

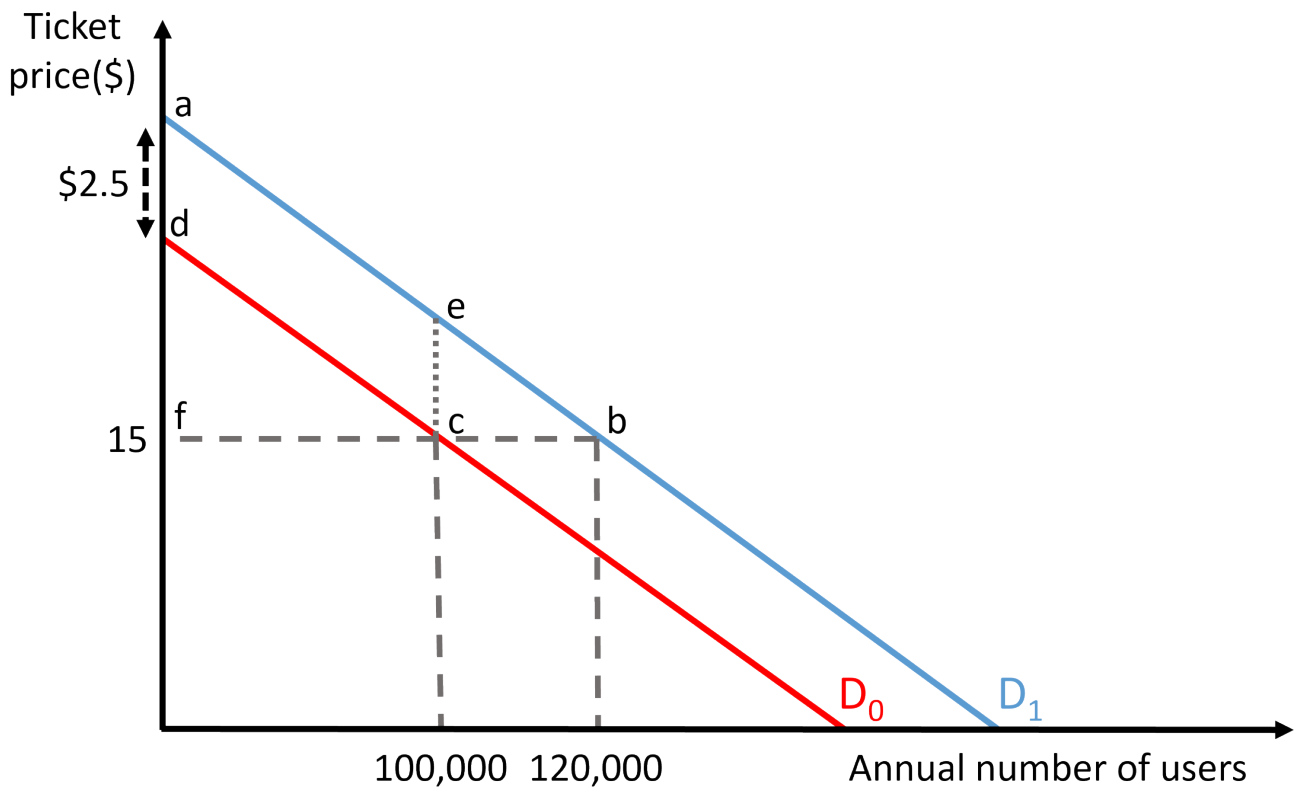
Determine the present value of the project costs such that the NPV is equal to zero.

Solution

The project improves service quality, which leads to an increase in demand, as in the heated swimming pool example. Figure 7.5 illustrates the initial demand, denoted D_0, which is imprecisely identified since only one point is observed. With the project, service quality improves, causing demand to shift upward to D_1. Ridership increases by 20%, while the fare remains at \$15.

The magnitude of the shift in the demand curve can be more precisely determined using the concept of the **value of time**, which is widely applied in transportation analysis. Chapter 16 discusses this concept in greater detail. For now, let us define the parameter ν as the value of time, expressed in dollars per hour. This parameter represents the average willingness to pay to save one hour of travel time.

In this example, $\nu = \$10$. The time saving generated by the project is 15 minutes, or 0.25 hours. The corresponding willingness to pay is therefore \$2.50, calculated as $\nu \times (15/60)$. Users would thus be willing, on average, to pay \$2.50 more for the faster service, implying a parallel upward shift of \$2.50 in the demand curve. This is, of course, a simplifying assumption, since willingness to pay for time savings is likely to vary across users.



It is now possible to calculate the benefits to users by distinguishing between existing users and new users, that is, **traffic induced** by the project. For current users, surplus increases by \$2.50 per passenger, resulting in a total benefit of \$250,000, corresponding to area aecd. For users attracted by the project, the average additional surplus is equal to one half of \$2.50, generating an additional benefit of \$25,000, corresponding to

area ebc.

Table 7.2 summarizes the results of this CBA and makes it possible to identify a break-even point. Specifically, the project will be socially profitable if its cost is less than $4,031,500.[5]

Table 7.2 Break-even point of the transport project

Stakeholder	Advantage	Cost	Present value
Common users	$250,000 (t = 1.5 @ t = 21.5)		$3,665,000
New users (Induced traffic)	$25,000 (t = 1.5 @ t = 21.5)		$366,500
Promoter		Cost of work	-X$
		NPV =	**$0**
Note: The annuity factor is 14.66, assuming that benefits accrue continuously over each year.			

Alternatively, one can use the concept of **generalized cost** (or generalized price), which explicitly incorporates the value of time. Decisions related to transportation—such as the choice of mode, route, and trip frequency—are influenced by this generalized price, denoted by p_g. It is defined as follows:

$$p_g = c + v \times t$$

where:

c is the monetary cost associated with the transportation decision (e.g., fares, parking fees, and fuel costs);

v is the value of time, expressed in dollars per hour;

t is travel time, expressed in hours.

In our example, we have:

Before the project:

$$p_g = 15\$ + 10\$ \times \frac{3}{4} = 22.5\$;$$

After the project:

$$p_g^P = 15\$ + 10\$ \times \frac{1}{2} = 20\$.$$

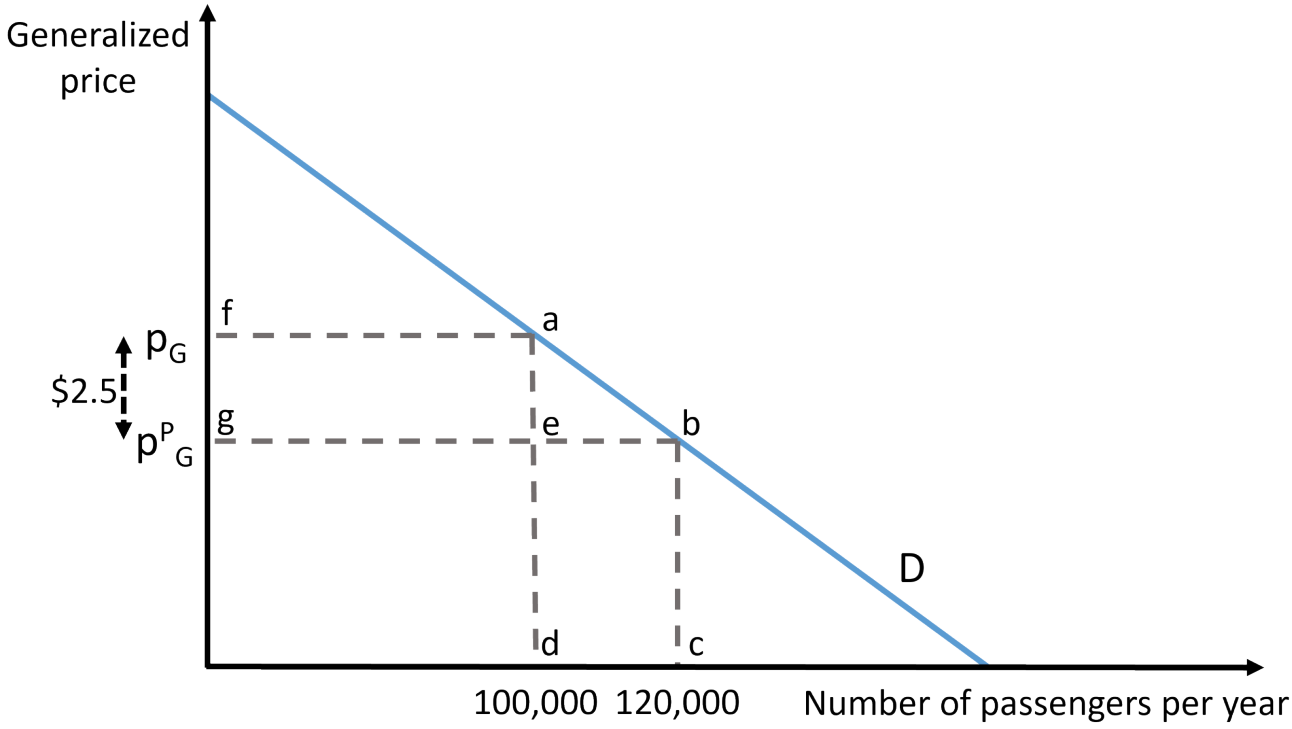
The project therefore leads to a reduction in the generalized price of $2.50.

The demand curve can now be represented in the generalized price–quantity space, as shown in Figure 7.6. This demand curve differs from the one presented in Figure 7.5, which illustrated the relationship between

5. Note that it is not necessary to account for changes in operating profits, since the fare covers operating costs both before and after the project, implying zero operating profit in both cases.

the number of trips and the ticket price alone. In Figure 7.6, the project reduces the generalized price by $2.50, resulting in an increase in quantity demanded from 100,000 to 120,000 trips. In this representation, the project generates **a movement along the demand curve** rather than a shift of the demand curve itself.

The impact of the project on users is measured by the increase in consumer surplus, corresponding to the area *fabg*. This area is composed of *faeg*, which captures the surplus gain of existing users, and *aeb*, which represents the surplus accruing to new users. As expected, these impacts are identical in magnitude to those obtained using the representation in Figure 7.5. This alternative formulation is widely used in the evaluation of transportation projects aimed at reducing travel time.



Warning: possible error!

CBAs that do not rely on a formal analytical framework sometimes make the mistake of valuing time savings for existing users and new users in the same way. In our example, this would amount to valuing the surplus generated by the additional 20,000 users at $2.50 per user, rather than at $1.25. In some situations, this approximation may be considered acceptable, particularly when induced traffic is small relative to existing traffic. However, this "error" is evident in the analysis of the Saguenay Bridge project and leads to an overestimation of time savings of approximately 10%.

7.3 The project increase supply in a market

A project may directly contribute to an increase in the supply of a good that is already traded in a competitive market. As we will show, the net present value (NPV) of such a project can be calculated using several alternative approaches. The key objective is to select the method that is most appropriate given the information available. We will also derive a practical valuation rule that is simple to apply and requires limited data. As in previous sections, we use a fictitious but realistic example to illustrate the analysis.

7.3.1 Example: A new cement plant



In order to stimulate the economic development of a given region, the government is considering supporting the establishment of a new cement plant intended to serve the national market. In this analysis, it is assumed that the degree of competition in the industry is sufficient to prevent the exercise of **market power**. The analyst therefore considers it appropriate to rely on the standard supply-and-demand framework under perfect competition to assess the impact of the project on the cement market. To simplify the exposition, the analysis is conducted over a single year[6].

The annualized construction and operating costs of the new plant are estimated at $400 million. At this stage, the analysis is limited to the effects of the project on the cement market itself.

From the outset, we can identify potential impacts on three groups of stakeholders:

- Cement buyers, who may benefit from the increase in market supply;
- Existing cement producers, who will have to adjust to the entry of a new plant;
- The new plant, which should generate an economic surplus if it operates efficiently.

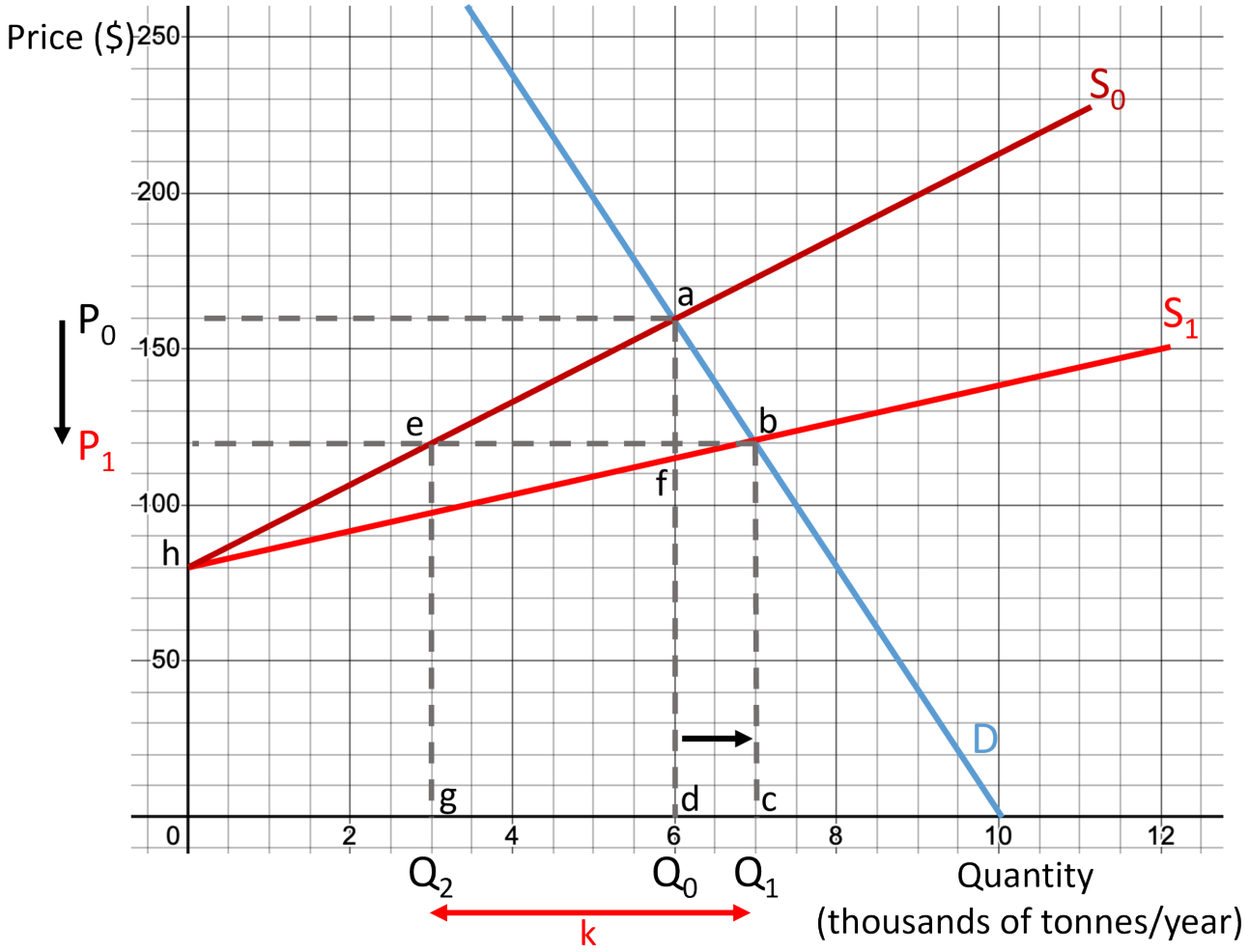
These impacts can be examined more closely using the supply-and-demand framework, assuming that the analyst knows the position of the relevant curves. Figure 7.7 illustrates the initial demand curve (D) and the

6. This assumes that market conditions remain stable over time, which is clearly a restrictive assumption. In practice, it would be necessary to forecast price and quantity adjustments over the life of the project, both with and without the project.

initial supply curve (O_0). The project adds a new production unit, shifting the supply curve to the right, from O_0 to O_1.[7]

The introduction of the new plant leads to the following outcomes:

1. The market price falls from P_0 = \$160 to P_1 = \$120;
2. Total quantity traded increases from Q_0 = 6 million tonnes to Q_1 = 7 million tonnes;
3. Existing producers reduce their output from Q_0 = 6 million tonnes to Q_2 = 3 million tonnes in response to the price decrease;
4. The new plant supplies the difference between Q_2 and Q_1, that is, 4 million tonnes of cement.



It is useful to analyze this situation using the social approach, as it allows us to derive a simple and practical valuation rule. Under this approach, three components must be assessed:

7. For simplicity, all costs are assumed to be variable, so that the supply curves correspond to long-run marginal cost curves. Under this assumption, the areas under the supply curves represent total production costs.

1. **The social value of the additional production** supplied to the market is measured by the area under the demand curve between Q_0 and Q_1, that is, area *abcd*, which is equal to $140 million;
2. **The social value of the resources released** by the project is represented by area *eadg*, estimated at $420 million. Indeed, incumbent producers reduce their output from 6 million to 3 million tonnes, thereby freeing production factors (labour, energy, capital). The value of these resources in their best alternative use is measured by the area under the initial supply curve O_0 between Q_0 and Q_2;
3. **The social cost of the project** corresponds to the construction and operating costs of the new plant, estimated at $400 million per year.[8]

The **net social value of the project** in the cement market is therefore $160 million per year. As an exercise, you can verify that applying the stakeholder (part-by-part) approach yields the same NPV (see Exercise 1).

7.3.2 A rule of practice

Once again, it is important to emphasize that, in practice, the analyst does not have access to perfectly observed supply and demand curves such as those illustrated in Figure 7.7. Nevertheless, it is possible to apply a rule of thumb based on information that the analyst would normally have at their disposal. These elements are summarized in Table 7.3.

Table 7.3 Data available for performing CBA

Variable	Value
Current market price (observed)	$160/ton
Price elasticity of demand (state of knowledge)	2/3
Price elasticity of supply (state of knowledge)	2
Current quantity (observed)	6 million tonnes per year
Quantity marketed by the project (estimated)	4 million tonnes per year
Total annual cost of project production (operating costs + annualized investment cost) (estimated)	$400 million per year

Based on this information, we can first predict the price change under the project scenario. This can be done

8. This cost is not straightforward to represent graphically. It can be obtained by calculating the difference between total production costs with the project—represented by the area *hbco* under the supply curve O_1 between 0 and Q_1—and the production costs of incumbent producers, represented by the area hego under the supply curve O_0 between 0 and Q_2.

by applying the formulas presented in Chapter 4, Section 4. Recall that the percentage change in price induced by the project is given by:

$$\Delta p\% = -\left(\frac{k}{Q_0}\right) \times \left(\frac{1}{\eta_D + \eta_O}\right)$$

In our example, this results in a 25% decrease in price, corresponding to a market price of $120 in the scenario with the project. Following this price reduction, the quantity traded in the market is expected to increase by 16.6%, that is, \eta_D \times 25%. At the same time, we can anticipate a contraction in the output of incumbent producers. A 25% decrease in price implies a 50% reduction in their production, or \eta_O \times 25%. These results are consistent with those obtained through the graphical analysis.

It is also important to note that the sum of the two benefits identified using the social approach—namely, the social value of the additional production and the value of the resources released—corresponds to the area eabcg in Figure 7.7. This observation leads to the following practical rule of thumb[9]:

> The social value of the production generated by a project implemented in a competitive market can be approximated[10] by the following expression:
>
> **Reference price × Quantity produced by the new plant**
>
> where the reference price is defined as:
>
> ½ × (price before the project + price after the project).
>
> In other words, the social benefit generated by the project's production corresponds to the additional quantity supplied by the project, valued at a reference price equal to the average of the pre-project and post-project prices.
>
> Within the social approach, this valuation captures both the gross value of the additional production and the value of the resources released as existing producers are partially displaced by the project. Under the stakeholder approach, the same effect is reflected through changes in consumer surplus, producer surplus for incumbent firms, and the income earned by the new producer.

In our example, the quantity supplied by the project amounts to 4 million tonnes per year. This quantity

9. See also Jenkins et al. (2011).

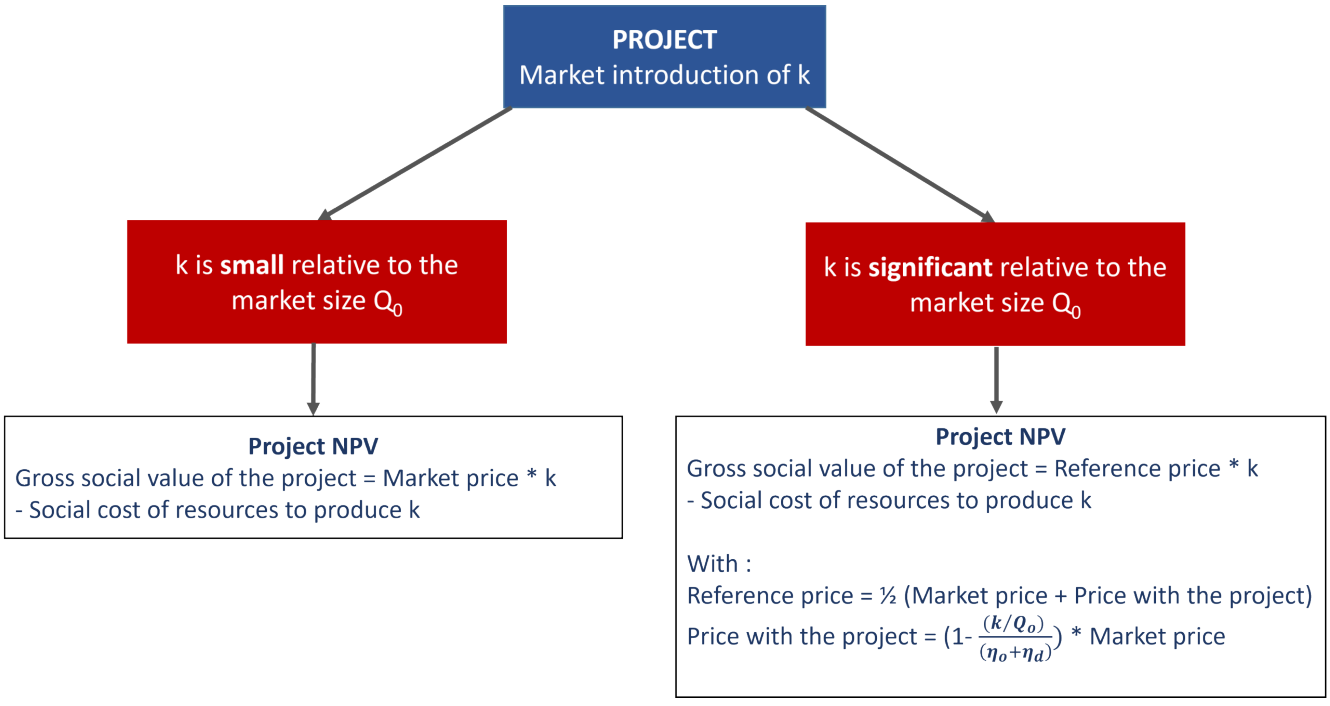
10. This formula is exact only when the supply and demand curves are linear.

should be valued at the average price of \$140 per tonne, that is, ½ (\$160 + \$120). The social value of the production introduced by the project therefore amounts to \$560 million per year. This value incorporates the impact of the project on consumers (an increase in consumer surplus), on incumbent producers (a reduction in producer surplus), and on the income earned by the new producer. Subtracting the project's costs then yields an NPV of \$160 million per year.

Finally, it is worth noting that in some cases the additional quantity introduced by a project may be small relative to the total volume traded in the market. In such situations, the effect on the equilibrium price—and consequently on existing consumers and producers—is negligible. The valuation can then be simplified by valuing the project's output at the prevailing market price.

> If the project supplies a quantity k that is small relative to the total volume traded in the market (Q^0), the valuation can be approximated by valuing this output at the initial market equilibrium price, that is, $P^0 \times k$.

Figure 7.8 summarizes the rule of practice for valuing the impacts of a project that supplies a quantity k in a competitive market.



7.4 Conclusions

In this chapter, we focused on valuing a project's outputs while abstracting from potential market distortions. The following chapters will examine in detail how such distortions can be incorporated into the analytical framework. At this stage, the main points to remember are:

Key takeaways

- The benefits of new infrastructure are assessed on the basis of users' willingness to pay (WTP).
- Total willingness to pay corresponds to the area under the user demand curve between zero and the expected level of usage.
- Estimating the demand curve for new infrastructure is often challenging.
- Because total willingness to pay is distributed among different stakeholders, it may be possible to assess part or all of this value by aggregating impacts on the relevant parties, such as operating profits, taxes collected by the State, consumer surplus, and operating costs.
- When a project improves the quality of a service, it leads to an upward shift in the demand curve. The area between the initial and the new demand curves measures the resulting benefit to users.
- In transportation, changes in travel time can be interpreted as variations in the generalized price, which correspond to movements along the demand curve expressed in terms of that generalized price.
- When a project significantly increases supply in a competitive market, the social value of the output introduced by the project can be estimated using a reference price equal to the average of the market price before and after the project. This valuation captures impacts on consumers, incumbent producers, and the income generated by the project.
- When the quantity added by the project is small relative to the size of the market, the valuation can be approximated using the prevailing market price.

Back to motivation

A medium-sized city is considering replacing a high-frequency express bus corridor with a more modern and efficient light rail transit (LRT) system. The proposed line would be approximately 14 km long and include 17 stations. The main expected benefits of the LRT project are as follows:

- Higher operating speed (about 34 km/h instead of 21 km/h), leading to shorter travel times;
- Increased passenger capacity to accommodate future population growth;
- Improved comfort and service reliability.

What analytical framework should be used to value these outputs in a cost–benefit analysis (CBA)?

Answer

The main benefit of this transport project lies in the time savings it generates for users. The analytical framework developed in Section 7.2.2 is therefore appropriate for evaluating this project. The analyst must assess the time savings enjoyed by existing users and measure the impact of traffic induced by the improvement. In addition, the enhancement in comfort can be analyzed using the framework presented in Section 7.2.1, which involves estimating users' willingness to pay for a higher level of comfort.

As an illustrative example, Metrolinx (2010) published a cost–benefit analysis of a comparable project implemented in the city of Hamilton (Canada). The study found that travel time savings accounted for the largest share of total benefits, representing roughly three quarters of the monetized impacts. These benefits were estimated using a transport demand model that captured not only gains for public transport users but also congestion relief for road users. Improvements in comfort and service quality were identified as relevant impacts but were not monetized, reflecting common data and methodological limitations in transport appraisal. Overall, the analysis illustrates that, in urban public transport projects, user time savings typically dominate the benefit profile, while other qualitative improvements, although important, often play a secondary role in the quantitative results.

Chapter 23 presents a case study of a regulatory intervention that increases production costs in the fuel oil and diesel industry.

Chapter 24 provides a detailed case study of the cost–benefit analysis of a project combining a tramway and a bus rapid transit system in the Québec region.

Exercises

(*) Indicates that the solution is available

(**) Indicates that the solution is available with restricted access

1. (*) In the example of the new cement plant in Section 7.3.1, verify that the stakeholder approach also yields $NPV = \$160$ million. Distinguish the following stakeholders: consumers, incumbent producers, and the new plant.
2. (*) A commuter rail line carries an average of 75,000 riders per year between the suburbs and the city centre. The $15 fare per trip covers the average operating cost. A project is designed to upgrade the line, reducing travel time from 45 minutes to 25 minutes. The average value of time for rail users is estimated at $7 per hour. In addition, the generalized price (or cost) elasticity of demand is estimated to be 0.7. The project will increase the average operating cost by 10%, but the fare per trip will not change. Assuming linear demand, determine the value of the impact on riders.
3. (**) A medium-sized municipality is considering building a biomethanization plant for its organic waste. One of the project outputs is natural gas that will be sold on the market. In your view, at what price should this output be valued? Explain.

    - In addition, the project will produce 400 tonnes of ecological fertilizers. Given transportation costs, the market for ecological fertilizers is regional. The project is therefore expected to double regional production of ecological fertilizers. Demand for these fertilizers is estimated to have a price elasticity of 3, while the supply elasticity is 0.1. The current price is $250 per tonne. What social value should be assigned to the additional production of ecological fertilizers from the new plant? Explain.

4. (*) A fine arts museum is considering hosting an international-calibre exhibition of Alberto Giacometti's work. The exhibition would cost $1 million and run for four months. Based on outcomes observed in other museums, it is expected to attract 120,000 additional visitors relative to the attendance anticipated

under the museum's permanent exhibition only. Additional revenue (tickets, parking, and gift shop sales) is estimated at $1.2 million. However, operating costs are expected to increase by $350,000. What must the average visitor surplus be for the exhibition to be justified on the basis of direct user benefits? Given the short duration of the project, discounting is not required.

5. (**) A project involves replacing a ferry service between two river banks with a bridge. The ferry service is operated by the Ferry Coorporation. The crossing costs $3, and annual traffic is 100,000 crossings. Ferry operating costs are estimated at $150,000 per year. With the construction of the bridge, the ferry can be sold for an estimated $25 million. The construction cost of the bridge, incurred at $t = 0$, is $100 million. The bridge would be tolled at $5 per crossing. The monetary value of travel time savings is estimated at $12 per crossing on average. In addition, traffic is expected to rise to 145,000 crossings per year once the bridge opens and to remain stable thereafter. Bridge operating and maintenance costs are estimated at $100,000 per year. The bridge has an expected life of 75 years, and the social discount rate is 5%. For simplicity, assume that the bridge is built at $t = 0$ and that the ferry is sold at $t = 0$. Also assume that annual operating benefits and costs accrue continuously each year, starting in year 1. Perform a CBA of this project.

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8.

TAXES, SUBSIDIES, AND IMPACTS ON COSTS

Motivation and learning objectives

To reduce CO2 emissions, many governments offer subsidies for the purchase of electric vehicles. Suppose you are asked to conduct a CBA of such a program. Should the subsidy be treated as a benefit, a cost, or a transfer? How will the resulting price reduction affect the number of electric vehicles sold? Once again, it becomes clear that an appropriate analytical framework is required.

Taxation is one of the most powerful tools available to governments. Taxes and duties are used to finance public activities, influence the distribution of income, and help stabilize the economy. However, taxation is also used to improve efficiency—for example, by taxing certain products more heavily to discourage their use (such as tobacco or pesticides), or, conversely, by providing tax relief to encourage the consumption or production of other goods and services (such as sales tax exemptions for books or tax credits for high-tech industries). Subsidies are also frequently used to attract investment in specific sectors. For instance, many governments offer financial support for factories in emerging industries, such as electric-vehicle battery production.

As discussed in Chapter 1, CBA is not well suited to analyzing broad tax measures, such as a general sales tax reduction. However, it can be applied to targeted fiscal measures that affect a limited set of goods or services.

Valuation in CBA must also account for existing taxes. For example, should a project's output be valued at its pre-tax price or at its price inclusive of taxes?

By the end of this chapter, you will be able to build an analytical framework for the CBA of a project that:

1. Introduces a new targeted tax;

2. Establishes a specific subsidy or tax advantage;
3. Increases supply in a market already subject to a tax or subsidy;
4. Changes operating costs in a market.

The final topic may appear to fall outside the scope of taxation. However, a project that changes operating costs is analyzed in essentially the same way as the incidence of a tax or subsidy, which justifies its inclusion in this chapter.

8.1 The imposition of a new tax

Taxation can serve as a tool to improve efficiency in markets that fail to allocate resources optimally (for example, through environmental taxes) or to positively influence the decisions of economic agents who are affected by **cognitive biases** (such as tax incentives for saving or taxes on sugary beverages). However, it is important to note that taxes are often introduced primarily to meet government financing needs, which can generate economic distortions, as we will show in the following sections.

8.1.1 The introduction of a unit tax

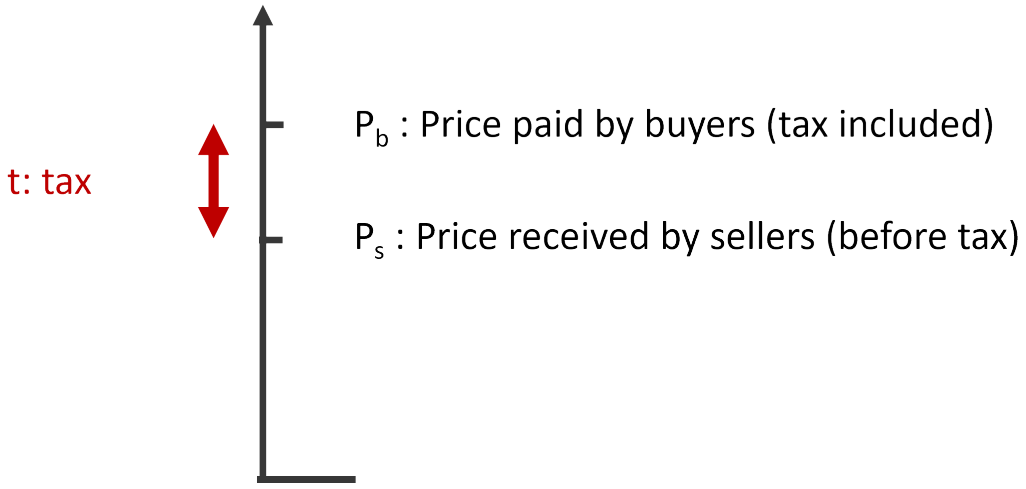
A unit tax is a fixed, mandatory levy imposed on each unit of a good. From an administrative perspective, a unit tax can be levied either on buyers (a purchase tax) or on sellers (a sales tax). From an economic perspective, however, the incidence of the tax is identical in both cases.

Specifically, a unit tax of amount t creates a **wedge** between the price paid by buyers, denoted Pb (the price inclusive of the tax), and the price received by producers, denoted Ps (the price net of the tax), such that:

$$Pb = Ps + t$$

This situation is illustrated in Figure 8.1. For example, a driver may pay $1.60 per litre of gasoline, while the seller receives only $1.00 per litre, with the difference collected by the government in the form of various taxes.

Figure 8.1 The Tax Wedge



To understand the effects of a tax on the different market participants and on **collective well-being**, consider the following simple example. A good sold in a competitive market is initially exempt from taxation. Figure 8.2 illustrates the supply and demand curves in this market. The **price elasticity of demand** is estimated at 1.5, while the price elasticity of supply is 3. The government is considering imposing a unit tax of $30 per unit. How can we conduct a CBA of the impacts of this policy?

In this example, the scenarios under consideration are as follows:

- The **baseline scenario** corresponds to the absence of taxation, with a market equilibrium at P = $60 and Q = 40,000 units, represented by point c in Figure 8.2.
- The scenario with the project corresponds to the introduction of a unit tax of $30. We must therefore determine how the market equilibrium changes. In particular, will producers fully pass the tax on to consumers, or will they absorb part of it?

The tax creates a wedge of $30 between the price paid by buyers, denoted *Pb*, and the price received by sellers, denoted *Ps*. Since *Pb* must be higher than the initial equilibrium price, the new equilibrium occurs to the left of the original equilibrium, at the point where the vertical distance between the **demand curve** and the supply curve is equal to the tax, that is, t = $30. This corresponds to the distance between points b and d in Figure 8.2.

From the figure, we can anticipate the new equilibrium in the presence of the tax: *Pb* = $80, *Ps* = $50, and the quantity traded falls to 20,000 units. In this example, two-thirds of the tax burden is passed on to consumers, as the price they pay increases by $20, while producers absorb the remaining third by accepting a $10 reduction in the price they receive.

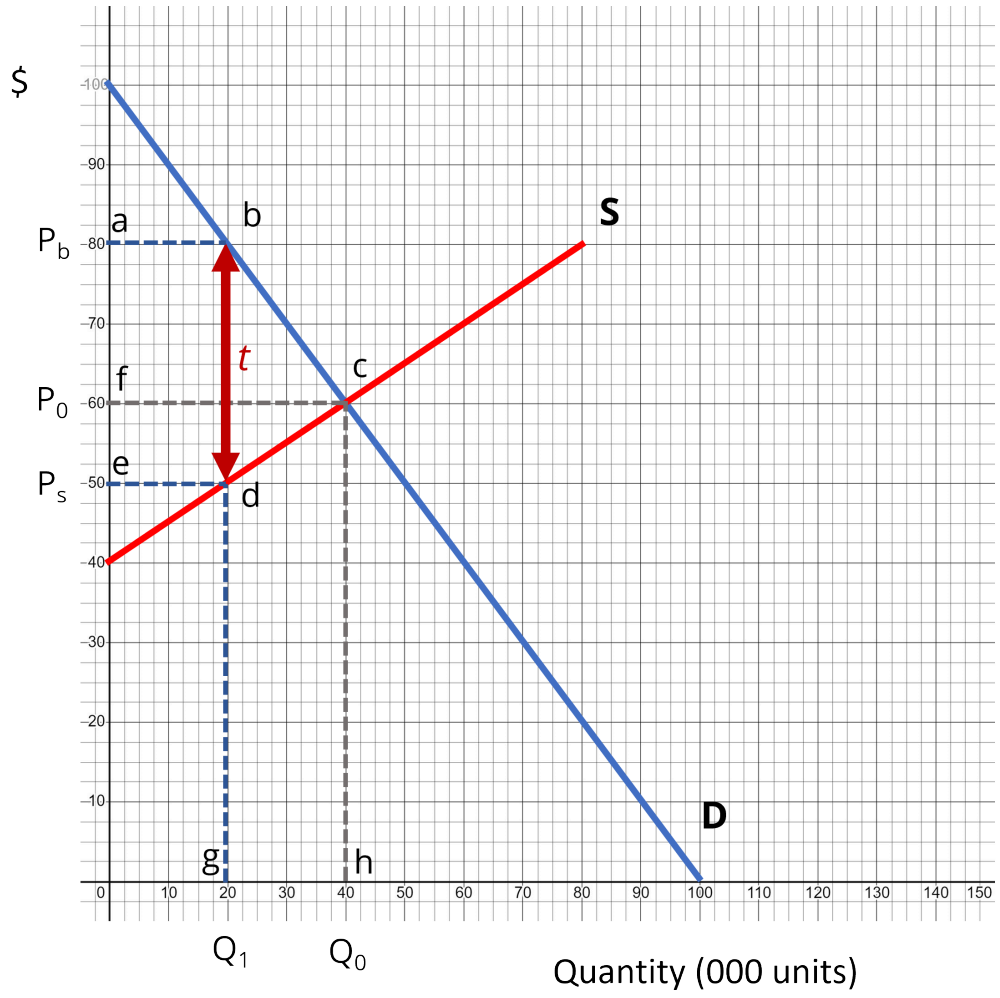


Figure 8.2 Impacts of a Tax in a Competitive Market

It is now possible to conduct the CBA of this project using the **stakeholder approach**. The relevant stakeholders are consumers, producers, and the State. The resulting changes in surplus are as follows:

- Consumers experience a reduction in surplus due to the increase in the price they pay (area *abcf*).
- Producers also experience a decrease in surplus as a result of the lower price they receive (area *fcde*).
- The State benefits from an increase in revenue equal to the tax receipts collected (the rectangular area corresponding to the tax revenue).

The net effect of the tax is a deadweight loss, measured by the area of triangle *bcd*. This loss reflects mutually beneficial exchanges that no longer occur because of the tax.

The **social approach** leads to the same conclusion:

- The social cost associated with the reduction in production is measured by area *bchg*.
- The social value of the resources released is measured by area *dchg*.

The numerical values associated with these effects are reported in Table 8.1.

Table 8.1 CBA results of tax imposition

Stakeholder approach	Net effect
Consumers	-600,000
Producers	-300,000
State	+600,000
Total effect =	**-$300,000**
Social approach	**Value**
Social value of change in quantity exchanged	-1,400,000
Social value of resources released	+1,100,000
Social cost of resources mobilized	0
Total effect =	**-$300,000**

8.1.2 The impact of a unit tax

In the previous example, we determined the post-tax equilibrium prices using the supply and demand curves illustrated in Figure 8.2. In practice, however, analysts rarely observe these curves directly. More often, they must rely on estimates of the price elasticities of demand and supply. Fortunately, these two parameters are sufficient to anticipate how the market will respond to the introduction of a tax.

A unit tax can be analyzed as an increase in production costs of amount *t*, or equivalently as an upward (vertical) shift in the supply curve, expressed as a function of the tax-inclusive price. In this setting, it is possible to apply the appropriate formula from Table 4.2 in Section 4 of Chapter 4. Recall that this formula allows us to predict the percentage increase in the price paid by buyers following the introduction of a unit tax *t*:

$$\Delta p\% = \left(\frac{t}{P_0}\right) \times \left(\frac{\eta_S}{\eta_D + \eta_S}\right)$$

By manipulating this expression and taking into account the relationship between prices paid by buyers and prices received by sellers—namely, $P_s = P_b - t$—we can derive the formulas for **tax incidence**. These formulas describe how the tax burden is shared between consumers and producers.

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The incidence of a tax in a competitive market is determined as follows[1]:

- The share of the tax borne by consumers is equal to $\frac{\eta_S}{\eta_D + \eta_S}$;
- The share of the tax borne by producers is equal to $\frac{\eta_D}{\eta_D + \eta_S}$.

These expressions show that the side of the market that is relatively less elastic bears a larger share of the tax burden.

Tax incidence is therefore determined by the relative magnitudes of the price elasticities of demand and supply. The intuition is straightforward. When demand is elastic, consumers can easily switch to substitutes or forgo consumption altogether. As a result, the more elastic demand is, the more difficult it is for producers to pass the tax on to consumers. Conversely, when supply is elastic, producers have alternative options—such as reallocating production to other markets—and are therefore less willing to absorb the tax themselves.

Figure 8.3 illustrates these extreme cases. Panel A shows a situation with perfectly elastic demand, in which producers bear the entire tax burden. Panel B presents the case of perfectly elastic supply, which leads to full pass-through of the tax to consumers.

1. For a formal derivation of these formulas, see *Economics in Many Lessons* (2018).

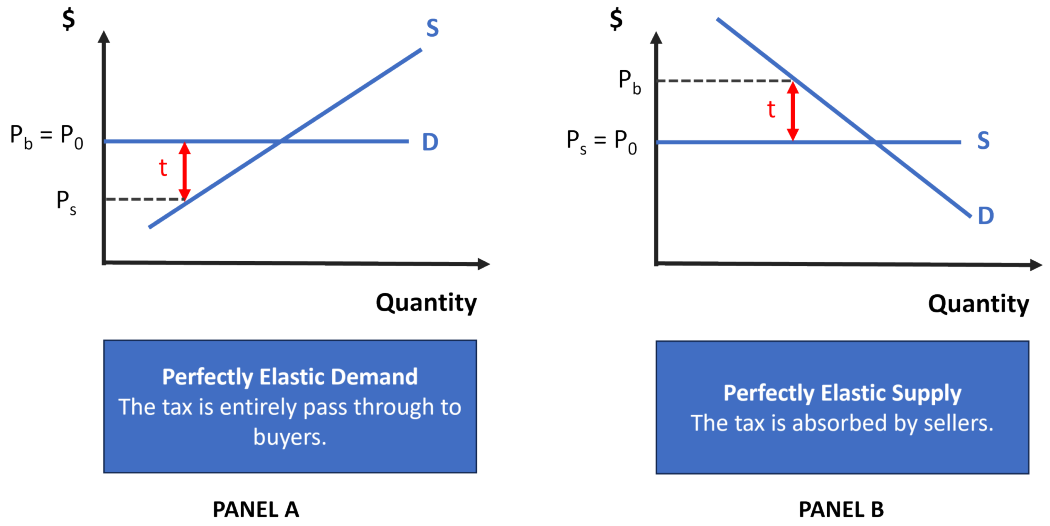


Figure 8.3 Supply and Demand price elasticity and Tax Incidence

Applying this rule to our example, we find that 66% of the tax burden is borne by consumers, equal to 3/(1.5 + 3), while the remaining 33% is absorbed by producers, equal to 1.5/(1.5 + 3).

This allows us to determine the post-tax equilibrium without having to observe the full supply and demand curves. The equilibrium prices with the tax are therefore:

- The price paid by buyers:
  $P_b = 60 + 0.66 \times 30 = \$80$;
- The price received by sellers:
  $P_s = 60 - 0.33 \times 30 = \$50$.

The equilibrium quantity can then be derived from the elasticity of demand (1.5) and the percentage increase in the price paid by consumers (+33%). This implies a reduction in quantity of 50%, that is, (1.5 x 33 %).[2]

Thus, elasticity estimates alone are sufficient to characterize the market adjustment induced by the tax.

8.1.3 An*ad valorem* tax

A tax on a good or service can also be expressed as a percentage of the sale price. This type of levy is known as an *ad valorem* tax. Let us examine this situation through a simple example. The equilibrium price in a competitive market is $50 per tonne, and the quantity traded is 130,000 tonnes per year. The government is considering

2. Alternatively, one can use the elasticity of supply together with the percentage decrease in the price received by producers (−16.7%) to obtain the same 50% reduction in the quantity traded (see Figure 8.3).

imposing a 20% tax on this market. According to a review of the literature, the price elasticities of demand and supply in this market are both equal to one. How can we determine the impacts of this tax?

The formulas used to assess tax incidence remain applicable. We can therefore anticipate that, in this example, consumers and producers will each bear half of the tax burden. However, this information alone is not sufficient to precisely determine the impacts on consumers, producers, and the State. In particular, the amount of tax paid per unit at the new equilibrium is not directly known. To determine it exactly, one would need to know the full supply and demand curves, allowing the analyst to identify the pre-tax price, the post-tax price, and the per-unit tax at equilibrium.

In the absence of this information, it is nevertheless possible to approximate the impacts by computing the tax amount based on the initial price (before the tax is imposed). In our example, this corresponds to 20% of $50, that is, $10 per unit. The situation can therefore be approximated as the introduction of a unit tax of $10. Under this assumption, the price paid by buyers increases to $50 + 1/2 x $10 = $55, while the price received by sellers falls to $50 – 1/2 x $10 = $45. The quantity traded then decreases by approximately 10%, to about 117,000 tonnes, since the price paid by consumers has increased by 10%.

This approach is only an approximation. If the price received by producers is $45, the tax amount is no longer $10, but rather $9, since it corresponds to 20% of $45. The approximation becomes more accurate when producers bear a relatively small share of the tax burden, that is, when demand is relatively inelastic compared to supply.

If the supply and demand curves are known, it is then possible to determine the impacts of the tax precisely. A full derivation of these effects is presented in Appendix 1 of this chapter.

8.2 Subsidies

Subsidies are widely used instruments of government intervention in the economy and can take many forms and names. They can be justified on economic grounds, such as the presence of positive externalities, the objective of improving equity, or the desire to reduce poverty. In some cases, subsidies serve as imperfect but more politically acceptable responses to a negative externality. For example, it is often politically easier to subsidize public transportation to reduce greenhouse gas emissions than to increase gasoline taxes. Subsidies may also reflect political considerations, such as the pursuit of electoral support or responses to pressure from interest groups (see Chapter 3).

In practice, a distinction can be made between production subsidies and consumption subsidies. Subsidies may be direct, involving an explicit transfer of funds (for example, subsidizing the construction of a factory), or indirect, taking the form of tax advantages (such as tax credits for research and innovation or sales tax exemptions). They can also be calculated on the basis of different criteria, including the level of production or consumption, income, the quantity of inputs used, or investments in fixed assets. Finally, subsidies may involve

a transfer of risk to the State, as in the case of loan guarantees or guaranteed income schemes. Table 8.2 presents a classification of subsidies based on the framework proposed by the OECD (2022).

Table 8.2 Typology of subsidies

Criteria for Determining the Grant	Direct	Indirect
Production	• Subsidy per unit produced (subsidy for solar energy production, subsidy for forest management work) • Regulated price (guaranteed price for the purchase of electricity from wind turbines)	• Production tax credits (cultural or agricultural industry)
Purchase	• Purchase subsidy (rebate on the purchase of electric vehicles) • Scholarships	• Tax credit (energy-efficient renovation tax credit, reduced interest rate for student loans)
Business income	• Operating subsidy	• Business income tax reduction
Costs of an intermediate input (quantity or value)	• Preferential rate (preferential electricity rate)	• Tax exemption (CO_2tax exemption)
Workforce	• Wage subsidy	• Payroll tax credit
Capital	• Direct subsidy for the purchase of capital (subsidy for the construction of a new factory)	• Investment tax credit
R&D	• Subsidy for R&D activities	• R&D tax credit
Transfer of risks	• Guaranteed price or income (support for agriculture). Guaranteed loan.	

8.2.1 Unit subsidies

Unit subsidies consist of granting a fixed amount per unit to buyers or producers. From an economic perspective, the effects are identical regardless of whether the subsidy is paid to buyers or to producers, and they can be analyzed in the same way as those of a unit tax.

A unit subsidy of amount *s* per unit creates a wedge between the price paid by buyers, denoted *Pb*, and the price received by sellers, denoted *Ps*. Unlike a tax, however, the subsidy implies that the price paid by buyers is lower than the price received by producers. Formally, this relationship is given by:

$$P_b = P_s - s$$

This situation is illustrated in Figure 8.4.

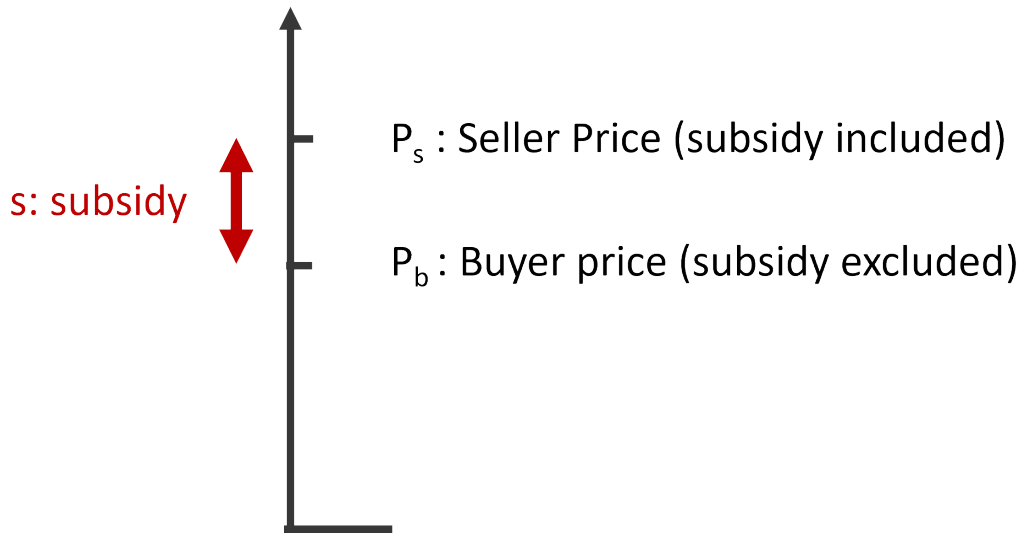


Figure 8.4 Price Wedge Created by a Subsidy

For example, a government offers a rebate of up to $13,000 to purchasers of electric vehicles. As a result, a Nissan Leaf sold by a dealer for $41,898 would cost the buyer only $28,898, with the difference covered by public subsidies—that is, financed by taxpayers.

As with taxes, the impact of a subsidy depends on the price elasticities of supply and demand:

- The share of the subsidy that benefits consumers, in the form of a reduction in the price paid (*Pb*), is equal to $\frac{\eta_S}{\eta_D + \eta_S}$;

- The share of the subsidy that benefits producers, in the form of an increase in the price received (*Ps*), is equal to $\frac{\eta_D}{\eta_D + \eta_S}$.

These expressions highlight that the side of the market that is relatively less elastic captures a larger share of the subsidy.

Exercises 4 and 5 provide a detailed illustration of the CBA of implementing a subsidy. When evaluating subsidy programs, governments often document the *opportunism rate*. This rate measures the share of program participants who receive financial assistance but would have undertaken the actions promoted by the program even in the absence of that assistance.

A low opportunism rate is associated with greater program effectiveness in encouraging the targeted behavior and, consequently, in generating the intended benefits (for example, greenhouse gas reductions in the case of subsidies for electric vehicle purchases). However, a low opportunism rate also implies a larger deadweight loss in the market. Indeed, individuals who participate only because a subsidy is available have a **willingness to pay** that is lower than the social cost of the good, thereby generating a deadweight loss.

Chapter 22 presents a case study on the application of cost–benefit analysis to tax credits designed to encourage the filming of foreign films and television programs in Canada.

8.2.2 Other forms of subsidies

Purchase or sales subsidies can also be expressed as a percentage of the price. The analysis of such subsidies follows the same logic as that used for ad valorem taxes.

Preferential tariffs—such as reduced electricity rates for certain users—can be analyzed as a reduction in the **marginal cost of production** in the market for the final good that benefits from the tariff. However, it is also possible to examine the impacts of these tariffs in the market for the input itself. In that case, the situation corresponds to the analysis of a unit (or ad valorem) subsidy that is available only to a subset of buyers. The analysis must then account for the effects on subsidized users as well as on those who do not have access to the preferential tariff.

Capital subsidies, through which governments finance part of a private investment—such as the construction of a new factory—are analyzed by assessing their impacts on the market for the relevant final product. It is essential to consider the effects on consumers, incumbent producers, the government, and any other affected stakeholders (see Section 7.3). Such projects may also influence equilibrium conditions in markets for specialized inputs (for example, the market for IT specialists), and these effects may need to be incorporated into the cost assessment of the project (see Chapter 11, Section 1).

8.3 The sale of a taxed or subsidized good

If a project adds supply to a good sold in a competitive market that is already subject to a unit tax, should the project's output be valued at the price excluding the tax, at the price including the tax, or using another reference price?

In this section, we directly present the rule of practice to be applied, along with the intuition behind it. Appendix 2 derives this rule formally using a numerical example.

As we learned in Chapter 7, Section 7.3, when a project increases supply in a competitive market, the equilibrium price generally falls and the quantity traded increases. However, we also saw that the increase in the quantity traded is typically smaller than the quantity supplied by the project, because the lower equilibrium price crowds out some production by incumbent firms. In other words, part of the project's output serves new consumers, while another part merely displaces existing economic activity.

Figure 8.5 illustrates these two effects for the new cement plant examined in Section 7.3. The project adds a quantity k = 4 million tonnes of cement to the market, causing the price to fall from $160 to $120. The total quantity traded increases by only 1 million tonnes, however, because incumbent producers reduce their output by 3 million tonnes.

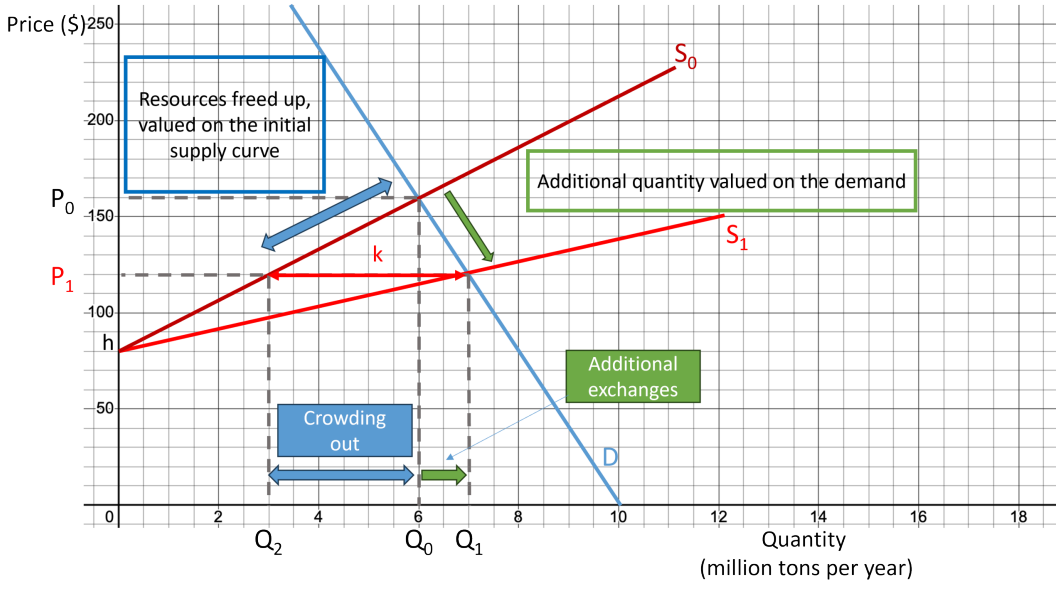


Figure 8.5
Valuation of an Increase in Supply

As we noted in Chapter 7, the valuation of the additional quantity exchanged on the market (from 6 to 7 million tonnes) must be carried out along the demand curve, that is, using the maximum willingness to pay for these additional units. By contrast, the quantity displaced by the project leads to a reduction in the resources previously mobilized, which must be valued along the initial supply curve.

Moreover, we know that a tax creates a wedge between the price including tax, which is relevant on the demand side, and the price excluding tax, which corresponds to the supply side. Consequently, when a project adds supply in a market where a tax is already in place, the additional quantity exchanged must be valued on the demand curve, and therefore at the price including tax. Conversely, the quantity displaced by the project frees up resources whose value must be assessed on the supply curve, that is, at the price excluding tax.

The corresponding rule of practice is therefore as follows[3]:

Rule of practice: valuation of project output in the presence of a tax

The social value of the production marketed by a project in a competitive market subject to a unit tax must be assessed using the following reference price:

$$p_r = \omega_D \bar{p}_b + \omega_S \bar{p}_s$$

where:

$\bar{p}_b$ is the average of the prices paid by buyers before and after the project (price including tax);

$\bar{p}_s$ is the average of the prices received by sellers before and after the project (price excluding tax);

ω_D is the share of the project's output that meets additional demand;

ω_S is the share of the project's output that displaces production by incumbent producers.

The weights can be approximated using the price elasticities of demand and supply as follows:

$$\omega_D = \frac{\eta_D}{\eta_D + \eta_S}$$

$$\omega_S = \frac{\eta_S}{\eta_D + \eta_S}$$

Prices in the scenario with the project can be approximated using the same formulas as those presented in Chapter 7.

3. See also Jenkins et al. (2011).

If the expected impact of the project on equilibrium prices is small relative to the price wedge created by the tax, the valuation can be simplified as:

$$p_r = \omega_D p_b + \omega_S p_s$$

where:

p_b is the price paid by buyers before the project (including tax);

p_s is the price received by sellers before the project (excluding tax).

In this approximation, price changes induced by the project are ignored, but the valuation explicitly accounts for the wedge created by the tax.

Under the social approach, the resulting valuation captures both the gross value of additional production and the value of the resources saved through the displacement of incumbent producers. Under the stakeholder (party-based) approach, the same valuation corresponds to the combined impacts on consumers, existing producers, tax revenues, and the revenues of the new producer.

In the presence of a subsidy, the valuation logic mirrors that developed for taxes, but with the direction of the price wedge reversed.

The portion of the project's output that serves additional buyers must be valued at the price actually paid by buyers, that is, the market price net of the subsidy. This valuation reflects the buyers' willingness to pay for the additional units consumed.

Conversely, the portion of the project's output that displaces production by already established sellers frees up resources whose opportunity cost is measured at the price received by sellers, which therefore includes the subsidy.

As in the case of a tax, the appropriate valuation depends on the relative shares of additional demand and displaced supply. The corresponding rule of practice for valuing project output in a market subject to a subsidy is presented in the box below.

Rule of practice: the valuation of the production of a project in the presence of a subsidy

The social valuation of the production of a project that contributes to supply in a competitive market where a unit subsidy exists is carried out using the following reference price:

$$p_r = \omega_D \bar{p}_b + \omega_S \bar{p}_s$$

With:

$\bar{p}_b$: the average of the prices paid by buyers before and after the project (i.e. net of the subsidy);

$\bar{p}_s$: the average of the prices received by sellers before and after the project (i.e. including the subsidy);

ω_D: the share of the project's production that serves additional customers;

ω_S: the share of the project's production that replaces production by already established producers.

The weights can be estimated from the price elasticities of demand and supply:

$$\omega_D = \frac{\eta_D}{\eta_D + \eta_S} \text{ and}$$
$$\omega_S = \frac{\eta_S}{\eta_D + \eta_S}$$

The determination of prices in the scenario with the project can be carried out approximately using the same formulas as those presented in Chapter 7. However, in the presence of a subsidy, this approximation is generally less precise, since the subsidy itself modifies the price signals faced by market participants.

If the anticipated impact of the project on equilibrium prices is small relative to the price wedge created by the subsidy, the valuation can be simplified as follows:

$$p_r = \omega_D p_b + \omega_S p_s$$

With:

p_b: the price paid by buyers before the project (net of the subsidy);

p_s: the price received by sellers before the project (including the subsidy).

In this case, price changes induced by the project are ignored, but the valuation explicitly accounts for the wedge created by the subsidy.

Under the social approach, the value thus calculated captures both the gross value of the additional production and the value of the resources saved due to the displacement of already established producers. Under the party-based approach, the measured effects correspond to impacts on consumers, on already established producers, on public finances through the budgetary cost of the subsidy, and on the income of the new producer.

Example

Ethanol producers receive a subsidy of 10 cents per litre. Assume the market is competitive. The price paid by buyers is $0.50 per litre, and the quantity traded is 50 billion litres per year. The price elasticity of demand is estimated at 0.5, and the price elasticity of supply at 1. The government must decide whether to approve the construction of a new ethanol plant that would add 1 billion litres annually. Determine the social value of the output produced by this new plant.

Resolution

Baseline scenario

The project adds 2% of the current market quantity (1/50). The impact on the equilibrium price is therefore expected to be approximately -1.33%, that is, 2% divided by the sum of the elasticities. We will ignore this price effect, as it is relatively small. In addition, we estimate that 33% of the additional production serves new customers, since ω_D = 0.50/1.50, while 66% crowds out production by incumbent plants.

The output is then valued using the following reference price:

$$p_r = 0.33 \times 0.50 + 0.66 \times 0.60 = 0.561\$/\text{litre}$$

The social value of the project's output is therefore $561 million per year.

A complete CBA of this project should also account for the cost of the resources mobilized by the new plant and for any change in external effects induced by the project, such as potential reductions in greenhouse gas emissions.

8.4 The project affects production costs

In Chapter 5, we examined projects that affect the marginal cost of production in a competitive industry. For example, we analyzed the introduction of workplace safety standards, which increase marginal costs and shift the supply curve upward. We also studied a case in which access to a preferential electricity tariff reduces the production cost of greenhouse tomatoes, thereby shifting the supply curve downward. In these examples, the new market equilibrium was determined using graphical analysis.

However, as has been emphasized several times, analysts do not always have access to a precise graphical representation of supply and demand curves. In such cases, it is possible to determine the post-project market

equilibrium by using the incidence formulas discussed in Section 8.1.2, which are themselves a special case of the more general formulas introduced in Chapter 4.

These formulas make it possible to determine how a change in production costs is shared between buyers and sellers. In other words, they allow the analyst to predict who will bear an increase in costs, or who will benefit from a cost reduction. By relying solely on estimates of the price elasticities of supply and demand, it is therefore possible to anticipate changes in equilibrium prices and quantities following a cost shock in a competitive market.

In this context, these relationships are commonly referred to as pass-through formulas, as they describe the extent to which changes in production costs are transmitted to final prices. Exercise 5 in this chapter illustrates the application of these formulas in the analysis of a ban on a pesticide used in apple production.

8.5 Conclusions

Key takeaways

- Introducing a tax or a subsidy into a market that is initially undistorted generates a net welfare loss.
- A tax or subsidy levied on each unit traded creates a wedge between the price paid by consumers and the price received by producers.
- The incidence of a tax or subsidy depends on the relative price elasticities of supply and demand. The party with the lower price elasticity bears a larger share of the tax burden and captures a larger share of a subsidy.
- In a competitive market, the distribution of a tax (or subsidy) between consumers and producers is determined by the price elasticities of supply and demand according to the following rules:
  \frac{\eta_S}{\eta_D + \eta_S} % is paid by buyers (or received in the case of a subsidy);
  \frac{\eta_D}{\eta_D + \eta_S} % is paid by sellers (or received in the case of a subsidy).
- The opportunism rate of a subsidy program corresponds to the share of agents who would have undertaken the subsidized action even in the absence of the program.

- When a project produces an output that is subject to a tax, the social valuation of that output must be based on a reference price equal to a weighted average of the price including the tax and the price excluding the tax. The weights reflect the share of the project's output that serves additional consumers (valued at the tax-inclusive price) and the share that displaces pre-existing production (valued at the tax-exclusive price). Under perfect competition, these weights are determined by the price elasticities of supply and demand.
- Finally, incidence formulas can also be used to predict how a change in marginal production costs, represented by a shift in the supply curve, is transmitted to final prices in a competitive market.

Back to motivation

To reduce CO2 emissions, many governments offer subsidies for the purchase of electric vehicles. Suppose you are asked to conduct a CBA of such a program. Should the subsidy be treated as a benefit, a cost, or a transfer? How will the resulting price reduction affect the number of electric vehicles sold? Once again, it becomes clear that an appropriate analytical framework is required.

Solution

Under the stakeholder approach, subsidies appear as a transfer from taxpayers to buyers and sellers of electric vehicles. However, this transfer does not eliminate efficiency losses: the subsidy still generates a net welfare effect in the form of a deadweight loss. From the social approach, the benefit corresponds to the value on the demand side of the additional electric vehicles purchased as a result of the subsidy, while the cost corresponds to the value of the resources mobilized to produce these additional vehicles. Because the production cost of these vehicles exceeds their willingness to pay for the marginal buyers induced by the subsidy, the policy generates a deadweight loss.

That said, it is essential to take into account the environmental benefits associated with replacing conventional vehicles with electric vehicles, such as reductions in greenhouse gas emissions and local air pollutants. In addition, consumers may underestimate future operating cost savings, due to

present bias or other behavioral factors that lead them to overweight upfront costs relative to future benefits.

As an illustration, Mercier, Lanoie, and Leroux (2015), as corrected by Barla (2018), show that the Quebec electric vehicle subsidy program generated a negative **Net Present Value (NPV)** of approximately $3 million in 2012. This result is based on an opportunism rate of about 50% and a marginal cost of public funds equal to 0.192.

Chapter 22 presents the results of a cost-benefit analysis of tax credit programs designed to encourage the filming of foreign movies and television programs in Canada.

Exercises

1. (*) A project plans to market 10,000 tonnes of a good whose tax-exclusive price is $100 per tonne. A 15% tax applies to this good. The project is expected to affect the market price, but for the purposes of this analysis, we will ignore this effect. The price elasticity of demand is 2, while the price elasticity of supply is 3. Before the project, the quantity traded in the market was 100,000 tonnes. Can you determine the social value of the output marketed by this project? Please explain your reasoning.

2. As a junior analyst at a public health authority, your task is to formulate tax recommendations aimed at improving population health. You are considering the introduction of an excise tax of $0.50 per kilogram on refined sugar intended for direct consumption. Before submitting this proposal to your supervisor, you compile the following key information:

    - The current average price of refined sugar is $1.50 per kilogram, and annual consumption is estimated at 60 kilograms per capita in a population of 8.4 million.

    - Available evidence suggests that the price elasticity of demand is very low (0.1), while the price elasticity of supply is relatively high (1.7).

    Based on this information, assess the likely impact of the tax on the sugar market. In light of your analysis, would you recommend submitting this proposal to your supervisor?

3. A government provides a large subsidy for the construction of a new aluminum smelter. It defends this use of public funds by emphasizing the project's expected fiscal benefits: "It should create jobs and stimulate economic activity, which will generate new tax revenues that will quickly recoup our initial investment." Explain how the price elasticities of supply and demand in this market can affect the magnitude of the expected fiscal benefits.
4. Create a fictitious example of a CBA involving the introduction of a unit subsidy of $s per unit in a competitive market where demand is more elastic than supply. Illustrate the impacts with a graph and perform the CBA using (i) the stakeholder approach and (ii) the social approach. Also explain how the opportunism rate would be calculated in your example.
5. The government is considering regulations that would prohibit the use of certain pesticides in domestic apple production. These pesticides are associated with serious health risks for people who apply them. It is estimated that banning these pesticides would generate benefits of about $5 million, mainly through reduced health care costs. However, the regulation is expected to increase domestic production costs by approximately $200 per tonne. Demand for domestic apples is highly elastic because domestic producers face strong competition from imported apples; the price elasticity of demand is estimated at 6. Before the regulation, annual sales of domestic apples are 13,000 tonnes at an average price of $1,200 per tonne. The price elasticity of supply is estimated at 1.2. Perform a CBA of this project.

Appendix 1. The Impact of an *ad valorem tax*

The initial equilibrium (baseline scenario) corresponds to point a in Figure 8.6, with a price of $50 and a traded quantity of 130,000 tonnes.

The tax is equivalent to an increase in producers' marginal costs and therefore leads to an upward shift in the supply curve. However, this shift is not parallel. Indeed, to continue supplying 130,000 tonnes, the price inclusive of tax would have to rise to (1.2) × $50 = $60. Repeating this calculation for all possible quantities yields the purple curve, which represents the quantity supplied as a function of the tax-inclusive price. The intersection of this curve with the demand curve determines the market equilibrium with the tax.

Although the graphical solution is imprecise, using the equations underlying the supply and demand curves allows us to determine the equilibrium more accurately. The equilibrium price inclusive of tax is $54.5, the price exclusive of tax is $45.4, and the quantity traded falls to 118,180 tonnes. In this case, the approximation presented earlier is therefore reasonably close to the exact solution.

As before, the cost–benefit analysis of imposing this tax yields a negative NPV, corresponding to the area abc, which is approximately $60,000.

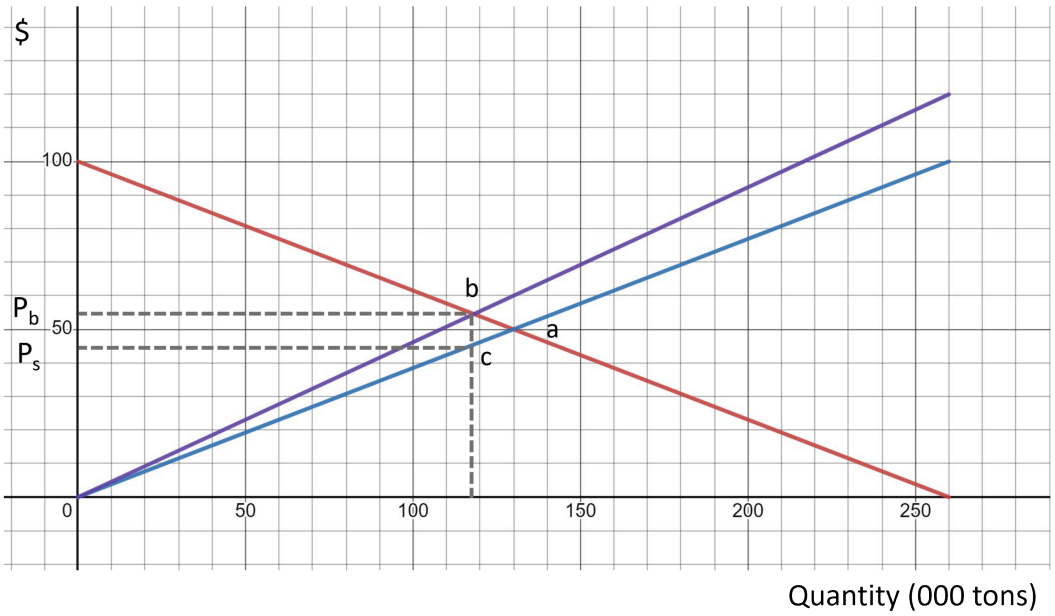


Figure 8.6 The impacts of an ad valorem tax

Appendix 2. Derivation of the rule of practice from Section 8.3

Supply and demand for a good are illustrated in Figure 8.7. The market is competitive, and a unit tax of $20 per unit applies. The government is considering financing the construction of a new production facility that would supply 30 million units, sold at the prevailing market price. What is the gross social value of the output generated by this project?

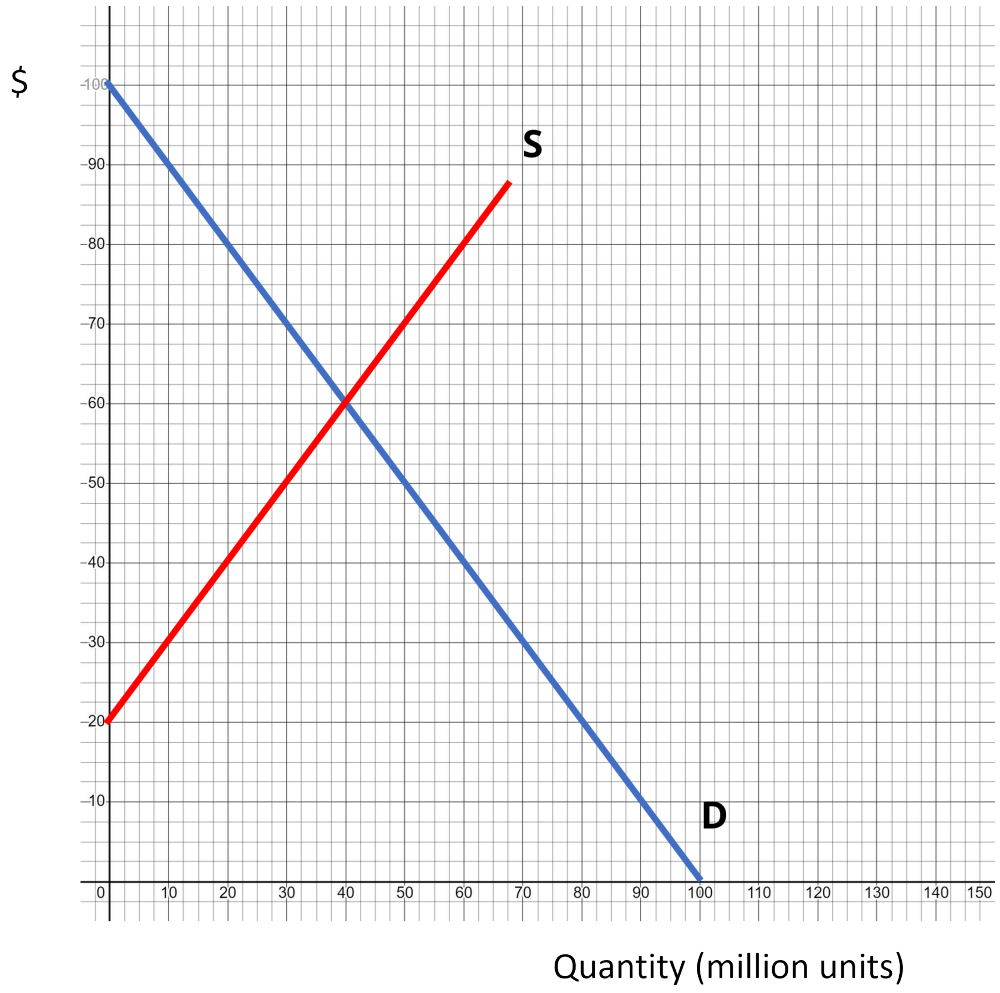


Figure 8.7 Initial supply and demand in the market

Resolution

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Figure 8.8 illustrates the solution to this problem. To clarify the reasoning, we distinguish between the baseline scenario (before the project) and the scenario with the project.

The reference scenario (before the project)

Taking into account the unit tax of $20, the initial market equilibrium is characterized by a quantity of Q_0 = 30 million units. The price received by producers (excluding tax) is $50, while the price paid by consumers (including tax) is $70.

The scenario with the project

The project adds 30 million units to the initial supply, resulting in a parallel outward shift of the supply curve from S_0 to S_1, as shown in Figure 8.8.

In the new equilibrium, the quantity traded increases to approximately Q_1 = 45 million units. The tax-exclusive price falls to $35, while the tax-inclusive price falls to $55. Importantly, the increase in the quantity traded is smaller than the additional production of 30 million units, because the price decline induces existing producers to reduce their output from 30 million to 15 million units.

We can now determine the gross social value of the 30 million units supplied by the project.

For the units that increase total market transactions (from 30 to 45 million units), social valuation is carried out along the demand curve. The social value of these additional units corresponds to the area shaded in orange, which is approximately $937.5 million. Equivalently, these units are valued at the average tax-inclusive price of $62.5, which is the average of $70 and $55.

For the units that displace production by existing producers (from 15 to 30 million units), social valuation is based on the initial supply curve S_0. The social value of these units corresponds to the area shaded in dark blue, equal to $637.5 million. This amount represents the value of the resources freed up by the project, measured in their best alternative use. These units are therefore valued at the average tax-exclusive price of $42.5, which is the average of $50 and $35.

The total social value of the output generated by the project is thus equal to the sum of these two shaded areas, or $1,575 million. This result provides the justification for the rule of practice presented in Section 8.3.

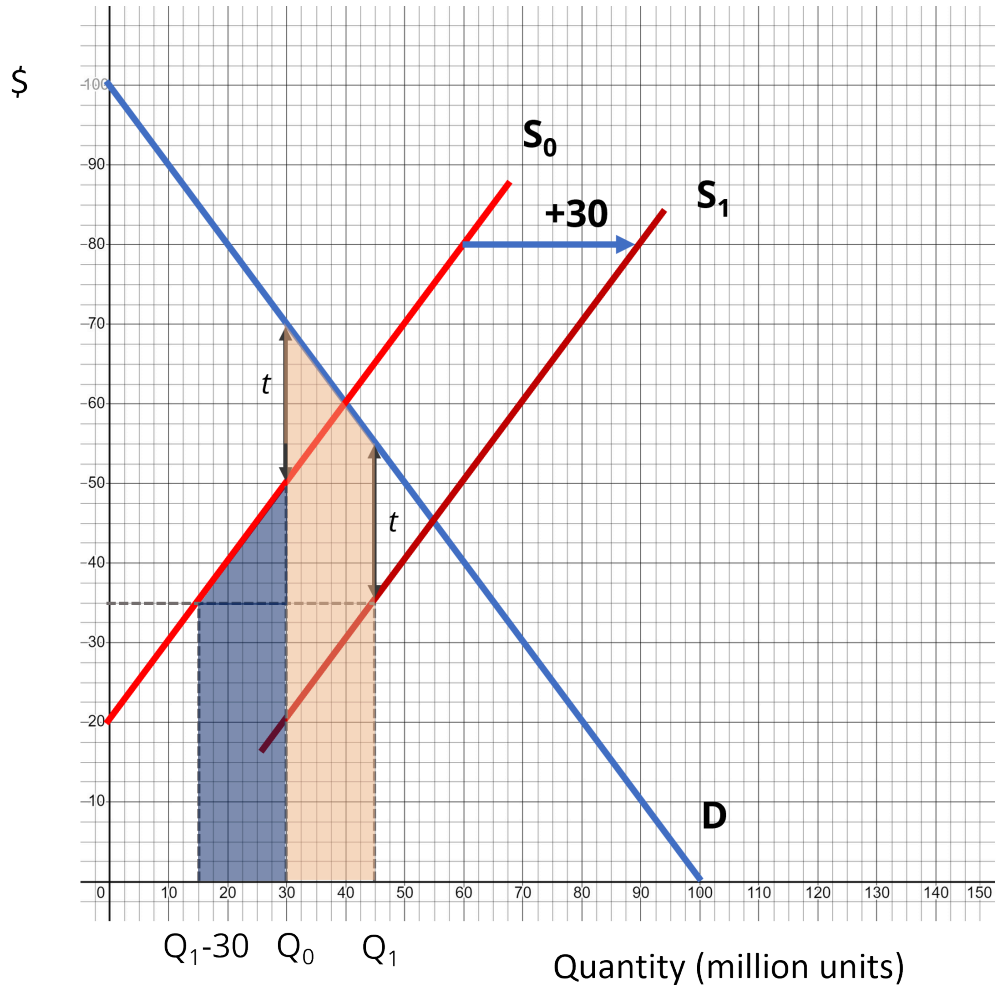


Figure 8.8 Social Valuation of Output in the Presence of a Tax

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9.

EXTERNAL EFFECTS

Motivation and learning objectives

In order to reduce CO^2 emissions resulting from gasoline consumption, the government is considering increasing the minimum ethanol content in gasoline from 5% to 10%. In the baseline scenario, gasoline consumption is estimated at 10 billion litres, with an average price of $1.50 per litre. According to expert opinion and a techno-economic study, this tightening of standards would increase the cost of producing a litre of gasoline by an average of 5 cents. A review of the literature indicates that the long-run price elasticity of demand for gasoline is 0.3, while the price elasticity of supply is 2. Currently, each litre of gasoline consumed generates 2.3 kilograms of CO^2, and the proposed regulation is expected to reduce this amount by 8%. In addition, the damage caused by the emission of one additional tonne of CO^2 is estimated at $300.

The following simplifying assumptions are made:

- The gasoline market is competitive;
- All taxes are assumed to be fixed at 50 cents per litre.

Based on this information, how should a cost-benefit analysis of this regulation be conducted?

In this chapter, we examine how externalities, whether positive or negative, can be incorporated into a cost-benefit analysis. As discussed in Chapter 3, externalities create a divergence between individual and collective incentives, leading to a deviation from the optimal allocation of resources. As a result, market prices no longer reflect the marginal social cost or the marginal social benefit of the last unit produced. Evaluating a project in the presence of externalities therefore requires explicit consideration of this gap. This chapter focuses on integrating externalities into the analytical framework, while Part III of the manual addresses the methods used to value these external effects.

By the end of this chapter, you will be able to construct a CBA framework for a project that:

1. Generates changes in external costs or benefits;
2. Internalizes external effects.

9.1 External costs

9.1.1 Definitions and examples

External costs, also known as **negative externalities**, occur when an individual's actions result in direct costs to others, without those others receiving compensation. In the presence of negative externalities, the private cost of an action underestimates its social cost.

External costs, also known as negative externalities, arise when an individual's actions impose direct costs on others without compensation. In the presence of negative externalities, the private cost of an activity understates its true social cost.

External costs are most often associated with environmental impacts. For example, pork production involves private production costs borne by producers, such as feed, labour, and energy. However, this activity also generates external costs in the form of noise, air, water, and soil pollution, as well as greenhouse gas emissions. These costs are borne by third parties, including nearby residents, users of contaminated water bodies, and individuals affected by climate change. As a result, the private cost of production fails to capture the full social cost of the activity.

It is important to emphasize that, to qualify as an external cost, the impact must be **direct**, meaning that it affects the quantity or quality of resources available to third parties. External costs should therefore be distinguished from indirect effects that operate through price changes. For instance, population growth in a city may put upward pressure on housing prices, thereby increasing housing costs for residents. This situation does not constitute a true externality, but rather a **pecuniary externality** transmitted through market prices. Pecuniary externalities do not give rise to market failures.

Since cost-benefit analysis seeks to account for both the social benefits and the social costs of a project, it is essential to explicitly incorporate external costs into the analysis. The box below presents another example of a negative externality that does not arise directly from environmental damage.

External costs are generally associated with environmental impacts. For example, pork production generates production costs that are borne by producers, such as food, labor, and energy costs. However, this production also generates direct external costs in the form of noise pollution, air, water, and soil pollution, and GHG emissions, which are borne by individuals affected by these pollutions, such as nearby residents, users of contaminated waterways, and victims of climate change. The main consequence of this situation is that the private cost does not fully reflect the social cost of the activity.

It is important to emphasize that the **cost must be direct**, that is, it must affect the quantity or quality of the resources of the third parties involved. These costs must therefore not be indirect, that is, manifested by a change in prices. For example, population growth in a city can put upward pressure on housing prices, thus imposing an additional cost on residents. This is not a real externality, but rather a **pecuniary externality**that is transmitted through prices. Pecuniary externalities do not generate **market failures**.

Since CBA aims to consider both the social benefits and costs of a project, it is imperative to integrate external costs into the analysis. The box below provides another example of a negative externality not directly arising from an environmental impact.

Road congestion and external cost



Congestion can be analyzed as a situation in which the private cost of a trip is lower than its social cost, leading to an excessive volume of traffic. Figure 9.1 illustrates the evolution of the private marginal cost and the social marginal cost of an additional trip as a function of total traffic volume on a road corridor. These costs are expressed in terms of generalized cost and therefore incorporate the value of travel time.

When traffic volume is below the level V^{FF}, congestion is absent and traffic flows under free-flow conditions. In this range, the private marginal cost and the social marginal cost of a trip are identical and constant at c_{FF}. For simplicity, other external costs associated with automobile use, such as air pollution, are ignored.

As traffic volume increases beyond V^{FF}, congestion emerges, resulting in lower speeds and longer

travel times. The private marginal cost of an additional trip ($MC^{private}$) increases, but at a slower rate than the social marginal cost (MC^{social}). The difference between these two curves represents the external marginal cost ($MC^{external}$), which reflects the congestion imposed by an additional vehicle on other users. Although the delay caused by one extra vehicle may be small for each individual user—on the order of a few seconds—its cumulative effect across all affected users can be substantial.

Given a peak demand for travel represented by D^{peak}, traffic volume reaches V, whereas the socially optimal level of traffic is V*. As a result, traffic volume exceeds the socially efficient level, leading to excessive congestion relative to the optimal outcome.

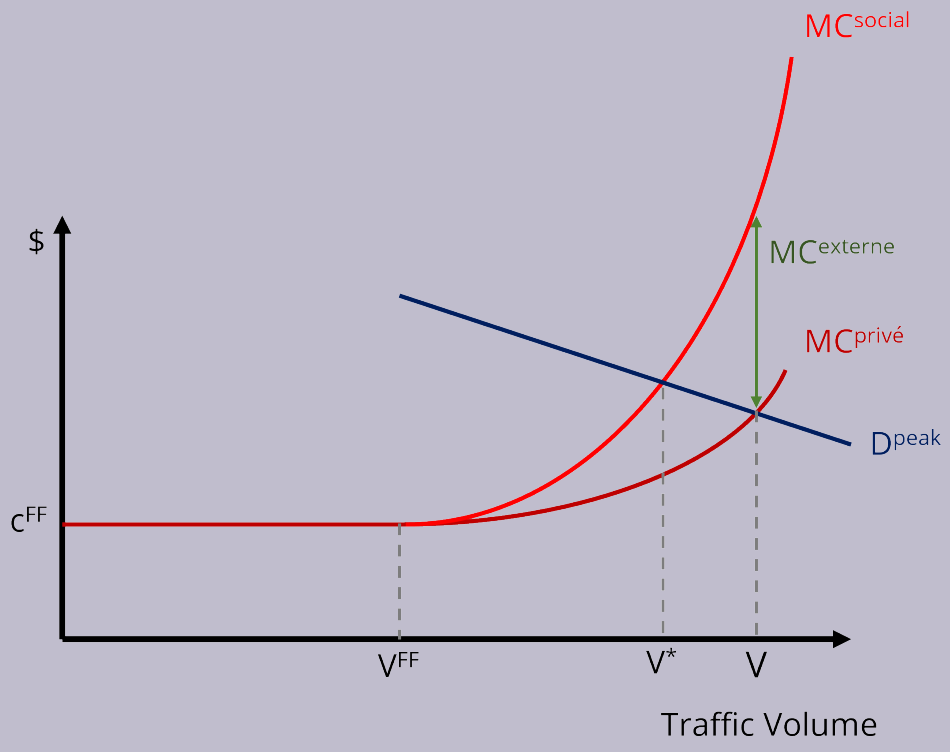


Figure 9.1 Representation of the road congestion phenomenon

9.1.2 The project generates external costs

When a project generates external costs for one or more stakeholders, these costs must be included in the social cost of the project.

The analyst must therefore identify and properly assess the main external costs induced by the project. Environmental impact assessments often constitute a key source of information for measuring these impacts in physical terms, such as the quantity of greenhouse gas emissions generated by the project or the surface area of wetlands destroyed. Valuing these impacts then requires assigning an appropriate reference value or unit cost, such as the social cost of a tonne of CO_2 or the social value of a hectare of wetlands.

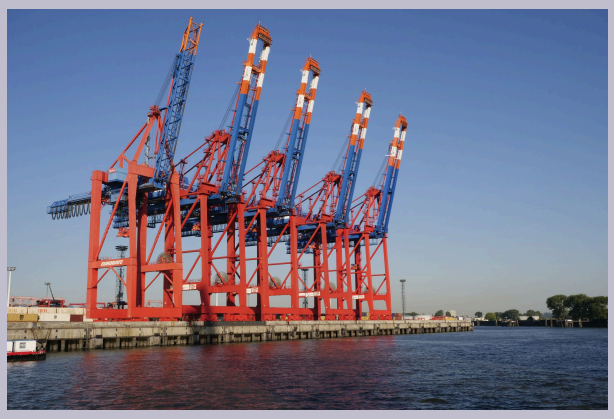
Determining these reference values is conceptually challenging, mainly because many external effects are non-market or intangible in nature. For instance, there is no explicit market for wetland conservation, and therefore no observable market price associated with it. Part 3 of this Handbook presents several methods for valuing non-market goods and services.

In practice, however, it is often possible to rely on reference values, prices, or unit costs derived from the existing literature. Once an appropriate reference value has been identified, the valuation of the external cost becomes relatively straightforward.[1] This process is illustrated in the example presented in the box below.

The development of port activities

1. In some cases, it may be necessary to adapt reference values drawn from previous studies to the specific context of the CBA. For example, values expressed in past dollars should be adjusted for inflation. See Chapter 15 on the benefit transfer method.

A project aims to support the expansion of container transport activities at a port. However, this project would lead to an increase in truck traffic in an urban area. It is estimated that this additional traffic would result in emissions of approximately three tonnes of fine particulate matter ($PM_{2.5}$) per year. Fine particles are associated with several adverse health effects, including asthma attacks and cardiovascular problems.



Based on an external reference, the external cost associated with one tonne of $PM_{2.5}$ emissions is estimated at $283,056 (expressed in 2019 prices). The cost–benefit analysis must therefore include an annual external cost of $849,168, corresponding to three tonnes of $PM_{2.5}$ emissions.

This example illustrates how external costs can be explicitly incorporated into a CBA by relying on available reference values to quantify health and environmental impacts.

9.1.3 The project reduces external costs

When a project aims to reduce or eliminate external costs borne by one or more stakeholders, the resulting reduction must be accounted for as a social benefit in the CBA.

For example, a project that requires trucks to be equipped with a profiling device to reduce diesel consumption—and consequently greenhouse gas (GHG) emissions—generates two types of benefits. First, it produces a private benefit in the form of lower fuel expenditures. Second, it generates a social benefit corresponding to the reduction in GHG emissions, which represents an avoided external cost.

The social cost of emitting an additional tonne of CO_2 in 2025 is estimated at $271 (Environment and Climate Change Canada, 2023, Table 1). If the mandatory use of profiling devices reduces CO_2 emissions by 0.5 megatonnes per year, the annual external benefit of this measure amounts to $135.5 million.

9.1.4 The project internalizes external costs

Some public policies are explicitly designed to correct market distortions created by external costs. Environmental taxes, often referred to as Pigouvian taxes, are a prime example. Their objective is to internalize the external costs associated with polluting activities by ensuring that polluters bear the full social cost of their actions. Unlike conventional taxes, which are primarily intended to generate government revenue (as discussed in Chapter 8), Pigouvian taxes do not create a deadweight loss. On the contrary, they reduce the deadweight loss caused by negative externalities. The example below illustrates this mechanism.

Example: Internalization of external costs in pork production

Consider the case of pork production, which generates external costs. Figure 9.2 illustrates the demand for pork and the competitive supply curve, which corresponds to the marginal private cost (MPC). Pork production is estimated to generate an external cost of $1.25 per kilogram. As a result, the marginal social cost (MSC) curve lies above the MPC curve by exactly this amount and is obtained by vertically adding the marginal external cost (MEC) of $1.25/kg to the MPC.

The government seeks to internalize these external costs and is therefore considering the introduction of an environmental tax of $1.25 per kilogram of pork. What would be the social impact of such a tax?

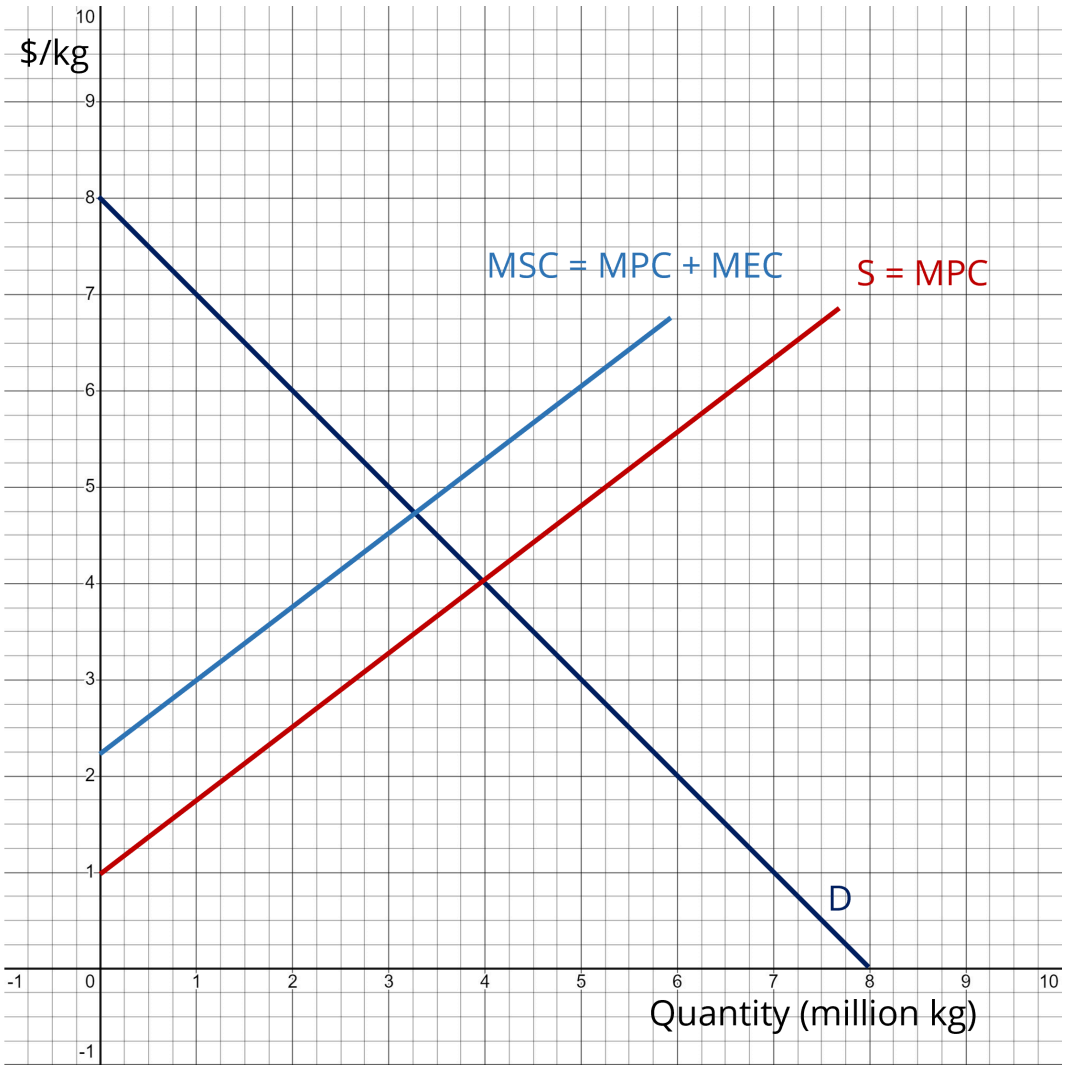


Figure 9.2 The pork market with a negative externality

Resolution

The no-tax baseline scenario

In the absence of a tax, the quantity traded is 4 million kg of pork at a price of $4 per kg, corresponding to point *c* at the intersection of the supply and demand curves in Figure 9.3. In this scenario, pork production generates a total external cost of $5 million, equal to $1.25 multiplied by 4 million kg. This external cost is represented by the area of trapezoid *hgci*.

The tax scenario

As discussed in Chapter 8, the introduction of the tax creates a wedge of $1.25 between the price paid by buyers (*Pb*) and the price received by sellers (*Ps*). The new equilibrium is reached at a production level of 3.25 million kg, with *Pb* = $4.75 and *Ps* = $3.50. Economically, the tax shifts the producers' marginal private cost curve upward by $1.25, making it coincide with the marginal social cost curve. The tax therefore fully internalizes the external cost.

We can now conduct a CBA of this policy using the **part-by-part approach**:

- Pork consumers experience a loss of **consumer surplus** of $2.72 million, represented by area *abcf*;
- Producers incur a reduction in surplus of $1.81 million, represented by area *fcde*;
- Government surplus increases by $4.06 million, corresponding to tax revenues represented by area *abde*;
- Individuals affected by pollution benefit from a reduction in external damages valued at $0.94 million. This corresponds to the avoided external cost of $1.25 per kg multiplied by the reduction in output of 0.75 million kg, represented by area *bgcd*;
- The net effect of the policy is positive and equal to $0.47 million, represented by area *bgc*.

Table 9.1 summarizes these results. In the absence of the tax, the market ignores external costs, leading to an equilibrium price that is too low and a level of production that is socially excessive. The ecotax therefore does not generate a deadweight loss. On the contrary, it increases social surplus by correcting the market distortion associated with the negative externality.

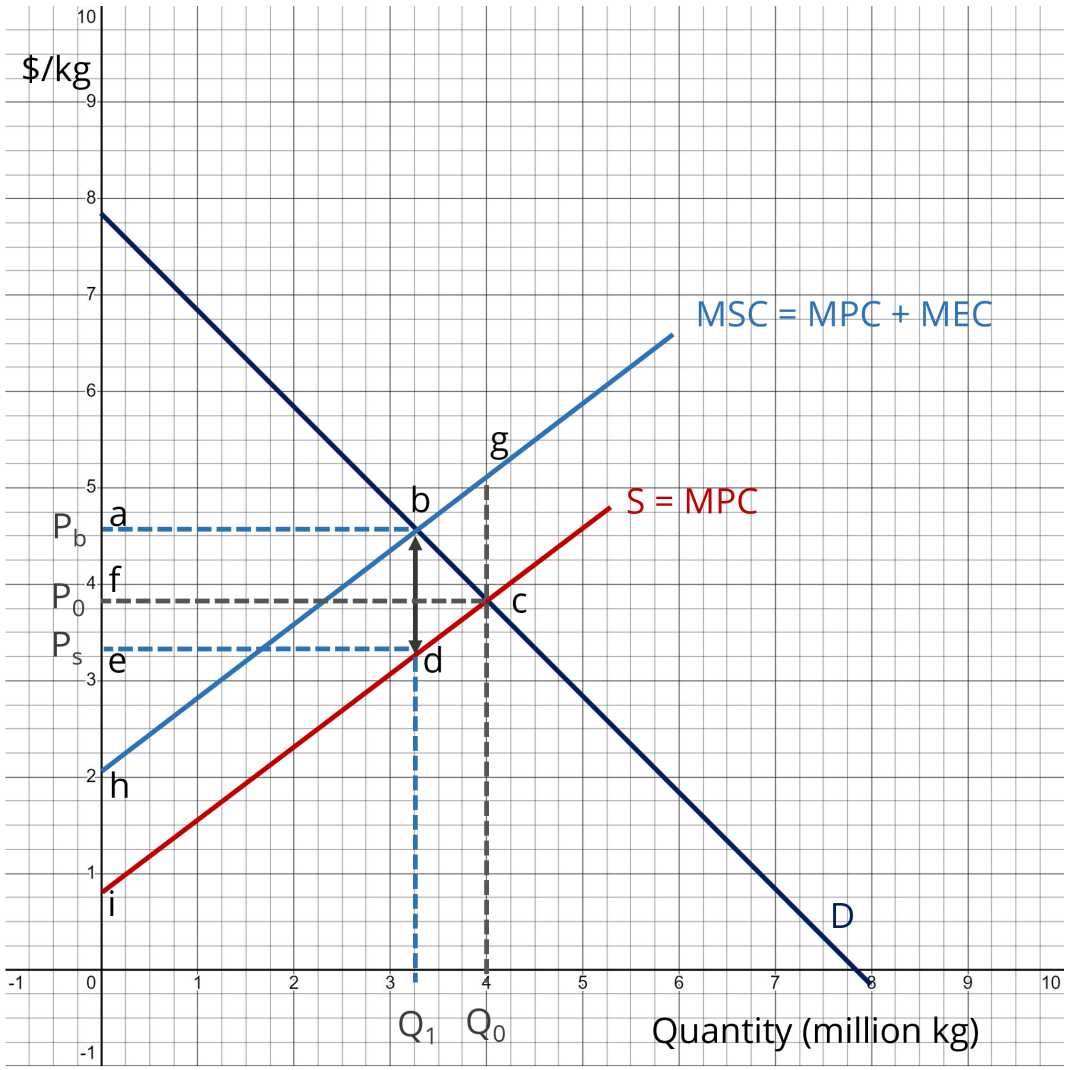


Figure 9.3 The impact of tax imposition in the pork market

Table 9.1 CBA of the imposition of an ecotax in the pork market (in millions of $)

Stakeholder	Cost	Benefits
Consumers	2.72 (surface *abcf*)	
Producers	1.81 (*fcde* surface)	
State		4.06 (surface *abde*)
Victims of pollution		0.94 (surface *bgcd*)
	Net Effect =	**+ 0.47 (*bgc*surface)**

The same conclusion is obtained using the **social approach**. The reduction in social value resulting from the decrease in production is measured by the area under the **demand curve**, between *b* and *c*. By contrast, the social value of the resources saved is measured by the area under the social marginal cost curve, between *b* and *g*. The net effect is once again represented by the area *bgc*.

It is important to emphasize that, to compute these impacts, it is not strictly necessary to know the full shapes of the supply and demand curves. An estimate of the price elasticities of supply and demand is sufficient to carry out the analysis.

9.2 External benefits

9.2.1 Definition and example

External benefits, or **positive externalities**, arise when an individual's action generates not only a private benefit for that individual but also **direct** benefits for third parties, without any compensation. In the presence of positive externalities, the demand curve understates the social benefit, because it reflects only private benefits and ignores the external benefits.

For example, when an individual gets vaccinated against influenza, they obtain a private benefit in the form of a lower risk of infection. However, this action also reduces the probability of transmitting influenza to others, which constitutes a direct external benefit. The individual primarily values their own private benefit, so

the maximum amount they are willing to pay for the vaccine understates its true social value, which includes benefits accruing to the wider community.[2]

Once again, it is essential to distinguish real externalities from pecuniary externalities. The effects on third parties must be direct and must not arise solely through price adjustments.

9.2.2 The project modifies external benefits

When a project generates significant external benefits, these benefits must be valued and included on the benefit side of the CBA. Conversely, if a project leads to a reduction in external benefits, this effect should be treated as a social cost.

For example, a program that supports the renovation of deteriorated buildings in urban areas should not be evaluated solely on the basis of the benefits accruing to property owners (such as owners' **willingness to pay** for renovations). It should also account for the real impacts on the surrounding neighborhood, including reductions in crime and improvements in the urban environment. These external benefits can be captured, for instance, through increases in nearby property values or positive effects on local commercial activity (see Chapter 13 for further discussion).

Conversely, a project that eliminates tax credits aimed at supporting research and development must consider not only the direct impacts on firms that receive these credits (such as a reduction in R&D activity), but also the external costs imposed on other economic actors, arising from the loss of knowledge spillovers and innovation benefits.

9.2.3 The project internalizes external benefits

A project may also aim to correct a market distortion arising from the presence of a positive externality. To illustrate this situation, Figure 9.4 shows the private demand (Dprivate) for vaccines against a communicable disease. Vaccines are purchased on the international market at a fixed price of $30 per dose.

Each additional dose generates an external benefit estimated at $20. This external benefit arises from the

2. It is possible that individuals partially internalize these external benefits out of altruism, by taking into account the well-being of others, but this valuation is likely to be incomplete.

reduced risk that a vaccinated individual transmits the disease to others who are not yet vaccinated, thereby lowering the health and economic costs borne by third parties. As a result, the marginal social value, or marginal social willingness to pay, for each dose is equal to the marginal private value ($D_{private}$) plus the external benefit of $20 per dose. This corresponds to a vertical summation of values.

The socially optimal number of doses is therefore determined at the intersection of the marginal social value curve and the price line. In Figure 9.4, this optimum is represented by point *b*, corresponding to 6 million doses per year.

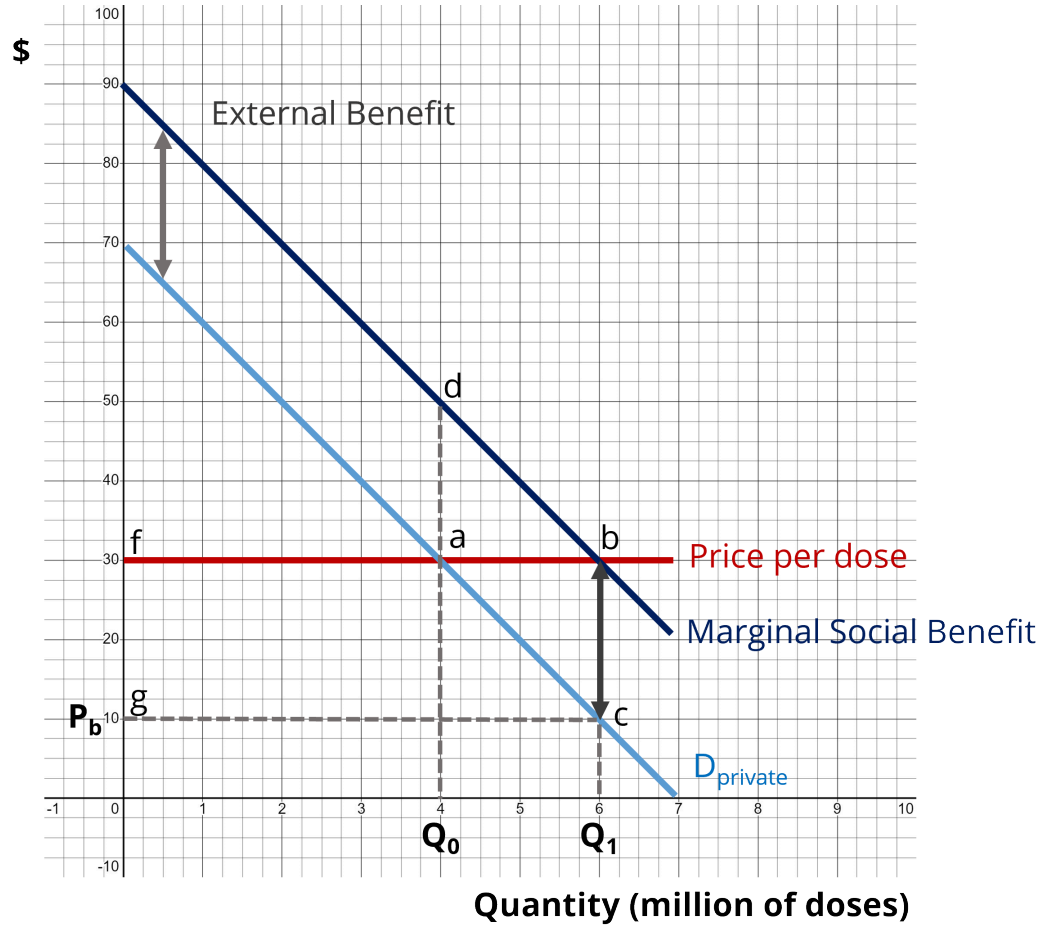


Figure 9.4 The impact of considering the external benefit of a vaccine

To correct this market failure, governments can subsidize the purchase of vaccines. In our example, a subsidy of $20—equal to the external benefit—reduces the price paid by buyers to $10. As a result, 6 million doses are purchased. This project generates a positive NPV, represented by the surface area *dba*, as shown in the part-by-part CBA of the project summarized in Table 9.2.

Table 9.2 CBA of a subsidy program for vaccination against a communicable disease (baseline scenario: the free market)

Impact on stakeholders	Millions of $ per year
CS increase caused by vaccine price drop from $30 to $10 The *facg surface*	$20 x 4 m + ½ ($20 x 2 m) = 100 m
No change on PS (= 0)	$0
Reduction of the GS (subsidy payment) The *fbcg surface*	-$20 x 6 m = -120 m
Impact on third parties (reduction in transmission caused by the 2 m of additional doses). The *dbca surface*	$20 x 2 m = 40 m
Net effect	20 m or the *dba surface*

9.3 Public goods

An extreme case of positive externalities arises with public goods. Recall that a pure public good is characterized by the absence of rivalry in consumption and by the impossibility of excluding certain users from benefiting from it (see Chapter 3 for more details). These characteristics imply that the quantity of a pure public good available is the same for all users.

Joint consumption has an important implication: the collective demand for a public good is obtained by adding individual demand curves vertically (that is, by summing values). As with private goods, each individual demand curve represents an agent's marginal willingness to pay as a function of the quantity of the good. However, because all individuals consume the same quantity of a public good, the collective demand reflects the sum of marginal willingness to pay across all agents for each possible quantity.

Figure 9.5 (left panel) shows the marginal willingness to pay, expressed in dollars per year, of an average household for air quality in a city. Assuming that the city contains 100,000 households, the right panel illustrates the resulting collective demand for air quality. When the air quality index is equal to 5, the marginal willingness to pay of the average household is $40. The corresponding collective marginal willingness to pay is therefore $4 million. Moreover, the total benefit of improving air quality from index 5 to index 6 is measured by the area under the collective demand curve between these two levels, which amounts to $3.5 million per year.

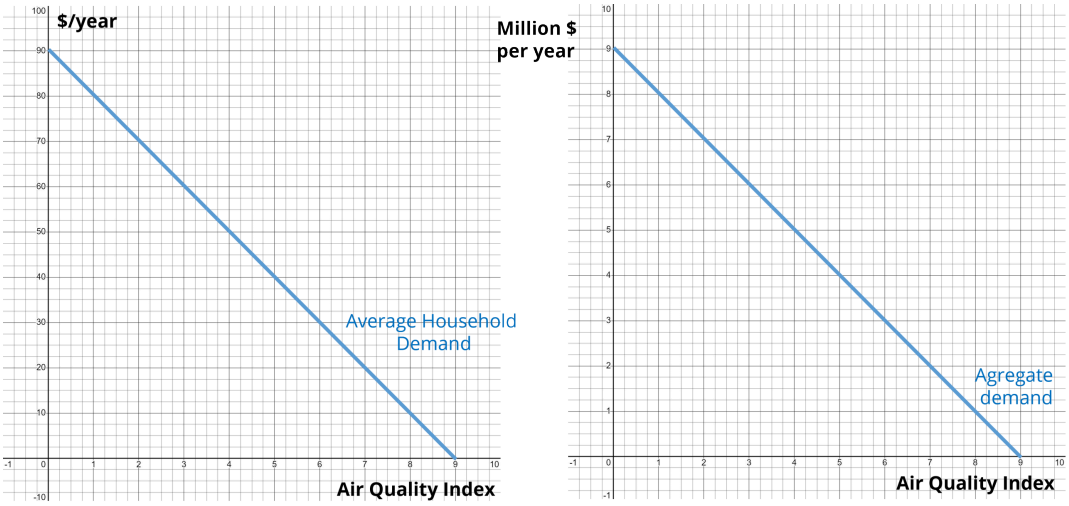


Figure 9.5 Individual and collective demands for a public good

From a conceptual standpoint, analyzing the benefits associated with a public good does not usually present major difficulties. The real challenge instead lies in estimating individual demand. Because the consumption of public goods is shared by all, individuals have little incentive to reveal their true willingness to pay. This behavior is commonly referred to as **free riding**: each individual hopes that others will bear the cost of financing the public good and therefore seeks to contribute as little as possible. In this sense, those who do contribute to the financing of a public good generate substantial external benefits for others. As a result, efficient markets for public goods rarely exist, and when markets do emerge, they typically lead to a suboptimal provision of public goods.

It is important to note that free riding is not limited to pure public goods. To varying degrees, it also affects all activities that generate external effects.

9.4 Conclusions

Key takeaways

- Externalities correspond to situations in which the agent undertaking an action does not bear all the costs (external costs) or does not capture all the benefits (external benefits) generated by that action.

- In the presence of external costs, private cost underestimates social cost, which leads the market to produce excessive quantities at prices that are too low.
- Imposing a tax can be a way to internalize external costs and thereby correct the associated market failure.
- Any change in external costs generated by a project must be explicitly taken into account in a CBA.
- In the presence of external benefits, private demand undervalues the social value of an activity, which results in insufficient production and prices that are too high relative to the socially optimal outcome.
- A subsidy is one policy instrument that can correct market failure when external benefits are present.
- Accordingly, the CBA must incorporate changes in external benefits induced by a project.
- Public goods represent an extreme case of external benefits, since individuals can benefit from them without paying once they are provided. This explains why free markets generally fail to supply public goods in sufficient quantity or quality.
- The free-rider problem poses a major challenge for estimating individual demands for a public good and, consequently, for deriving collective demand through the vertical aggregation of individual demand curves.

Back to the motivation: the CBA for increasing the ethanol content of gasoline

In order to reduce CO^2 emissions resulting from gasoline consumption, the government is considering increasing the minimum ethanol content in gasoline from 5% to 10%. In the baseline scenario, gasoline consumption is estimated at 10 billion litres, with an average price of $1.50 per litre. According to expert opinion and a techno-economic study, this tightening of standards would

increase the cost of producing a litre of gasoline by an average of 5 cents. A review of the literature indicates that the long-run price elasticity of demand for gasoline is 0.3, while the price elasticity of supply is 2. Currently, each litre of gasoline consumed generates 2.3 kilograms of CO^2, and the proposed regulation is expected to reduce this amount by 8%. In addition, the damage caused by the emission of one additional tonne of CO^2 is estimated at $300.

The following simplifying assumptions are made:

- The gasoline market is competitive;
- All taxes are assumed to be fixed at 50 cents per litre.

Based on this information, how should a cost-benefit analysis of this regulation be conducted?

Resolution

Figure 9.6 illustrates the market equilibrium in the baseline and project scenarios.

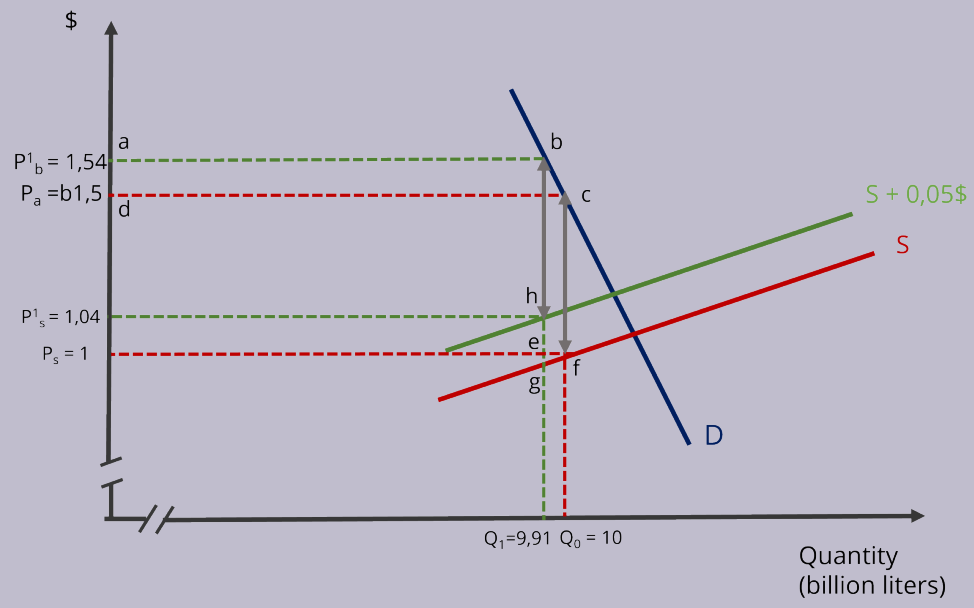


Figure 9.6 Market equilibrium in the two scenarios

Market equilibrium in the reference scenario

- The price paid by buyers (including taxes) = P_b= $1.5;
- The price received by sellers (excluding tax) = P_S = $1;
- Quantity exchanged = Q_0 = 10 billion liters;
- The initial equilibrium is represented by points *c* and *f* in Figure 9.6.

Market equilibrium in the scenario including the project

The project causes a vertical shift of +$0.05 in the supply curve. By applying the cost transmission formula from Chapter 4 (Section 4), we can estimate the increase in price and the reduction in quantity generated by the project:

$$\Delta p\% = \left(\frac{c}{P_0}\right) \times \left(\frac{\eta_O}{\eta_D + \eta_O}\right) = \left(\frac{0.05}{1.5}\right) \times \left(\frac{2}{2.3}\right) = +2.89\%$$

$$\Delta Q\% = -0.3 \times 2.89\% = -0.87\%$$

The price including tax is therefore expected to increase to $1.54, and the quantity exchanged is expected to decrease to Q = 9.91 billion liters. The price excluding tax will increase to $1.04. With the project, we therefore anticipate:

- The price paid by buyers (with taxes) = P_a^1 = $1.54;
- The price received by sellers (excluding tax) = P_v^1 = $1.04;
- The quantity exchanged = Q_1 = 9.91 billion liters.

CBA by stakeholder

- Buyers experience a price increase that reduces consumer surplus. This reduction corresponds to the area of surface *abcd* in Figure 9.6, or $0.4 billion.
- Sellers also experience a reduction in producer surplus as a result of the increase in costs. This reduction is measured by the change in operating profit, which can be calculated as follows: for the 9.91 billion litres produced by the project, producers lose $0.05 due to the increase in cost but recover $0.04 due to the increase in the price excluding tax, for a net effect of $0.0991 billion. We must also take into account the loss of surplus due to the reduction in production from 10 to 9.91 billion litres, which is measured by the area of triangle *efg*. We can determine the coordinates of point *g* by noting that its height corresponds to that of point *h* at $1.04 minus $0.05, which gives $0.99. Thus the area of triangle *efg* is equal to $0.00045 billion.
- The social value of GHG reduction is measured by the social value of carbon ($300) multiplied by the reduction in emissions expressed in tonnes. It is determined by taking into account the 8% reduction in the GHG emissions rate per litre (i.e. 8% of 0.0023 tonnes per litre) and the reduction in the quantity of gasoline consumed from 10 to 9.91 billion litres.

Table 9.3 presents the impacts of this project on the different stakeholders.

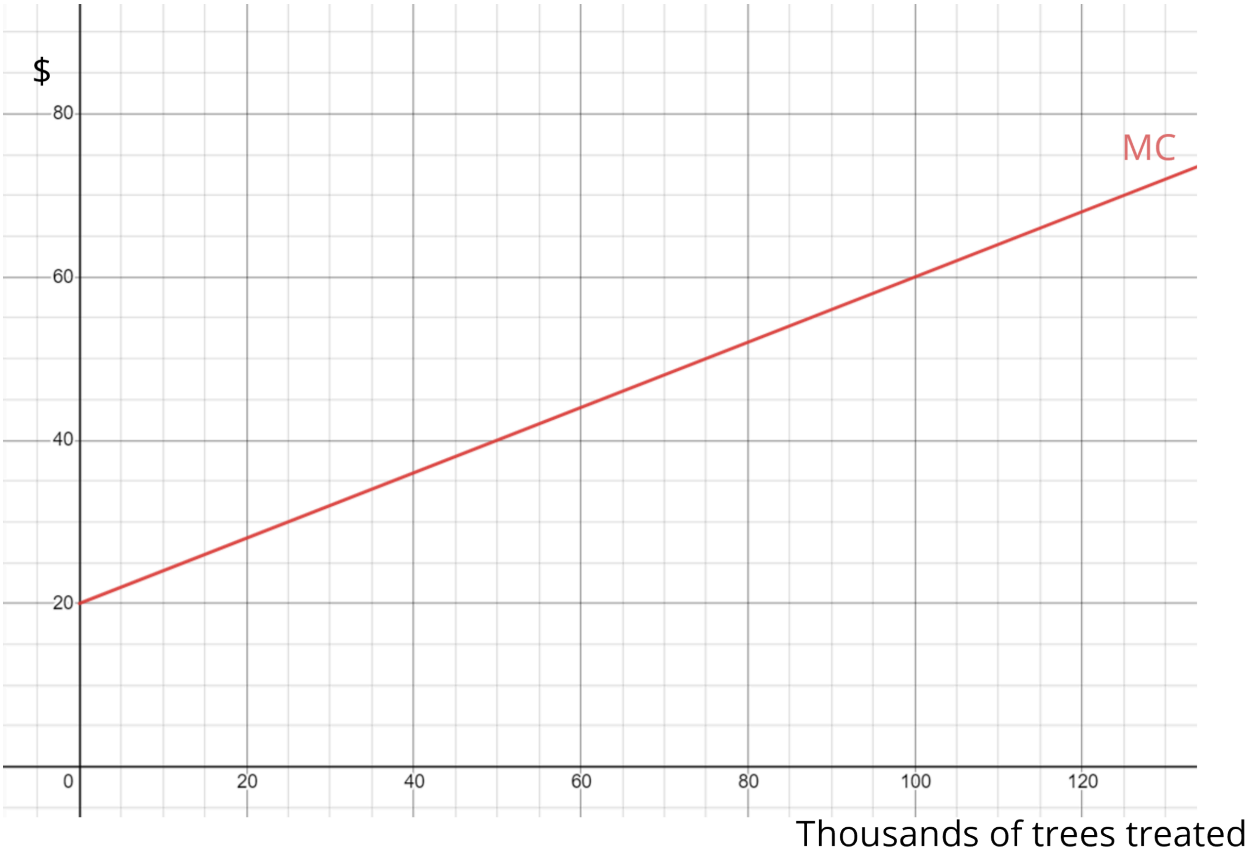
Table 9.3 CBA of the draft strengthening of minimum standards for ethanol in gasoline

Stakeholder	Impact	Valuation (in billions of dollars)
Consumers	SC drop linked to price increase	– 0.4
Producers	SP drop linked to rising costs	– 0.01
Third party	Reduction of GHG emissions	+ 0.609
	Net effect	+ 0.199

Chapter 21 presents a case study of the CBA of a regulation imposing a minimum biofuel content in diesel and heating oil in Canada.

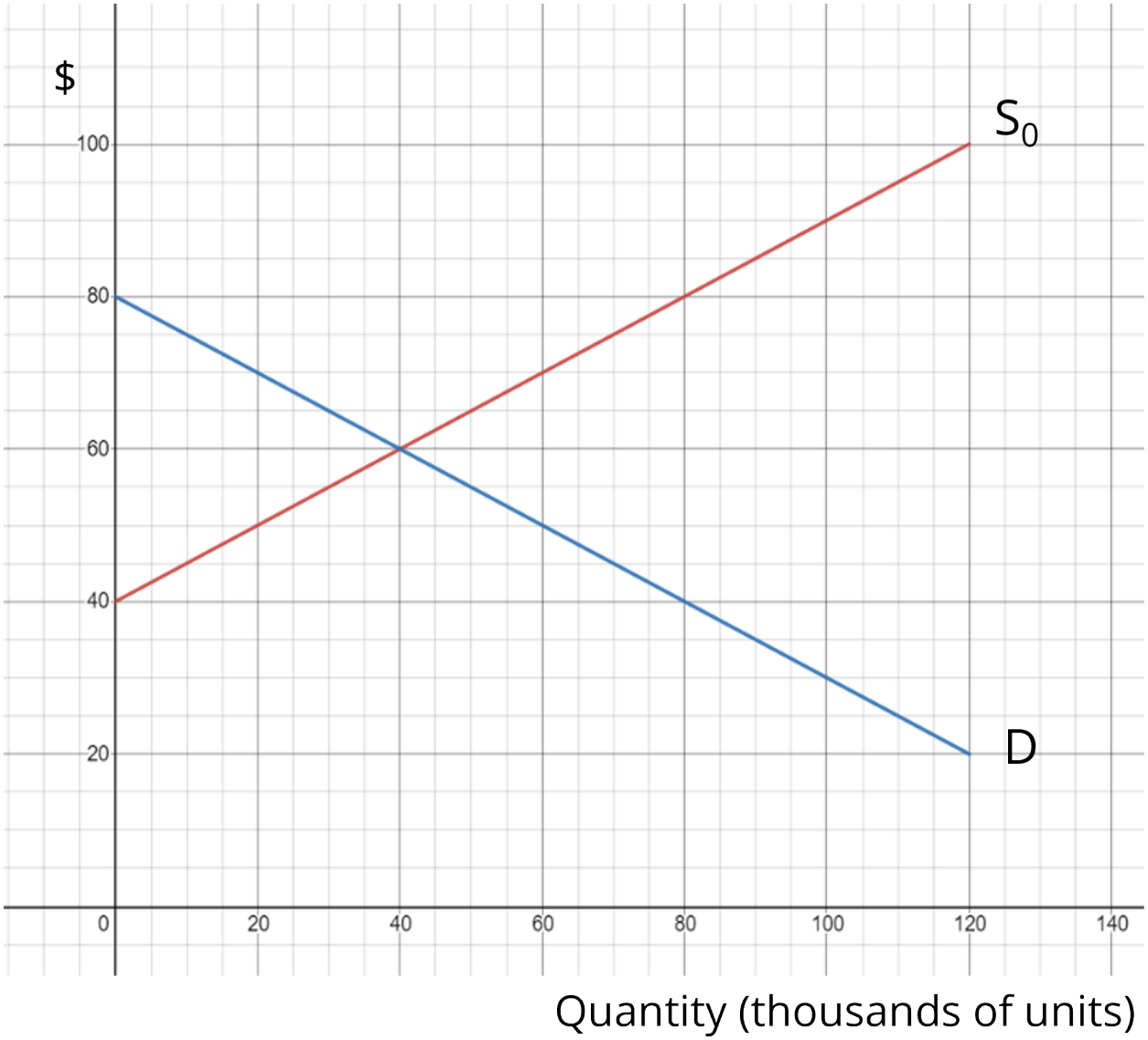
Exercises

1. (*) A city is considering implementing a program to control Dutch slippery elm disease. The graph below shows the marginal cost of the program as a function of the quantity of trees treated (MC). The value of each tree treated is estimated at $40. In addition, the program is expected to reduce infestation in neighboring cities, creating an external benefit valued at $10 per tree treated.Conduct a CBA of this program, first from a municipal perspective and then from a universal perspective. Note that the optimal number of trees treated may differ depending on the perspective adopted.



2. (*) The graph below shows supply and demand in a competitive market for a material commonly used in the construction sector. The government is considering regulations to reduce the flammability of this material. The regulation would increase the private cost of producing the material by $10 per unit. In addition, production of the material under the new flammability requirements would generate an external environmental cost estimated at $5 per unit.

   What must be the minimum benefit generated by this regulation for it to pass the CBA test?



3. A region is considering building a second bridge to connect its two banks in order to reduce congestion. The new bridge (NB) would be located immediately next to the existing bridge (EB). The NB would be tolled, while the EB would remain free. For simplicity, assume that the opening of the new bridge will not change total traffic volume; that is, there will be no induced traffic.

   You are conducting a CBA for this project and have received a proposed valuation of impacts from a colleague. Provide feedback on this proposal. In your answer, develop an analytical framework for the CBA.

Table 9.4 Proposed impacts to be considered in the CBA

Benefits	Costs
Value of time savings for bridge users due to reduced congestion	Cost of building the new bridge
Toll revenue	Change in operating and maintenance costs
Reduction of vehicle operating costs	
Residual value of the new bridge	

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Department of Environment and Climate Change Canada. (2023). *Estimating the Social Cost of Greenhouse Gases: Updated Interim Guidance for the Government of Canada. Government of Canada.* https://www.canada.ca/en/environment-climate-change/services/climate-change/research-data/social-cost-ghg.html

10.

OTHER DISTORTIONS

Motivation and learning objectives



To encourage competition in the pharmaceutical market, a project would support a generic drug manufacturer planning to begin producing a cancer treatment. The drug is currently supplied exclusively by a single firm, which sells it for $500 per dose. The entry of a generic competitor could reduce the price by about half. The generic manufacturer plans to produce 15,000 doses per year, roughly 75% of current sales. How should the social value generated by this new production be calculated? Should these doses be valued at the current price of $500, at the expected post-entry price, or using an alternative reference price?

This chapter completes the analysis of project outputs in settings with distortions beyond those examined previously. By the end of the chapter, you will understand the main issues that arise in CBA under the following conditions:

1. The exercise of market power by buyers or sellers;
2. Information asymmetries between stakeholders;
3. Limits to decision-makers' rationality.

10.1 Market power

So far, the analysis has focused on competitive markets characterized by a large number of buyers and sellers,

in which no individual participant can significantly influence the market price. However, this assumption of atomicity does not always hold. Market structures such as monopoly or oligopoly on the supply side, and monopsony or oligopsony on the demand side, depart from this benchmark.[1] In these contexts, some agents are able to influence prices.

Market power arises when one or more entities in a market, by virtue of their size or strategic position, have the ability to affect the price at which transactions occur.

10.1.1 Market Power of Sellers

When the number of sellers is limited, or when a market is dominated by a small number of large firms, sellers understand that restricting the quantity supplied allows them to maintain prices above the level that would prevail under competition, thereby potentially increasing profits. Seller market power therefore results in a positive gap between price and marginal cost. The extent of this market power is commonly measured using the Lerner index, defined as the difference between price and marginal cost relative to price:

$$L = \frac{P - Cm}{P}$$

Under perfect competition, this index is equal to zero, since price equals marginal cost (P = Cm). It reaches its theoretical maximum of 1 when marginal cost is zero (Cm = 0). More generally, market power, and thus the value of L, tends to increase with the following factors:

- Market concentration. A market is more concentrated when it includes a small number of firms or when a few firms account for a large share of total sales. As concentration increases, firms become more aware of the impact of their production decisions on market prices. Higher concentration is therefore typically associated with greater market power.[2]
- Price inelasticity of demand. For a given level of concentration, demand that is less price elastic implies that consumers have fewer substitutes or find it more difficult to reduce consumption when prices increase. The more captive consumers are, the greater the potential market power of sellers.

1. There are also situations in which market power exists on both sides of the market, such as bilateral monopoly and bilateral oligopoly.

2. The Hirschman–Herfindahl Index (HHI) is commonly used to measure market concentration. It is calculated as the sum of the squared market shares of all firms in the market, expressed in percentage points. A monopoly has an HHI of 10,000, indicating maximum concentration, whereas in a perfectly competitive market the index tends toward zero, reflecting extreme dispersion.

Figure 10.1 illustrates the effect of market power in a simple case where average cost is constant. Suppose the price is maintained at $60 per tonne rather than $40 per tonne, which would prevail under perfect competition. The resulting Lerner index is therefore 0.33.[3]

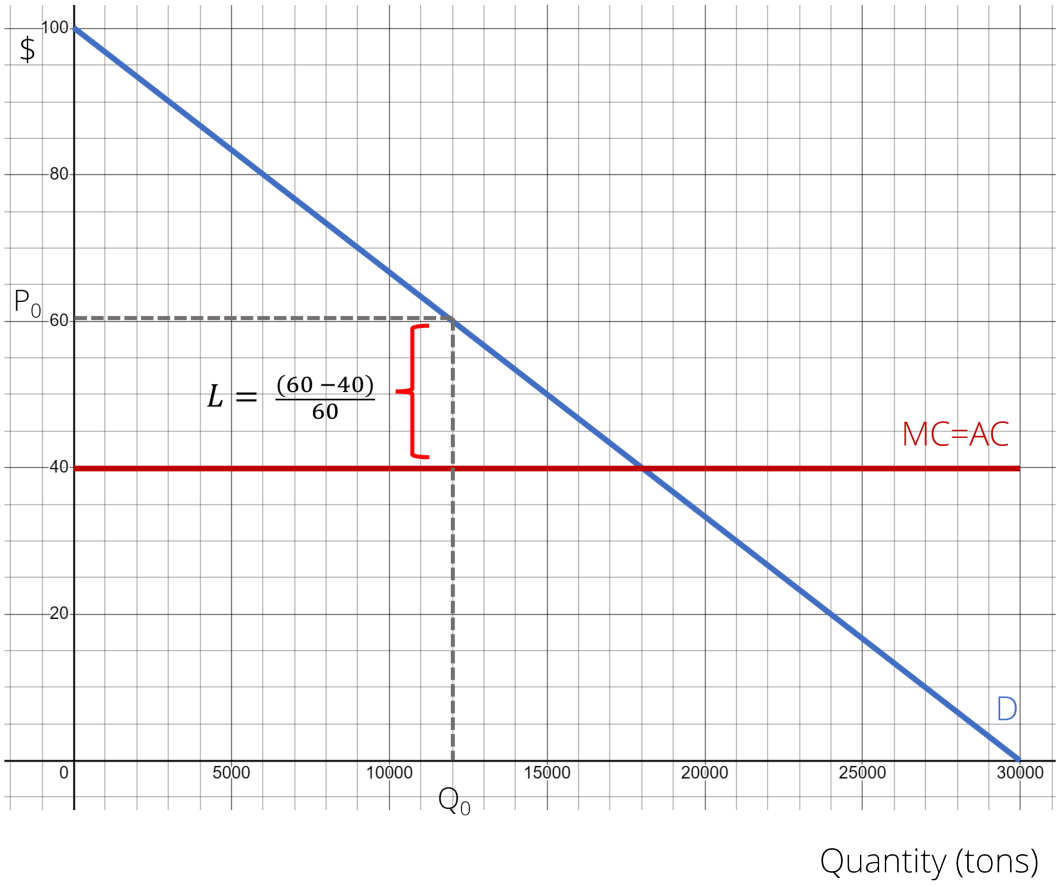


Figure 10.1 Market with presence of sellers' market power

The presence of market power has important implications for cost–benefit analysis, as it affects both the way projects should be assessed and the nature of the economic impacts generated by their implementation. From this perspective, two broad categories of projects can be distinguished:

1. Projects that aim to control or eliminate market power;
2. Projects that add supply in a market where market power already exists.

1. The project aims to eliminate market power

Market power leads to allocative inefficiency because prices are maintained above marginal cost, which

3. This does not represent the maximum possible value of the index in this market. A monopolist would optimally restrict output further, raising the price to $70 per tonne (as shown in Appendix 1), which would imply a Lerner index of 0.428.

restricts trade and reduces total social surplus. Antitrust and competition policies are specifically designed to address these inefficiencies by limiting or eliminating market power.

Returning to the previous example, suppose that a project explicitly aims to restore competitive conditions in the market. As a result, the price would fall from $60 to $40, while the quantity traded would increase from 12,000 tonnes to 18,000 tonnes, as illustrated in Figure 10.2. Such an intervention could take several forms, including reducing barriers to entry, facilitating the entry of new firms, breaking up dominant incumbents, or preventing collusive behavior among existing firms.

The CBA of this type of project consists in comparing the total surplus in the baseline scenario, characterized by the presence of market power, with the total surplus in the scenario where the market becomes competitive. The difference between these two situations measures the social gains associated with the reduction or elimination of market power.

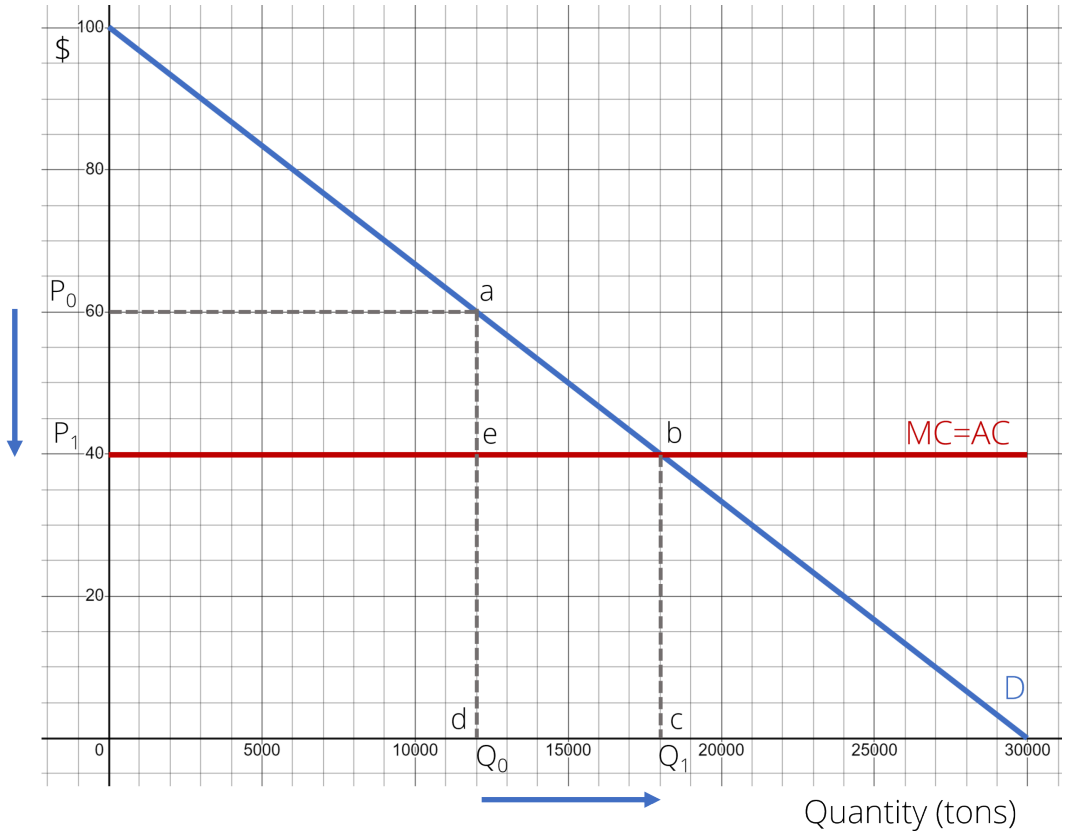


Figure 10.2 The CBA of a project aimed at eliminating market power

Reference scenario(market power):

P_0 = $60 and Q_0 = 12,000 tonnes

Scenario with the project(competitive market):

P_1 = $40 and Q_1 = 18,000 tonnes

Social approach (increase in quantity from 12,000 tonnes to 18,000 tonnes):

Social value of additional production: Area *(abcd)*= $50 x 6,000 = $300,000

Social cost of resources mobilized: Surface (*ebcd*) = 40 x 6000 = $240,000

Social value of resources released: $0

Net effect: Surface (*abe*) = $60,000

Stakeholder approach(price decrease from $60 to $40):

Increase in **consumer surplus**: Area (P_0abP_1) = $20 x 15,000 = $300,000

Decrease in producer surplus: Area (P_0aeP_1) = $20 x 12,000 = $240,000

Net effect : Surface (*abe*) = $60,000

This example illustrates the welfare consequences associated with the exercise of market power by sellers.

Market power on the supply side has important implications for market outcomes when compared to a fully competitive setting. These consequences can be summarized as follows:

1. **Quantity restriction**
   Firms with market power deliberately limit the quantity supplied in order to sustain higher prices. This behavior deviates from the allocative efficiency condition according to which output should be set where price equals marginal cost.
2. **Prices above marginal cost**
   In competitive markets, prices tend to reflect marginal production costs. In contrast, market power allows sellers to maintain prices above marginal cost, reflecting their ability to influence market conditions.
3. **Increase in producer surplus**
   By raising prices and restricting output, firms with market power are able to capture higher producer surplus.
4. **Reduction in consumer surplus**
   Higher prices and lower quantities reduce consumer surplus relative to the competitive outcome.
5. **Deadweight loss**
   Market power generates deadweight loss because mutually beneficial exchanges do not take place. This loss reflects allocative inefficiency: society as a whole experiences a reduction in total surplus due to artificially high prices and suboptimal production levels.

However, market concentration and market power may also present certain advantages:

- Market concentration can facilitate the exploitation of economies of scale;
- Profits associated with market power can create incentives for innovation.

Market concentration and economies of scale

In the presence of economies of scale, it may be more efficient to operate large firms in order to minimize average production costs. A typical example is that of a natural monopoly, in which average cost decreases continuously as output expands. This situation is illustrated in Figure 10.3, which depicts a natural monopoly characterized by a decreasing average cost curve and a constant marginal cost curve that remains below average cost over the relevant range of production.

This cost structure generally arises from the presence of large fixed costs. As output increases, fixed costs are spread over a larger number of units, causing average fixed cost—and therefore average total cost—to decline. In such contexts, concentrating production within a single firm or a small number of firms can be technologically efficient, even though it may raise concerns regarding pricing behavior and allocative efficiency.

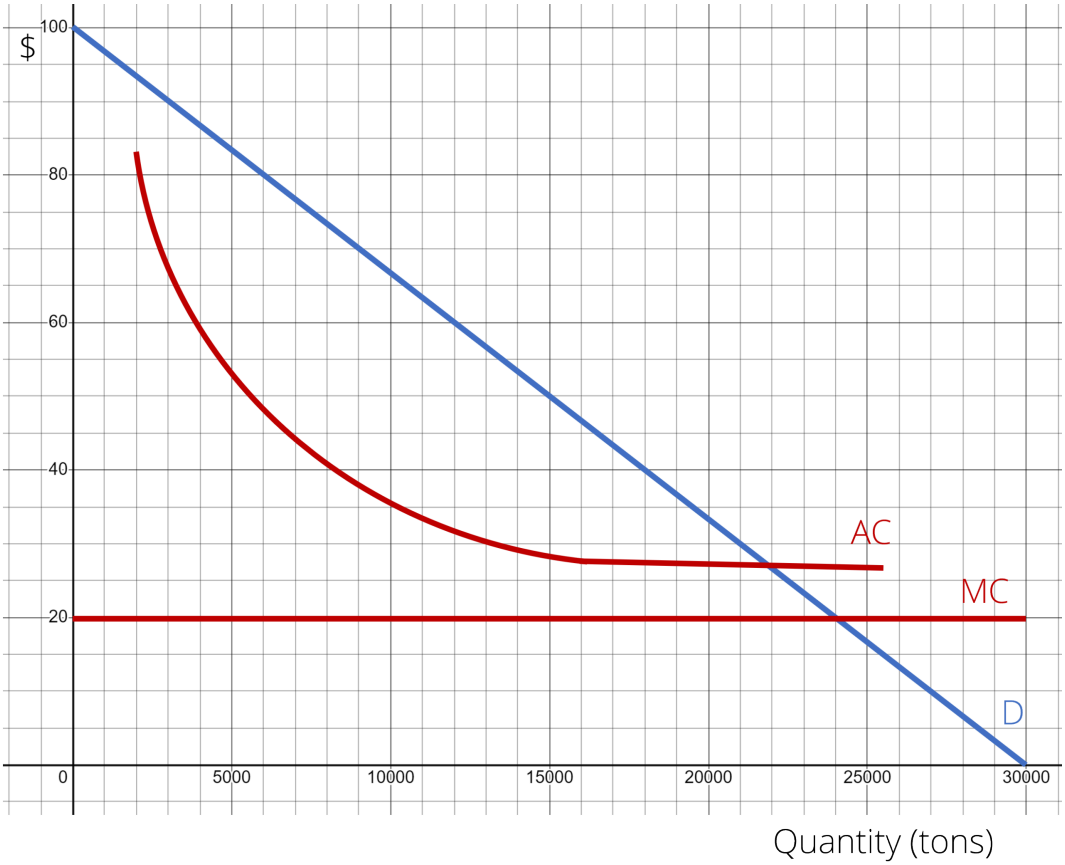


Figure 10.3 The natural monopoly

In such situations, a fundamental trade-off arises between exploiting economies of scale and limiting market power. On the one hand, concentrating production within a single firm can lower average production costs relative to an industry composed of several smaller firms. On the other hand, this concentration confers substantial market power on the firm, enabling it to raise prices above marginal cost and restrict output.

One possible institutional response to this trade-off is to grant a single firm monopoly status while subjecting its behavior to regulation, particularly with respect to pricing. This approach is commonly adopted in sectors characterized by natural monopoly, such as electricity distribution or water supply. However,

regulation is not without challenges. A key difficulty lies in information asymmetry between the monopolist and the regulator. The firm generally possesses more detailed and accurate information about its costs, technologies, and demand conditions than the regulatory authority. This informational advantage can hinder the regulator's ability to design and enforce efficient pricing rules, potentially leading either to excessive prices or to insufficient incentives for cost reduction and investment.

Market power and innovation

Market power can also play a role in fostering innovation. The economic profits generated by market power may provide firms with the financial resources and incentives necessary to invest in research and development. A classic illustration is the patent system, which grants inventors temporary monopoly rights over their innovations. During the patent period, the monopolistic profits earned by the innovator can compensate for the substantial fixed costs associated with research and development activities. This prospect of future monopoly rents encourages firms to undertake risky and costly innovation projects that might not be viable under conditions of perfect competition, where prices are driven toward marginal cost and profits are limited.

2. The project increases supply in a market where there is market power

A project may also contribute to increasing supply in a market characterized by market power, for example through the construction of a new power plant in a market dominated by a small number of producers. In such a context, a key question for the CBA is how to value the output brought to market by the project. Should it be valued at the prevailing market price, at the project's production cost, or at some other reference price?

As in the situations discussed earlier, the presence of market power implies that the market price no longer reflects the true cost of the resources mobilized. Prices are typically above marginal cost, and quantities traded are below the socially efficient level. Consequently, valuing additional production solely at the market price would not correctly capture its social value.

As illustrated in Figure 10.4, the appropriate valuation depends on the nature of the additional production introduced by the project. Two effects must be distinguished:

The portion of the project's output that increases the total quantity traded on the market should be valued at the market price. This price reflects the marginal willingness to pay of buyers and therefore measures the social value of the additional consumption generated by the project.

- The portion of the project's output that replaces production previously supplied by incumbent producers gives rise to a crowding-out effect. This displaced production frees up resources that can be reallocated elsewhere in the economy. The social value of this effect must therefore be measured by the marginal cost of production of the displaced producers, which represents the value of the resources saved in their best alternative use.
- In the presence of market power, the social valuation of a supply-increasing project thus requires decomposing the project's output into these two components and valuing each accordingly, rather than relying on a single market price.

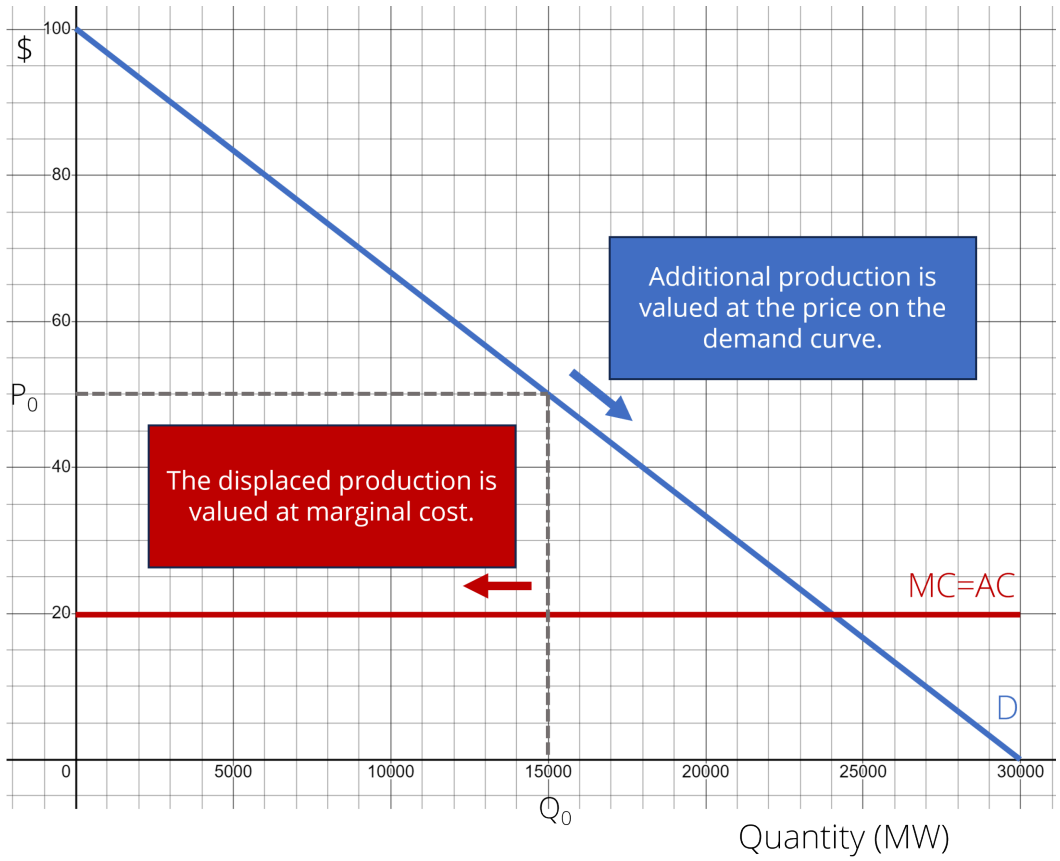


Figure 10.4 The valuation of additional production in the presence of market power

When the price reduction induced by the project is small relative to the gap between the market price and the marginal cost, the valuation can be carried out as follows:

$$p_r = \omega_D p + \omega_S Cm$$

with:

ω_D measuring the share of the project's production that increases total trade on the market;

p denoting the market price observed prior to the project;

ω_S measuring the share of the project's output that crowds out the production of other firms $(\omega_S = 1 - \omega_D)$;

Cm corresponding to the marginal cost of production of the firms whose output is displaced.

Unfortunately, there is no simple rule for determining the values of ω_D and ω_S. The response of incumbent producers to the introduction of new production depends on several factors, including:

- The **elasticity of demand**: the more elastic demand is, the stronger the incentive to accommodate the project's output in order to avoid a large price reduction;
- The number of producers in the market: the greater the number of producers, the higher the risk of free-riding, since each firm may hope that others will reduce their output instead;
- The cost structure of firms: when economies of scale are present, reducing output may increase average costs, which weakens the incentive for incumbent producers to accommodate the project.

The analyst must therefore rely on informed judgment, taking into account the specific characteristics of the market under consideration. Moreover, a **sensitivity analysis** with respect to ω_D may be required when the value of this parameter has a significant influence on the **NPV**. The review of the motivating example at the end of this chapter illustrates how these concepts can be applied in practice.

10.1.2 Market power of buyers

In some markets, there is a large number of sellers and a small number of buyers. This configuration is common in the agricultural sector, where many farmers sell their output to a limited number of processors. It is also observed in certain regional labour markets dominated by a single large employer.

Under these conditions, buyers understand that increasing their purchases can exert upward pressure on prices. They therefore have an incentive to restrict their demand in order to keep prices below the level that would prevail in a perfectly competitive market. Appendix 2 illustrates, through a numerical example, how prices and quantities are determined in the extreme case of a monopsony.

Figure 10.5 illustrates more generally the effects of buyer market power. In this example, supply under competition corresponds to the marginal cost curve, while demand from the limited number of buyers is represented by curve D. In a **competitive equilibrium**, the price would be P0 = $40 for a quantity exchanged of Q0 = 18,000 litres. However, if buyers restrict their purchases to Q1 = 15,000 litres, the price falls to P1 = $35. At this level of purchases, the marginal benefit to buyers is $50.

Buyer market power therefore creates a wedge between the market price and buyers' marginal benefit. This divergence has important implications for CBA, since prices no longer reflect the true social value of the last unit exchanged.

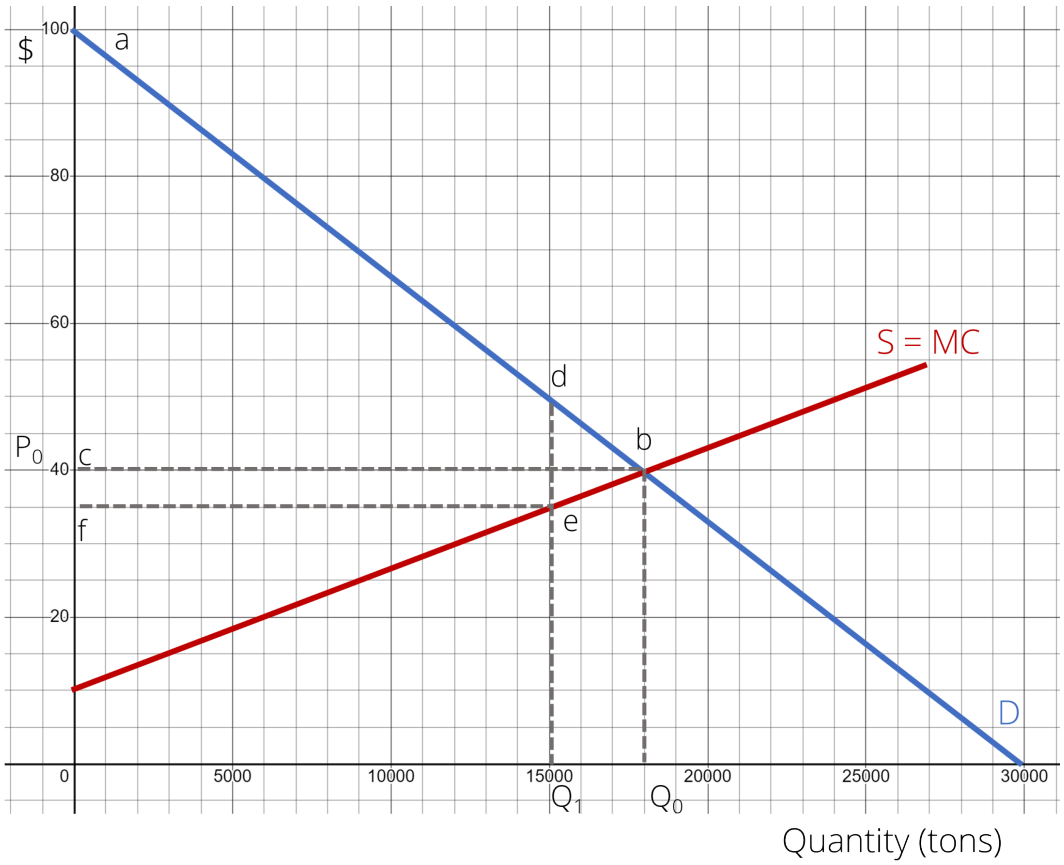


Figure 10.5 Market with presence of buyer market power

When the price is set at $35, buyers benefit from a surplus of $600,000, represented by the area *adef*, which is greater than that observed under perfect competition, where consumer surplus amounts to $540,000 (corresponding to the area of the triangle *abc*). This additional gain is realized at the expense of sellers, whose surplus is reduced by the area *cbef*. From a social perspective, buyer market power generates a deadweight loss corresponding to the area *dbe*. This example makes it possible to conduct the CBA of a project aimed at countering buyer market power (see Exercise 1). It also provides a basis for analyzing how the valuation of a project that increases demand should be carried out in such a context.

As with seller market power, buyer concentration may also have advantages, notably by facilitating the more efficient exploitation of economies of scale. For example, the presence of a small number of large slaughterhouses can allow economies of scale to be realized at this stage of the meat production chain. However, it may also confer market power on these entities and potentially lead to higher transportation costs.

10.2 Information asymmetry

Information asymmetry occurs when one party to a transaction has access to more relevant information than the other. This uneven distribution of information can generate inefficiencies in markets.

Consider the example of a dentist recommending that a patient undergo a dental cleaning every six months rather than once a year. The patient may question whether this recommendation is medically justified or whether it primarily serves to increase the dentist's revenue. This uncertainty can reduce the patient's willingness to pay for the service, potentially leading to a suboptimal allocation of resources.

To mitigate information asymmetry, governments may intervene through regulation, for example by overseeing professions via professional orders.[4] These bodies can establish standards of conduct and mechanisms of supervision. Markets themselves may also respond to information asymmetry through private mechanisms, such as third-party certification, labeling schemes, or the provision of guarantees.

How should the impacts of projects aimed at reducing or eliminating information asymmetry be assessed in a CBA? Once again, a simple example helps to clarify the main mechanisms at work.

Example: The CBA of an organic apple certification program

The market for organic apples is affected by the presence of unscrupulous producers who sell apples labeled as "organic" even though they do not meet organic standards.

This behavior undermines consumer confidence and reduces demand. In Figure 10.6, D represents the demand for organic apples under perfect information, while D_{AI} represents actual demand in the presence of information asymmetry. Demand D_{AI} is lower, reflecting a reduced **willingness to pay**, as consumers fear that the apples they purchase may not truly be organic.

The government is considering implementing a certification and monitoring program designed to eliminate this information asymmetry. The key question for the CBA is therefore to determine the benefits generated by restoring consumer confidence and allowing demand to move from D_{AI} back toward D.

4. Such interventions must be assessed with caution, since there is a risk that they may be diverted from their primary objective. Professional orders are often criticized for prioritizing the interests of their members, who finance them, over the public interest.

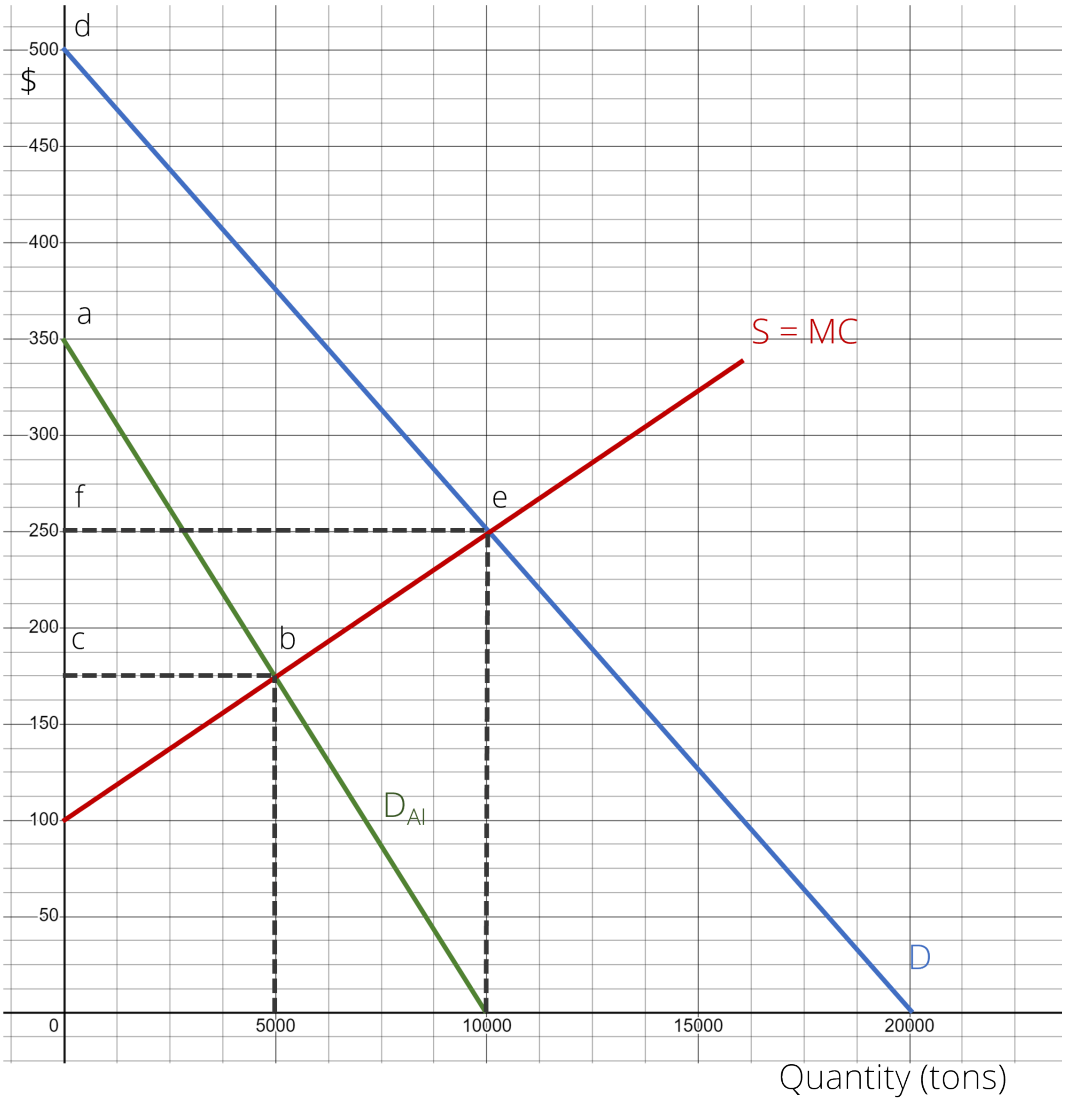


Figure 10.6 The market for organic apples

Resolution

Let us first determine the market equilibrium in the baseline scenario and in the one with certification.

Reference scenario (information asymmetry):

The equilibrium occurs at the intersection of demand D_{AI} and supply *S*,so that:

$Q_0 = 5000$ and $P_0 = \$175$ per ton.

Scenario with the project (certification eliminates information asymmetry):

The equilibrium is now determined by the demand *D*and the supply curve *S*,so that:

$Q_1 = 10{,}000$ and $P_1 = \$250$ ton.

Let us then determine the impacts on the stakeholders, namely consumers and producers.

The impact on consumers

The consumer surplus in the initial scenario is measured by the area of surface *abc*, or $437,500. The surplus with certification is measured by the area of surface *def*,or $1.25 million. This represents a gain of $812,500.

The impact on producers

The project increases producer surplus of the *febc* surface area to $562,500.

The net effect is therefore $1.375 million. In fact, this project can be analyzed in the same way as improving the quality of a good[5] (see Chapter 7).

Note that the analyst must question consumers' expectations relative to the actual fraud rate. In our resolution approach, we implicitly assumed that consumers correctly anticipate fraud risks, so that demand D_{AI} correctly reflects the anticipated value of an organic apple, given the probability of fraud. However, if consumers overestimate fraud risks, demand may understate the social value in the baseline scenario. In the limit, if fraud is in fact negligible, the social value of apples in the baseline scenario should be measured from curve D, not D_{AI}.

10.3 Bounded rationality

As discussed in Chapter 3, individuals do not always behave in a perfectly rational manner, giving rise to intrapersonal externalities. Such situations may justify government intervention. In addition, insights from behavioral economics regarding cognitive biases can improve the design of public policies and help better predict their effects. However, bounded rationality also raises a fundamental question for cost–benefit analysis: should these biases be taken into account or neutralized when valuing the costs and benefits of a project (see Weiner, 2017)?

Consider, for example, loss aversion. Should this bias be reflected directly in the impact assessment of a project? If it is taken into account, a loss subjectively evaluated at $1,000 would not be treated as equivalent to an objectively measured gain of $1,000. Conversely, if the bias is neutralized, the analyst would adjust downward a loss that individuals perceive as $1,000, on the grounds that this perception overstates the true economic cost.

One of the foundations of CBA is the valuation of impacts based on individuals' preferences, as revealed through their willingness to pay or willingness to accept compensation. From this perspective, if cognitive biases affect these measures, they should in principle be reflected in the valuation. However, these same biases can lead individuals to make choices that are not aligned with their own long-term interests. If such biased preferences are incorporated mechanically into WTP or WTA measures, the CBA may end up endorsing projects that reduce collective welfare rather than enhance it.

For this reason, the prevailing recommendation in applied CBA is to neutralize, as much as possible, the effects of cognitive biases when valuing costs and benefits. This implies relying on valuations that reflect informed, well-considered preferences rather than momentary or systematically distorted perceptions. We will

5. Fraudsters are penalized by this project, but their well-being should not be taken into account, since they are acting illegally. The costs of setting up and monitoring the certification program must also be taken into account.

return to this issue in Part 3 of the manual, particularly in Chapter 15. Exercise 2 also explores valuation issues in the presence of goods that generate dependency.

10.4 Conclusions

Key takeaways

- In the presence of market power on the supply side, the market price exceeds marginal cost.
- This gap generates a net loss, since some exchanges that would be socially profitable under competitive conditions do not take place.
- It also affects the valuation of projects that add supply to such a market: the portion of additional output that increases total trade should be valued at the market price, while the portion that crowds out existing production should be valued at the marginal cost of the displaced producers.
- In markets where buyers exercise market power, the price equals marginal cost but remains below the marginal benefit of demanders.
  This divergence also generates a net loss and has implications for the valuation of project impacts.
- Information asymmetry can impair the proper functioning of markets, notably by reducing the quantity exchanged relative to the efficient level.
- Cognitive biases may need to be considered to better predict the effects of a project and to design more effective public policies.
- However, when assessing impacts in a cost–benefit analysis, it is essential to neutralize the effects of cognitive biases in order to avoid endorsing projects that reduce collective welfare.

Back to motivation

To encourage competition in the pharmaceutical market, a project would support a generic drug manufacturer planning to begin producing a cancer treatment. The drug is currently supplied exclusively by a single firm, which sells it for $500 per dose. The entry of a generic competitor could reduce the price by about half. The generic manufacturer plans to produce 15,000 doses per year, roughly 75% of current sales. How should the social value generated by this new production be calculated? Should these doses be valued at the current price of $500, at the expected post-entry price, or using an alternative reference price?

Resolution

We do not have all the information required to calculate the impacts of this project precisely, but we can establish an analytical framework that highlights the additional data needed and the assumptions that must be validated. Figure 10.7 illustrates the demand for this drug. The project results in a price reduction from $500 to $250, which should cause the quantity traded to increase from Q_0 to Q_1. However, the analyst will need to estimate the quantity Q_1.

In the simplest case, $Q_1 = Q_0 + 15{,}000$, that is, the incumbent firm maintains its production at Q_0, which is estimated at 20,000 doses, since the additional production represents 75% of the initial output. Under this assumption, the valuation of the additional production is straightforward and can be carried out at the average price before and after the project:

Social value of additional production linked to the project: $375 x 15,000 = $5.625 million.

However, it is also possible that the incumbent firm will partially reduce its output in order to limit the price decrease. This situation is illustrated in Figure 10.7, where the original firm reduces its production to Q'. In this case, the social approach proceeds as follows:

- Valuation of additional production: $350 x ($Q_1$-$Q_0$);
- Valuation of released resources: marginal cost of the original firm x (Q_0-Q');
- Cost of resources mobilized by the project: to be determined within the CBA.

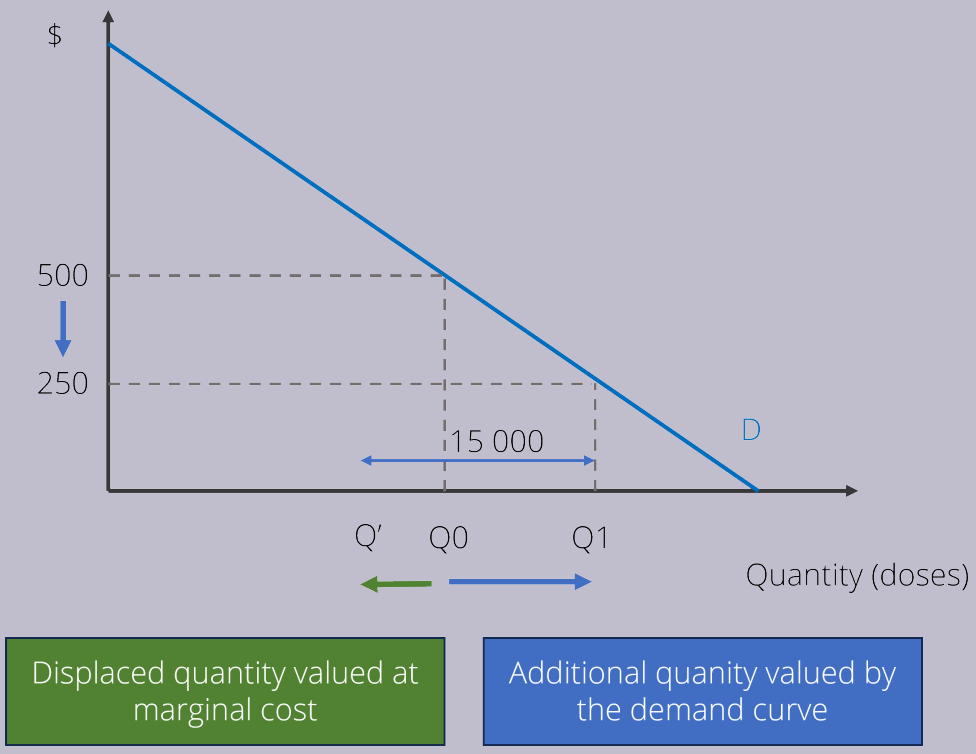


Figure 10.7 Possible impact of adding production in the drug market

It should also be noted that the incumbent firm could react to the entry of the generic producer by increasing its own production in order to limit the market share available to the entrant, with the objective of placing it in financial difficulty.

More generally, the analytical framework outlined above relies on several assumptions that must be carefully examined by the analyst. A first key assumption is that the original drug and the generic drug are perceived as perfectly identical by users and are therefore sold at the same price. In practice, this assumption may not hold. Patients may perceive generic drugs, rightly or wrongly, as being of lower quality, which could lead to product differentiation and to price differences between the two versions.

Furthermore, even if the two products are considered equivalent in quality, prices may still differ if the generic producer is unable to meet total market demand at a price of $250 per dose. In such a case, the incumbent firm could retain a degree of market power by acting as a monopolist on the residual demand that is not served by the generic producer. This strategic behavior would affect both the equilibrium prices and quantities, and therefore the valuation of the project's impacts in the CBA.

Exercises

1. (*) In a given country, coffee production is carried out by a large number of small producers. However, all harvests are purchased by a single buyer authorized by the government. A project is currently being considered to liberalize this market, which would lead to a substantial increase in the number of buyers.

   To assess the potential impacts of this project on the coffee market, you are provided with the following information:

   - The current market price is $2,000 per tonne;
   - The quantity traded is 10 million tonnes;
   - The price elasticity of supply is estimated at 2, while the price elasticity of demand is estimated at 1.

   Develop an analytical framework to identify and value the impacts of this project on the coffee market. Explain how the price elasticities of supply and demand influence the net effect in the market. In addition, discuss other effects that may need to be taken into account in a comprehensive cost–benefit analysis of this project.
   [The resolution should be based on the concepts developed in Appendix 2.]
2. (*) A project aims to reduce alcohol addiction. The typical demand of an addicted individual is represented in Figure 10.8 by curve DD, while the typical demand of a non-addicted individual is represented by curve D. The average price of alcohol is $10 per litre.

   Discuss the challenges involved in valuing the effects of this project from the perspectives of expenditure and consumer surplus.

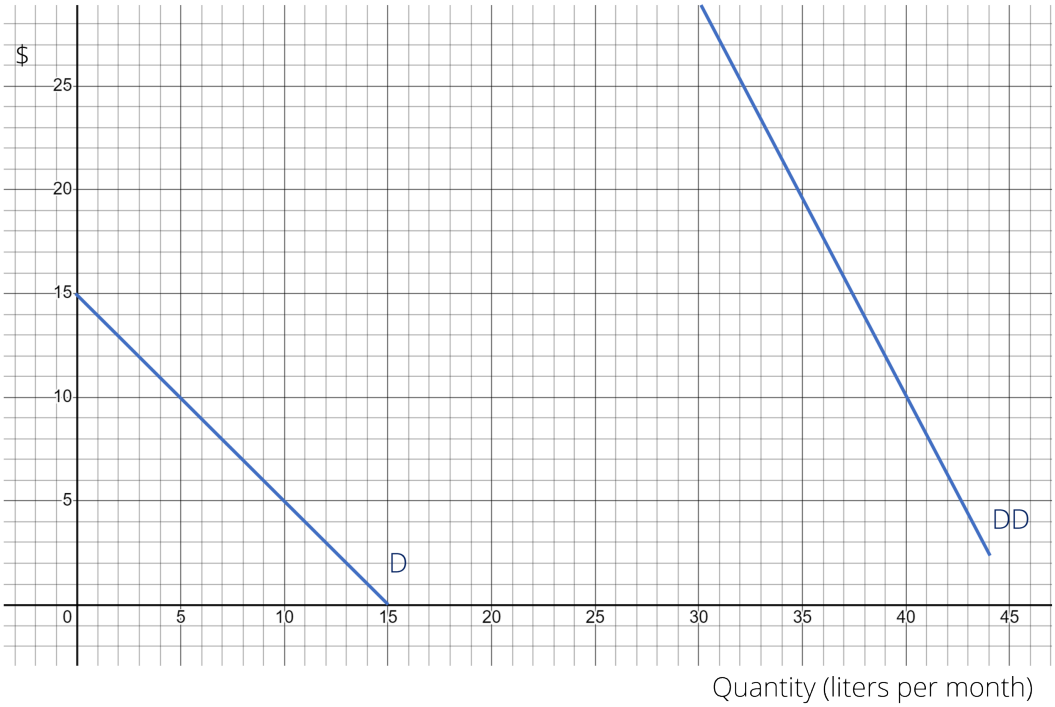


Figure 10.8 Typical request from an alcohol dependent and non-alcoholic person

Appendix 1 : The monopoly

How are equilibrium price and quantity determined in the presence of a monopoly? A monopolist maximizes its profit by following a principle similar to that of a firm operating in a competitive market: it produces all units for which marginal revenue exceeds marginal cost. Equivalently, the monopolist chooses its level of output such that marginal revenue equals marginal cost.

Figure 10.9 illustrates the case of a monopolist facing the market demand curve D, with constant average cost equal to marginal cost (MC = AC). To understand the monopolist's decision, consider the effect of increasing output by 1,000 tonnes, starting from an initial production level of 5,000 tonnes.

To sell these additional 1,000 tonnes, the monopolist must lower the market price from $85 to $80. As a result, the marginal revenue associated with this increase in output has two components:

- The additional revenue generated by selling the extra 1,000 tonnes at the new price, equal to $80,000 (that is, $80 × 1,000), represented by the blue shaded rectangle;

- The loss of revenue resulting from the price reduction on the 5,000 units previously sold. These units could have been sold at $85 but are now sold at $80, generating a loss of $25,000 (that is, $5 × 5,000), represented by the red shaded rectangle.

Marginal revenue is therefore lower than the price, reflecting the fact that a monopolist must reduce the price

on all units sold in order to increase output. This fundamental difference between monopoly and perfect competition explains why monopolists restrict output and charge prices above marginal cost.

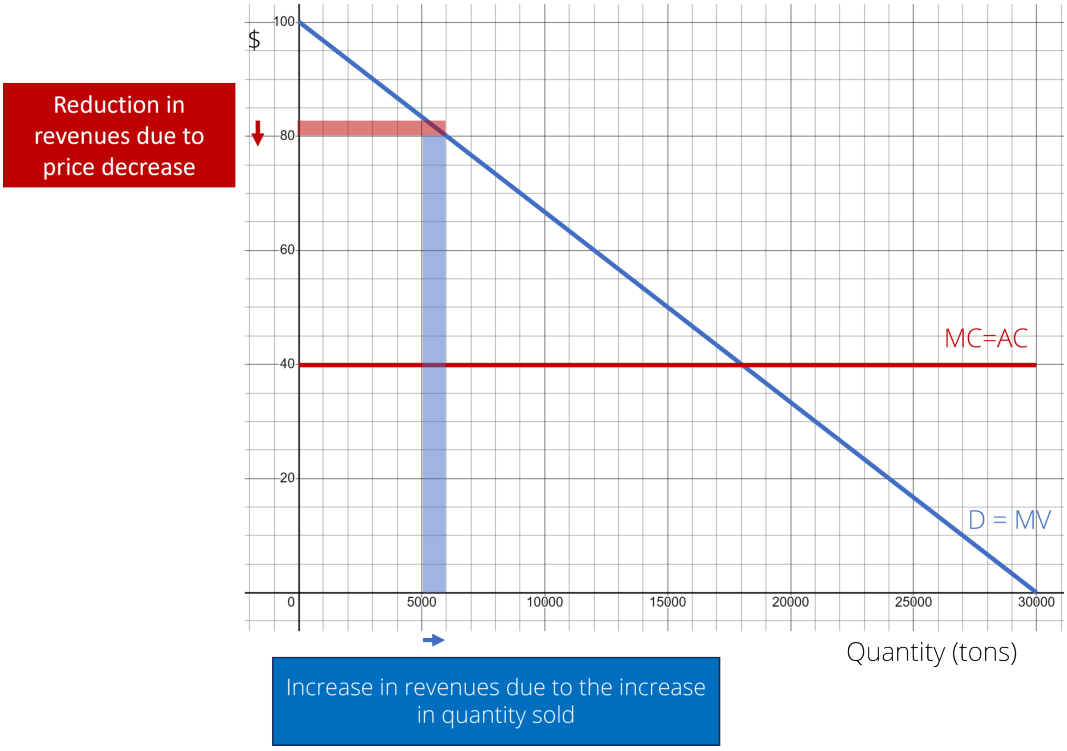


Figure 10.9 Monopoly Market and Determinant of Marginal Revenue

Thus, marginal revenue is equal to $55,000, which is lower than the revenue generated by the additional sales alone. More generally, when the demand curve is downward sloping, it can be shown that the marginal revenue associated with a small increase in the quantity sold is represented by a curve whose slope is twice as steep as that of the demand curve.[6]

The curve Rm shown in Figure 10.10 therefore represents the monopolist's marginal revenue. The intuition behind this curve is straightforward: in order to sell additional units, the monopolist must lower the price not only for the marginal units, but also for all units previously sold. This effect reduces marginal revenue below the market price.

This feature constitutes a fundamental difference between monopoly and perfect competition. Under perfect competition, firms take the market price as given; the demand they face is therefore perfectly elastic, and marginal revenue is equal to the selling price.

6. If demand is given by the linear function P = a – bQ, total revenue (TR) earned by the monopolist is TR = P × Q = (a – bQ)Q, and marginal revenue is obtained by differentiating TR with respect to Q, yielding $\frac{\Delta RT}{\Delta Q} = a - 2bQ$.

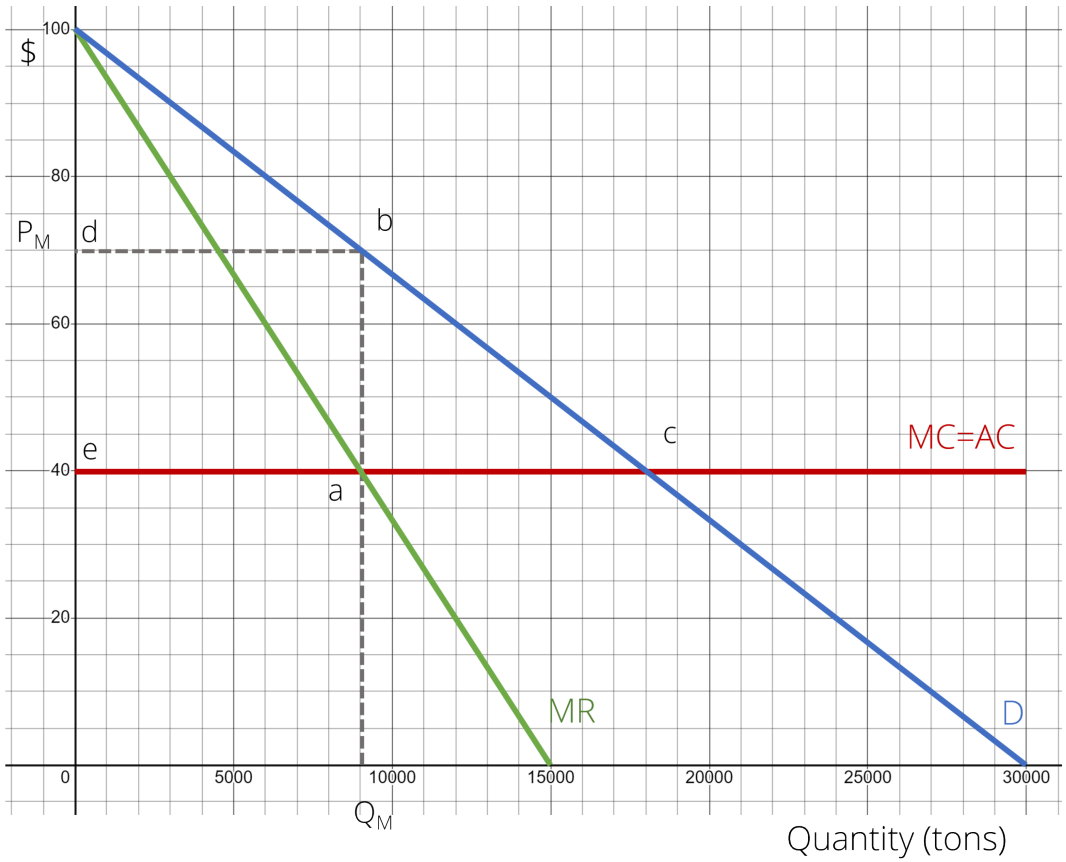


Figure 10.10
Monopoly
Equilibrium

The monopolist maximizes its profit by supplying the quantity Q_M = 9,000 tons to the market and charging the price determined by demand curve, namely P_M = \$70. The resulting profit corresponds to the area of surface *dbae*, equal to \$270,000. Indeed, profit is measured as the difference between the price (\$70) and the average cost (\$40), multiplied by the quantity produced (9,000 tons).

This profit is obtained at the expense of consumer surplus and allocative efficiency, since monopoly pricing generates a deadweight loss equal to the area of surface *bac*. This deadweight loss reflects mutually beneficial exchanges that do not take place because the monopolist restricts output in order to raise price.

It can also be shown that the Lerner index at the monopoly equilibrium is inversely related to the price elasticity of demand:

$$L = \frac{P - Cm}{P} = \frac{1}{\eta_D}$$

This relationship holds in our example, since

$$L = \frac{(70\$ - 40\$)}{70\$} = 0.428$$

and

$$\eta_D = 2.33$$

when $Q = Q_M$.

Appendix 2: The monopsony

In a market where a single buyer interacts with many producers, a natural question arises: how much should the buyer purchase in order to maximize its surplus? The answer is straightforward: the buyer has an incentive to acquire all units for which the benefit exceeds the cost. In other words, the buyer should purchase all units for which the marginal value (MV) is greater than the marginal expenditure (ME). Determining the buyer's optimal purchasing decision therefore requires identifying both the marginal value and the marginal expenditure.

These concepts can be illustrated with a concrete example. Consider a firm that is the dominant buyer of bulk potatoes produced by numerous farmers in a given region. The firm processes these potatoes into frozen French fries. In Figure 10.12, curve D represents the processor's demand for potatoes, which also corresponds to market demand. As usual, this demand curve reflects the marginal value, or the additional benefit, that the processor derives from each additional unit purchased.

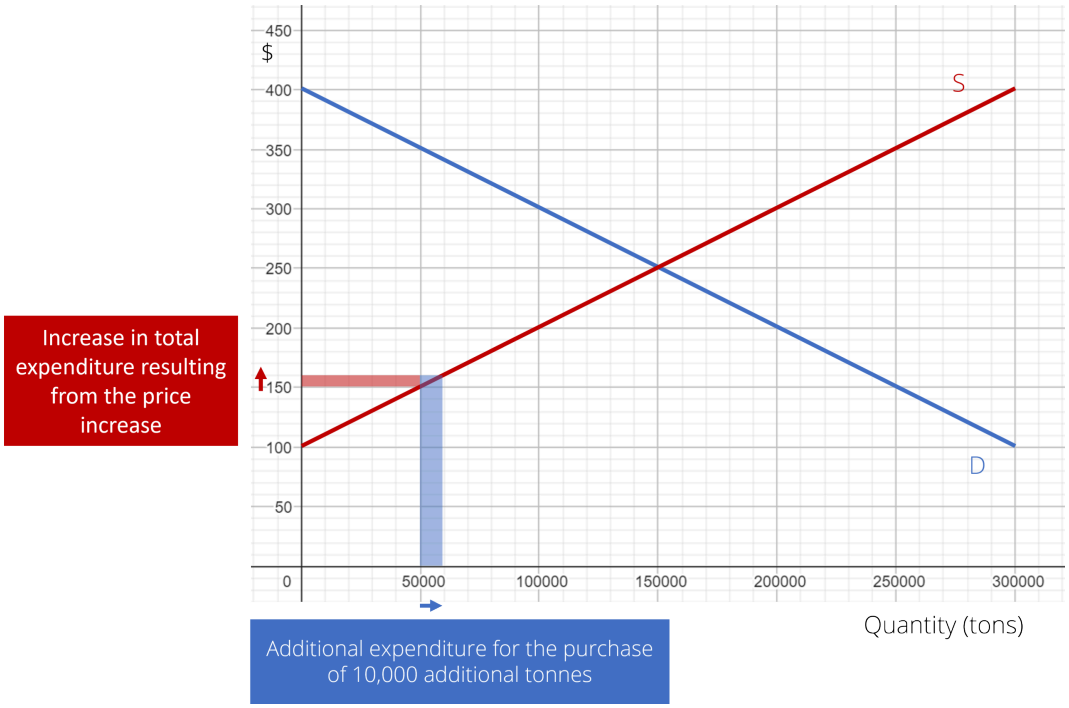


Figure 10.11 Regional bulk potato market and monopsony marginal expense

Let us now determine the processor's marginal expenditure. Figure 10.11 illustrates how to establish the marginal expenditure associated with purchasing an additional 10,000 tons, starting from an initial quantity of 50,000 tons. To increase the quantity supplied from 50,000 tons to 60,000 tons, the price must rise from $150 to $160. The marginal expenditure therefore has two components:

- The additional expense associated with purchasing the extra 10,000 units, equal to $1.6 million ($160 × 10,000), which corresponds to the area of the blue shaded surface in Figure 10.12;

The increase in total expenditure resulting from the higher price applied to the 50,000 intramarginal units, represented by the red shaded rectangle, amounting to $0.5 million ($10 × 50,000 tonnes).

- The marginal expenditure is therefore $2.1 million, which exceeds the cost of purchasing the additional units alone. When the supply curve is upward sloping, the marginal expenditure associated with a small increase in quantity is represented by a curve whose slope is twice that of the supply curve. The *ME* curve in Figure 10.12 thus represents the processor's marginal expenditure.

The processor maximizes its surplus by limiting its purchases to Q_M = 100,000 tons, which allows it to obtain a price of P_M = $200. Its surplus is measured by the area of the surface *abcd*, equal to $15 million. This surplus is larger than that obtained under perfect competition, where consumer surplus corresponds to the area *aef*, or $11.25 million. This gain for the buyer comes at the expense of producers, whose surplus declines, and of overall economic efficiency, since the monopsony generates a deadweight loss represented by the area of the surface *bec*.

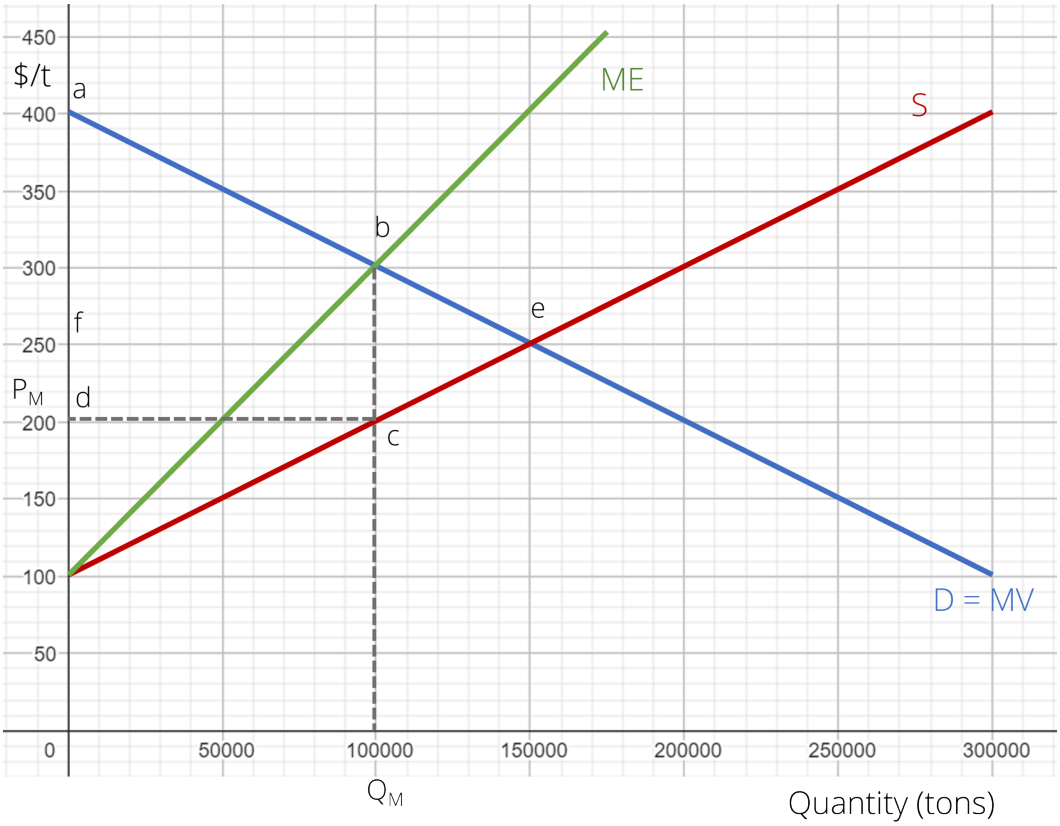


Figure 12. Équilibre du marché de monopsone

Note that in the case of a monopsony, the Lerner index is defined as follows:

$$L = \frac{MV - P}{MV}$$

It can also be shown that at monopsony equilibrium, the Lerner index is inversely proportional to the price elasticity of supply:

$$L = \frac{1}{\eta_S}$$

This relationship is verified in our example, since $L = \frac{300\$ - 200\$}{300\$} = 0.33$ and $\eta_O = 3$ when Q = Q_M.

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11.

VALUING INPUTS

Motivation and learning objectives

A project requires the purchase of 3,000 steel beams at a tax-inclusive price of $5,000 each. The tax-exclusive price is $4,500 per unit. The price elasticity of supply of steel beams is estimated at 3, while the price elasticity of existing demand is 1. The total expenditure amounts to $15 million. Should this amount be treated as the social cost in the CBA of this project?

In this chapter, we examine the social valuation of inputs mobilized by a project. In practice, the valuation challenges involved are of the same nature as those encountered when establishing the social value of a project's outputs.

After completing this chapter, you will be able to assess the social cost of:

1. inputs traded in efficient markets;
2. inputs traded in distorted markets;
3. labour.

The final section focuses in particular on the social valuation of labour, as it is an essential input in virtually all projects. Moreover, in discussions surrounding project justification, job creation is often mistakenly presented as a benefit in itself. Understanding how labour should be valued is therefore crucial to avoid common analytical pitfalls.

11.1 Valuation of inputs purchased on efficient markets

A competitive market for an input, such as the market for auto mechanics, functions in the same way as a

market for a final good. The equilibrium price (P*), or the equilibrium wage (w*) in the case of labour, is determined by the intersection of supply and demand, as illustrated in Figure 11.1.

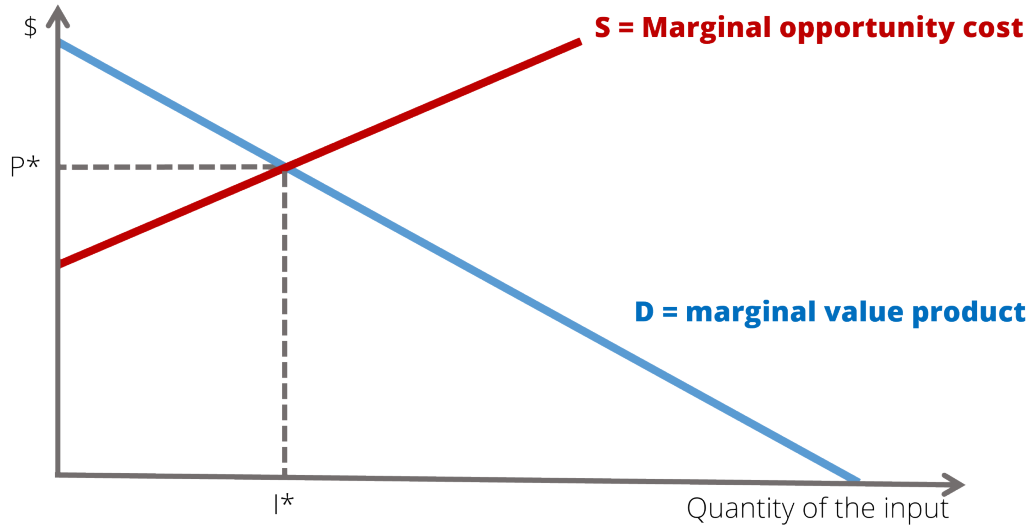


Figure 11.1 The competitive market for an input

11.1.1 Demand for an input

Input markets have a distinctive feature: demand is said to be "derived," meaning that it stems from the demand for the goods and services produced using that input. In our example, the demand for mechanics arises directly from the demand for car repair services. As a result, the demand curve for an input corresponds to **the marginal value product** .

> **The marginal value product of an input** is defined as the marginal physical product of the input—that is, the additional output generated by employing one more unit of the input—multiplied by the market price of the output. This curve is generally downward sloping because of the **law of diminishing marginal returns**.

Consider a garage that is contemplating hiring an additional mechanic. Suppose that doing so would allow the garage to perform 10 additional repairs per week, and that the average price of a repair is $200. The marginal value product of this mechanic is therefore $2,000 per week. The garage would thus find it profitable to hire this additional mechanic as long as the weekly wage does not exceed $2,000.

Moreover, as the garage employs more mechanics, marginal productivity typically declines, in accordance with the law of diminishing marginal returns. This law states that, holding all other factors constant, the marginal contribution of an additional unit of an input decreases as the quantity of that input increases. Consequently, the maximum willingness to pay for an additional unit of an input falls as the quantity already employed rises, as illustrated in Figure 11.1.



11.1.2 Supply of an input

The supply of an input in a competitive market reflects its marginal cost. An additional unit of concrete, for example, will be supplied only if the market price covers its marginal cost of production. Recall that these are economic costs, which include the normal remuneration of all factors of production employed, including capital and entrepreneurship.

In the labor market, the supply of labor reflects workers' trade-off between labor income and the value they place on time devoted to activities other than work, commonly referred to by economists as "leisure." The labor supply curve therefore measures the minimum compensation a worker requires to give up an additional unit of leisure time, that is, the marginal value of leisure. Moreover, this value generally increases with the quantity of labor L already supplied[1], which implies that labor supply typically rises with the wage, as illustrated in Figure 11.1.

11.1.3 The impact of a project

At the competitive equilibrium in an input market, the price (or wage) simultaneously reflects the marginal value product of the input and its opportunity cost at the margin.

We now turn to the social valuation of inputs mobilized by a project. The implementation of a project increases demand for the input relative to the baseline situation. Two cases can be distinguished, depending on whether the project is expected to affect the equilibrium price of the input.

Situation 1: The project has no impact on the price of an input

1. As available leisure time becomes scarcer, its value increases.

Rule of practice

When the additional demand for an input generated by a project is small relative to the size of the market, or when the supply of the input is highly elastic, the project has no significant effect on the equilibrium price of that input. In this case, the budgetary expenditure on the input provides an accurate measure of its social cost. In other words, the cost to be included in the CBA is simply the market price multiplied by the quantity of the input used by the project.

Often, therefore, expenditure provides an adequate measure of social cost. Consider a project that requires the purchase of 100 m^3 of wood, a quantity too small to affect the market price of wood. In this situation, with a purchase price of \$70 per m^3, the social cost is equal to the expenditure, that is, \$70 × 100 = \$7,000.

Situation 2: The project causes a change in the price of the input

Some large-scale projects may require a substantial quantity of an input or rely on an input with a low supply elasticity. In such cases, the project will lead to an increase in the input's price, and the social valuation must then follow the rule of practice below.

Rule of practice

If the additional demand (k) generated by a project leads to an increase in price from P_0 to P_1, the social valuation is carried out according to the following rule:

$$\text{Social cost} = \frac{(P_0 + P_1)}{2} \times k$$

In other words, valuation is based on a reference price equal to the average of the input price before the project (P_0) and the expected price after the project (P_1). This valuation is exact under the assumption of linearity of the supply and demand curves.

The anticipated price (P_1) can be estimated using the price elasticities of supply (η_S) and demand (

η_D) of the input, following the procedure presented in Section 4 of Chapter 4. As a reminder, the expected percentage increase in price is given by:

$$\Delta p\% = \frac{(\mathrm{P}_1 - \mathrm{P}_0)}{\mathrm{P}_0}\% = + \left(\frac{k}{Q_0}\right) times \left(\frac{1}{\eta_D + \eta_S}\right)$$

Valuation at this reference price captures both the cost associated with the increase in the quantity of the input exchanged and the crowding-out effect on the initial demand for the input caused by the price increase.

The intuition underlying this rule of practice is very similar to that introduced earlier for the valuation of an output (see Chapter 7, Section 1). The following example illustrates the foundations of this rule.

Example: Purchasing concrete for a mega dam

Supply and demand in the regional concrete market are illustrated in Figure 11.2. The construction of a mega dam requires an additional 40,000 tonnes of concrete. The question is therefore how to determine the social cost of this input to be included in the CBA.



Figure 11.2. The ciment market before the project

Resolution

The implementation of the project generates an additional demand of 40,000 tonnes, resulting in a horizontal shift of the demand curve from D to D + k, as illustrated in Figure 11.3. The project therefore increases the price of the input from $40 per tonne to $60 per tonne. It is important to note, however, that the additional quantity of concrete supplied to the market amounts to only 20,000 tonnes. The remainder of the quantity required by the project comes from a reduction in demand by existing users, implying a reallocation of economic activity rather than a net increase in production.

The cost of the additional units of input produced and traded in the market is measured by the area under the supply curve, represented by area *abcd* (shaded in red), with a value of $1 million. For the units of input displaced from their initial uses, the opportunity cost is measured under the initial demand curve, represented by area *eadf* (shaded in blue), which is also valued at $1 million. This demand curve reflects the value generated by these units in their original use.

Overall, the total social cost is represented by the area *eabcf*. Equivalently, this cost can be computed by multiplying the quantity of input mobilized by the project (k) by a reference price equal to the average of the price before and after the project, i.e. ½ (P_0 + P_1). In this example, the social cost of the input is therefore $50 × 40,000, for a total of $2 million.

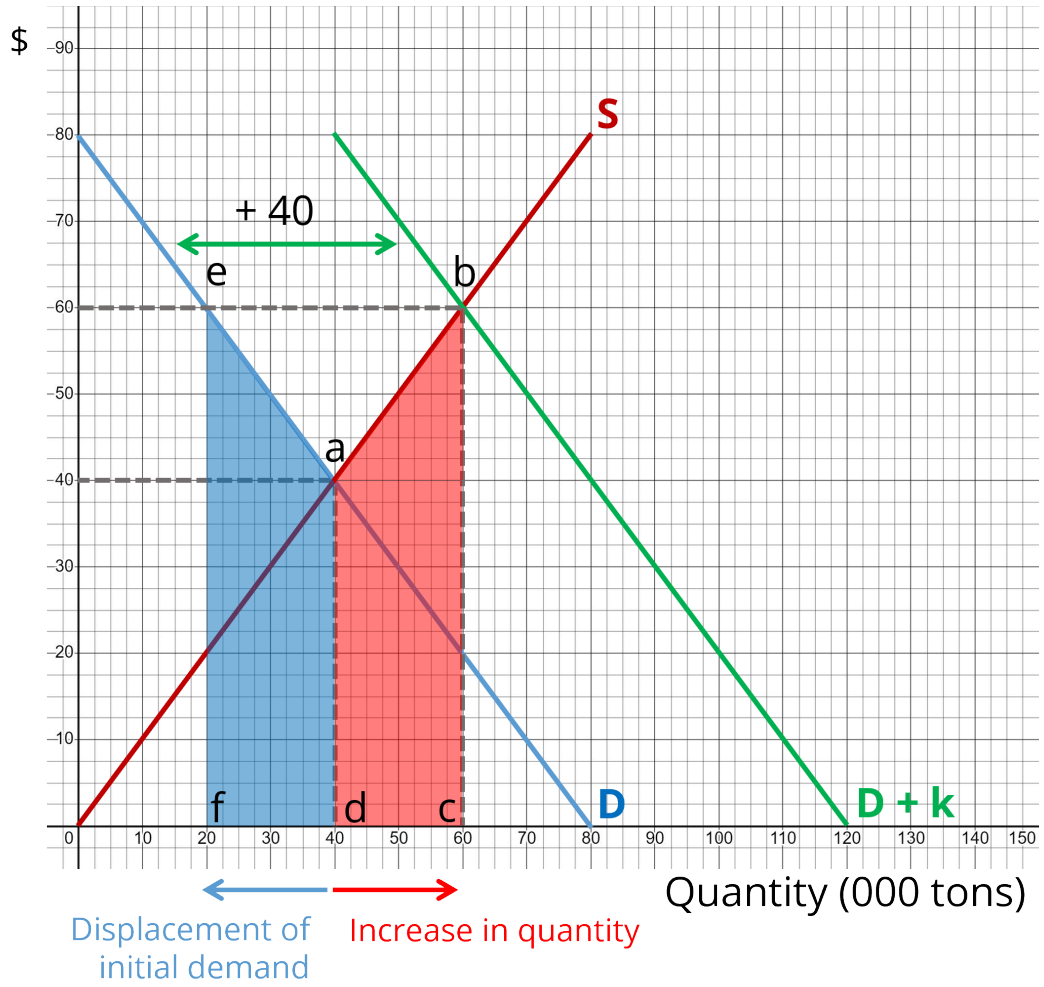


Figure 3. Project impact on ciment market

11.2 Valuation in the presence of distortions

As with output valuation, the presence of market distortions has important implications for the assessment of project costs. We begin by examining the valuation of inputs in the presence of taxation.

11.2.1 Valuation of an input subject to a tax

This situation closely parallels the one examined in Chapter 7 (Section 1) for the valuation of a taxed output. Figure 11.4 illustrates the effects generated by an increase in demand for a taxed input. As a result of adding k to the initial demand, the quantity of inputs traded increases from Q_0 to Q_1. As in the case of a taxed output, whether the tax should be included in the valuation depends on the source of the input used by the project.

Specifically:

1. The portion of the input used by the project that comes from an increase in the quantity exchanged on the market, that is, between Q_0 and Q_1, must be valued under the supply curve, represented by area *abcd*. If the price variation between points *a* and *b* is small relative to the tax wedge *t*, this area can be approximated by the red shaded rectangle. In this case, only the current prices with and without tax are required for the valuation.
2. The portion of the input used by the project that comes from the crowding out of existing demand, that is, between Q' and Q_0, must be valued on the initial demand curve, represented by area *efdg*. Once again, if the price difference between points *e* and *f* is small compared to *t*, this area can be approximated by the blue shaded rectangle.

The relative importance of these two sources of inputs used by the project depends on the price elasticities of supply and demand. The corresponding rule of thumb is as follows:

Rule of practice

If the project has an impact on the input price that is small relative to the wedge created by the tax, the social value to be included in the project's CBA can be approximated as:

$$\text{Social cost} = P_r \times k$$

where k is the quantity of the input used by the project and P_r is the following reference price:

$$P_r = \alpha_S P + \alpha_D (P + t)$$

With :

- ***P***: the price of the input excluding tax observed before the implementation of the project;
- ***t***: the amount of the **unit tax** applied on the input;
- α_S: the share of the project input that comes from the increase in supply, evaluated as $\frac{\eta_S}{\eta_O + \eta_D}$;
- α_D: the share of the project's input that comes from the crowding out of existing demand, evaluated as $\frac{\eta_D}{\eta_S + \eta_D}$;
- η_S, η_D: the price elasticity of supply and demand of the input, respectively.

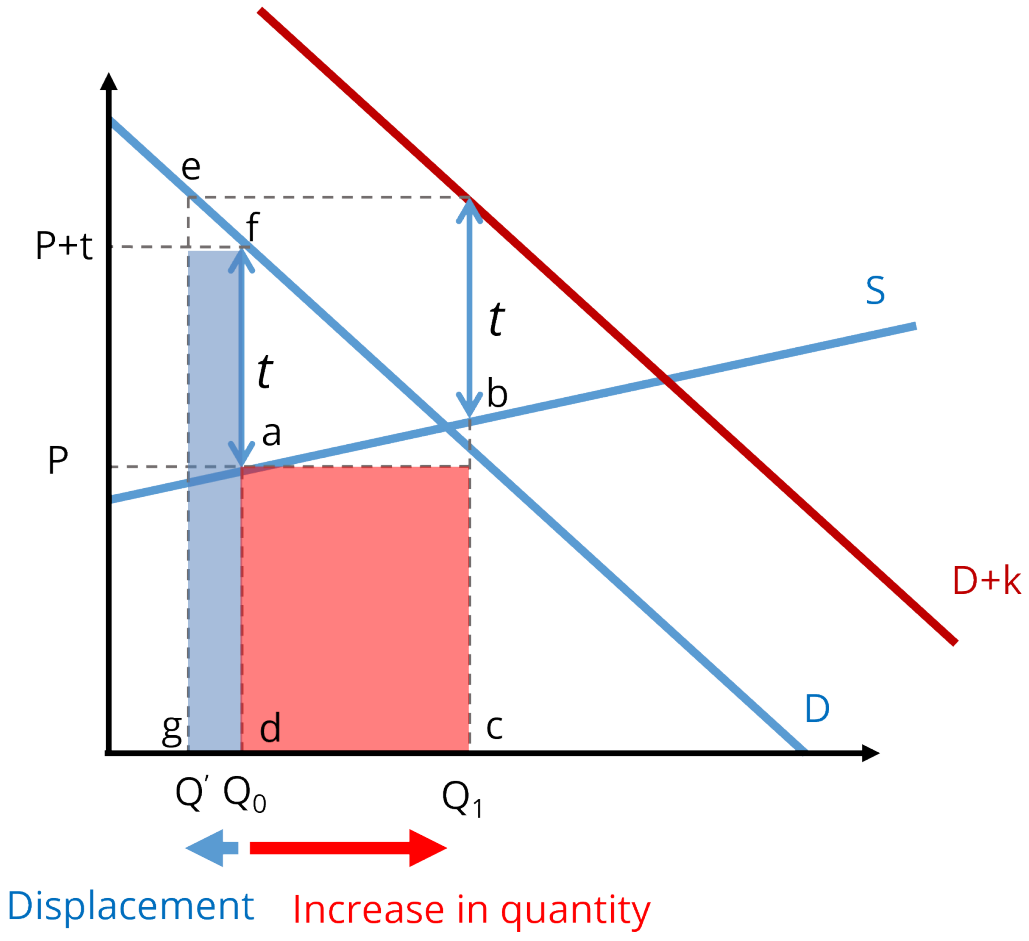


Figure 11.4 The valuation of a taxed input (approximation)

11.2.2 Valorisation of a subsidized input

In the case of a subsidized input, the reference price takes the following form:

$$P_r = \alpha_S P + \alpha_D (P - s)$$

In this case, the portion of the input that comes from an increase in the quantity supplied is valued at the supply price (P), while the portion that crowds out pre-existing demand is valued at the price faced on the demand side, that is $P - s$, where s denotes the amount of the unit subsidy. This reasoning implicitly assumes that demand prior to the project also benefits from the subsidy. If this is not the case, the valuation must be carried out entirely at the price P.

11.2.3 Other distortions

Other distortions may affect the input market. For example, the production of an input may generate external costs that must be taken into account in the CBA. If a project requires the use of energy produced from fossil fuels, the associated **external costs** must be included in the analysis. When the quantity of energy demanded by the project comes entirely from an increase in production—for instance, when supply is perfectly elastic—the external cost to be included in the CBA is equal to the external cost per unit of input multiplied by the total quantity used by the project.

However, if part of the quantity used by the project results from the crowding out of pre-existing demand, the external costs associated with this portion should not be included. These external costs would occur regardless of whether the project is implemented. Once again, the price elasticities of supply and demand help determine the origin of the quantity used by the project.

The input market may also be affected by the presence of **market power**. In such cases, the additional production of the input induced by the project should be valued at marginal cost rather than at price.[2] In contrast, the portion of the input resulting from the crowding out of existing demand should be valued at the prevailing market price.

More complex situations may also arise. The analyst must therefore remain vigilant and always assess whether the price paid for the input used by the project truly reflects its social cost. When this is not the case, the budgetary expenditure must be adjusted accordingly.

2. It is assumed here that firms with market power are stakeholders in the CBA, so that the markup ($P - Cm$) represents a transfer between consumers and producers. If these firms are not stakeholders (for example, if they are foreign firms), the entire quantity of inputs used by the project should be valued at the price paid.

11.3 The social value of work

11.3.1 The social cost of labor depends on its source



As with other inputs, the labour used in a project entails an opportunity cost corresponding to the value forgone by mobilizing workers for that project. Although the term "labour market" is often used in a general sense, in practice multiple labour markets coexist, with conditions that can vary substantially across occupations and skill levels. For example, in a project aimed at computerizing medical records, it is essential to distinguish between the market for computer scientists and the market for administrative support staff, as market conditions may differ markedly between these two groups.

As with any other input, the social value of labour mobilized by a project depends on the origin of the workers, since this determines their opportunity cost. Workers employed by the project may fall into one of the following categories:

1. Workers who already hold a job of comparable level and are therefore **displaced** from their previous employment by the project;
2. Workers who are drawn into the labour market as a result of the project, and are thus considered **new entrants**;
3. Workers who were **unemployed** prior to the project, for whom the project provides an opportunity to re-enter the labour market..

1) Displaced workers

> The social cost of **workers displaced** by a project must be assessed on the basis of their gross wage (w_B), since this wage reflects the economic value they generate in their current employment.

Indeed, the gross wage measures the marginal productivity of labour in value terms and corresponds to the

demand for labour. It therefore represents the value that society forgoes when these workers are reallocated from their existing jobs to the project.

2) Workers attracted by the project

For **workers who are drawn into the labour market** as a result of the project, the relevant social cost corresponds to the value of the "leisure" they give up. This value is measured by the net wage (w_N) paid by the project.

When a worker chooses to enter the labour market at the net wage w_N offered by the project, this reveals that the wage compensates for the value of the leisure foregone. In other words, the net wage represents the opportunity cost of the worker's participation in the project in terms of the sacrificed non-working time.

3) Workers coming from unemployment

When macroeconomic conditions are weak, a project may help reduce unemployment by hiring unemployed individuals directly or by employing workers who, in turn, free up positions that can be filled by unemployed workers. In this case, the social cost corresponds to the value of the "leisure" time that unemployed individuals give up.

It is important to emphasize that unemployment benefits are transfers and therefore should not be included in the calculation of social cost. A first approximation of the social cost for workers reintegrated into the labour market is the net wage minus unemployment benefits. However, the true social cost is likely to be even lower, since some unemployed individuals may have been willing to accept employment at a wage below the one offered by the project. This situation is particularly plausible when unemployment results from the presence of a minimum wage.[3]

In practice, several approaches are used to estimate the social value of leisure for unemployed individuals who re-enter the labour market:

1. Boardman et al. (2018, p. 152) propose using a reference wage equal to 50% of the net wage, corresponding to the average between the net wage and zero. This rule of thumb is justified by the assumption that the reservation wage is zero.

3. For a reminder of the effects of the minimum wage, see Marginal Revolution (2015) (2015).

2. In contexts where involuntary unemployment is significant in both the short and long run, the European Commission (Sartori et al., 2015) recommends adjusting net wages downward by applying the correction factor (1 – u), where *u* denotes the unemployment rate. This approach is also adopted by the Government of Canada (Government of Canada, 2023, Table 2).

11.3.2 Valuation based on a weighted average

The social value of labour therefore depends on the origin of the workers, and the relative importance of each source is shaped by the specific conditions prevailing in a given labour market. As a result, the valuation of labour for a particular occupational category can be based on a reference wage calculated as the following weighted average:

$$w_r = \alpha_D w_B + \alpha_S w_N + \alpha_C w_L$$

With :

- w_r: the reference wage for the category of workers hired by the project;
- α_D: the share of project workers who were already employed;
- w_B : the gross salary;
- α_S: the share of project workers who are attracted into the labor market by the project;
- w_N : the net wage;
- α_C: the share of workers coming from involuntary unemployment;
- w_L : an assessment of the value of leisure for unemployed individuals.

Naturally, not all three sources are always relevant. For instance, in an occupation experiencing a labour shortage, it is likely that most workers hired by the project would have been employed even in the absence of the project. In such a case, assuming $\alpha_D = 1$ may be appropriate. Determining the weights therefore requires a careful analysis of the labour market conditions specific to each category of employment.

11.3.3 Other possible distortions in the labour market

Job creation in certain sectors is often encouraged through subsidies linked to payroll expenditures. For example, in some jurisdictions, video game developers benefit from payroll tax credits that cover a fixed percentage of eligible wage costs, subject to a per-worker cap. In this context, the social cost of workers hired by a project who were previously employed in non-subsidized sectors should be measured by their gross wage. By contrast, if these workers come from a subsidized sector, the **opportunity cost** of labour corresponds to the gross wage minus the value of the subsidy, since the subsidy represents a transfer rather than a real use of resources.

The wage paid by a project may also include a wage rent, particularly when compensation levels are shaped by collective bargaining or institutional arrangements. In such cases, the observed wage overstates the social cost of labour, because the wage that workers could earn in their best alternative employment would be lower. This situation is illustrated in the following example.

Example: Rationalization in a state-owned alcohol retailer

As part of a rationalization initiative, a state-owned enterprise holding a monopoly on alcohol retail sales within a given jurisdiction is considering the introduction of self-service checkout stations that allow customers to scan products themselves. The main benefit of this initiative would be the elimination of 300 full-time cashier positions. At present, full-time cashiers earn an average gross annual salary of $35,500.

Labour market conditions suggest that these employees would find alternative employment quickly and would remain active in the labour force. However, given their skills and experience, their expected gross annual salary in their best alternative job is estimated at $23,700.

The annual cost of the project is estimated at $8 million. The question is therefore whether this project is socially profitable.

Resolution

From the perspective of the **private profitability** of the enterprise, the project is profitable, since it generates a reduction in wage costs of 300 × $35,500, or $10.65 million, which exceeds the project cost of $8 million.

However, the social valuation of the benefits must be based on the value of the output that these displaced workers can generate in their best alternative employment. This value amounts to 300 × $23,700, or $7.11 million. The difference of $11,800 per worker reflects a wage rent enjoyed by cashiers in their current positions. This rent constitutes a transfer from the enterprise to the workers rather than a real use of resources. As a result, the project primarily reallocates this rent from workers to the enterprise and does not, in itself, generate genuine efficiency gains.[4]

11.3.4 The social value of work: A warning

It is worth emphasizing once again that the use of labour in a project represents a social cost rather than a benefit, contrary to what is often claimed by project proponents. However, as we have just seen, this social cost may, in certain circumstances, be lower than the wage bill, particularly when a project attracts workers into the labour market or helps reduce unemployment.

In such situations, it is essential to conduct **sensitivity analyses** of the project's **NPV** under different

4. If the enterprise were to reduce retail prices as a result of the project, this could generate real effects by increasing gains from exchange in the alcohol retail market.

assumptions regarding the social cost of labour. Great caution is required before recommending a project with a positive NPV that relies primarily on downward adjustments to labour costs. Adverse labour market conditions may be temporary, especially during an economic downturn. If unemployment proves persistent, it is generally preferable to pursue structural reforms rather than attempt to conceal the problem through the adoption of socially unprofitable projects.

Finally, additional caution is warranted because the impact of a project on unemployment is often difficult to predict. For instance, a project may attract workers through migration flows, in which case the unemployment rate may not decline. Similarly, a project may reduce unemployment in one region while increasing it in another, if it leads to a reallocation of economic activity.

11.4 Conclusions

Key takeaways

- Budgetary expenditure represents the social cost of an input when the market for that input is free of significant distortions and the project's demand does not affect its price.
- If the project's demand leads to an increase in the price of an input, the social cost should be evaluated using the average price of the input before and after the project.
- In the presence of taxes or subsidies, the social cost must reflect the source of the input used by the project. The portion resulting from an increase in the quantity exchanged in the input market must be valued at the price excluding taxes and subsidies. The portion resulting from the crowding out of other economic activities using the input must be valued at the price including taxes or net of subsidies. The relative importance of these two components depends on the price elasticities of supply and demand.
- When other distortions are present, budgetary expenditure must be adjusted to reflect the true social cost.
- The social cost of labour depends on the origin of the workers mobilized by the project: whether they are already employed, newly entering the labour market, or coming from unemployment.
- The valuation of workers already employed is based on the gross wage; that of new entrants is based on the net wage; and that of previously unemployed workers is based on the social value of leisure.

- Labour valuation can be carried out using a reference wage that is a weighted average reflecting the relative importance of these three sources of labour.
- The analysis should be conducted separately for different categories of workers, taking into account the specific conditions prevailing in each segment of the labour market.
- Finally, it is essential to conduct sensitivity analyses based on alternative assumptions regarding the social cost of labour.

Back to motivation

A project requires the purchase of 3,000 steel beams at a tax-inclusive price of $5,000 each. The tax-exclusive price is $4,500 per unit. The price elasticity of supply of steel beams is estimated at 3, while the price elasticity of existing demand is 1. The total expenditure amounts to $15 million. Should this amount be treated as the social cost in the CBA of this project?

Resolution

Based on the price elasticities, it can be predicted that three quarters of the demand for steel beams generated by the project will come from an increase in the quantity traded in the market. This portion should therefore be valued at the price excluding tax. The remaining quarter will result from the displacement of other economic activities, and its social cost should be valued at the price including tax.

The reference price is therefore:

$P_r = (3/4) \times 4{,}500 + (1/4) \times 5{,}000 = \$4{,}625$

The social cost of the steel beams used by the project is thus equal to $4,625 × 3,000 = $13.87 million.

Exercices

1. (*) A major infrastructure project requires 2 million tonnes of cement, representing about 10% of current market production. The price elasticity of demand for cement is estimated at 0.2, while the price elasticity of supply is estimated at 2. The current market price of cement is $200 per tonne. Determine the social

cost of this input to be considered in a CBA.

2. (*) A project requires the use of a fleet of trucks and is expected to consume 50,000 litres of diesel per year. The price of diesel is $1.20 per litre, including $0.30 in taxes. The supply of diesel is assumed to be sufficiently elastic so that this additional demand does not affect the market price. What is the social cost associated with the use of this input to be included in a CBA? How would your answer change if the supply of diesel were perfectly inelastic?
3. (*) The government is considering a shingles vaccination program for people aged 65 and over. It is estimated that 100,000 doses will be required in the first year. The vaccine is produced by a firm holding an exclusive patent and is sold at a price of $120 per dose. Discuss the issues involved in the social valuation of these vaccines.
4. (*) A government intends to set an example in the electrification of transportation by requiring that a certain percentage of the government vehicle fleet be converted to electric vehicles. If a CBA of this project is to be carried out, what inputs should be considered and how should they be valued?
5. (*) In a neighbourhood, there is a fixed supply of 70 building lots owned by several landowners. Private demand for land in this area is represented by a downward-sloping curve. The market price of a lot is estimated at P = $40,000. The municipality plans to create a conservation area on this land in order to preserve water quality and intends to use its power of expropriation, offering each owner the market value of $40,000 per lot. The project's budgeted expenditure is therefore 40,000 × 70 = $2,800,000. Is this an appropriate measure of the social cost? If so, explain why. If not, determine the true social cost.
6. A municipality is considering hiring a person for one year to promote regional economic development. To do so, it receives a government grant of $10,000, on the condition that the person hired is currently unemployed. The gross salary for the position is $50,000, corresponding to a net salary of $35,000. On average, individuals with the required skills receive unemployment benefits of $18,000 per year. What social cost should be included in the CBA of this project?
7. In accordance with Section 11.3.1, workers engaged in a project may come from three distinct sources, each associated with a specific social cost of labour. Using the **party approach**, identify the costs and benefits (including transfers) for each party involved in order to reconstruct the appropriate social cost. For example, in the case of displaced workers, the relevant parties are the original employer and the project employer.

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12.

SECONDARY AND INDUCED EFFECTS

Motivation and learning objectives



You are required to conduct a cost–benefit analysis of a $5,000 subsidy program for the purchase of an electric vehicle. The primary market affected by this measure is, naturally, the market for electric vehicles. However, the program also affects secondary markets, notably the markets for conventional vehicles and charging infrastructure. Should these secondary effects be taken into account in the CBA? Is it necessary to account for the reduction in gasoline expenditures and the increase in electricity consumption? Is there not a risk of **double counting**?

In this chapter, we use this example to illustrate the complex issues surrounding whether and how secondary effects should be incorporated into a CBA.

As indicated in Chapter 2, the analyst must first identify all the impacts of a project and then classify them into the following categories:

- Impacts that must be included in the CBA;
- Impacts that could, in principle, be included but are excluded because they are considered minor, diffuse, or too complex to value;
- Impacts that should not be included in the CBA because they are already accounted for or because they are not additional.

In this chapter, we establish several rules of practice regarding the inclusion or exclusion of side

effects and induced effects in a CBA. Although this is a complex issue, it is essential to master it in order to avoid major analytical errors.

By the end of this chapter, you will be able to:

1. Identify the different types of side effects;
2. Determine the conditions under which side effects should be included in a CBA;
3. Understand when induced effects may be legitimately considered, as well as the limitations associated with their measurement.

12.1 Primary effects and secondary effects

As a reminder, a project has a **primary** (or direct) effect in a market if it directly causes a change in the quantity or quality of a good available on that market (project outputs) or in the quantity of resources used (inputs).

A **secondary** (or indirect) effect arises when the equilibrium of a market changes as a result of interactions between that market—referred to as a "secondary" market—and a primary market. Various types of interactions can link these markets, including substitution or complementarity relationships in consumption or production, as well as links stemming from participation in the same value chain.

In the example of the electric vehicle purchase subsidy program, the primary market is the market for electric vehicles. Secondary markets include those for conventional vehicles and gasoline (substitutes in consumption), as well as charging stations and electricity (complements in consumption).

Figure 12.1 illustrates the impact of the program on the **primary market**. To simplify the analysis, we assume that electric vehicles are a homogeneous product, which justifies the existence of a single price of $45,000 in this example. We also assume that the supply of electric vehicles is perfectly elastic. These assumptions are plausible, as the jurisdiction implementing the program is relatively small, so an increase in the quantity sold has only a negligible effect on production costs.

In this example, the $5,000 subsidy is fully passed on to buyers, reducing the purchase price to $40,000. This price decrease leads to an increase in the quantity sold, from 1,000 to 1,500 electric vehicles.

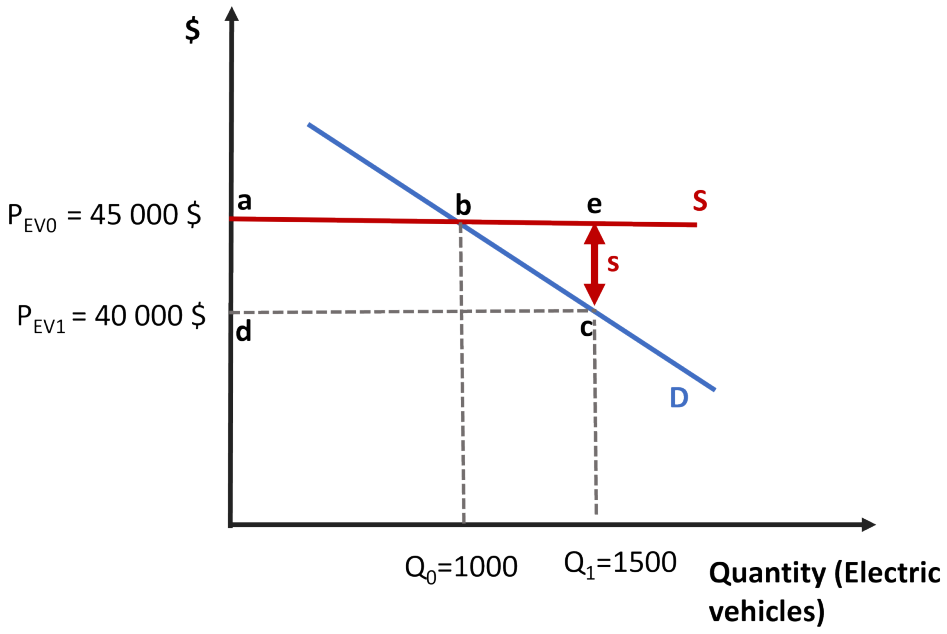


Figure 12.1 Impacts on the primary market of electric vehicles

In this context, the primary effects to be considered in a CBA using the **part-by-part approach** are as follows:

- Electric vehicle buyers benefit from an increase in surplus equal to the area of surface *abcd*, or $6.25 million;
- There is no impact on the surplus of electric vehicle producers;
- The government bears the cost of the subsidy, resulting in a reduction in its surplus equal to the area of surface *aecd*, or $7.5 million.

The net effect on the primary market is therefore a loss of surplus equal to the area *bec* (–$1.25 million).

We now turn to secondary effects, which can be grouped into three categories:

1. **Mirror effects** correspond to alternative expressions of primary effects and should therefore not be counted, in order to avoid double counting;
2. **Price effects** arise from price changes in secondary markets induced by the project. These price changes can generate real effects that may need to be taken into account;
3. **Distortion-related effects** correspond to changes induced by the project in the impacts generated by pre-existing distortions in secondary markets. These effects must be taken into account.

Each of these three categories of secondary effects is examined in more detail in the following sections.

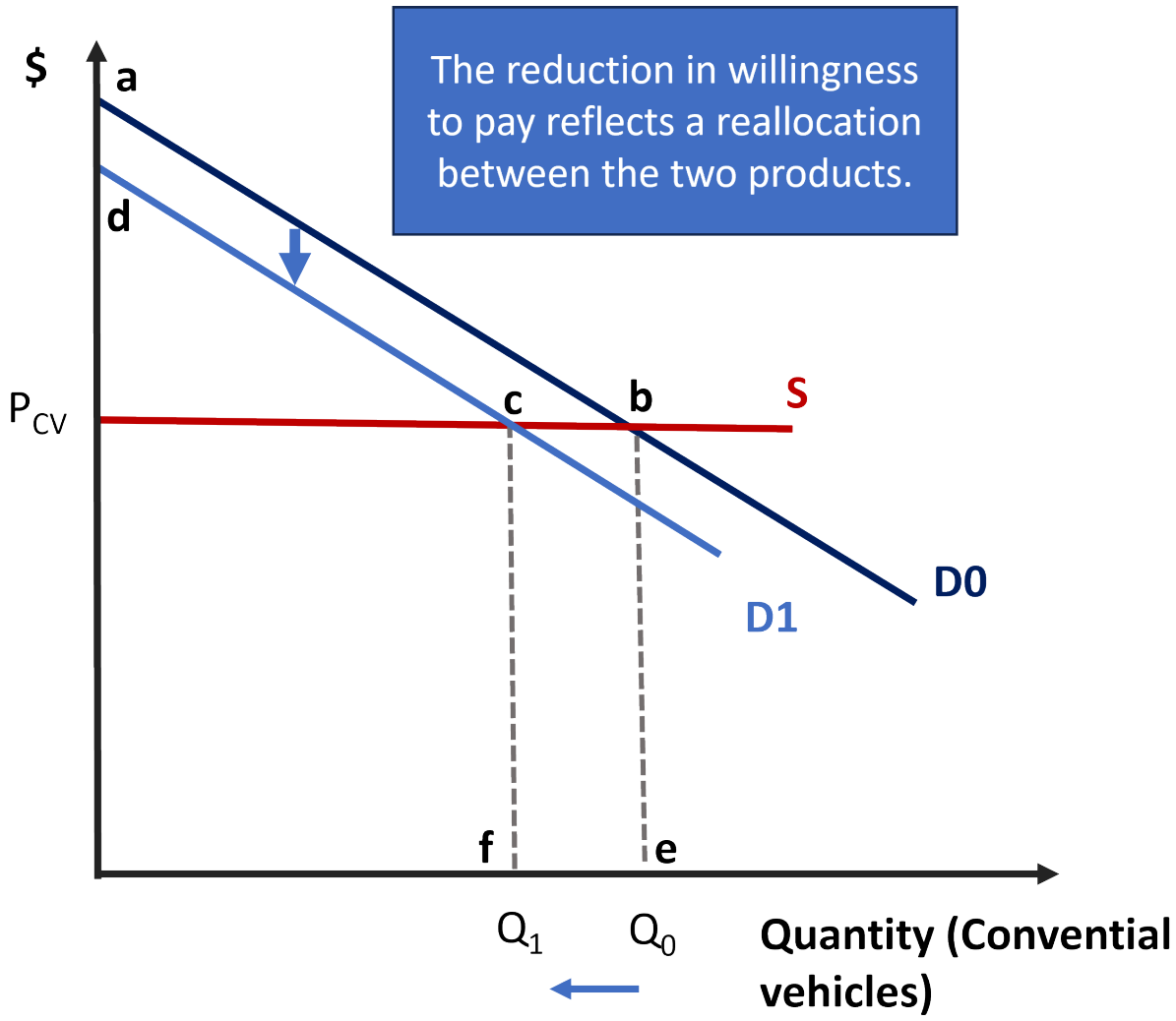
12.2 Mirror effects

Mirror effects are secondary effects generated by a project that merely represent an alternative manifestation of the direct effects. As a result, they should not be included in the CBA **if the corresponding direct effects are already taken into account**.

To better understand these effects, it is useful to analyze them in simplified settings where other types of secondary effects are absent. We therefore assume that prices in secondary markets do not change (no price effects) and that these markets are free of distortions (no distortion-related effects). We will successively examine mirror effects in the case of substitute goods and complementary goods in consumption. The same reasoning applies to other types of relationships between markets, such as those arising within a value chain, as illustrated in Exercise 1.

12.2.1 Impacts in a substitute market

A conventional vehicle is a substitute in consumption for an electric vehicle, since both satisfy the same mobility needs. Figure 12.2 illustrates the indirect impact of the subsidy on this secondary market: the demand curve for conventional vehicles shifts downward from D_0 to D_1, reflecting the decrease in the price of the substitute good. We assume that the supply of conventional vehicles is perfectly elastic, so that their price is unaffected by the reduction in demand. In addition, we abstract from any distortions in the market for conventional vehicles. These assumptions are adopted in order to isolate the mirror effect.



It might seem relevant to include in the CBA of the program the area of the surface *abcd* in Figure 12.2 as a loss of surplus for consumers of conventional vehicles. However, doing so would be incorrect, because this effect does not represent a social cost but rather a reallocation of willingness to pay between two substitute goods. In other words, the overall willingness to pay for vehicle ownership and use—whether conventional or electric—has not changed. What the subsidy modifies are the parameters that influence the choice between a conventional vehicle and an electric vehicle. Consequently, the effect observed in the secondary market is merely a reflection of the primary effect (a mirror effect) that has already been accounted for in the CBA.

Note that this mirror effect does not generally have the same magnitude as the corresponding primary effect. In other words, the area of the surface *abcd* in Figure 12.2 does not generally have the same value as the surface *abcd* in Figure 12.1. This implies that the mirror effect most often represents a "deformation" of the primary effect. Nevertheless, under certain assumptions and within a formal theoretical framework, it is possible to recover the value of the primary effect from the value of the secondary effect (see Chapter 14).

One might also ask whether the reduction in expenditure in the conventional vehicle market, represented by the area *cbef*, should be considered a benefit. Once again, there is no need to include this effect, since this

expenditure is simply reallocated to the electric vehicle market, where it contributes to generating additional surplus that is already captured in the primary effect.

12.2.2 Impacts in a complementary market

The decrease in the price of electric vehicles resulting from the subsidy will also lead to an increase in demand for home charging stations. In Figure 12.3, this effect is illustrated by a rightward shift in the demand curve for charging stations from *D0* to *D1*. We assume that the supply of charging stations is perfectly elastic, so that their price remains unchanged (i.e., there is no price effect).

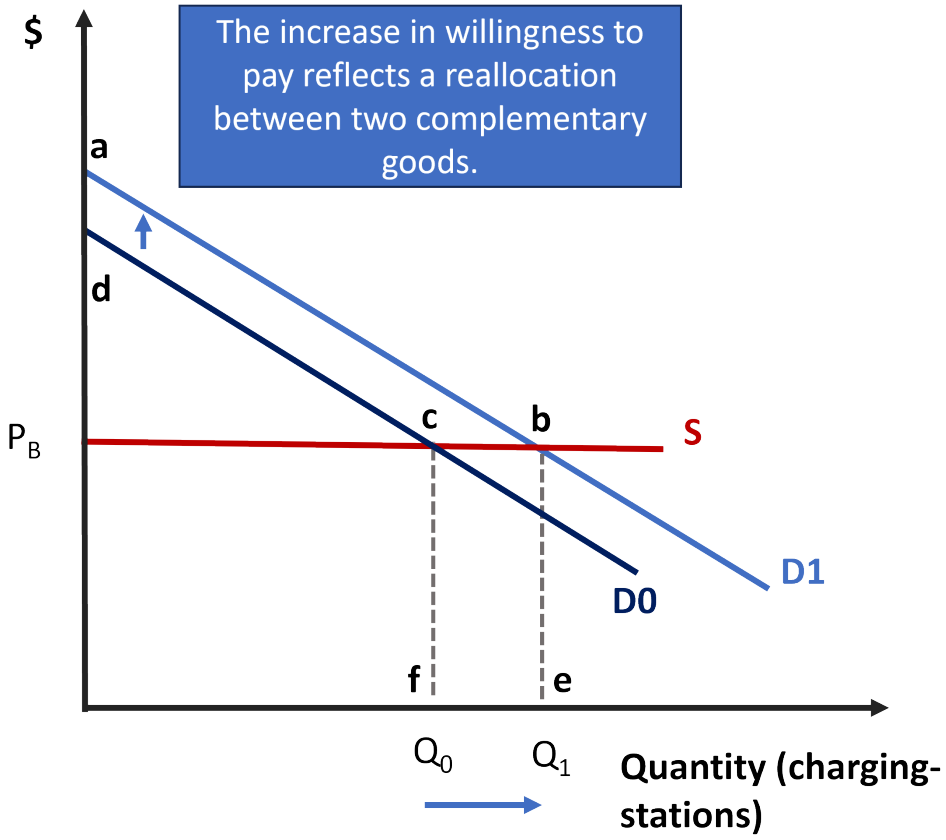


Figure 12.3 The impact of the subsidy for the purchase of an electric vehicle on the market for the complementary good of home charging stations

Again, it would be inappropriate to include the area *abcd* in Figure 12.3 in the CBA. The increase in willingness to pay for a charging station merely reflects a reallocation of willingness to pay between two complementary goods. The subsidy reduces the price of an electric vehicle by $5,000, and this amount can therefore be reallocated to the willingness to pay for a charging station. Including this mirror effect in the CBA would amount to double counting.

12.3 Price effects

So far, we have considered situations in which the equilibrium price in the secondary market is not affected by the project. However, mirror effects can lead to changes in the equilibrium price in the secondary market, generating additional side effects known as price effects.

Suppose, therefore, that the increase in demand for home charging stations resulting from the electric vehicle subsidy program leads to an increase in the price of installing these stations. Figure 12.4 illustrates this situation. Because supply is not perfectly elastic, the increase in demand raises the equilibrium price of installation from P_{B0} to P_{B1}.

As before, the mirror effect associated with the increase in willingness to pay for charging stations should not be taken into account, since it merely reflects a reallocation of willingness to pay already captured in the primary market.

By contrast, the increase in the equilibrium price has additional consequences for consumer and producer surplus in this secondary market. The higher price reduces consumer surplus, evaluated from demand D_1, by the area *abcd*. Part of this loss is transferred to charging station installers, whose surplus increases by the area *abed*. The net effect associated with the price change in the secondary market is therefore a loss of surplus equal to the area *bce*. This impact is not a mirror effect and must be included in the CBA. Its valuation requires determining the quantity that would be sold under demand D_1 at the initial price (that is, at point *c*).

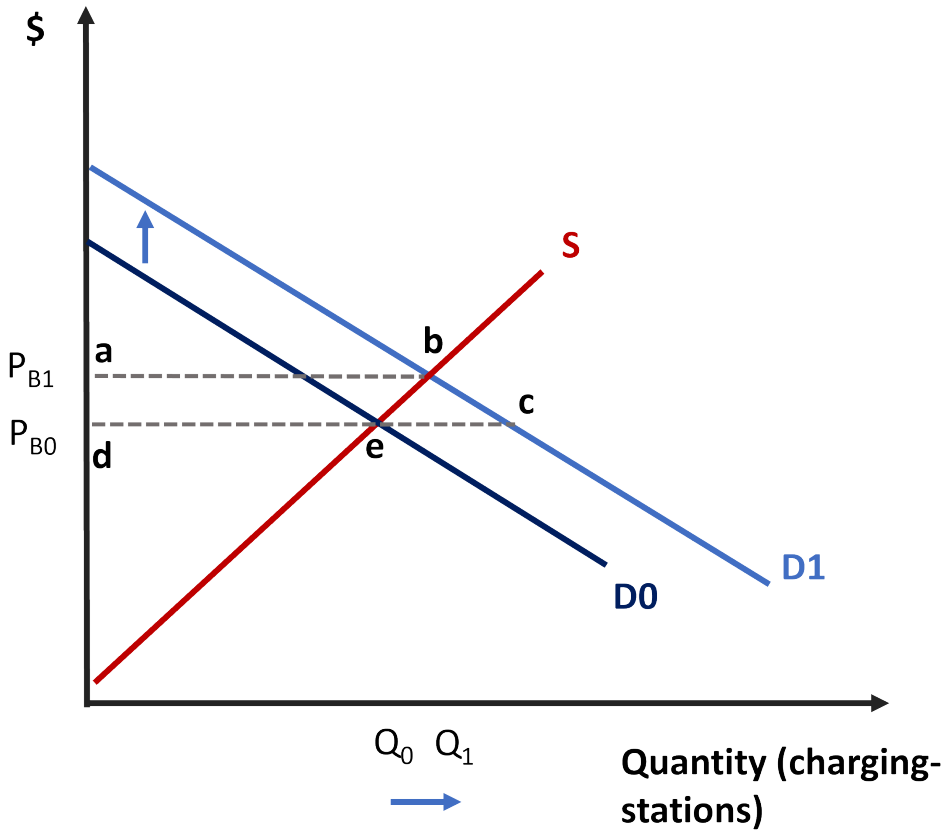


Figure 12.4 Impacts on the terminal market with increasing supply

The price effect in a secondary market can sometimes be ignored

Boardman et al. (2018) argue that a price effect in a secondary market may be ignored when the supply and demand curves used in the primary market analysis do not explicitly incorporate feedback effects arising from price changes in the secondary market. This idea can be clarified by returning to the example of the charging-station market.

In our example, the increase in the price of charging stations would, in principle, lead to a downward adjustment in the demand for electric vehicles, since charging stations are a complementary good and their higher price raises the full cost of owning an electric vehicle. However, in practice, the evaluation of the direct effect in the electric vehicle market often ignores this feedback mechanism. This occurs, for instance, when the demand function used to value the primary effect does not explicitly include the price of charging stations as one of its determinants.

In such a case, the direct effect on the primary market is overstated, because it implicitly assumes that the price of complementary goods remains unchanged. Importantly, the magnitude of this overestimation is of the same order as the price effect observed in the secondary market. Consequently, ignoring the price effect in the secondary market can, in this specific context, partially or fully offset the overvaluation of the primary effect.

This argument provides a pragmatic justification for excluding certain secondary price effects from the CBA, provided that the analyst is aware of the underlying assumptions and that the demand functions used in the primary market do not already internalize these feedback mechanisms.

Rule of practice

If the assessment of the direct effect is based on supply and demand curves that do not explicitly account for prices in a secondary market, ignoring the price effect in the secondary market helps offset the overestimation of the effect in the primary market.

12.4 Effects associated with distortion

If the secondary market is affected by a distortion whose consequences are modified by the project, the CBA must account for these changes.

The most straightforward case concerns the presence of external costs in the secondary market. In the example of the electric vehicle subsidy program, the project also leads to a reduction in gasoline demand, since gasoline is a substitute (see Figure 12.5). If the price of gasoline does not fully reflect the social costs associated with its consumption—for example, if greenhouse gas emissions and air pollution are not perfectly internalized—then the CBA of the subsidy program must incorporate the reduction in external costs resulting from lower gasoline consumption.

In Figure 12.5, the avoided environmental cost is represented by the area abcd. However, it is important to emphasize once again that the reduction in gasoline expenditures (the area dcef) should not be included in the CBA, because this effect is already captured in the primary effect on the electric vehicle market. Indeed, the willingness to pay for an electric vehicle—and therefore consumer surplus—increases when the price of gasoline is higher.

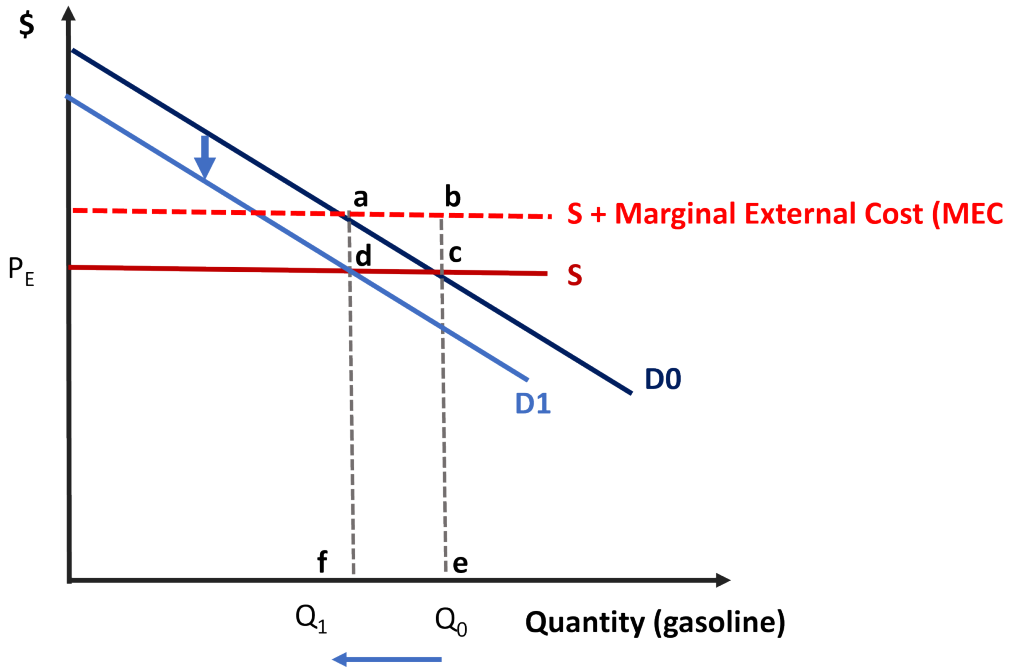


Figure 12.5 The impact on a secondary market in the presence of distortion

12.5 Valuation of side effects as an alternative

As indicated above, mirror effects are reflections of primary effects. This opens up the possibility of valuing secondary effects when the assessment of primary effects is not feasible or not relevant. Let us consider these two situations in turn.

12.5.1 Primary effects cannot be assessed

Some projects generate primary effects that should, in principle, be included in the CBA, but that are difficult

or impossible to measure. This may occur, for example, when data on the primary market are unavailable, or when the primary effect takes place in a "missing" market, that is, a market without price-based transactions between buyers and sellers. Such situations are particularly common for intangible effects, such as those related to health, the environment, or mortality risks.

In these circumstances, the analyst may rely on the valuation of secondary effects. In Chapter 14, we examine several techniques for valuing intangible effects that are based on this indirect approach. The box below presents a simple example of valuation through secondary effects.

Example: Valuing the cost of polluting a river

A municipality is planning to install a sewer system that will discharge its effluent into a river. This will result in a deterioration of downstream water quality, affecting a local cranberry producer who uses river water for harvesting and pre-washing berries. The producer sells cranberries on a competitive international market. How can this negative impact be assessed?



Resolution

The primary market affected by the project is the market for water. Panel A of Figure 12.6 illustrates the cranberry producer's demand for water as a function of its price. Initially, the price of water is P_0 = \$0. The project increases the producer's implicit price of water to P_1, since the producer may need, for example, to transport clean water by tanker trucks or to treat contaminated river water. The resulting loss of consumer surplus (area *abcd*) therefore represents the cost that must be included in the CBA.

However, there is likely to be little direct information on this primary market, given the absence of explicit transactions. In other words, this is a "missing" market. It may therefore be more practical to assess the project's impact through a secondary market further down the value chain, namely the cranberry market (see Panel B of Figure 12.6). In this market, the effect of the project takes the form of an increase in production costs, which reduces producer surplus—that is, the operating profit of the cranberry operation—represented by area *efgh*.

In this particular context, the mirror effect in the secondary market should closely reflect the primary effect, so that area *efgh* should be close in value to area *abcd*. In more complex situations, however, it may be necessary to develop a formal theoretical model to determine how the primary effect can be recovered from the observed secondary effect.

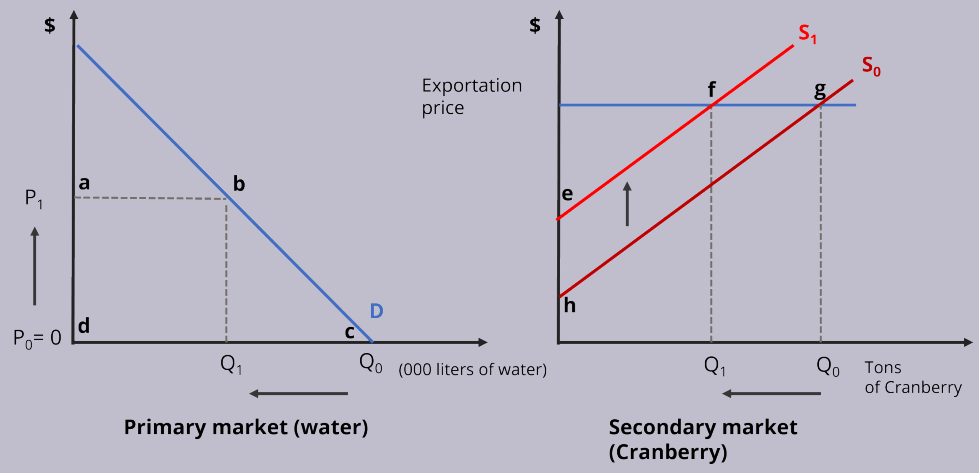


Figure 12.6 The primary market for water and the secondary market for cranberries

12.5.2 Primary effects are not relevant

Some projects, because of the spatial definition of their analytical horizon, make the primary effect irrelevant (for example, impacts on the surplus of foreign producers). In such cases, the mirror effect in a secondary market is obviously no more relevant. However, potential price effects in secondary markets must still be taken into account. Effects related to existing distortions must also be included.

Example: An international conference

A municipality is considering providing financial support for the organization of an international conference aimed at attracting foreign participants, and it is evaluating this project using a local **spatial horizon**.

In this context, the primary market affected by the project is the conference itself. The project generates surplus for conference participants, but this surplus is not relevant given the chosen

spatial horizon of the CBA. Assuming that registration fees cover average variable costs, the producer surplus associated with the conference is zero. Under these conditions, it becomes essential to examine the repercussions on secondary markets.

For example, hosting the conference may stimulate demand for hotel rooms, which are a complementary good to the conference. If the event increases operating profits for local hoteliers, this effect should be included in the CBA. The same reasoning applies to the restaurant sector. However, it is important to note that if meal prices rise as a result of the conference, this may negatively affect the welfare of local consumers. In addition, increased greenhouse gas emissions associated with local transportation of participants, as well as other local environmental impacts of the event, must also be taken into account as distortion-related effects.

Finally, it is essential to distinguish clearly between a CBA and **a tourism impact assessment**. The latter typically evaluates a project based on the total expenditure by foreign visitors attracted by the event, without accounting for the associated costs.

12.6 Induced effects

As we have repeatedly emphasized, induced effects, or multiplier effects, are generally excluded from CBAs for three fundamental reasons:

1. **They are often not additional**: If a government invests $1 billion in building a hospital, it is not appropriate to include spillover effects, since similar spillovers could arise if the same amount were spent on renovating schools. CBA operates under the assumption that the order of magnitude of spillover effects would be comparable across alternative uses of public funds.
2. **They do not measure net benefits**: Spillover measures typically combine both social costs and social benefits. For example, value added includes both operating profits (a benefit) and labor costs (a cost), making it unsuitable as a measure of net social gains.
3. **They often assume the absence of constraints on available resources**: Induced effects are frequently estimated using input–output models, which assume an economy in which productive resources are systematically underutilized. In such models, adjustments occur only through changes in quantities, as prices are assumed to be constant (perfectly elastic supply). This assumption is unrealistic in economies operating near full employment, where a project may lead to price increases and crowding-out effects on other activities.

That said, some projects generate economic impacts that are genuinely additional, in the sense that they inject

new resources into the economy. A clear example is a foreign investment of one billion dollars to build a factory. At the national level, this investment does not directly generate an opportunity cost, since it comes from a promoter outside the spatial horizon. In this case, induced effects may therefore be relevant.

However, the two other limitations of spillover analyses remain: induced effects do not measure net benefits, and they ignore the risk of displacement of economic activity when certain resources, such as labor, are scarce.

12.7 Conclusions

Key takeaways

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- Whether or not to account for side effects in a CBA is a complex issue, as these effects can take different forms.
- A mirror effect corresponds to the reflection of a primary effect in a secondary market and should therefore not be included if the CBA already incorporates an assessment of the primary effect.
- A price effect refers to the incidental impacts arising from a change in the equilibrium price in a secondary market as a result of the mirror effect.
- A price effect should be included in the CBA, unless the primary effect has been overestimated because the supply and demand curves used do not account for prices in the secondary market.
- The valuation of price effects in secondary markets becomes essential when measuring the primary effect is not feasible or not relevant.
- A distortion-related effect corresponds to a change in the impacts of an existing distortion in a secondary market caused by the project.
- Effects associated with distortions must be included in the CBA.
- In some projects, induced effects may be additional, making their consideration relevant for assessing the **social profitability** of the project. However, traditional measures of spillovers are often inadequate, as they combine both benefits and costs. Moreover, they are generally based on the assumption that the project does not crowd out other economic activities.

- Finally, the valuation of a primary effect may sometimes be inferred by measuring its reflection in a secondary market. This approach, however, requires the development of a theoretical framework and the adoption of specific assumptions to clarify the relationship between the value of the primary effect and that of the secondary effect.

Exercises

1. (*) A project aims to promote the quality of national cheeses abroad in order to increase their export prices. Using a graphical analysis, examine the impact of this project on the primary cheese market and on the secondary milk market, which is a key input in cheese production. Then determine whether it is appropriate to take the impacts on the milk market into account in the CBA of this project.

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PART III
VALUING INTANGIBLE EFFECTS

As Figure 1 illustrates, a project that reduces the quantity or quality of a non-market good generates intangible costs. For example, building a new road increases air pollution in a region. Conversely, the opposite can also occur: constructing a tramway, by reducing car traffic, can improve air quality.

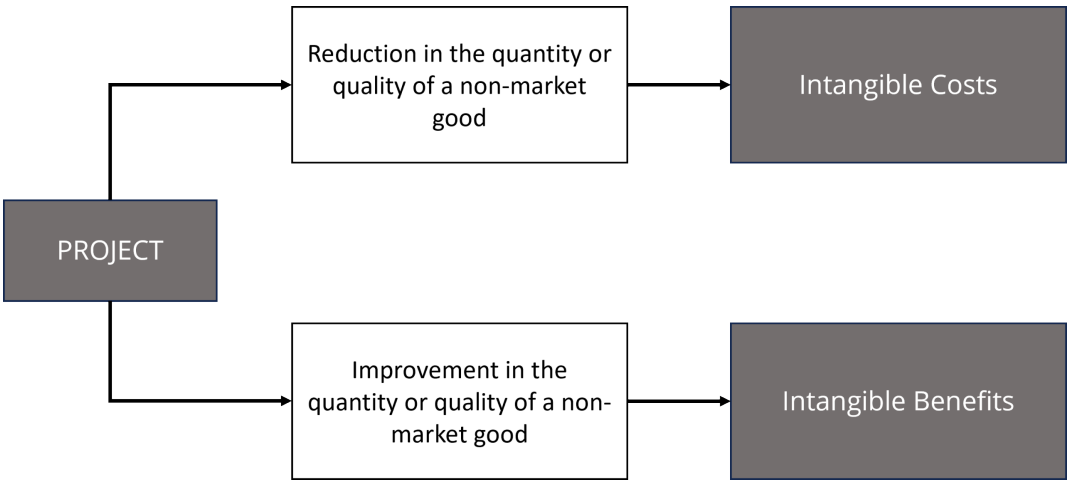


Figure 1. The intangible impacts of a project

In the previous section, we established that intangible effects can be analyzed conceptually using the tools of microeconomics. In this perspective, it is possible to conceive of a demand for air quality that reflects individuals' willingness to pay for access to clean air.

In practice, however, intangible effects are associated with resources for which no explicit market exists. There is no market in which clean air can be bought or sold. The absence of a market implies the absence of direct transactions and observable prices, which makes valuation more complex. To address this difficulty, a variety of valuation techniques have been developed. Figure 2 classifies these approaches into three broad categories:

- Pragmatic approaches, which are often used despite not being grounded in explicit theoretical frameworks. This category includes the assessment of monetary impacts and the benefit transfer method (see Chapter 13);
- Revealed preference methods, also known as indirect methods, which value intangible effects by examining how these effects are reflected in related or secondary markets (see Chapter 14);
- Stated preference methods, or direct methods, which estimate willingness to pay for a non-market good by constructing hypothetical markets (see Chapter 15).

In Chapter 16, we show how these different techniques have been applied to estimate the value of time, human life, and carbon emissions.

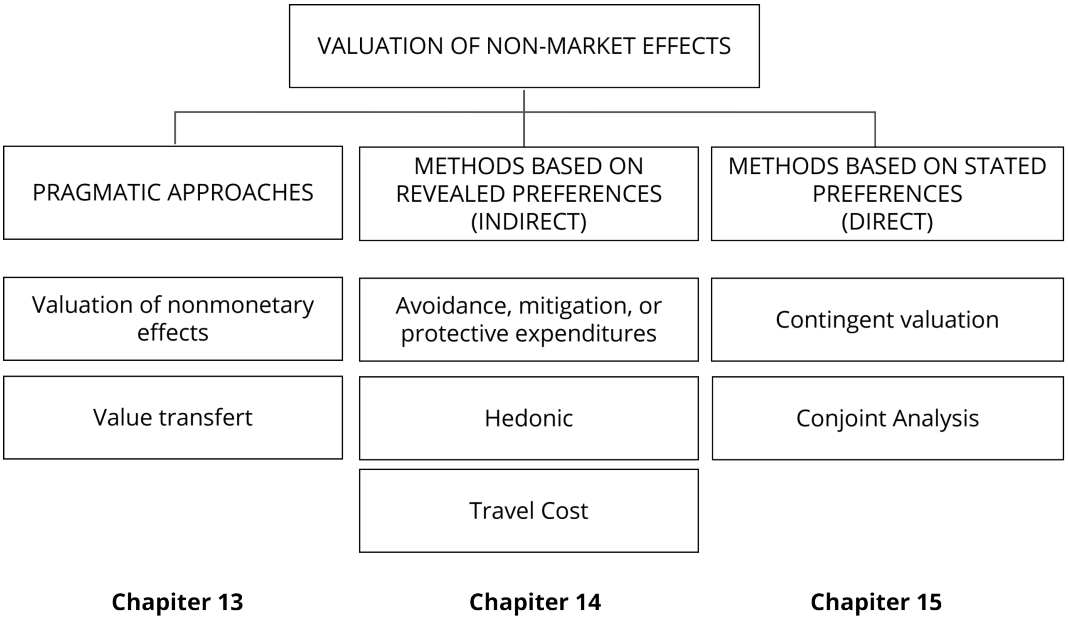


Figure 2. Classification of techniques for evaluating intangible or non-market effects

Total economic value

Before examining these techniques, it is important to clarify the sources of a resource's economic value. Figure 3 illustrates the different components that together define total economic value.

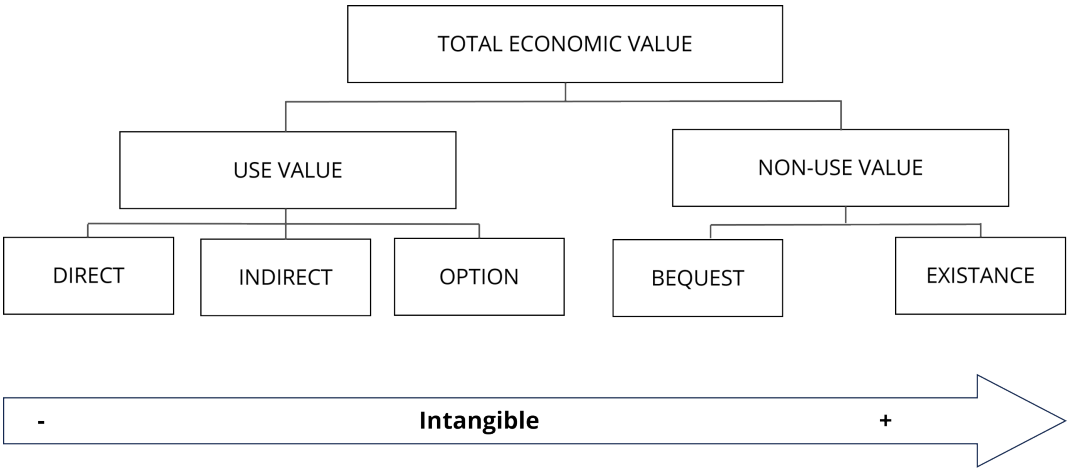


Figure 3. Components of total economic value

The first source of value attributed to a resource is linked to its use, which may be direct, indirect, or optional.

- **Direct use value** is associated with the primary use of a resource and often involves its consumption. For example, a forest provides direct consumptive use value through activities such as logging, hunting, fishing, or mushroom picking. However, direct use also includes non-consumptive uses, that is, activities

that do not reduce the quantity or quality of the resource. Walking in a forest and enjoying the scenery are examples of direct uses that generally have no impact on the resource itself.

- **Indirect use value** arises from secondary functions provided by a resource, without requiring a direct interaction with it. For example, a forest contributes to water filtration, carbon sequestration, and biodiversity conservation. These environmental functions generate indirect use values that do not require a physical presence in the forest.
- **Option value** reflects the value placed on a resource because of its potential future use. Part of the justification for protecting the Amazon rainforest, for instance, lies in the possibility that it contains yet undiscovered resources that could become valuable in the future, such as a fungus that might lead to the development of a new medical treatment. There is therefore a willingness to pay to preserve the option of exploiting such resources in the future.

Value may also arise for reasons unrelated to use. Two additional sources are commonly distinguished.

- **Bequest value** refers to the importance attributed to a resource for the purpose of passing it on to future generations. For example, individuals may be willing to contribute to the preservation of primary forests even in the absence of direct or indirect benefits, motivated by the desire to leave this resource to future generations.
- **Existence value** reflects a willingness to pay to protect a resource regardless of any current or future use by humans. For example, people may be willing to pay to preserve endangered species or unique natural sites, independent of any anthropocentric benefit.

As indicated by the arrow in Figure 3, these sources of value are arranged from left to right according to their degree of intangibility. Direct uses often give rise to market transactions, such as the timber trade, whereas existence value is highly intangible and relates more closely to ethical, spiritual, or philosophical considerations.

This classification is most commonly used in the valuation of environmental resources, such as ecosystems or biodiversity. However, it can also be applied to human-made infrastructure. For instance, an airport may generate direct use value through air travel, indirect use value through improved regional connectivity, and option value through potential future uses. There may also be a bequest value associated with preserving this infrastructure for future generations.

Warning

A rigorous analysis of non-market valuation techniques requires complex mathematical models and advanced statistical methods that lie beyond the scope of this handbook. The following chapters therefore provide an introductory overview of these techniques, focusing on their underlying principles, areas of application, strengths, and limitations. Champ, Boyle, and Brown (2017) present a much more formal treatment of these methods and discuss recent methodological developments.

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13.

TWO PRAGMATIC APPROACHES

Motivation and learning objectives

An industrial project will emit air pollutants that degrade air quality in a region. This pollution will have adverse effects on residents' respiratory and cardiovascular health, as well as cause premature deterioration of buildings and infrastructure.

How should these impacts be valued in a CBA?

Rigorous valuation of intangible effects is often complex and costly to implement, which means that, in practice, analysts frequently rely on simplified approaches. In this chapter, we examine two pragmatic valuation methods that are commonly used, while also highlighting their limitations. By the end of this chapter, you will understand the principles, advantages, and limitations of:

1. Monetary impact assessment (or damage assessment);
2. The transfer method.

13.1 Assessment of monetary impacts

13.1.1. The principle and scope of application

Monetary impact assessment is not, strictly speaking, a method for valuing **intangible effects**, but rather a strategy for valuing the more tangible impacts resulting from a change in the quantity or quality of a non-market good. In some contexts, this approach is also referred to as "avoided damage assessment."

As noted earlier, a project may affect the quantity or quality of a non-market good. For example, an industrial project may degrade air quality, which is a non-market good. Ideally, one would seek to assess the **willingness to pay (WTP)** to avoid this deterioration in air quality, or the **willingness to receive (WTR)**

compensation to accept it. As illustrated in Figure 13.1, this is conceptually equivalent to measuring the area under the **demand curve** between the level of air quality before and after the project. In practice, however, this assessment is difficult because there is no market from which a demand curve for air quality can be directly inferred.

Nevertheless, WTP or WTR will depend on the damages caused by the deterioration in air quality. Some of these damages may be relatively tangible and easier to express in monetary terms, such as the accelerated deterioration of buildings requiring additional maintenance. Others are more intangible, such as the physical suffering associated with respiratory illnesses or the inconvenience of having to remain indoors during periods of severe air pollution.

> Monetary impact assessment (or avoided damage assessment) consists of approximating part of the willingness to pay or willingness to receive associated with a change in a non-market good by valuing **its most tangible impacts**.

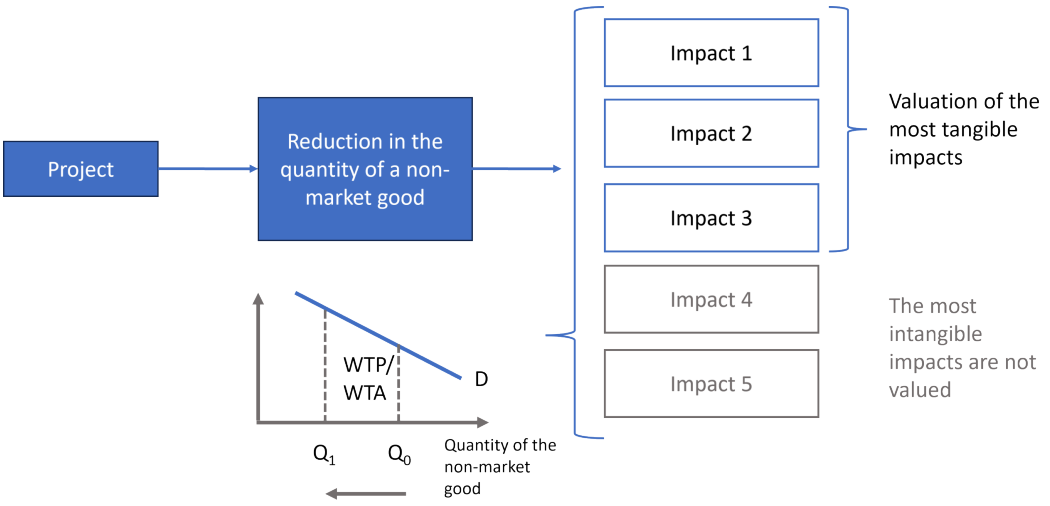


Figure 13.1 The principle of the monetary impact assessment approach

In our example, the most tangible damages associated with air pollution include:

- Maintenance and repair costs for buildings and infrastructure;
- Direct health care costs resulting from pollution-related illnesses (hospitalizations, medical treatments);
- Indirect health-related costs, including productivity losses due to absenteeism;
- The costs associated with premature mortality.

This approach is conceptually relatively straightforward, but its implementation can nevertheless be demanding, particularly when precise estimates are required. The box below summarizes the steps involved in estimating the cost of air pollution in Canada.

Example: The health costs of air pollution in Canada



Air pollution has significant health impacts. It is the fifth leading risk factor for premature mortality worldwide (Health Canada, 2021). Three indicators of air pollution are commonly used: fine particulate matter (PM2.5), ground-level ozone (ozone), and nitrogen dioxide (NO2). This pollution is mainly caused by human activities such as fossil fuel combustion, but it can also result from natural events such as forest fires. Health Canada (2021) regularly assesses the health costs of air pollution in Canada. The methodology involves three main steps:

1. Estimating population exposure to pollutants across different regions of the country, taking into account emissions, their geographic distribution, and processes of dispersion and chemical transformation. These estimates are based on ground monitoring, satellite data, and atmospheric models;

2. Determining, using dose–response functions, the increase in health risks associated with different outcomes (e.g. asthma symptoms, chronic bronchitis, premature mortality). A distinction is made between acute exposure (pollution peaks) and chronic exposure;

3. Monetarily valuing the costs associated with these impacts (health care expenditures, productivity losses, and the value of statistical life). Health Canada relies on values drawn from the existing literature using the transfer method.

The results indicate that air pollution caused approximately 15,300 deaths per year in Canada in 2016, corresponding to an annual cost of $114 billion, or about $3,000 per person and 5.6% of GDP. Morbidity-related impacts add an additional cost of $5.6 billion.

13.1.2 Advantages and limitations

This approach is conceptually simple and, for some projects, it makes it possible to account for the main consequences associated with a change in a non-market good. However, it also has several limitations:

1. It provides only a partial assessment of willingness to pay. Some intangible impacts are not captured;
2. These models often fail to account for behavioral responses to changes in a non-market good. For example, individuals who are sensitive to pollution may purchase air purifiers or avoid outdoor activities during pollution peaks. Such mitigation behaviors and their associated costs are frequently ignored;
3. Implementation can be complex and often requires the use of reference values drawn from other studies (for example, estimates of the value of human life).

13.2 The transfer method

13.2.1 The principle and scope of application

The **transfer** (or plug-in) method involves using reference values drawn from existing studies. The transfer may be direct, or it may require adjustments to account for differences in context between the project being analyzed and the study from which the values are taken.

The scope of this approach is obviously very broad. Moreover, it can also be used to obtain other parameters for a CBA, including elasticities.

Meta-analyses are particularly useful for applying this method. These systematic reviews of the literature use statistical techniques to identify the factors that explain variations in estimates across primary studies addressing the same issue. For example, a meta-analysis of the value of a statistical life (VSL) examines how this value varies with average income per capita, average age, or the methodology used (Organisation for Economic Co-operation and Development, 2012). Such results make it possible to adjust reference values, notably to account for income differences between the context of the project and that of the study used to establish the original value.

Several inventories of non-market valuation studies can be useful for value transfer, including the Environmental Valuation Reference Inventory (EVRI) in Canada, ENVALUE in Australia, and the New

Zealand Non-Market Valuation Database. To illustrate how this approach works, we present below the results of a transfer analysis based on a meta-analysis of wetland valuation.

Example: The value of wetlands in the watersheds of the Yamaska and Bécancour rivers



Wetlands provide a wide range of non-market ecosystem services, such as water filtration, habitat for flora and fauna, and flood protection. He et al. (2015) conducted a meta-analysis based on 51 studies from 21 countries with the objective of valuing wetlands in the Yamaska and Bécancour River watersheds in Quebec.

The studies included in the meta-analysis rely on different valuation techniques, such as the travel cost method (Chapter 14) and the contingent valuation method (Chapter 15). In total, the 51 studies provide 106 estimates of wetland values expressed in U.S. dollars per hectare per year. These estimates display substantial variability. For instance, studies conducted in Asia report an average value of approximately $60,000, whereas those conducted in North America report an average of about $160,000. Since several factors may explain these differences, He et al. (2015) estimate a multiple regression model using the 106 observations. The model takes the following form:

$$\ln V_i = a + b_{serv}X_{serv} + b_{cara}X_{cara} + b_{reg}X_{reg} + b_{meth}$$

With:

V_i: the value in U.S. dollars per hectare per year obtained from observation i; a and b_* are the regression parameters to be estimated;

X_{serv}: variables characterizing the importance of the ecosystem services provided by the wetland in observation i. For example, these variables may indicate whether the wetland has high biodiversity, plays a critical role in flood control, or is used for water filtration;

X_{cara}: variables measuring certain characteristics of the wetland, such as its size, or whether it is isolated or surrounded by other wetlands;

X_{reg}: variables characterizing the region of observation i, such as the presence of agricultural or forestry activities and the level of income per capita;

X_{meth}: variables describing the methodology used to obtain observation i, for example whether the valuation method is based on stated or revealed preferences.

The results indicate that wetland value is positively influenced by the importance of biodiversity protection, flood protection, and the scale of commercial activities generated, particularly fishing. In addition, income per capita has a positive effect, with an elasticity of 1.3. By contrast, wetland area has a negative effect on value per hectare.

Based on these estimates, it is then possible to calculate the value of wetlands in the Yamaska and Bécancour watersheds. This is done by using the estimated coefficients in the equation above (a and b_*) together with the values of the X variables for each wetland being assessed. This approach yields, for each wetland, a value that reflects both its specific characteristics and those of its region.

This value transfer exercise results in an average value of $9,080 per hectare for wetlands in the Yamaska watershed and $4,702 per hectare for those located in the Bécancour watershed. The total annual value of wetlands is therefore estimated at $170 million for the Yamaska watershed and $131 million for the Bécancour River watershed.

13.2.2 Advantages and limitations

The main advantages of this approach are its simplicity and its very low cost in terms of time and financial resources. However, it also has several limitations:

- The analytical context of the project under study often differs significantly from that of the study from which the value is transferred. While some adjustments can be made based on observable characteristics, there are always differences that cannot be fully controlled;
- The quality of the study underlying the transferred value must be carefully assessed in order to avoid propagating errors. In addition, sensitivity analyses with respect to the transferred values should be carried out.

13.3 Conclusions

Key takeaways

- Monetary impact assessment focuses on valuing the most tangible impacts of a change in a non-market good.
- This approach provides a lower bound on impacts, but it can sometimes lead to a substantial underestimation of the true social effects of a project.
  Moreover, it often requires the use of reference prices for other non-market goods.
- The transfer method consists of using reference values for non-market effects that have been estimated in other contexts.
- It is a simple, rapid, and low-cost approach.
- The validity of a transfer depends not only on the credibility of the source study, but also on the degree of similarity between the context of the CBA and that of the original study.
- When there are significant differences between these contexts, adjustments to the reference value may be necessary.

Back to motivation

An industrial project will emit air pollutants that degrade air quality in a region. This pollution will have adverse effects on residents' respiratory and cardiovascular health, as well as cause premature deterioration of buildings and infrastructure.

How should these impacts be valued in a CBA?

Resolution

As explained in the chapter, it is possible to value the most tangible damages, such as additional health care costs or productivity losses resulting from increased absenteeism.

It is also possible to rely on reference values associated with the external costs generated by pollutants, as estimated in other studies. For example, Rojas et al. (2023) estimate a reference value of $23,084 per tonne of SOx, based on a review of the existing literature.

Exercises

1. Numerous studies on the statistical value of life (SVL) have been conducted in the United States. The current consensus places the SVL at US$5 million. In addition, the income elasticity of the SVL is estimated to be 0.8. A jurisdiction wishes to transfer this value while taking into account the following factors:
   – The jurisdiction's per capita income is 15% lower than that of the United States;
   – The median age in the jurisdiction is 42.3 years, compared with 38.1 years in the United States.

   What should the SVL be in this jurisdiction, expressed in U.S. dollars?

2. (*) Radon is a colorless and odorless gas resulting from the natural decay of radioactive elements in the Earth's crust. This gas can accumulate at high concentrations inside homes, increasing the risk of lung cancer. In Canada, the maximum recommended standard for radon exposure is 200 becquerels per cubic meter (Bq/m^3). However, the World Health Organization (WHO) recommends a lower threshold of 100 Bq/m^3 to minimize health risks. Evidence shows that the higher and longer the exposure to radon, the greater the risk of developing lung cancer. To date, research has established a link between radon exposure and lung cancer, without identifying other significant health impacts associated with this gas.

   As an analyst, develop a protocol to assess the costs associated with radon exposure in a given jurisdiction.

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14.

INDIRECT METHODS

Motivation and learning objectives

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A project aims to expand nighttime cargo operations at an airport, which will generate noise pollution for nearby residents. How can a value be assigned to these intangible costs? Given that there is no explicit market for noise levels, is it possible to infer the costs of noise from observed impacts in secondary markets?

As noted earlier, assessing willingness to pay or willingness to receive for a change in a non-market good is challenging, since such goods typically do not have an explicit market. However, in Chapter 12 we explained that, in some cases, mirror effects observed in secondary markets can be used when direct valuation of the primary effect is not feasible. This strategy underlies indirect methods, which rely on observing actual choices made in related markets. For this reason, these approaches are also referred to as **revealed preference methods**. They are particularly well suited to valuing environmental, social, and health impacts.

By the end of this chapter, you will be able to understand the principles, advantages, and limitations of:

1. The mitigation expenditure method;
2. The hedonic method;
3. The travel cost method.

14.1 The mitigation expenditure method

This approach is also referred to as the *avoidance*, *mitigation*, or *protective expenditure* method.

14.1.1 The principle and scope of application

To cope with an undesirable intangible impact such as noise, affected individuals may invest in avoidance, mitigation, or protective measures. For example, residents living near a noisy roadway may install triple-glazed windows. These mitigation expenditures can be directly included in the **monetary assessment of damages** (see Section 13.1), since they represent a real economic cost.

Alternatively, mitigation expenditures can also be used to infer the **willingness to pay** for a non-market good. This approach exploits the substitution relationship between the **primary effect** (the change in the non-market good) and the **secondary effect** (expenditures on a market good), as illustrated in Figure 14.1. Using a theoretical model, it is possible to recover the primary effect from the **mirror effect** (see Dickie, 2017).

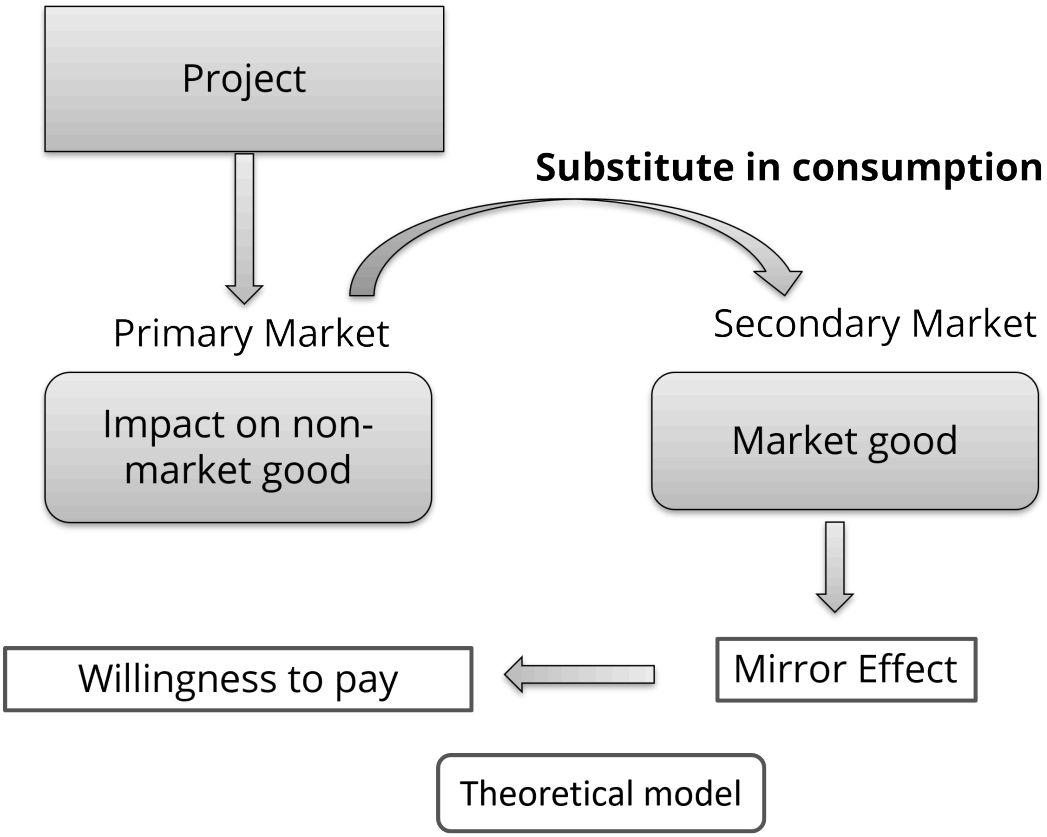


Figure 14.1 The principle of the mitigation expenditure method

This approach often relies on the idea that there is a "production function" that determines the level of a characteristic that directly provides utility[1] to the individual. For example, an individual values their lung health. The available level of this characteristic is produced jointly by a non-market public good and a market private good. The lung health of a person with asthma depends positively on air quality and on medications used to reduce asthma attacks, such as bronchodilators. Air quality and bronchodilators are therefore substitutes in the "production" of lung health. More formally, the model takes the following form:

$$U_i(S_i, x_i)$$

Ui is the utility (or welfare) function of individual i, which depends positively on Si, the level of lung health, and xi, which generically represents other determinants. Furthermore, Si is a function of ambient air quality (AQ), a non-market public good, and the use of medication (mi) to control asthma attacks, a market private good[2]. We therefore have:

1. In economics, preferences are modeled by a utility function that depends on the quantity of goods, including public goods. Individuals determine the quantity of private goods they consume by maximizing this function subject to an income constraint. They generally have no direct control over the quantity of public goods (see Bruneau and Mahoney, Module 1, 2022).

2. More concretely, Si could measure the number of days per year without an asthma attack, and QA the number of days when air quality is good and the need for medication is therefore low.

$$S_i = S(QA, m_i)$$

QA and mi are therefore substitute inputs in the production function of an individual's lung health. Clearly, this theoretical specification relies on assumptions whose validity must be carefully assessed by the analyst. In this example, is it realistic to assume that QA has no direct effect on utility?

An industrial project that leads to a reduction in QA will cause an increase in mi. Avoidance expenditure is therefore measured by $P_m * \Delta m_i$, where Pm is the price of the medication. The theoretical model makes it possible to infer willingness to pay associated with a deterioration in air quality from observed avoidance expenditures. It also highlights the assumptions required for this conversion to be valid. In very specific cases, or under restrictive assumptions, the mirror effect may directly measure the primary effect. In most cases, however, the relationship is more complex.

To apply this method, there must exist market goods that can substitute for the non-market good affected by the project. Table 14.1 presents several examples of such applications.

Table 14.1 Examples of applications of the protection expenditure method

Intangible effects	Substitute marketable goods
Pollution that affects health	Medicines, healthcare, air purifiers, masks, reducing outdoor activities, purchasing indoor sports equipment
Water pollution	Filtration systems, bottled water purchases
Climate change	Air conditioning
Value of human life	Expenses to reduce risks: • Motor vehicle security system; • Fire detectors; • Work safety measures; • Bicycle helmets; • Spending on sunscreen.

14.1.2 Advantages and limitations

This method has the advantage of relying on the observation of real choices made by individuals. When applied rigorously, it makes it possible to estimate willingness to pay and to clearly state the assumptions and limitations underlying this estimate. However, developing the theoretical model and carrying out the corresponding empirical analysis can be complex. As a result, in practice, studies are often limited to valuing avoidance expenditures, without rigorously converting them into a measure of the primary effect. This raises several issues.

1. Avoidance expenditures underestimate the direct effect

The quantity demanded of the characteristic valued by the individual (S_i in our example) is likely to change as a result of the project. Indeed, the industrial project degrades air quality, which increases the implicit price required to attain a given level of lung health S_i. After the project, the level of S_i is therefore likely to decline. As a consequence, the observed avoidance expenditures underestimate the true impact of the project on QA. Ideally, one would like to estimate the level of avoidance expenditures that would be required to keep S_i at its pre-project level.

2. Private goods may generate additional benefits

The cost of installing triple-glazed windows to reduce traffic noise from a new highway can be used to estimate the external cost of the noise generated by the project. However, such windows also improve energy efficiency. In this case, mitigation expenditures may overestimate the noise-related impacts of the project, since part of these costs may be motivated by energy savings rather than by noise reduction alone.

3. Avoidance costs depend on the level of information

Market responses to the degradation of an intangible attribute depend on individuals' level of information about the associated harmful effects. If a project affects the quality of groundwater in a region, but residents are not informed of the consequences, no avoidance expenditures will be observed, even though the damage is real.

In conclusion, this method can either complement a monetary impact assessment (see Chapter 13) by adding avoidance expenditures, or be used to infer the primary effect by developing a rigorous theoretical framework. The next box provides an example of the application of this approach.

Example: Shale gas, water contamination and avoidance expenditure



Using an econometric analysis of household data from 2005 to 2010, Wrenn, Klaiber, and Jaenicke (2016) estimate changes in household expenditures on bottled water in Pennsylvania counties following the development of unconventional gas fields. These gas fields pose a risk of contaminating groundwater and surface water. The effect is identified by comparing changes in bottled water expenditures before and after gas field development within affected counties, and by contrasting

these changes with those observed in a group of comparable counties in Ohio where no such development occurred (the control group).

The results indicate that households in counties with gas fields spend, on average, about US$11 more per year on bottled water than comparable households in counties without gas fields. At the aggregate level, this corresponds to approximately $19 million in annual protection expenditures for the affected population in Pennsylvania in 2010. This estimate should be interpreted as a lower bound, since some households may adopt other protective strategies besides purchasing bottled water, others may be unaware of the pollution risks, and some may simply accept the associated risks.

14.2 The hedonic method

14.2.1 The principle and scope of application

This method is based on analyzing the value of heterogeneous or differentiated goods, such as houses or cars. The basic principle is that the value of a good depends not only on its own characteristics, but also on the quantity and/or quality of non-market goods. For example, the value of a house depends on characteristics such as its floor area, the number of bathrooms, and the presence of a garage, but it also reflects the quality of the surrounding environment. An otherwise identical house will sell for less if it is located in a noisier neighborhood. Thus, by analyzing how property values decline as a result of higher noise levels, it is possible to infer the willingness to pay for peace and quiet. Other intangible characteristics can also be valued using this approach, such as air quality, proximity to a lake, or nuisances associated with wind turbines.

Most hedonic studies focus on housing markets, but some also examine the prices of motor vehicles in order to analyze willingness to pay for reductions in mortality risk. Certain vehicles are equipped with safety features that reduce accident risk, and these features are reflected in their market prices.

Several hedonic studies also exploit variations in wage rates across jobs with different working conditions, such as noise exposure, air quality, or occupational mortality risks. In this section, we illustrate the method using property values, but Chapter 16 provides an example of a hedonic analysis based on wages to estimate the value of a statistical life.

A hedonic study typically involves two steps. The first step is to econometrically estimate a **hedonic function**, from which hedonic prices are derived. The second step is to estimate **the demand for the intangible good**. We examine these two steps in more detail using an example that aims to measure the gross benefit of an air quality improvement project in an urban area based on property values.

Step 1: Estimation of the hedonic function

To conduct a hedonic study, one must have data that allow the statistical identification of the relationship between market value and the intangible characteristic of interest, all else being equal. In our example, this requires real estate transaction data that include property characteristics as well as one or more indicators of neighborhood air quality. The data must display sufficient variation in air quality to isolate the specific effect of this characteristic on sale prices. These data are used to estimate a hedonic function of the following form:

$$PV_i = f(c1_i, c2_i \ldots, cn_i, QA_i, Z_i)$$

where VPi is the market value of property i, c1i, c2i ... cni represent its characteristics (for example, dwelling size, lot size, number of bathrooms, or the presence of a swimming pool), QAi is a measure of neighborhood air quality, and Zi denotes other control variables. The econometric estimation of this relationship makes it possible to identify the effect of air quality (QA) on property values (PV), holding all other characteristics constant.

Economic theory predicts that an improvement in air quality increases property values, but that this effect diminishes as air quality improves further, due to a saturation effect. This implies that the estimated PV function should be concave, as illustrated in the left panel of Figure 14.2.

The results of Step 1 already allow for the assessment of certain projects, as illustrated in the box on the CBA of industrial site remediation in Nova Scotia.

Example: CBA for the decontamination of industrial sites

Ferrara, McComb, and Missios (2007) estimate the costs and benefits of remediating metal-industry contaminated sites in Sydney, Nova Scotia. These sites increase cancer risks for nearby residents. The benefits of remediation are estimated by examining how proximity to contaminated sites affects property values. The authors use data on 390 property transactions over the period 1998–2003.

The hedonic function includes variables such as property age, property size, number of bathrooms, the presence of a fireplace, garage or carport, number of storeys, lot size, distance from downtown, and distance from contaminated sites. The results indicate a loss in property value of approximately $7,700 for a house located 500 meters from a contaminated site, compared with an otherwise identical house located 1,500 meters away. The estimated functional form shows that this negative effect diminishes with distance from the site.

To assess the benefits of remediation, the authors estimate the expected increase in the value of the affected properties (approximately 15,000 dwellings) by simulating their relocation to a

distance at which property values are no longer influenced by the contaminated sites (about 6 km). This exercise yields an estimated benefit of roughly $170 million. This amount covers a substantial share of the remediation costs, suggesting that the project is likely to be cost-effective once additional benefits, such as reductions in health care costs, are taken into account.

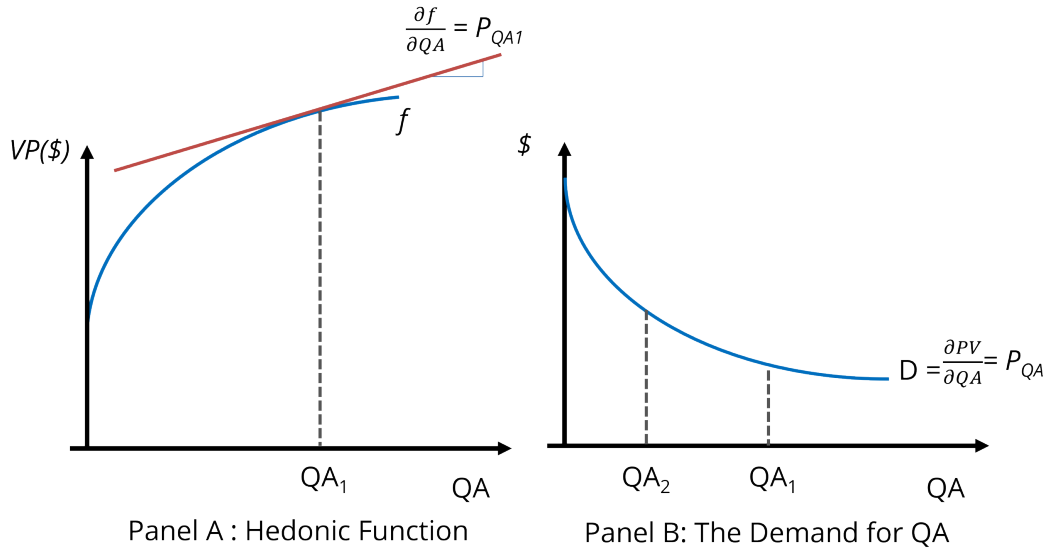


Figure 14.2 The hedonic function and derived demand for air quality

Functional form and interpretation of coefficients

A functional form often used in empirical studies is the log-linear or semi-log-linear specification, such as the following:

$$log(PV) = a_0 + a_1 log(X) - 0.03 log(NB) + 0.05 Park$$

where *X* represents the physical characteristics of the property, *NB* is an indicator of the level of outdoor noise, and *Park* is a binary variable equal to 1 if the property is located less than 500 metres from an urban park and 0 otherwise.

The relationship between *PV* and *NB* is log–log, so the estimated coefficient can be interpreted as an elasticity. If the coefficient is statistically significant, the results indicate that a 10% increase in outdoor noise levels reduces property value by 0.3%.

The relationship between *PV* and *Park* is semi-logarithmic, which is appropriate given the binary nature of the *Park* variable. In this case, the presence of a park within 500 metres increases property value by 5%. This result can therefore be used to evaluate the gross benefit associated with the creation of a new urban park. Specifically, the benefit can be measured as a 5% increase in the land value of properties located within a 500-metre radius.

Step 2 : Deriving the demand for QA

From the estimation of the hedonic function, hedonic prices (P_{QA} in our example) are obtained by taking the partial derivative of VP with respect to QA, so that

$$P_{QA} = \frac{\delta VP}{\delta QA}.$$

Graphically, P_{QA} corresponds to the slope of the tangent to the VP function. These prices measure the marginal willingness to pay for QA as a function of the level of QA and therefore correspond to observations along the **demand curve** for QA. Panel B of Figure 14.2 illustrates the demand curve derived from the hedonic function. The cost of a project that degrades air quality from QA1 to QA2 is measured by the area under curve D between QA1 and QA2.

It should be noted that this area represents a present value (or "capitalized" value, in real estate terminology), meaning that it measures the present value of the annual willingness to pay to avoid this degradation. This capitalization relies on a discount rate that reflects buyers' intertemporal preferences, which does not necessarily coincide with the **social discount rate**.

For the hedonic prices obtained in this way to measure the marginal willingness to pay for QA, several conditions must be satisfied. In particular, it is necessary that:

- The real estate market is competitive and in long-run equilibrium, with a large number of buyers and sellers;
- Transaction costs are low;
- The market is not affected by other significant distortions, such as price controls;
- Buyers genuinely have the option to trade off housing prices against air quality;
- Information on QA is known to buyers.

Moreover, in practice, heterogeneity among owners must also be taken into account. For example, willingness to pay for QA is likely to depend on income levels. This complicates the estimation of D, since socioeconomic characteristics of buyers must then be incorporated. In addition, demand for QA may depend on the hedonic prices of other characteristics that are substitutes for or complements to QA. Consequently, the second step consists of specifying and statistically estimating a model of demand for QA.

1 4 .2.2 Advantages and limitations

This approach has the advantage of resting on solid theoretical foundations and, provided that the required assumptions are satisfied, of delivering an estimate of willingness to pay for a non-market good based on actual choices.

However, it also has several limitations:

- Access to the data required to conduct a hedonic study can be difficult. For example, real estate transaction data are often costly to obtain. In addition, the sample must be sufficiently large and include a wide range of characteristics in order to avoid bias arising from omitted variables;
- As noted earlier, the market for the good used in the analysis must be active and relatively free of major distortions, which can limit the scope of application. For instance, it is not advisable to conduct a hedonic analysis of housing prices in a rural area with few transactions or in a region where housing prices are heavily regulated;
- This type of analysis is subject to statistical challenges, including selection bias, multicollinearity, heteroskedasticity, and correlation of error terms;
- Finally, it should be recalled that the effect on the value of a durable good, such as a house or a car, reflects a capitalization of annual impacts. This capitalization is based on a private discount rate that is not directly observable and does not necessarily correspond to the social discount rate.

14.3 The transportation cost method

1 4.3.1 The principle and scope of application

This method is mainly used to estimate the benefits generated by recreational sites such as natural parks, beaches, museums, or scenic landscapes. It can also be used to assess the value of non-market characteristics of a site, for example, the value associated with a lake having water quality suitable for swimming.

The technique exploits a complementary relationship between a free non-market good, or a good whose price is not determined by market forces, and a market good. As a result, the price of the non-market good does not vary sufficiently over time to allow demand to be identified. For instance, museum admission fees tend to change very little over time or adjust only to **inflation**.

More specifically, the method relies on the fact that, in order to benefit from a recreational site, users must incur travel costs that vary according to their place of origin. This source of variation can therefore be exploited to infer how demand for the site responds to changes in the generalized price, or to assess how demand depends on the site's intangible characteristics.

From a methodological perspective, two main approaches can be distinguished:

1. Single-site models;
2. Random utility models.

Single-site models directly estimate demand for a site, typically using information on access costs and the number of visits made. Random utility models aim to explain the choice of a site among a set of possible alternatives. Each of these approaches has many variants that cannot be discussed in detail in this chapter (see Parsons, 2017, for further discussion). In this section, we present the general principle of the travel cost method using a simplified hypothetical example and a basic single-site model.

Example: the value of a beach

To assess the value of a hypothetical beach, a survey was conducted among its visitors to determine their place of origin, their socio-demographic characteristics, and the annual frequency of visits to the site. In addition, it is known that 40,550 visitors paid an entrance fee of $4 per day during the reference year. For simplicity, we assume that all visitors traveled to the beach by car. Table 14.2 presents the responses from a subset of respondents.

Table 14.2 Some observations from the beach attendance database

Respondent	Origin	Frequency	Income class s	Age	Family situation	Number of accompanying persons
1	City A	3	50-75	45	Couple	2
2	City B	1	> 100	57	Couple	1
3	City B	2	75-100	34	Family	3
4	City C	5	75-100	65	Couple	2
5	City D	7	< 50	25	Alone	0

In our example, origin refers to the city of residence, but in practice it can be identified more precisely using a postal code or an exact home address. Additional sociodemographic variables may also be included, such as education level, the types of activities practiced at the beach, or visits to other beaches during the year.

Using the location information, it is possible to calculate, for each respondent, the generalized price of a visit. This price depends on round-trip travel time, the value of time (which is itself related to the respondent's income), vehicle operating costs, the entrance fee, and possibly parking costs. The calculation of the generalized price must also account for the number of accompanying persons, for example by dividing the total cost of a visit by the number of people in the group.

This yields a scatter plot in which each point corresponds to a respondent, with the number of visits per year on the horizontal axis and the generalized price on the vertical axis, as illustrated in Figure 14.3.

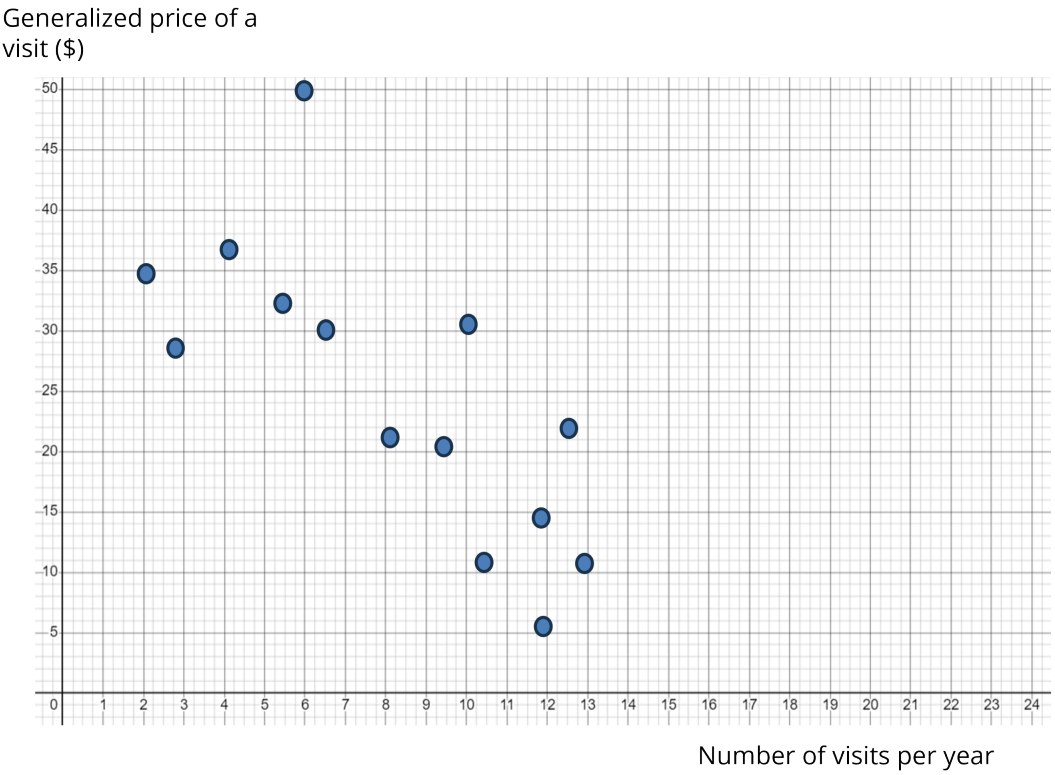


Figure 14.3 Point cloud formed by the observations

From these data, it is possible to statistically estimate the following demand function:

$$\text{Visit}_i = f\left(\text{Price}_i, \text{PS}_i, \text{SD}_i\right)$$

where:

Visit_i : the number of annual visits to the beach by respondent i;

Price_i : the generalized price of a visit to the beach;

PS_i : prices generalized to substitute beachess for respondent i . Based on information about the respondent's place of residence, it is possible to determine the generalized price of visits to other accessible beaches. This variable therefore captures the prices of substitute goods;

SD_i : the sociodemographic characteristics of respondent i that shape preferences (e.g. income, family structure, type of beach activities, age, etc.).

A simple functional form that is often estimated is the log-linear specification:

$$\ln\left(\text{Visit}_i\right) = \alpha\text{Price}_i + \beta\text{PS}_i + \gamma\text{SD}_i$$

Statistical analysis (e.g., ordinary least squares) makes it possible to obtain estimates of the parameters α, β, and γ. This procedure allows the demand curve of respondent i to be derived by substituting SDi and PSi with their observed values. For example, one may obtain:

$$\ln\left(\text{Visit}_i\right) = -0.01\text{Price}_i + 1.5$$

Inverting this function yields the inverse demand function, which expresses price as a function of quantity. Figure 14.4 illustrates this example. Suppose that the generalized price for respondent i is $50 per visit; the model then predicts 2.75 visits per year. The **consumer surplus** for this respondent is given by the area SC_i.

With a log-linear demand function, consumer surplus is equal to $\text{Visit}_i / (-\alpha)$, which in this example is 2.75/0.01, or $275. It is therefore possible to calculate the surplus for each respondent and then extrapolate the total surplus for all visitors, assuming that the sample is representative.

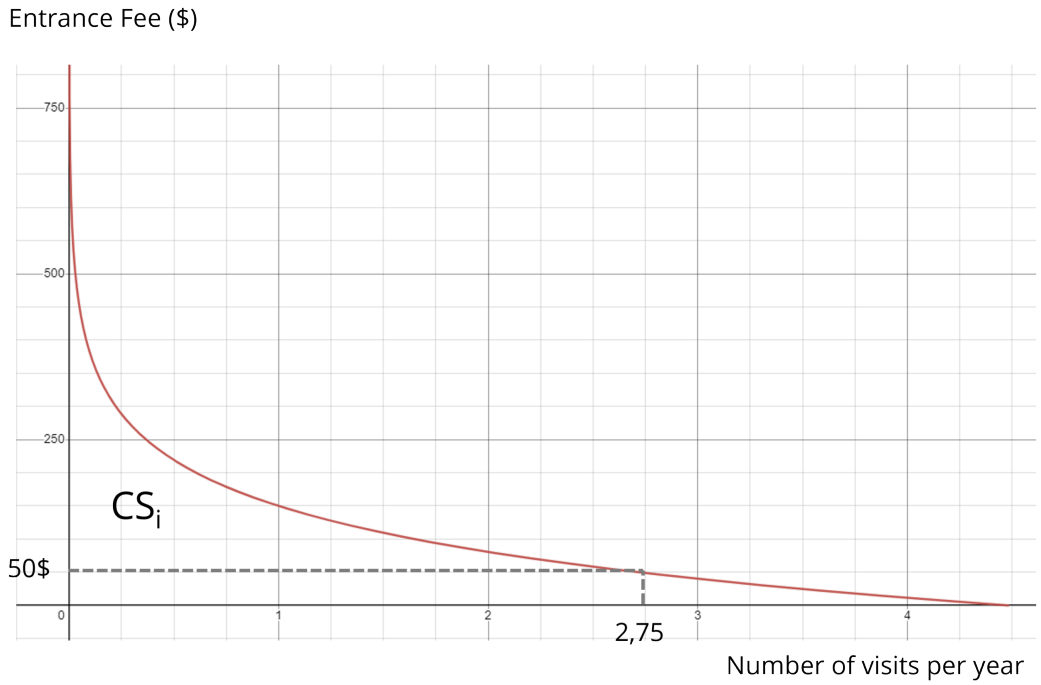


Figure 14.4 Example of estimated demand curve for a respondent

Example: The Social value of a museum

What social value does a museum generate? Martin (1994) uses the travel cost method to estimate the use value, that is, the value derived by visitors to the Musée de la Civilisation in Quebec City. A survey conducted in 1991 measured visit rates to the museum by zone (with the province divided into 16 zones), as well as by sex and age group. This information makes it possible to econometrically estimate visit rates as a function of travel costs, using 156 observations. Based on this analysis, user surplus is estimated at $5.2 million per year. When ticket revenues are added, the total gross benefit reaches approximately $6 million per year.

Of course, a museum also generates other benefits, such as the preservation of collective memory for future generations (bequest value) and a sense of regional pride (external benefits).

14.3.2 Advantages and limitations

Many tourist or recreational sites collect data on the geographical origin of their visitors, so such information is generally available. Moreover, this method fits naturally within the framework of microeconomic theory.

However, several challenges arise in applying this approach:

1. A single trip is often undertaken for multiple purposes (visiting friends, visiting other sites, work). In the case of multi-purpose trips, allocating travel costs across purposes greatly complicates the analysis (see Paterson, 2017).

2. The method may suffer from selection bias, leading to an overestimation of the benefits associated with using the site. Visitors may have unobservable characteristics that partly explain their interest in the site (for example, a particular preference for beaches). As a result, extrapolating estimated values to the entire population may be problematic. It may therefore be advisable to survey not only visitors, but also the broader population affected by the site.

3. The value of time is a key parameter that can significantly influence the results. However, valuing time for leisure-related trips is challenging, since the value placed on time may be low or even negative. For example, time spent traveling along a scenic route may itself generate utility.

14.4 Conclusions

Key takeaways

- Indirect, or revealed preference, methods value non-market impacts by examining secondary effects observed in market transactions.
- The mitigation expenditure method (also known as avoidance, protection, or abatement) exploits a substitution relationship in consumption between an intangible good and a market good. This method has several limitations, and its scope of application is relatively narrow.
- The hedonic method relies on the relationship between an intangible attribute and a durable market good, most often real estate. By analyzing how the intangible attribute affects the value of the durable good, it is possible to infer the marginal willingness to pay for the

intangible good and to derive its demand curve. This approach also includes studies that examine the effect of intangible characteristics on wages.

- The travel cost method exploits a complementary relationship between a market good and a non-market good. In this case, variations in travel costs to a recreational site make it possible to identify demand for the site, even when the entrance fee is zero or varies only slightly.

Revisiting the motivation: Valuing airport noise

A project aims to expand nighttime cargo operations at an airport, which will generate noise pollution for nearby residents. How can a value be assigned to these intangible costs? Given that there is no explicit market for noise levels, is it possible to infer the costs of noise from observed impacts in secondary markets?

Resolution

Although the avoidance expenditure method could be applied, the hedonic method is most commonly used to value these external costs. For example, Nelson (2004) presents a meta-analysis of the impact of airport noise pollution based on hedonic studies conducted around 23 airports in Canada and the United States. The results indicate a reduction in property values of about 10 to 12% when noise levels increase from 55 dB to 75 dB.

Exercises

(*) 1. A beach is accessible free of charge. A survey reveals that people living within 10 km of the beach visit it an average of four times per year. Their travel cost to visit the beach is estimated at $10 per visit per person. People living between 10 km and 20 km from the beach visit it an average of two times per year, with an average travel cost of $20 per visit per person. Approximately 10,000 people live within 10 km of the beach, and 25,000 live between 10 km and 20 km away. Based on these data, determine the surplus generated by the beach for the population living within 10 km. [Use linear extrapolation.]

(*) 2. A hedonic study was conducted to assess the impact of nuisances created by proximity to wind turbines in a region. The econometric estimation of the hedonic function yields the following results:

$\log(PV) = a_0 + a_1 \log X - 0.03\ D[500_1000] - 0.07\ D[<500]$

where:

PV denotes property value;

X represents control variables;

D[500_1000] is a binary variable equal to one if the property is located between 500 meters and 1,000 meters from a wind turbine;

D[<500] is a binary variable equal to one if the property is located less than 500 meters from a wind turbine.

The coefficients reported above are statistically significant. The hedonic study also indicates that there is no statistically significant effect on properties located more than one kilometer from a wind turbine. Table 14.3 presents the average property value by area and the number of affected properties. Based on this information, value the nuisances associated with the presence of wind turbines in this region.

Table 14.3 Average property values

Affected areas	Average property value	Number of properties
500 to 1000 meters	$115,000	750
< 500 meters	$95,000	69

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15.

DIRECT METHODS

Motivation and learning objectives

A project aims to rehabilitate wetlands that have been filled in. How can we establish the social value generated by this project, and in particular, how can we determine the existence value of these ecosystems?

The indirect methods described in the previous chapter measure the traces left by **intangible effects** in markets. This approach requires the construction of a complex theoretical framework and is not always applicable in all contexts. Moreover, these indirect methods primarily capture use values. To address these limitations, direct methods were developed. These methods consist of asking, through a survey of a representative sample, individuals' maximum willingness to pay for a change in a non-market good.

This approach therefore relies on stated preferences rather than preferences revealed through actual choices. Respondents are placed in a hypothetical context, which may influence the amounts they report; this constitutes the main criticism of these methods. Over the past few decades, however, these techniques have been refined, and the validity of their results has been extensively examined. Because of their flexibility, they are now widely used.

By the end of this chapter, you will be able to understand the principles, advantages, and limitations of:

1. Contingent valuation;
2. Conjoint analysis.

15.1 Contingent valuation

15.1.1 The principle and scope of application

The principle of the **contingent valuation method** is to directly ask a representative sample of the affected population to state their **maximum willingness to pay (WTP)** or their **minimum willingness to receive (WTR)** for a change in a non-market good.

For example, respondents may be asked: "What is the maximum amount you would be willing to pay to purchase a vehicle that is 75% less polluting than a conventional vehicle?" or "What is the maximum amount you would be willing to pay each year to protect a specific ecosystem?" or "What would be the minimum annual compensation that would make you willing to accept the installation of a wind turbine in your neighborhood?"

This approach places respondents in a hypothetical market setting in which they are asked to make a choice. It therefore relies on stated preferences rather than preferences revealed through actual behavior.

Because of its hypothetical nature, this method has a very broad scope of application, as illustrated by the examples presented in Table 15.1. In addition, it has the advantage of making it possible to assess the total economic value of a non-market good, not only its use value, as is generally the case with indirect methods. In principle, respondents are expected to take all sources of value into account when stating their willingness to pay. For instance, it is possible to estimate willingness to pay for the preservation of an animal species that has no direct use for humans.

Table 15.1 Some examples of the use of contingent valuation

Reference	Domain	Non-marketable property
Pollicino and Maddison (2001)	Culture	Agreeing to pay to clean cathedral facades
Abate *et al*., (2020)	Environment	Willingness to pay to reduce ocean plastic pollution
Laframboise and Michaud (1995)	Environment	Economic value of the impact of high-voltage lines on landscapes
Alberini A. *et al*., (2004)	Health	Willingness to pay to reduce mortality risks (value of life)
Dieng, He, Power (2020)	Health	Consent to pay for taking ovulation-promoting drugs in cases of infertility
Johnson, Groothuis and Whitehead (2001)	Sport	Willingness to pay for the "pride" of having a professional hockey team (existence value)

The main methodological challenge of contingent valuation lies in constructing hypothetical scenarios that are credible, understandable, and acceptable to respondents. Over the past decades, this method has been the subject of extensive methodological research aimed at improving value elicitation and assessing the reliability of the resulting estimates.

In 1993, a panel of experts published a set of guidelines for the U.S. National Oceanic and Atmospheric Administration to ensure that contingent valuation studies produce results that are as reliable as possible (see Johnston et al., 2017, for more recent guidelines). Following this report, U.S. courts began to accept valuations based on these techniques to assess damages, such as those resulting from the Exxon Valdez oil spill in Alaska in 1989. Contingent valuation is widely used in environmental economics, but it has also gained prominence in the fields of health, culture, and sports.

15.2 Steps in conducting a contingent valuation

Conducting a contingent valuation typically involves three main stages:

1. Defining the hypothetical choice context;
2. Designing the questionnaire and conducting the survey;
3. Performing the statistical analysis of the results.

15.2.1 Defining the hypothetical choice context

The first step in contingent valuation is to clearly identify the non-market effect to be evaluated and to construct a hypothetical context that is as realistic as possible and that will be presented to survey respondents. For example, power lines may negatively affect landscapes. To assess this impact, one could design a hypothetical project to bury the lines and survey the affected population about their maximum willingness to pay for this project. The challenge lies in creating a scenario that is clear, plausible, and concrete. In this example, the visual impact of the project can be illustrated by showing digitally altered photographs in which the power lines have been removed.

It is essential to describe in detail both the status quo and the proposed project, including how the project would be financed (for example, through higher property taxes, voluntary contributions, or increased sales taxes). The more concrete and realistic the scenarios presented to respondents, the more likely it is that the elicited values will be meaningful. It is also important to specify the value elicitation format, as discussed in Section 15.3.

15.2.2 Designing the questionnaire and conducting the survey

The second step in contingent valuation consists of designing the questionnaire, testing it, and administering it to a representative sample of the target population. Typically, the questionnaire is structured around three components:

1. A set of questions assessing the respondent's level of knowledge and familiarity with the issue being evaluated, for example their understanding of threats to biodiversity;

2. A presentation of the initial situation (the status quo) and the contingent scenario(s), followed by questions eliciting willingness to pay or willingness to receive. At this stage, it is recommended to remind respondents of the budgetary implications of their responses. It may also be useful to ask the valuation question several times and in different formats, for instance by using follow-up questions or reminders;

3. Questions on the respondent's socioeconomic characteristics.

As with any survey, the design and wording of the questionnaire require great care. The questionnaire should be pre-tested, either through focus groups or a pilot survey. The sample must be representative of the target population and of sufficient size, and the mode of administration must be chosen appropriately (in-person, telephone, online, etc.).

It is also important to recognize that the source of value may differ across population groups. For example,

individuals living near a wildlife reserve may derive use value if they visit the site, whereas individuals living farther away may derive only existence value. As a result, the questionnaire may need to be adapted to different target groups. For respondents living close to the reserve, it may be relevant to collect information on visit frequency. Tailoring the questionnaire to the specific characteristics of different groups can therefore help identify the various sources of value associated with the non-market effect under study.

Champ (2017) presents best practices for collecting data on the valuation of intangible effects and provides a useful reference for designing and implementing contingent valuation surveys.

15.2.3 Statistical analysis of the results

The final step of contingent valuation involves conducting a statistical analysis of the survey responses in order to assess how project characteristics and socioeconomic factors influence stated willingness to pay. This analysis makes it possible to evaluate the internal consistency and reliability of the valuation by testing whether the results align with the predictions of economic theory. For example, one can verify whether stated willingness to pay increases with the size of the ecosystem protected, whether income has a positive effect on willingness to pay (assuming the good is normal), or whether demand for the non-market good decreases as the "price" increases.

Statistical analysis also plays a key role in enabling value transfer to other projects, as discussed in Chapter 13 in relation to the transfer method.

15.3 Approaches to revealing value

15.3.1 Willingness To Pay (WTP) or Willingness To Receive (WTR)

The analyst must first decide whether the survey will elicit willingness to pay (WTP), willingness to receive (WTR), or both. Whenever possible, it is generally recommended to rely on WTP. Questionnaires based on WTR tend to produce substantially higher valuations than those based on WTP. One explanation for this difference is that budget constraints are likely to be more salient when individuals are asked how much they would be willing to pay, rather than how much they would require as compensation.

That said, there are contexts in which asking respondents about their WTP would be inappropriate and could lead to protest responses or implausible answers (see Whittington et al., 2017). For example, it would be difficult to credibly ask residents how much they would be willing to pay to prevent the installation of a landfill in their neighborhood.

In the remainder of this chapter, we focus primarily on the elicitation of WTP, while acknowledging situations in which the use of WTR may be more appropriate or even necessary.

15.3.2 Different approaches to eliciting Willingness to Pay

Several approaches can be used to elicit respondents' willingness to pay. The main ones are presented in Table 15.2, using the example of a project to bury power lines. The table also summarizes the advantages and limitations of each approach, which helps assess their relevance and applicability in the specific context of a contingent valuation exercise for this type of project.



Table 15.2 Approaches to reveal the WTP of power line burial

Approaches and examples	Advantages/Limitations
Open question "What is the maximum amount you would be willing to pay per year to have the power line buried? The payment will be made in the form of an increase in your property taxes."	(+) Simple. (-) Risks of out-of-standard values and non-response.
Question in the form of an auction "Would you be willing to pay $25 more in municipal taxes per year to have the lines buried?" If so, we ask for a higher amount (for example, $35) and continue until the respondent refuses. Otherwise, we lower the amount.	(+) Reduces extreme values. (-) Risk of starting point bias (anchoring effect). (-) Risk of fatigue for the respondent.
Question with payment card "Among the annual municipal tax supplements proposed below, what is the maximum you would be willing to pay to have the lines buried: $0, $50, $100, $200 or $500?"	(+) Avoid out of range values. (-) Risk of bias linked to the choice of amounts on the card.
Dichotomous choice method (referendum) "Are you willing to pay an additional $x in annual municipal taxes to have the lines buried?" With $x, an amount that varies according to respondents.	(+) Simple approach for the respondent. (+) Less risk of bias. (-) Little information collected per respondent. More complex statistical processing.
Double proposition dichotomous choice method Same question as the dichotomous choice method, but the question is asked a second time with a higher amount if the first amount was accepted, or a lower amount if the first amount was rejected.	(+) Collects more information than with the dichotomous method. (-) Risk of anchoring effect.

The first approach is to ask an **open-ended question** in which respondents are invited to state the maximum amount they would be willing to pay. This method has the advantage of simplicity and does not influence respondents by suggesting specific values. However, it requires considerable cognitive effort, since respondents must assign a value to a good for which they often have few reference points. Moreover, it departs from the way markets usually operate, which can result in extreme responses or lower response rates.

Another approach is the **auction method**, in which respondents are presented with increasing amounts until they reach their willingness to pay. This method reduces the risk of extreme values and more closely resembles the functioning of certain markets. However, it is subject to anchoring effects, whereby the initial amount proposed can influence subsequent responses. In addition, the repeated questioning involved in the auction process can lead to respondent fatigue.

A third approach is the **payment card method**, in which respondents select an amount from a predefined list of values. This method is straightforward and limits extreme responses, but the range and spacing of the amounts presented on the card may influence respondents' choices.

The **dichotomous choice or referendum approach** consists of asking respondents whether they would accept or refuse to pay a specific amount for a change in a non-market good. This method avoids extreme values, anchoring effects, and issues related to the upper bound of payment cards. It also more closely mirrors a typical market decision.

However, this approach requires a larger sample size, as it provides less information per respondent. Specifically, it only reveals whether an individual's willingness to pay is higher (in the case of acceptance) or lower (in the case of rejection) than the proposed amount. As a result, the statistical analysis of the data is more complex.

Figure 15.1 illustrates an example of a scatter plot derived from a referendum-style question. On this graph, the horizontal axis represents the proportion of respondents who accept the offer, while the vertical axis shows the proposed willingness to pay. For instance, when the proposed amount is $100, 10% of respondents accept the offer. The figure also presents a linear regression line corresponding to the average respondent's demand curve. In this context, the horizontal axis measures the probability of accepting the project rather than a quantity. Nonetheless, the area under the curve—approximately $60 per year—provides an estimate of the average willingness to pay.

It should be noted that, in practice, such scatter plots typically contain many more observations. Moreover, the estimated statistical model is generally more sophisticated, particularly because the dependent variable is bounded between 0 and 1. The demand estimation also incorporates additional explanatory variables, including respondents' sociodemographic characteristics such as income, age, and gender.

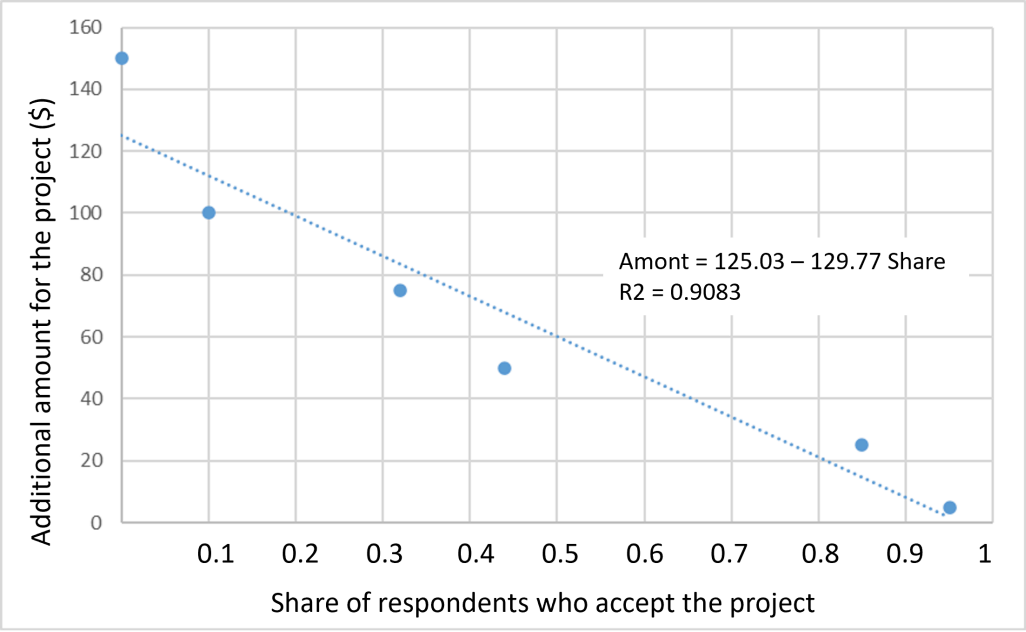


Figure 15.1 Representation of responses and estimated demand for an average respondent

OECD (2018) notes that this method tends to generate higher WTP estimates than other approaches. This

may be explained by an acquiescence bias, whereby respondents are more inclined to give affirmative answers. Nevertheless, this approach is generally regarded as consistent with best practices.

Finally, the double-bounded dichotomous choice method is a variation of the previous approach. After responding "yes" or "no" to an initial offer, the respondent is presented with a second offer that is adjusted based on the first response. The proposed amount is increased if the respondent accepted the first offer and decreased if the respondent rejected it. This method allows more information to be collected from each respondent, since the second question is tailored to the initial response. However, it may be affected by anchoring bias, as the first proposed amount inevitably influences the response to the second.

15.3.3 Mean or median WTP

As noted above, some responses may be atypical. For example, in the case of open-ended questions, certain respondents may report extremely high WTP values, either because they misunderstood the question or because they are behaving strategically. Such extreme values can strongly influence the calculation of the mean WTP. To mitigate this issue, it is advisable to also compute the median WTP, which is less sensitive to outliers and provides a more robust measure of central tendency. In addition, various statistical techniques can be used to identify and exclude problematic observations (outliers) that could otherwise distort the analysis of the results.

15.4 Conjoint analysis

Conjoint analysis, also known as discrete choice analysis, is a stated-preference method. It makes it possible to assess not only quantitative changes but also qualitative changes in a non-market good. As such, conjoint analysis is particularly well suited to evaluating changes in the attributes of non-market goods.

For example, conjoint analysis can be used to assess willingness to pay (WTP) for projects aimed at improving lake quality. Such projects can be characterized by several **attributes**, including biodiversity, water clarity, flood-control functions, and suitability for swimming. The cost of the project itself can be included as a separate attribute. It is also essential to clearly define the **possible levels** of each attribute; for instance, biodiversity might be described as low, medium, or high. Particular care must be taken to explain these attributes and their levels clearly to respondents, so that they can make informed and meaningful choices.

Table 15.3 Example of a choice scenario proposed in a conjoint analysis

Here are two projects that improve different aspects of the lake's water quality. If you choose Project A or Project B, you will have to pay the annual cost in the form of an increase in municipal taxes. If you choose the status quo, there will be no additional payment, but the lake's water quality will not improve.			
	Project A	**Project B**	**Status quo**
Level of biodiversity	Average	High	Weak
Water clarity (transparency)	Average	Good	Average
Flood protection	Good	Forte	Average
Possibility of swimming there	No	Yes	No
Annual cost	$250	$400	$0
I prefer	◊	◊	◊

Once the data have been collected, it is possible to estimate the willingness to pay associated with each attribute using appropriate statistical methods (Louviere et al., 2000; Hensher et al., 2005; Holmes et al., 2017). For example, one can estimate the median willingness to pay to make a lake suitable for swimming or to preserve a high level of biodiversity. Section 15.6.2 presents a concrete example of conjoint analysis applied to the valuation of ecological services provided by wetlands in Quebec.

15.5 Bias and reliability

These direct valuation techniques have been extensively studied in order to identify and minimize potential sources of bias. In parallel, a large body of research has examined the reliability of the estimates obtained using these methods.

15.5.1 Hypothetical bias

Hypothetical bias refers to the tendency of respondents to overstate their maximum willingness to pay when answering hypothetical questions, precisely because their responses have no real financial consequences.

As noted earlier, these methods are based on hypothetical choices rather than actual behavior. As a result, respondents' answers do not directly affect their budgets, which may lead them to report higher amounts, for instance to appear generous or supportive of the proposed project.

This issue is particularly problematic when valuing goods or resources for which respondents have rarely, if ever, had to think in monetary terms. To mitigate this bias, it is essential to present scenarios that are as realistic and concrete as possible.

It is also recommended to explicitly draw respondents' attention to this issue. For example, survey instructions can include a reminder about hypothetical bias and encourage respondents to state their willingness to pay as if they were actually required to make the payment.

15.5.2 Strategic bias

In a hypothetical choice setting, respondents may be influenced by strategic considerations. For example, a respondent who supports a project may overstate their maximum willingness to pay if they believe this will increase the likelihood that the project is implemented, while assuming that their response will not affect the amount they will actually have to pay. Conversely, a respondent may understate their willingness to pay because they fear that their response could influence the amount they would ultimately be required to pay, leading to free-riding behavior.

15.5.3 Inclusion bias

> **Inclusion bias**, also referred to as embedding bias or insensitivity to scope, corresponds to the absence of a positive relationship between reported willingness to pay and the magnitude of the change in the non-market good.

Economic theory predicts that maximum willingness to pay for a good, including a non-market good, should increase with the quantity of the good provided. For example, the willingness to pay to protect 100 hectares of an ecosystem should be higher than the willingness to pay to protect 10 hectares. However, in practice, this expected relationship does not always appear in contingent valuation responses. When this occurs, it may indicate that respondents are not valuing the specific quantity of the non-market good, but rather expressing a general support for a "good cause."

This issue seems particularly prevalent when the non-market good is unfamiliar or when the magnitude of the change is difficult to grasp (for example, a project that reduces mortality risk by 1 in 10,000). It is

therefore advisable to use tools that help convey the scale of the scenarios being evaluated. Visual aids can be especially useful in this respect. In addition, questionnaires should be designed in such a way that the relationship between quantity and willingness to pay can be tested, making it possible to detect inconsistencies with theoretical expectations.

15.5.4 Anchoring bias

As noted earlier, **anchoring bias**, also known as "starting point bias," refers to the tendency of respondents to rely heavily on the first piece of information or initial option presented when forming their judgments.

Anchoring bias can cause the initial value or choice offered to unduly influence subsequent responses. This is particularly likely when respondents are presented with complex or unfamiliar valuation tasks, as they may use the initial information as a reference point, even if it does not reflect their true preferences. This underscores the importance of carefully designing contingent valuation questionnaires to minimize anchoring effects, for example by randomizing the presentation of scenarios or using elicitation formats that reduce dependence on initial values.

15.5.5 Information bias

Information bias, sometimes referred to as framing bias, arises when reported willingness to pay depends on the quantity, quality, or presentation of the information provided to respondents. Responses may therefore be influenced not only by the content of the information, but also by how it is framed or emphasized. For instance, providing highly detailed or emotionally charged information about a non-market good may affect respondents' valuation of that good.

To mitigate information bias in contingent valuation studies, it is recommended to provide respondents with information that is accurate, credible, and easy to understand. Visual aids, such as photographs or videos, can

be effective tools for conveying information clearly and consistently. The timing of information delivery is also important, as it may influence how respondents process and evaluate the scenarios.

One approach is to present all relevant information about the proposed scenarios before asking respondents to state their willingness to pay. This allows respondents to consider the full set of options before making a decision. Alternatively, information can be presented sequentially, with respondents asked to express their preferences after each scenario is introduced. While this approach can reduce information overload and help respondents focus on individual scenarios, it may increase the risk of anchoring bias.

15.5.6 Other biases

In addition to the biases specific to contingent valuation, this method is also subject to the usual challenges associated with survey-based research. These include:

1. Sample representativeness: It is essential that the sample of respondents be representative of the target population so that the results can be generalized. A non-representative sample may introduce systematic bias into the estimates;
2. Non-response bias: When some individuals selected for the survey choose not to participate, bias may arise if these individuals differ systematically from those who do respond. For example, if individuals with particularly strong opinions are more likely to participate, the results may be skewed;
3. Question wording bias: The formulation of questions can influence respondents' answers. Ambiguous, leading, or emotionally charged wording may distort responses and compromise accuracy;
4. Question order bias: The sequence in which questions are presented can affect responses. For instance, earlier questions may frame or influence how subsequent questions are interpreted;
5. Social desirability bias: Respondents may provide answers they perceive as socially acceptable rather than those that reflect their true preferences, leading to biased results.

To mitigate these issues, careful survey design is essential. This includes using appropriate sampling strategies, ensuring clear and neutral question wording, and implementing procedures to reduce non-response and social desirability biases.

15.5.7 Reliability of estimates

Several approaches have been used to assess the reliability of estimates obtained through direct valuation methods [1].

1. Comparison of valuation methods: Studies compare values obtained for the same non-market effect using different valuation techniques. Correlations between estimates derived from direct and indirect methods are generally high, often in the range of 0.8 to 0.9, suggesting a reasonable degree of consistency across approaches;
2. Replication of contingent valuation studies: Repeating contingent valuation exercises on different samples provides another way to assess reliability. Research such as McConnell et al. (1998) generally finds stability in the order of magnitude of the estimated values;
3. Experiments with real payments: Another informative approach involves experiments in which some participants state their willingness to pay or willingness to receive in a hypothetical setting, while others do so in a context involving real financial consequences. For example, Heberlein and Bishop (1986) examined valuations of a Wisconsin hunting license by comparing hypothetical and real contexts. They found that willingness to receive in the hypothetical setting was more than 2.7 times higher than in the real setting, whereas willingness to pay was relatively similar across the two contexts.

15.6 Two examples

15.6.1 WTP for a less polluting vehicle

Poder and He (2017) assessed willingness to pay for less polluting vehicles using a survey conducted in Quebec and France. The online survey collected responses from 418 participants in Quebec and 445 in France. Willingness to pay was elicited using a single-bounded dichotomous choice approach. The main question posed to respondents was the following:



"Given the problems caused by vehicle emissions (increased respiratory diseases, global warming, etc.), how

1. See Boardman et al. (2018) and OECD (2018). For a critical assessment of contingent valuation, see Hausman (2012).

much more would you be willing to pay for your next vehicle so that it emits X% [50% or 75%] fewer air pollutants than another vehicle in the same class? Would you be willing to pay $Y more for this type of greener vehicle?"

Half of the questionnaires presented a 50% emissions reduction, while the other half presented a 75% reduction. For each reduction level, eight bid amounts were randomly assigned, ranging from $300 to $10,000. The questionnaire also included questions on socio-demographic characteristics such as age, income, and education, as well as respondents' environmental attitudes.

The results indicate that, on average, willingness to pay for an emissions reduction of 62.2% (the mean of the values presented) amounts to $4,875 in Quebec and $5,865 in France. Age has a negative and statistically significant effect on willingness to pay, while income has a positive effect. However, these amounts are lower than the estimated additional production cost of a vehicle with emissions reduced by 60%.

It should be noted that these values likely overestimate willingness to pay for improved air quality, since respondents may also anticipate private benefits from owning a greener vehicle, such as lower operating costs. This is particularly relevant for electric vehicles, which generally have lower operating costs than gasoline-powered vehicles.

15.6.2 Valuation of environmental services provided by wetlands

He, Dupras, and Poder (2017) assessed willingness to pay for the ecological services provided by wetlands in Quebec. These ecosystems perform several functions, including biodiversity conservation, flood risk reduction through buffer effects, water filtration that reduces pollution, and carbon storage.

Approximately 50% of wetlands in southern Quebec have disappeared over the past forty years due to human activities. The objective of the study was to assess willingness to pay for a project that would double the current area of wetlands in order to restore conditions to previous levels. Two valuation approaches were compared.

The first approach relied on a single-bounded dichotomous choice question: "Would you be willing to pay $X per year more on your annual water and sewer bill for this project, or zero for the status quo?" The proposed amounts ranged from $5 to $600, and the sample included 859 respondents.

In parallel, a conjoint analysis was conducted with a sample of 886 respondents. Participants were asked to choose between the status quo and two wetland restoration projects characterized by different levels of ecological services and costs, defined by five attributes. This approach made it possible to estimate the marginal willingness to pay for each ecological service.

Both approaches yielded similar results. Average willingness to pay was estimated at approximately $450 per year per household. When extrapolated to all households, this corresponds to a total willingness to pay of about $1.5 billion to restore 400,000 hectares of wetlands, or roughly $3,700 per hectare. This estimate falls within the range of values reported in other studies, particularly those conducted in the United States.

15.7 Conclusions

Key takeaways

- Direct methods involve presenting hypothetical market scenarios for non-market goods to a representative sample of the target population.
- They rely on stated preferences rather than revealed preferences, which constitutes their main weakness.
- These approaches have a broad scope of application and are widely used today.
- Contingent valuation directly asks respondents about their maximum willingness to pay (or minimum willingness to receive) for a change in the quantity or quality of a non-market good.
- Several strategies can be used to elicit willingness to pay, including open-ended questions, auctions, payment cards, and single- or double-bounded dichotomous choice formats.
- The dichotomous choice method is generally considered the preferred approach, although the payment card method is also frequently used.
- The questionnaire must be carefully designed to ensure that it is understandable and as realistic as possible. The payment mechanism should be credible and appropriate. The questionnaire should be pretested through a pilot survey or focus groups.
- Willingness to pay is generally the preferred measure, unless the context justifies the use of willingness to receive.
- It is essential to validate the responses through statistical analysis and to assess their consistency with the predictions of economic theory.
- Conjoint analysis presents respondents with alternative hypothetical choice scenarios defined by different values of the attributes that characterize the quality of a non-market good.
- This approach makes it possible to estimate willingness to pay for each attribute considered.
- Direct methods are subject to several potential biases, the most important being hypothetical bias, anchoring bias, and information bias.
- Reliability analyses suggest a tendency toward overestimation, particularly for willingness to receive. However, the values obtained using direct methods are generally fairly strongly correlated with those derived from other valuation approaches.

Back to motivation

A project aims to rehabilitate wetlands that have been filled in. How can we establish the social value generated by this project, and in particular, how can we determine the existence value of these ecosystems?

Resolution

The study by He, Dupras, and Poder (2017) illustrates one possible approach to assessing the benefits of such a project. A contingent valuation study could be conducted to estimate the use value of wetlands associated with the project. Alternatively, a conjoint analysis could be used to assess willingness to pay for the different services provided by wetlands. This approach would make it possible to design the project so as to maximize its social value. In addition, the existence value of wetlands could be estimated by comparing the willingness to pay of respondents who directly benefit from wetland uses (for example, through boardwalk access or water filtration services) with that of respondents who do not directly benefit from these uses.

Exercises

1. What are the main criticisms or limitations of the contingent valuation method? Use an example to illustrate your answer.
2. An airport used for freight transport generates nighttime noise pollution in several neighborhoods located under its takeoff and landing paths. As part of a CBA of a project to ban night flights, you are asked to design a questionnaire (around ten questions) and to propose strategies to make the context as concrete and realistic as possible for respondents.
3. Briefly explain the main difference between contingent valuation and conjoint analysis, using an example to illustrate your answer.
4. You are asked to conduct a contingent valuation study of a project to create a maple syrup museum in a tourist city. Discuss the issues related to defining the target population to be surveyed, the different possible sources of value associated with this project, and how these sources of value could be distinguished using contingent valuation.

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16.

APPLICATIONS: THE VALUE OF TIME, LIFE, AND CARBON

Motivation and learning objectives

A government is considering increasing the speed limit on its motorways from 100 km/h to 120 km/h. The main impacts to be assessed in a CBA of this project are:

- Time savings resulting from higher travel speeds;
- Impacts on road safety, given that the project could increase the risk of accidents and fatalities;
- Environmental impacts, particularly with respect to climate change.

Conducting this CBA therefore requires the estimation of "reference prices," notably for an hour of travel time saved, a human life, and a tonne of carbon. How do the methods presented in the previous chapters make it possible to determine these values?

This chapter aims to answer this question. The valuation of time, human life, and a tonne of carbon involves intangible impacts that are frequently encountered in CBAs. The chapter also provides an overview of the current state of knowledge, as well as the unresolved challenges associated with valuing these effects.

By the end of this chapter, you will be able to understand the issues involved in the valuation of:

1. Time;
2. Human life;
3. Carbon

16.1 The value of time

16.1.1 Definition of the concept

Time is a valuable resource that can be affected by a project. For example, a public transportation improvement project may reduce commuting times, while investments in emergency services may shorten waiting times. To assess these benefits, it is necessary to estimate the value of time, more precisely the value of time saved.

> **The value of time** (VT) refers to the monetary value individuals assign to reducing the amount of time they must devote to a specific activity. It is commonly expressed in monetary terms per hour saved.

VT can therefore be defined as the maximum amount individuals are willing to pay to save one hour that they would otherwise have spent on a given activity. This value is determined by the opportunity cost of time, that is, the value of the hour in its best alternative use. The most obvious alternative use is paid work, for which a monetary value exists in the form of net wages. However, individuals may wish to allocate the saved hour to activities other than work. Does this affect VT?

Becker (1965) proposed a theoretical model of optimal time allocation in which time is treated both as an input into income production (work time) and into consumption (for example, time spent cooking, watching a movie, or engaging in sports). In this framework, the individual's optimal time allocation implies that the marginal value of time is equal across all activities, including work. Under these assumptions, VT is equal to net wages, regardless of how the saved hour is used. As a result, VT is often approximated by net wages.

However, this model assumes that individuals can freely choose the number of hours they work. In reality, working time is often constrained, which can lead VT to differ from wages. For example, if an individual is required to work more hours than desired (such as a full-time employee who cannot reduce working hours or who is required to work overtime), net wages may underestimate the true value of time.

Moreover, the time spent on an activity can directly affect utility, making the value of time subjective and dependent on both the activity and the individual. For instance, travel time may be perceived as a benefit rather than a cost by some individuals if they enjoy the journey or the scenery. In addition, the willingness to pay to save an hour spent in traffic congestion may be higher than the willingness to pay to save an hour of travel time under uncongested conditions. Similarly, an hour spent waiting at a bus stop may have a different value than an hour spent on the bus. The value of time may also depend on context and scale: saving 15 minutes on a one-hour trip may not have the same value as saving 15 minutes on a ten-hour trip.

In summary, net wages can serve as a first approximation of the value of time. However, when time savings constitute an important component of a CBA, it is essential to estimate the value of time more precisely for the specific activity concerned. This is particularly important when individual preferences, constraints on time allocation, or the nature of the activity itself are likely to influence how individuals value their time.

16.1.2 Empirical determination of the value of time

Most empirical studies on the value of time have been conducted in the field of transportation. As explained in Chapter 7, transportation choices depend on the generalized price, which includes both monetary costs and implicit costs, notably time costs. As a result, VT can be inferred by examining actual or hypothetical transportation choices. For example, the value of time can be estimated by observing travelers' choices between transport modes with different costs and travel times, such as driving versus flying, or between a faster toll road and a slower but free congested route.

Increasingly, conjoint analysis (see Chapter 15) is used for this purpose. This approach presents individuals with hypothetical transportation choices that involve explicit trade-offs between time and money. One advantage of this method is that it allows analysts to study responses to new or hypothetical transport options, such as the introduction of a light rail system.

Estimating VT from real or hypothetical choices requires the specification and estimation of formal mathematical models, which is beyond the scope of this manual. However, Appendix 1 of this chapter provides a brief introduction to the additive random utility model, which underpins many transportation analyses. The box below also illustrates an example of VT estimation based on conjoint analysis.

Finally, the value of time associated with a specific activity can also be estimated using the contingent valuation method. For example, Van den Berg, Gafni, and Portrait (2017) assessed patients' value of time in a hospital setting in Amsterdam, the Netherlands, by estimating their willingness to pay to reduce admission time, treatment time, waiting time, and travel time.

VT in an academic context

Barla et al. (2015) assess the value of time (VT) of members of Université Laval who primarily commute to campus by private car. This assessment is based on an online survey in which participants are asked to make hypothetical transportation choices among private cars, buses, and non-motorized modes of travel. The scenarios are defined using two main attributes: travel time and selected components of monetary costs.



Source: René Bélanger, CC0, via Wikimedia Commons

To make the hypothetical scenarios more realistic, respondents are first reminded of their current commuting situation, and the scenarios are then calibrated accordingly. For example, participants may be asked which mode of transportation they would choose if parking fees were doubled or if bus travel time were reduced by 50%. An illustration of this type of scenario is provided in Table 16.1.

Table 16.1 Example of a hypothetical personalized mode choice

Below is your current (approximate) situation which makes you choose the automobile as your main mode of transport.		
Automobile	**Bus**	**Non-motorized mode**
Cost of parking	**Subscription**	**Cost**
$300 per session	$200 per session	the same as you are currently paying.
Travel time	**Travel time**	**Travel time**
35 min.	70 min.	the same as you are currently paying.

Which mode of transportation would you choose if you were faced with the following conditions?		
Automobile	**Bus**	**Non-motorized mode**
Cost of parking	**Subscription**	**Cost**
$600 per session	Free	the same as you are currently paying.
Travel time	**Travel time**	**Travel time**
43.75min.	70 min.	the same as you are currently paying.

The statistical analysis of these choice data is based on the estimation of a multinomial logit model with random effects. By analyzing the trade-off between time and monetary cost, this approach makes it possible to estimate the value of time, which may vary across modes of transport and according to respondents' characteristics. The results of the study suggest an average value of time of $4 per hour for car travel and $6 per hour for bus travel.

16.1.3 Consensus and challenges regarding the value of time

A large body of empirical research has sought to estimate the value of time (VT), primarily in the context of transportation. Boardman et al. (2018) and the Victoria Transport Policy Institute (n.d.) provide comprehensive overviews of this literature. Several meta-analyses have also been conducted, notably by Abrantes and Wardman (2011) for the United Kingdom and by Wardman et al. (2016) for Europe. By contrast, empirical studies on VT in the Canadian context remain relatively scarce.

Several areas of consensus emerge from this literature:

- VT depends positively and strongly on income. In practice, it is often expressed as a fraction of gross wages, which implicitly assumes a proportional relationship between VT and income. The meta-analysis by Wardman et al. (2016) confirms that this assumption is broadly consistent with the empirical evidence.

- The purpose of travel is a key determinant of VT. It is essential to distinguish between work-related travel and other types of travel, such as commuting, leisure travel, or travel for personal reasons.

- VT increases with travel distance, with an estimated elasticity generally between 0.1 and 0.2. However, this relationship is unlikely to be linear, and many studies distinguish between local and intercity travel.

- Travel conditions, such as waiting time or congestion, play an important role in determining VT.
- The mode of transport influences VT, although it is often difficult to disentangle the effect of the mode itself from that of the socioeconomic characteristics of its users. For example, the higher valuation of time savings for air travel is likely due in part to the higher average income of air passengers.
- VT appears to be higher in Europe than in North America.
- The level of comfort associated with a public transport mode affects VT, with vehicle occupancy being a key determinant of perceived comfort.
- Travel time reliability also has a distinct value, for which individuals are willing to pay.

Several public authorities have developed detailed guidelines for valuing time in transportation projects. In France, Baumstark et al. (2013) devote two chapters to this issue. In the United Kingdom, the Department for Transport publishes detailed guidance on recommended values of time for use in transport project appraisal (see the Transport Analysis Guidance).

In Canada, Zhang et al. (2004) provide a review of the literature on the value of time in transportation. Their main recommendations are summarized in Table 16.2. In particular, they recommend the use of adjustment factors for situations involving congestion, walking, or waiting. These adjustments are intended to reflect the additional disutility associated with such conditions.

Table 16.2 Recommendations for VT in transportation in Canada

Element	**VT recommended**
Private travel (leisure and commuting)	50% of net salary
Business travel (paid by employer)	Gross salary plus other benefits
Travel during congestion	2 x VT
Travel on foot	2 x VT
Waiting time	2.5 x VT
VT elasticity with respect to income	0.75
VT elasticity with respect to distance	0.3
Source: Based on recommendations from Zhang *et al.*, (2004).	

It is worth noting that technological innovations, particularly improved connectivity, have likely reduced the

value of time, especially for modes of transport that do not require constant attention. Travel time can now be used productively for online work or for entertainment, thanks to these new technologies (see ITF, 2019).

16.2 The Value of Statistical Life (VSL)

16.2.1 Definition and use of the concept

Reducing mortality risks is often an objective of projects in the fields of health, transportation, safety, or the environment. To assess this benefit, it is necessary to establish a value of human life. Although this may seem ethically sensitive, it is important to emphasize that this does not involve assigning a value to the life of a specific individual facing certain death.

The **Value of a Statistical Life** (VSL) measures individuals' willingness to pay to reduce the risk of premature mortality. By convention, it is expressed as the willingness to pay to save one life, even though it is in fact derived from the willingness to pay for small reductions in mortality risk.

Example: VSL and the risk of fatal disease

The maximum willingness to pay to eliminate the risk of premature death from a disease has been estimated at $200 per year for each exposed individual. It is also known that the risk of premature death from this disease is 1 in 10,000, and that the population exposed to this risk consists of 200,000 people. Determine the VSL in this situation.

Answer

- Total willingness to pay of the population = $200 x 200,000 = $40 million;
- The average number of lives saved per year = = $\frac{1}{10\,000} \times 200\,000$ = 20;
- The VSL is therefore, in this example, $\frac{40 \text{ millions}}{20}$ = 2 million dollars.

An alternative way to obtain the same result is to divide the individual willingness to pay by the reduction in risk, namely:

$$\frac{200\$}{\left(\frac{1}{10\,000}\right)} = 2 \text{ million dollars}$$

The VSL concept is now widely used in the United States and other jurisdictions to assess the benefits of interventions that modify the risks of premature mortality. Its use helps introduce greater coherence into collective decision-making and reduces arbitrariness in public policy choices.

In this regard, Viscusi et al. (1997) calculated the implicit VSL associated with various health and safety regulations adopted in the United States during the 1970s and 1980s, that is, before cost–benefit analyses became mandatory. Their results reveal substantial variation in the implied VSL values. For example, some regulations, such as the requirement to install airbags in automobiles, saved lives at relatively low cost (around $100,000 per life saved in 1984 dollars). In contrast, other regulations implied VSLs exceeding $1 billion, such as the 1987 occupational exposure limits for formaldehyde.

16.2.2 Empirical determination of VSL

Historically, the VSL was based on an individual's net contribution to collective wealth. For example, the cost associated with premature death was assessed by calculating the net income, after consumption, that an individual would have generated had they lived a normal lifespan.

This approach has been widely criticized, however, because it led to questionable results, including negative values for some individuals, and because it did not reflect the concept of willingness to pay to reduce mortality risks.

Today, the estimation of the VSL relies on more sophisticated techniques, such as those discussed in previous chapters. The following paragraphs briefly describe some applications of these methods.

The hedonic method of wages

The hedonic wage method, initially proposed by Thaler and Rosen (1975), consists of estimating a wage equation, often referred to as a Mincer equation, of the following form:

$$ln(w_{i,j,k}) = \alpha + \beta \text{Risk}_{j,k} + \gamma X_{i,j,k} + \epsilon_{i,j,k}$$

where:

$w_{i,j,k}$: the hourly wage of worker i employed in industry j and occupation k;

$\text{Risk}_{j,k}$: the risk of mortality from a work-related accident in industry j and occupation k. This variable typically comes from official statistics and is measured as the annual number of work-related deaths per 100,000 workers;

$X_{i,j,k}$: a set of variables that determine income levels (such as age, gender, education, experience, and working conditions);

$\epsilon_{i,j,k}$: a random error term capturing factors that affect wages but are not observable;

α, β, γ: parameters to be estimated using appropriate statistical techniques.

The estimation must be based on data with a sufficiently large number of observations to identify the wage premium required to compensate for an additional unit of risk, all else being equal. In this context, the objective is to estimate the **willingness to receive**.

Estimating this wage equation raises several econometric challenges, which are not discussed here. Once the relevant parameter is estimated, the VSL can be derived as follows[1]:

$$VSL = \beta \times w \times h \times 100,000$$

where h denotes the number of working hours per year.

Using this approach, Kniesner et al. (2012) estimated a wage equation based on U.S. data for 2,036 men observed repeatedly between 1993 and 2001. The average annual mortality risk in their sample was 6.4 deaths per 100,000 workers. Their econometric analysis yielded VSL estimates ranging from US$4 million to US$10 million.

The main criticisms of this approach are as follows:

1. Selection bias: Individuals who choose riskier occupations may be less risk-averse than the general population. In this case, the observed wage premium would underestimate the willingness to pay to reduce risk for society as a whole;
2. Information about risk: If workers have imperfect information about job-related risks, wages may not fully reflect objective risk levels;
3. Labor market imperfections: Distortions such as union bargaining or monopsony power can prevent wage premiums from accurately reflecting the statistical value of life;
4. Other risks: Wage premiums may also compensate for non-fatal risks, such as injuries or disabilities. Because the risks of fatal and non-fatal events are often highly correlated, it is difficult to isolate the portion of the premium attributable solely to mortality risk.

These critiques highlight the limitations and challenges associated with using the hedonic wage approach to estimate the statistical value of life.

The hedonic method on durable goods

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1. Given the semi-log specification of the wage equation, we obtain $\left(\frac{\delta w}{\delta \text{Risk}}\right) \times \left(\frac{1}{w}\right) = \beta$, so the hourly wage premium associated with a risk increase of 1 per 100,000 workers is $\frac{\delta w}{\delta \text{Risk}} = \beta w$. To obtain an annual value, this amount is multiplied by h. Finally, multiplying by 100,000 (the inverse of the risk change) yields the value of a statistical life.

The hedonic method can also be applied to durable goods whose value is influenced by mortality risk. For example, some studies analyze housing prices as a function of neighborhood-level mortality risks. Gayer, Hamilton, and Viscusi (2000) obtained a VSL of US$7.2 million by examining the relationship between property values and proximity to a contaminated chemical site, which increases the probability of cancer-related mortality.

In addition, some studies estimate the VSL using hedonic regressions of automobile prices, since certain vehicles offer higher levels of safety than others. For example, Rohlfs, Sullivan, and Kniesner (2015) inferred a VSL of between US$9 million and US$10 million based on the price premium paid for vehicles equipped with airbags in the late 1990s.

Avoidance expenditures

Expenditures on goods or services that are motivated by a reduction in mortality risk can also be used to infer a lower bound for the VSL. For example, if a dietary supplement costs $25 per year and its only benefit is to reduce the annual mortality risk by 1 in 100,000, this implies a VSL of at least $2.5 million for individuals who choose to purchase the product.

In practice, however, safety-related goods and services often provide additional benefits, such as reducing the risk of non-fatal illnesses or injuries, which complicates the analysis. Nevertheless, VSL estimates have been derived from expenditures on bicycle helmets (Jenkins, Owens, and Wiggins, 2001), smoke detectors (Garbacz, 1989), and organic baby food (Maguire et al., 2004).

Stated preference approaches

Contingent valuation and related stated preference methods are increasingly used to estimate the VSL (Kniesner and Viscusi, 2019; OECD, 2012). The principle of these approaches is to ask a representative sample of the population how much they would be willing to pay to reduce their risk of death. The main challenge lies in presenting risk reductions and payment scenarios in a way that is clear, credible, and realistic for respondents.

In Canada, studies based on stated preference data remain relatively scarce, and most are somewhat dated. One example is the study by Chestnut, Rowe, and Breffle (2012), which is summarized in the box below.

Cancer or heart attack and VSL in Canada and the United States



Chestnut, Rowe, and Breffle (2012) conducted two online surveys of adults aged 35 to 84: one with 885 respondents in the United States and another with 641 respondents in Canada (excluding Quebec). The surveys assessed individuals' willingness to pay to reduce their annual risk of death from cancer or heart disease by 1, 2, or 5 per 10,000.

Respondents were asked to consider a hypothetical payment to participate in costly prevention activities, such as annual screening tests not covered by insurance or the purchase of supplements and natural products. The questionnaires specified that these programs had no side effects and that respondents would have to pay annually for the rest of their lives in order to obtain the expected risk reduction.

Willingness to pay was elicited using four binary choice questions, in which participants had to choose between a risk reduction paired with a given cost and an alternative option. Some choice sets included the status quo, that is, no risk reduction and no additional cost.

In addition to these binary choices, respondents were asked to state their maximum willingness to pay to reduce their risk of death from cancer or heart disease using a payment card with values ranging from $0 to $6,200 per year. To help respondents understand the choices presented, the questionnaire began with information on actual age-specific mortality risks from cancer and heart disease, followed by questions designed to test respondents' comprehension.

The statistical analysis examined the effect of several explanatory factors on willingness to pay, including the nature of the risk (cancer or heart attack), the magnitude of the risk reduction, age, household income, expected quality of life over the next ten years, attitudes toward risk, and the presence of children.

The main results from the binary choice analysis are as follows:

- Willingness to pay increases with the magnitude of the risk reduction, with an estimated elasticity of 0.3;
- There is no specific premium for avoiding cancer relative to heart disease, implying that willingness to pay does not depend on the cause of mortality;
- The elasticity of willingness to pay with respect to income is estimated at approximately 0.5;

- Age has no statistically significant effect on willingness to pay to reduce mortality risks;
- Greater risk aversion is associated with a higher willingness to pay;
- The results are very similar for Canada and the United States.

The analysis of the determinants of willingness to pay based on payment card responses yields broadly similar results, with a few notable differences. For example, in this approach, age appears to have a positive effect on willingness to pay.

The estimated statistical value of life (VSL) derived from the binary choice responses ranges between US$4 million and US$5 million (in 2012 dollars). By contrast, the VSL estimated from payment card responses is approximately half that amount. The authors suggest that respondents may place less weight on cost considerations in the binary choice framework, as this approach requires them to process more information simultaneously.

The Transfer of Value

Value transfer is a particularly relevant approach for assessing the VSL, since a large number of VSL estimates already exist across a wide range of contexts and have been obtained using different methodologies. Numerous meta-analyses have examined the contextual factors that may influence these values. Common adjustments include exchange rates and income levels. With respect to income, several studies have analyzed how the VSL varies with income. The next section reviews the current state of knowledge on the VSL, with particular attention to its relationship with income.

16.2.3 The state of knowledge and challenges regarding the VSL

Estimates of the VSL vary substantially across studies. For example, the OECD conducted a meta-analysis of 856 VSL estimates derived from stated preference data. Among these estimates, 32% were below 1 million (2005 US dollars), 24% were between 1 million and 3 million, and 15% exceeded 20 million dollars.

The benchmark values used by public authorities also differ markedly. According to Robinson et al. (2010), the values applied by US regulatory agencies range from 1 to 21 million US dollars (2007 dollars). The European Commission, by contrast, recommends a range of 1 to 2 million euros (2000 euros). In Canada, the 2023 *Cost-Benefit Analysis Guide for Canada* recommends a value of 6.5 million Canadian dollars (in 2007 dollars), adjusted for inflation. In Quebec, Rojas et al. (2023) propose two distinct estimates of the VSL. The

first, equal to 4.1 million dollars, is derived using a willingness-to-pay approach. The second, estimated at 2.6 million dollars, is based on the human capital method. Both values are expressed in 2019 Canadian dollars.

Based on the results of its meta-analysis, the OECD (2012) makes the following recommendations:

- Within a given jurisdiction, it is recommended, for ethical reasons, to use a single statistical value of life for all individuals, regardless of income. In particular, applying a lower VSL to projects affecting low-income populations should be avoided.

- Across jurisdictions, however, it is appropriate to adjust the VSL according to average income levels. For example, it is reasonable for Quebec to use a lower VSL than the United States, given its lower average standard of living. When applying value transfer, the OECD recommends using an income elasticity of 0.8 for developed countries, with a sensitivity analysis using a value of 0.4. It is also recommended to adjust the VSL over time to reflect economic growth.

- There is no strong empirical evidence that willingness to pay to reduce mortality risk declines with age. Consequently, adjusting the VSL downward based on age is not recommended. By contrast, there is some evidence that willingness to pay to reduce child mortality risk is higher, which may justify the application of a premium for children.

- Finally, the available evidence does not support a clear or systematic relationship between the nature of the risk and the VSL. While some studies suggest a premium for avoiding specific risks, such as cancer, the results are too limited and inconsistent to justify standardized adjustments.

The challenges of the VSL

Beyond the limitations associated with the estimation methods discussed above, the concept and use of the value of a statistical life (VSL) raise additional challenges (Bosworth, Hunter, & Kibria, 2017).

1. A measure based on small changes in risk

During the COVID-19 pandemic, the VSL was used to conduct CBAs of various public policies, such as social distancing measures (e.g., Thunström et al., 2020). The use of the VSL in this context has been contested (Colmer, 2020), since this value is derived from individuals' willingness to pay for very small reductions in mortality risk. It may therefore be ill-suited to situations such as a pandemic, where mortality risks are large, highly uncertain, and widespread.

2. Cognitive biases in risk perception

Stated preference methods are particularly sensitive to cognitive biases in risk perception. Research shows that individuals tend to overestimate rare risks, such as plane crashes or terrorist attacks, while underestimating more common risks, such as mortality from car accidents or excessive consumption of processed foods.

In addition, individuals often display ambiguity aversion, that is, a preference for situations in which risks

are well defined rather than uncertain. This aversion to ambiguity can lead to an overestimation of the VSL when it is inferred from poorly defined or unfamiliar risks.

3. Biases in the publication process

The academic publication process may also introduce bias. Researchers are more likely to publish results that are high, statistically significant, and consistent with existing consensus. As a result, studies yielding relatively low VSL estimates may be less likely to be published or even submitted.

To address this issue, some meta-analyses weight estimates by their standard deviation, giving greater importance to more precise estimates. Applying this correction can lead to a substantial reduction in the estimated VSL (Doucouliagos et al., 2012).

4. The risk of instrumentalization

Finally, the wide range of plausible VSL values creates a risk of instrumentalization. Analysts may be tempted to select a relatively high VSL in order to justify a larger number of regulatory interventions. Such choices can influence policy decisions and resource allocation, potentially undermining the credibility and neutrality of CBA.

16.3 The Social Cost of Carbon (SCC)

The fight against climate change has become a central concern of public policy in recent decades. In this context, the analysis of climate policies requires assigning a value to a tonne of carbon emitted—or, conversely, reduced or avoided.

> **The social cost of carbon** (SCC) is a monetary measure of the present and future damages caused by emitting one additional tonne of carbon dioxide (CO^2) into the atmosphere in a given year.

Several key aspects of this definition should be emphasized:

1. The SCC is intended to measure damages at the global scale;

2. Because of the long residence time of carbon in the atmosphere, the time horizon considered typically extends over 100 years or more. As a result, the choice of the social discount rate used to aggregate impacts over time is of critical importance;

3. The SCC is a marginal cost, as it represents the damage caused by one additional tonne of CO_2, taking

into account the existing stock of carbon in the atmosphere. This implies that the SCC increases over time, since atmospheric carbon concentrations—and therefore marginal damages—rise year after year.

Incorporating global damages into the estimation of the SCC often leads to spatial asymmetry in the assessment of costs and benefits associated with climate policies. For example, while the costs of a greenhouse gas reduction program are typically borne at the national level, the benefits are largely global.

It should be recalled, however, that the Organisation for Economic Co-operation and Development (OECD) recommends accounting for international impacts when international agreements require such consideration, or when ethical considerations justify it (see Chapter 2).

Estimating the SCC is inherently complex and involves substantial uncertainty. In Canada, the SCC used by the federal government is based on the transfer method, drawing on estimates developed in the United States. The main adjustment consists of converting values into Canadian dollars. The most recent update was released in December 2022.

The U.S. guidelines used by Environment and Climate Change Canada were originally developed in 2009 under President Obama by an interagency working group, with subsequent updates in 2016 and 2021. Until the most recent revision, SCC estimates were based on three integrated assessment models: DICE, PAGE, and FUND, which are briefly described in the box below. Since 2021, the SCC has been estimated using an updated integrated assessment framework that incorporates recent advances in climate science and economics (US EPA, 2023).

Integrated assessment models

Integrated assessment models are multidisciplinary frameworks that combine an economic model with models of the climate system, including the atmosphere, oceans, and the carbon cycle, among others. Figure 16.1 illustrates the general structure of these models.

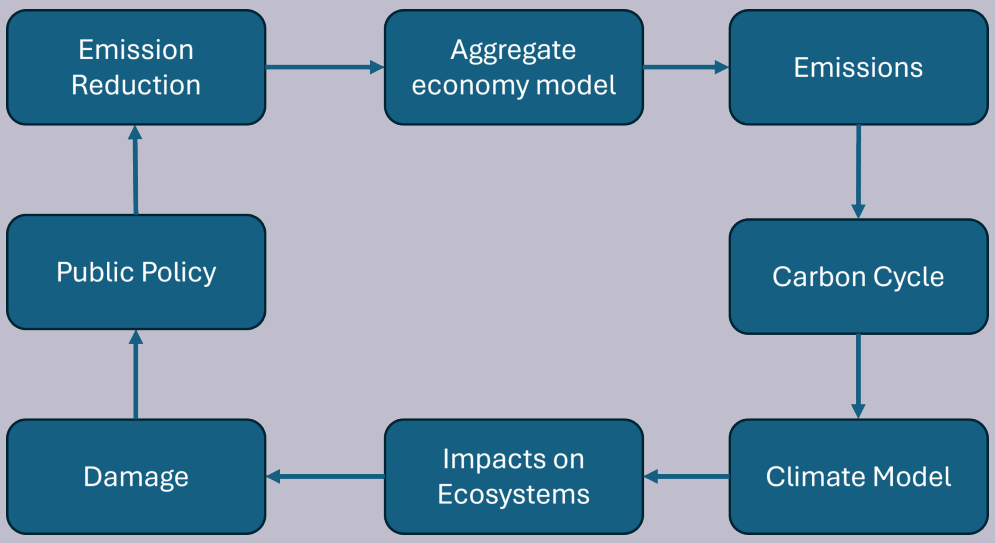


Figure 16.1 structure of integrated assessment models (adapted from Metcalf and Stock, 2017, p. 82)

These are probabilistic models in which parameter values are drawn from probability distributions. According to Metcalf and Stock (2017), the main sources of variation across models include climate sensitivity to CO^2 concentrations, the specification of damage functions, the treatment of low-probability but catastrophic events, and the choice of the discount rate.

The reliability of these models has been questioned by some economists, notably Robert Pindyck, who argues:

> "A plethora of integrated assessment models (IAMs) have been constructed and used to estimate the social cost of carbon (SCC) and evaluate alternative abatement policies. These models have crucial flaws that make them close to useless as tools for policy analysis: certain inputs (eg, the discount rate) are arbitrary, but have huge effects on the SCC estimates the models produce; the models' descriptions of the impact of climate change are completely ad hoc, with no theoretical or empirical foundation; and the models can tell us nothing about the most important driver of the SCC, the possibility of a catastrophic climate outcome. IAM-based analyzes of climate policy create a perception of knowledge and precision, but that perception is illusory and misleading."

Source: Pindyck, 2013, p. 860

DICE

The DICE model, short for "Dynamic Integrated model of Climate and the Economy," was developed by William Nordhaus, recipient of the 2018 Nobel Prize in Economics. It is an integrated assessment model designed to evaluate climate policies by capturing interactions between the economy, the carbon cycle, climate change, and public policy. DICE is based on a neoclassical growth framework in which greenhouse gas emissions reduce natural capital and generate future damages. Investments in emissions reductions reduce current consumption but help avoid future losses. Policy recommendations are derived from the non-linear optimization of a social welfare function.

FUND

The FUND model, which stands for "Climate Framework for Uncertainty, Negotiation and Distribution," integrates simplified representations of population dynamics, technology, economic activity, emissions, atmospheric chemistry, climate processes, and sea-level rise. The model distinguishes 16 world regions and covers the period from 1950 to 2300. Originally developed by the Dutch economist Richard Tol, FUND has been widely used by the Intergovernmental Panel on Climate Change (IPCC). It is generally known to produce lower estimates of the social cost of carbon than the DICE and PAGE models.

PAGE

The PAGE model, or "Policy Analysis of the Greenhouse Effect," was developed by Chris Hope at the University of Cambridge. It spans ten time periods from 2000 to 2200 and divides the world into nine regions. PAGE is a stochastic model in which key parameters are specified as probability distributions. It incorporates both economic and non-economic damages, as well as the possibility of catastrophic climate outcomes.

PAGE was used as the basis for the cost–benefit analysis of climate change in the 2007 Stern Review, commissioned by the UK government. In that context, a discount rate of 1.4% was applied. The model also incorporates equity considerations by accounting for the diminishing marginal utility of consumption.

Table 16.3 presents a selection of values recommended by Environment Canada (2023) for the social cost of carbon [2]. It is important to note that the carbon price set by Quebec's cap-and-trade system does not necessarily correspond to the SCC. Indeed, this price depends on the quantity of emission permits issued by the government. It will only be equal to the SCC if the number of permits corresponds to the socially optimal level of emissions [3].

2. Environment Canada sets the SCC between 2020 and 2080 and that of two other greenhouse gases, namely methane and nitrous oxide.

3. In 2023, the price on the carbon market is approximately $50 per tonne.

Table 16.3 SCC (CO_2) between 2020 and 2050 (in 2021 CAD, 2% discount rate) for use by Government of Canada departments and agencies

Year	SCC CO_2
2020	247
2021	252
2022	256
2023	261
2024	266
2025	271
2030	294
2040	341
2050	394
Source: Environment and Climate Change Canada (2023)	

16.4 Conclusions

Key takeaways

- The value of time is a parameter frequently used in CBAs in the transportation sector.
- It measures individuals' willingness to pay to save travel time.
- This value is related to wages, but it also depends on preferences and travel conditions.
- Empirical estimates of the value of time are obtained by analyzing real or hypothetical choices that involve trade-offs between time and monetary costs.
- A large body of research has examined the value of time and its determinants, which makes the use of the transfer method possible.
- Although the statistical value of life is expressed in terms of the willingness to pay to avoid a death, it is in fact based on the willingness to pay for a small reduction in the risk of death.
- The value of life can be estimated using hedonic wage studies, analyses of durable goods, or

avoidance expenditures. However, direct methods are increasingly used.

- Estimates of the value of life vary widely, but in developed countries they most often fall in the range of $5 million to $10 million. This value tends to increase with a country's standard of living.
- There is no empirical justification for reducing the value of life with age, although a premium for children may be justified.
- The social cost of carbon measures the value of the total current and future damages caused by the emission of an additional tonne of carbon.
- It is a key parameter in CBAs of climate policies.
- Estimating the social cost of carbon relies on complex integrated assessment models.
- There is substantial uncertainty surrounding this parameter, and its value depends in particular on the discount rate used to aggregate damages over time.
- Several jurisdictions provide official guidance on the values that should be used in public policy CBAs.

Back to motivation

A government is considering increasing the speed limit on its motorways from 100 km/h to 120 km/h. The main impacts to be assessed in a CBA of this project are:

1. Time savings resulting from higher travel speeds;
2. Impacts on road safety, given that the project could increase the risk of accidents and fatalities;
3. Environmental impacts, particularly with respect to climate change.

Conducting this CBA therefore requires the estimation of "reference prices," notably for an hour of travel time saved, a human life, and a tonne of carbon. How do the methods presented in the previous chapters make it possible to determine these values?

Resolution

The main purpose of this chapter is to address the questions raised in this example. In addition, Van

Benthem (2015) examines the social benefits and costs associated with increasing highway speed limits from 55 to 65 mph in the western United States between 1987 and 1996. According to this analysis, a 10 mph increase in the posted speed limit leads to an increase in actual driving speeds of about 3 to 4 mph. This, in turn, results in a 9 to 15% increase in traffic accidents, many of which involve fatalities. The higher speeds are also associated with a deterioration in air quality, with significant consequences for public health.

Overall, the study finds that the social costs generated by the increase in speed limits are between two and seven times greater than the associated social benefits. The author further argues that this conclusion remains robust even after accounting for improvements in the safety performance of newer vehicles.

Exercises

1.(*) To dissolve a blood clot during a heart attack, the drug currently in use carries a risk of fatal allergic reactions of 5 cases per 100,000 treatments. Health authorities are considering the use of a new drug that is more expensive but reduces the risk of fatal reactions to 3 cases per 100,000. In all other respects, the two drugs are equivalent. The authorities rely on a Statistical Value of Life of 5 million dollars as a guideline when approving new drugs. Under these conditions, what is the maximum additional cost per treatment that the new drug can have in order to be accepted under this guideline?

a) $40;
b) $55;
c) $75;
d) $100;
(e) $150;
f) $175;
g) $250;
h) None of the above.

2. What role does the Social Cost of Carbon play in the evaluation of low-carbon investments and projects?

3. (*) In the United States, the first Trump administration (2017–2021) revised the methodology used to calculate the social cost of carbon that had been proposed under the Obama administration (2009–2017). The two main changes were: (i) limiting the assessment of damages to those occurring within the United States rather than considering global damages; and (ii) applying a discount rate of 7–10% instead of 3%. Explain how these changes are likely to have affected the estimated value of the social cost of carbon. Discuss the rationale behind these methodological changes.

4. With respect to the concept of the value of time saved, briefly answer the following questions:

(a) How is the value of time saved generally measured and expressed?

b) Why is the value of time saved not always equal to net salary?

(c) How does the value of time saved vary depending on the mode of transport (car, public transport, walking, etc.) and the type of travel (work, leisure, shopping, etc.)?

Annex 1

Data collected on real or hypothetical choices are most often discrete in nature, meaning that the variable to be explained (for example, the choice of mode of transportation) is not continuous but instead takes on a limited number of possible values. For instance, if a worker can choose to commute by car, by bus, or by a non-motorized mode, the variable "choice of mode of transportation" has three possible outcomes, such as 1 = car, 2 = bus, and 3 = non-motorized mode. The econometric analysis of such discrete variables requires the use of specific techniques—known as **discrete choice econometrics**—the detailed presentation of which is beyond the scope of this manual. It is sufficient here to note that these techniques are often based on the additive random utility model introduced by McFadden (1974). In this model, it is assumed that an individual i chooses a mode of transportation by comparing the level of utility he or she would obtain from each option, according to the following function:

$$U_{im} = V_{im} + \epsilon_{im}$$

with :

i: the respondent indicator.

m: the mode indicator (m = 1 for car, m = 2 for bus and m = 3 for non-motorized mode).

V_{im}: the systematic part of utility, that is, it can be explained.

ϵ_{im}: an error term that represents the unobservable characteristics of the respondent and those alternatives that will influence his choice (for example, his level of ecological awareness or his taste for driving).

For the systematic part, we assume that:

$$V_{im} = V(z_{im}, s_i; \beta)$$

with :

z_{im}: attribute variables that characterize mode $m$for respondent i, for example, travel time, cost of the mode, its comfort level.

s_i: the variables that characterize respondent $i$and that affect his utility for the different modes, such as age, gender or income level.

β: represents the parameters that we aim to estimate.

The functions U_{im} and V_{im} are indirect utility functions conditional on the choice of a specific mode. Thus, U_{i1} represents the level of utility that respondent i can achieve conditional on choosing the car.

Moreover, these are indirect utility functions derived from an optimization process under budget constraints, and therefore depend on prices and income rather than on quantities.

We assume that decision makers are rational, so that respondent i chooses the mode that yields the highest level of conditional utility. For example, the car will be chosen if $U_{i1} > U_{i2}$ and $U_{i1} > U_{i3}$. However, since U_{im} is not directly observable (because ϵ_{im} is unobserved), choices must be analyzed in probabilistic terms. Accordingly, the probability that respondent i chooses the car is given by:

$$P_{i1} = \Pr[U_{i1} > U_{i2} \text{ and } U_{i1} > U_{i3}]$$

If we assume that ϵ_{im} is identically and independently distributed according to a Gumbel distribution, we obtain a multinomial logit model, so that the probability takes the following explicit form [4] :

$$P_{i1} = \frac{e^{V_{i1}}}{e^{V_{i1}} + e^{V_{i2}} + e^{V_{i3}}}$$

with :

c_{im}: the monetary cost of a trip with mode *m*for respondent *i.*

t_{im}: the travel time with mode *m*for respondent *i.*

z_{im}: other attribute variables.

s_i: the control variables for the characteristics of individual *i.*

With appropriate data, it is possible to estimate the parameters of this model. From these estimates, the marginal willingness to pay to reduce travel time while holding utility constant—that is, the value of time (VT)—is given by:

$$\left.\frac{\Delta c}{\Delta t}\right|_{\Delta V=0} = -\frac{\beta_t}{\beta_c} = V_T$$

Using more flexible specifications, the value of time can be allowed to vary across individuals, depending on their socioeconomic characteristics, or across modes of transportation.

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4. If we assume normal distributions instead, we obtain the multinomial probit model.

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PART IV
OTHER ELEMENTS OF CBA

In this part, we explore several additional dimensions of cost–benefit analysis (CBA). Chapter 17 examines the challenges associated with choosing a social discount rate, a complex and crucial issue. Chapter 18 focuses on the management of uncertainty, risk, and biases encountered in CBA. Chapter 19 is devoted to best practices in drafting CBA reports. Finally, Chapter 20 introduces several methodologies related to CBA, such as cost-effectiveness analysis and cost–utility analysis, thereby broadening the range of analytical tools available to practitioners.

17.

THE SOCIAL DISCOUNT RATE

Motivation and learning objectives

If we use a social discount rate of 7%, the **net present value (NPV)** of a tramway project is negative, but it becomes positive when a rate of 4% is used. How should a recommendation be formulated in this context?

The choice of the social discount rate (SDR) can have a significant impact on CBA results. As explained in Chapter 6, a higher rate assigns less weight to a project's future impacts. For projects such as a tramway, which involve large upfront costs but generate steady revenue streams over their lifetime, a higher discount rate will often tend to reduce the NPV.

Determining the TAS is therefore a crucial issue that remains subject to debate. It should be recalled that the TAS is intended to measure the social opportunity cost of the resources mobilized by the project. This chapter examines the methods and issues related to the choice of this key parameter.

By the end of this chapter, you will be able to understand:

1. The method for determining the TAS based on a weighted average of market rates;
2. The method based on the evaluation of intertemporal preferences;
3. The challenges associated with discounting over long time horizons;
4. The approaches and rates used by different jurisdictions.

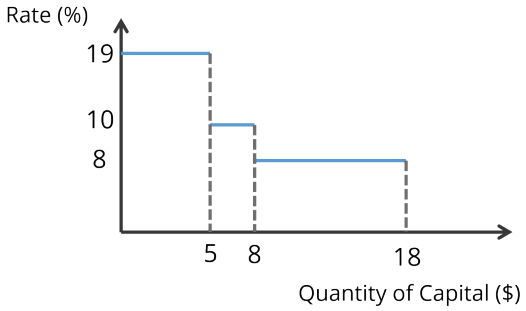
17.1 The social discount rate as a weighted average of market rates

17.1.1 The capital market

To understand this approach, it is useful to briefly describe how a capital market operates in a very simple context: that of a closed and undistorted economy. This implies that there are no inflows or outflows of capital from the country, no taxes, no risks, and no **information asymmetry**. In this idealized setting, the demand for capital reflects firms' investment decisions, while the supply reflects individuals' saving decisions.

The demand for capital

At any given time, there is a set of investment projects, each with its own private **internal rate of return**, ρ_i for project i. Figure 17.1 presents an example of three investment projects ranked in descending order of their internal rates of return. The decision to undertake each project depends on a comparison between the market interest rate and the internal rate of return. For example, if the interest rate at which the firm can finance a project exceeds 19%, none of the projects will be profitable, and the demand for capital will be zero. If the rate is 19% or less but greater than 10%, only project A will be undertaken, and the demand for capital will be $5 million. In the range between 8% and 10%, both projects A and B will be profitable, resulting in a demand of $8 million. Finally, for a rate less than or equal to 8%, all three projects will be profitable, and the demand for capital will rise to $18 million. Figure 17.1 illustrates the demand for capital in this example. With a very large number of potential projects, the demand for capital can be represented by a continuous, downward-sloping curve, as shown in Figure 17.2.



Project	Investment (million of $)	Internal Rate of Return (ρ_i)
A	5	19%
B	3	10%
C	10	8%

Figure 17.1 Investment decision and demand for capital

The **demand for capital** reflects the trade-off between the internal rate of return on investment projects and the market interest rate, that is, the cost of financing those projects. For a given

interest rate, the marginal investment project undertaken therefore has an internal rate of return equal to the interest rate.

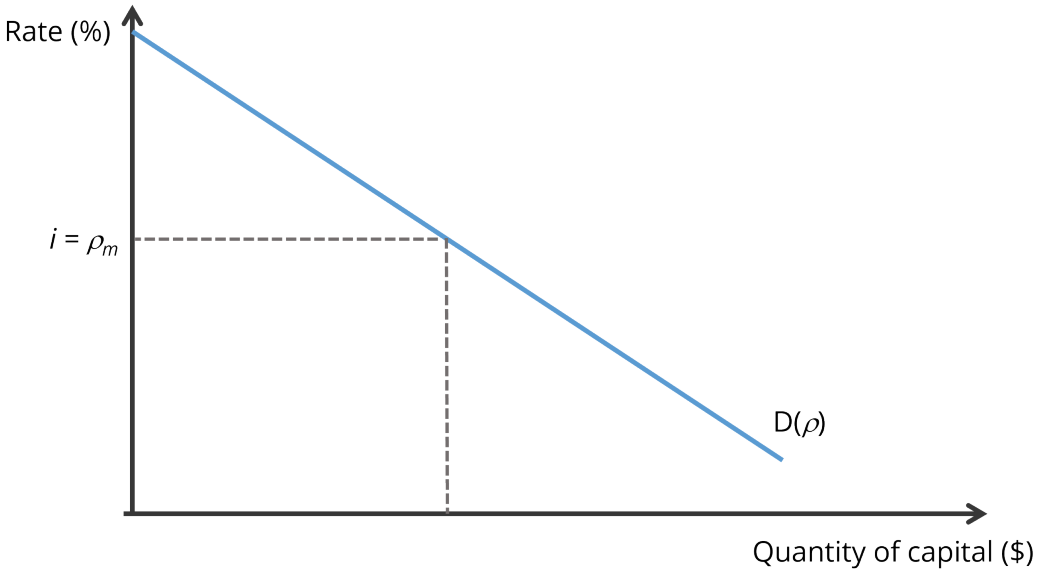


Figure 17.2 Capital Demand Curve

The supply of capital

In our simplified economy, the supply of capital comes from individuals' savings. Saving decisions reflect the trade-off between current consumption and future consumption. Indeed, saving is a way of shifting consumption over time. This trade-off depends on the intertemporal preference rate.

The **intertemporal preference rate**, denoted by **δ**, measures the minimum interest rate required to forgo consuming $1 today in order to be able to consume (1 + **δ**%) in the future.

If a person has a δ equal to 20%, this means that he or she will be willing to consume less today only if the amount saved earns an interest rate of 20%. At the individual level, δ is expected to increase as the amount already saved increases. As a result, the individual supply of savings increases with the interest rate. Moreover, the intertemporal preference rate varies across individuals within the population. This implies that the aggregate capital supply curve slopes upward with the interest rate, since higher interest rates induce more people to save. Figure 17.3 shows the capital supply curve. If the interest rate is i %, the quantity of capital

supplied is Q0, and the intertemporal preference rate at the margin is i %. The marginal saver is therefore indifferent between saving and consuming more today.

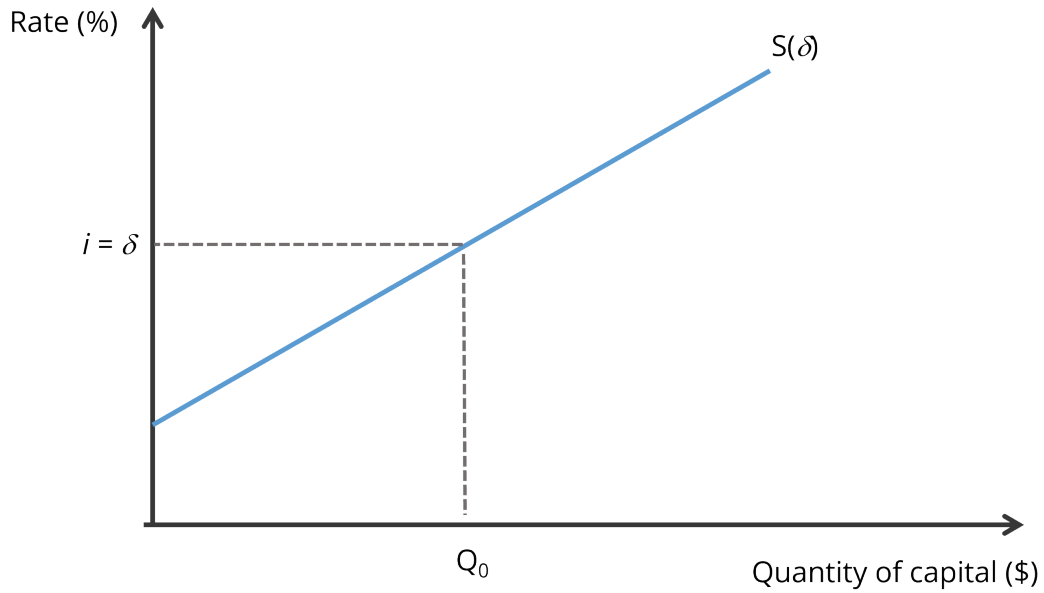


Figure 17.3 The Supply of Capital

Capital market equilibrium

In this idealized setting, equilibrium occurs at the intersection of supply and demand, at the equilibrium interest rate i* (see Figure 17.4). This rate represents both the opportunity cost of investment at the margin and the intertemporal preference rate at the margin.

In this context, the CBA of an additional project whose scale is unlikely to affect the equilibrium interest rate should be evaluated using a TAS equal to i*. Indeed, whether the funds invested in the project come from increased savings or from the crowding out of other projects is irrelevant: the opportunity cost is i*, since i* = ρ = δ.

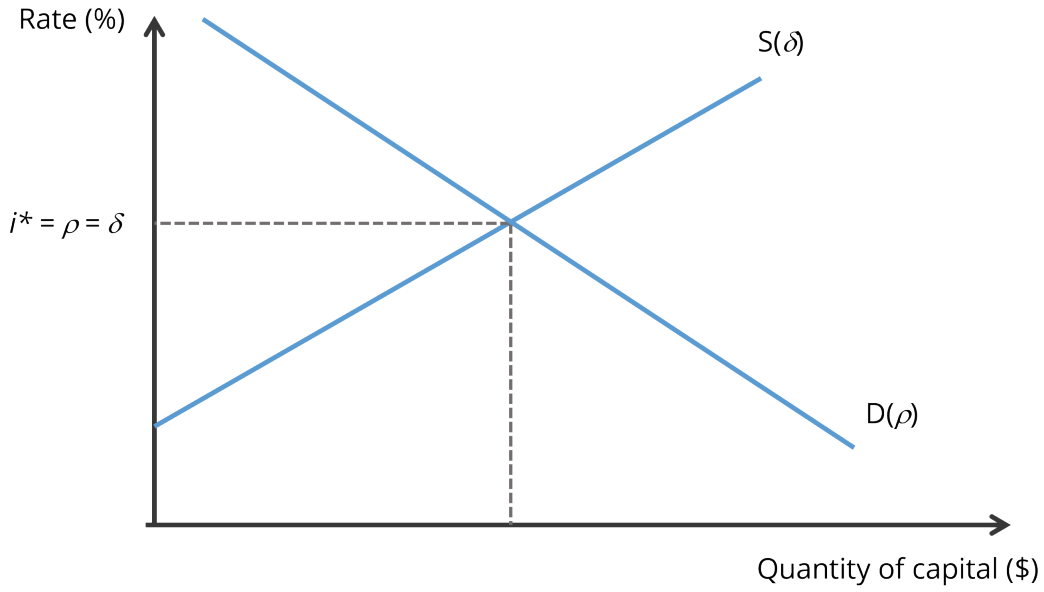


Figure 17.4 Undistorted capital market equilibrium

In the presence of distortion

As in other markets, the capital market is subject to distortions, which cause the opportunity cost of investing in a project to vary depending on its source of financing. This can be illustrated by assuming a savings tax of t %. As mentioned earlier, this tax creates a wedge between the rate paid by those who demand capital and the rate received by those who supply it. In Figure 17.5, the equilibrium interest rate i* reflects the rate of return on investment at the margin, but it no longer represents the intertemporal preference rate at the margin, since $\delta = i^* - t$.

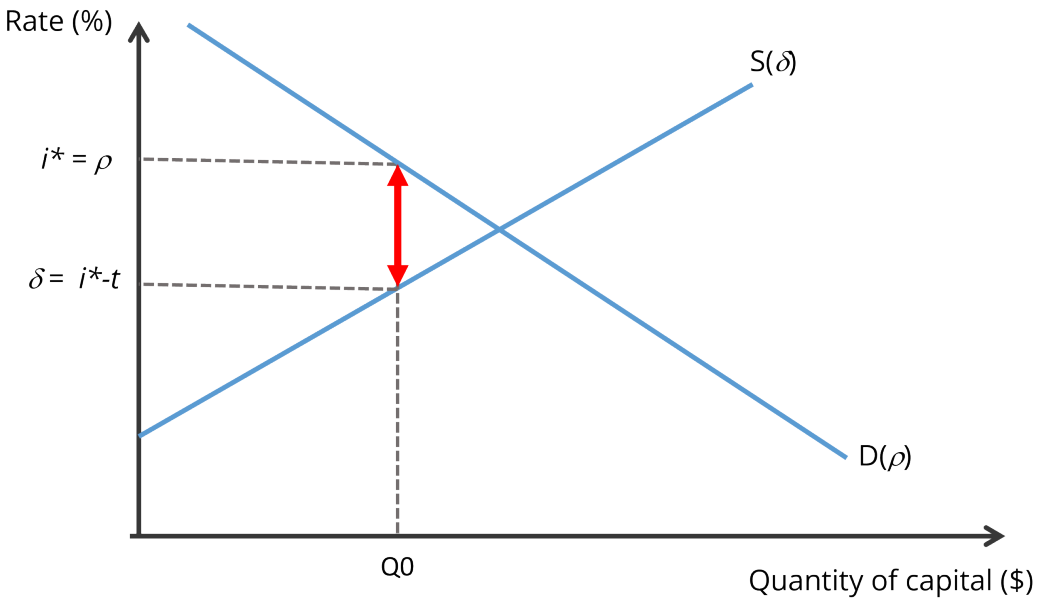


Figure 17.5 Market Equilibrium in the Presence of a Savings Tax

A new project (P) shifts the demand for capital to the right (see Figure 17.6). Part of the capital used by the project comes from the crowding out of other projects (between Q′ and Q) and is valued at the opportunity cost i*. By contrast, the portion that results from an increase in saving (between Q0 and Q1) has an opportunity cost of i* – t. This follows the same line of reasoning used for other inputs in Chapter 11.

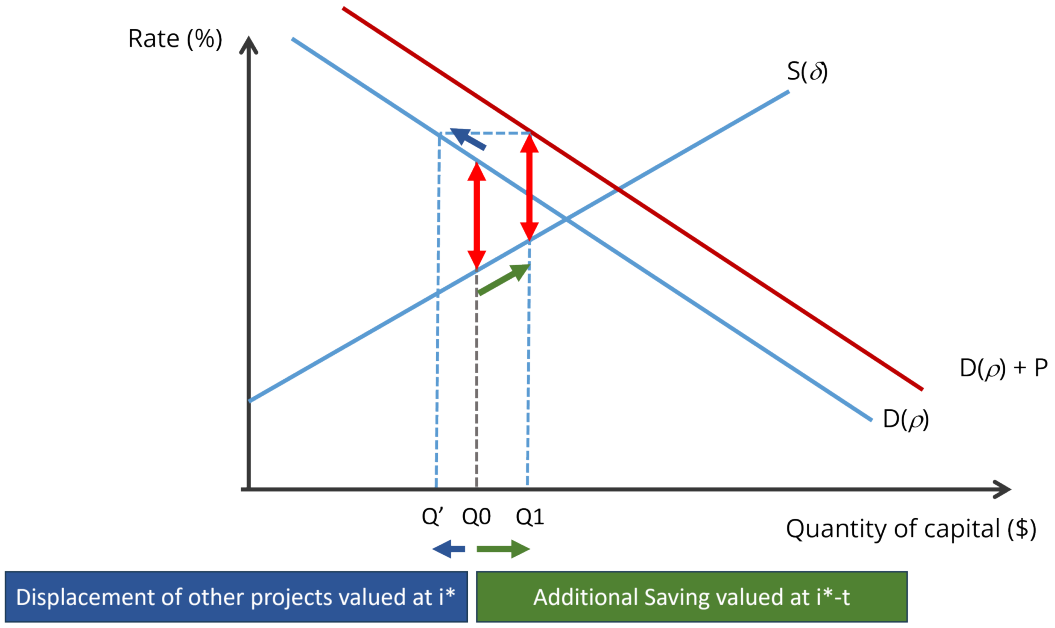


Figure 17.6 Opportunity cost and source of capital for a project P

This example illustrates that the source of capital for a project determines the appropriate discount rate. Harberger (1969) therefore proposes evaluating the social discount rate as a weighted average according to the source of funds, as described in the next subsection.

TAS as a weighted average of market rates

In an open economy, funds to finance a project may also come from external borrowing. In this context, the social discount rate can be evaluated as a weighted average according to the following formula:

$$TAS\% = a\,\rho\% + b\,\delta\% + (1-a-bi)\%$$

in which

TAS% : represents the social discount rate, expressed as a percentage;

a : the share of project resources that comes from the crowding out of private investment in the domestic economy;

ρ% : the internal rate of return at the margin of private investments;

b : the share of project resources coming from a crowding out of private consumption (savings);

δ% : the intertemporal preference rate at the margin;

i% : the interest rate on foreign loans at the margin.

The practical implementation of this formula requires assigning values to each of these parameters, which raises several challenges:

1. Rates should reflect marginal rather than average conditions. For example, if a government project crowds out private investment, it will displace an investment at the margin, which typically has a lower return than the average investment. Using an average rate of return on investments therefore risks overestimating the marginal rate. Conversely, the average return on savings tends to underestimate the intertemporal preference rate at the margin;

2. Capital markets offer a wide range of rates, which vary notably with risk. Each project subject to a CBA is also characterized by a specific risk profile, which could in principle justify incorporating a project-specific risk premium into the social discount rate. However, this is not the generally recommended approach. Instead, it is usually proposed to use a social discount rate without a specific risk premium, on the grounds that governments undertake a large portfolio of projects, allowing for the diversification of project-specific risks. That said, as Boyer, Gravel, and Mokbel (2013) note, projects may also involve non-diversifiable systemic risk. This issue is discussed further in Section 17.2 and Chapter 18;
3. Estimating the weights is not straightforward, as it requires assessing the elasticity of the different potential sources of capital in response to changes in interest rates.

Confusion between the financing rate of a project and the social discount rate



It is crucial not to confuse the rate at which governments can finance a project with the social discount rate, as explained by Boyer, Gravel, and Mokbel (2013). Governments generally benefit from advantageous financing rates because they are not required to pay a risk premium to lenders. However, this does not mean that the risk associated with these public projects disappears. In reality, it is the population, through taxes, that bears the risk and, therefore, the cost in the event of a problem in a project. Thus, the use of rates on government bonds for determining the SAR is questionable.

17.2 The TAS and the social intertemporal preference rate

An alternative strategy for assessing the SAR is based on the Social Intertemporal Preference Rate (SIPR), which is the implicit rate chosen by society to allocate resources between current and future consumption. This method is particularly relevant in contexts where the financing of government projects comes mainly from current tax revenues or from increases in public debt, which will eventually have to be repaid through

future taxes. From this perspective, government projects therefore tend to substitute primarily for consumption, whether current or future, rather than for private investment.

The social intertemporal preference rate is, of course, related to the rate δ discussed earlier. However, it is also necessary to take into account expected growth in the standard of living and changes in the marginal utility of consumption. More precisely, drawing on a neoclassical growth model, Ramsey (1928) derived the following formula:

$$TPIS = \delta + g\,\varepsilon$$

in which:

TPIS : represents the social time preference rate;

δ : the intertemporal preference rate, often described as "pure," to distinguish it more clearly from the TPIS;

g : the expected growth rate of consumption per capita;

ε : the absolute value of the elasticity of the marginal utility of consumption with respect to growth, that is, the percentage reduction in the marginal utility of consumption following a 1% increase in the level of consumption.

The explanation of the equation known as the "Ramsey formula" is based on a clear principle: the allocation of resources between present and future consumption must take into account both individuals' "pure" impatience and the adjustment required for anticipated economic growth. The latter affects the marginal utility of a dollar of future consumption, making it lower than that of a dollar consumed today, assuming continued economic growth. In other words, the Ramsey formula incorporates both the desire for immediate gratification and expectations about future economic growth, which influence the value assigned to future consumption relative to current consumption.

The analysis of this formula in a multigenerational context is particularly illuminating. Indeed, the fight against climate change requires the current generation to make sacrifices in order to generate benefits (more precisely, to avoid costs) for future generations. The trade-off must therefore take into account the fact that future generations are likely, if economic development continues, to be richer, implying that their marginal utility of consumption will be lower than that of the current generation. In other words, a foregone dollar reduces current welfare more than the welfare gain associated with an additional dollar in the future.

Based on the historical evolution of the growth rate in Canada, Boardman et al. (2010) propose using g = 1.7%, with a **sensitivity analysis** at 1.5% and 2%. For ε and ρ, these authors review existing estimates and propose a value of 1.5 for ε, with a sensitivity analysis at 1 and 4, and a value of 1 for ρ. On this basis, the SAR in Canada should be 3.5%, with a sensitivity range from 1.5% to 7%.

In France, the application of the Ramsey formula has been extended to incorporate the systemic risk associated with a project (Baumstark et al., 2013). From this perspective, the systemic risk of a project cannot be eliminated through diversification because of its correlation with overall economic trends. For example, the net benefits of a transport project are often positively correlated with economic growth, implying a risk of lower returns in the event of a deterioration in general economic conditions. Such risk should therefore be

reflected in a higher TAS. Conversely, a project whose net benefits are likely to increase during an economic downturn exhibits negative specific risk, thereby justifying the use of a lower TAS. Hospital utilization, which tends to increase during economic recessions, provides an illustrative example.

A committee of experts mandated by the French government (Gostner and Ni, 2023) recommends adjusting the TAS according to the systemic risk of a project using the following formula:

$$\text{TAS} = \text{Risk-free TAS} + \beta \times \text{Systemic risk premium}$$

where β measures the sensitivity of the project's future net benefits to growth in GDP per capita. The risk-free TAS is determined using the Ramsey formula.

For the year 2021, the committee recommends the following values:

Risk-free rate of 1.2%;

Systemic risk premium of 2%;

$\beta = 1.1$ for urban transport projects;

$\beta = 1.2$ for regional transport projects;

$\beta = 1.7$ for long-distance transport projects;

$\beta = 1.4$ for rail freight transport projects;

$\beta = 1$ for other projects, pending the results of additional sectoral studies.

17.3 The TAS and time horizon

As mentioned in Chapter 6, **discounting** causes the value assigned to future benefits to decline geometrically over time. As a result, future consequences are eventually considered negligible. Consider a social discount rate of 3.5%. Under this rate, a sum of $1 billion received in 50 years has an NPV of $179 million. If the same amount is received in 100 years, the NPV falls to $32 million, and it declines further to $10 million if the payment occurs in 200 years.

This can be problematic when analyzing projects with consequences for future generations, as it assigns them very little weight. There is therefore a risk of a "dictatorship of the present." A project that entails a small cost today in order to prevent substantial damage in the distant future may fail the CBA test. This issue is particularly salient in the context of climate change mitigation. Accordingly, some researchers, such as Stern (2007), recommend using a TAS equal to zero (or very low) to analyze multigenerational projects (typically when $T > 50$ years).

However, as Nordhaus (2007) points out, using a very low TAS can instead lead to a "dictatorship of the future." Because future generations will outnumber the current one, a project that requires very large sacrifices today to generate modest but persistent benefits over time could pass the CBA test. For example, a project that costs $1 billion today and generates $11 million per year over 100 years would be deemed profitable.

Determining the TAS for projects with very long time horizons therefore remains a subject of debate. One

proposed solution is to allow the TAS to decline over time. For instance, Boardman et al. (2010) propose the following TAS structure:

$$\text{TAS} = \begin{cases} 3.5\% &\text{for } t = 1 \text{ to } 50 \\ 2.5\% &\text{for } t = 51 \text{ to } 100 \\ 2\% &\text{for } t = 101 \text{ to } 200 \\ 1.5\% &\text{for } t > 200 \end{cases}$$

This approach, similar to hyperbolic discounting, is based on the idea that the importance assigned to future benefits declines rapidly at first and then more gradually as the time horizon extends. This notion is supported in particular by experimental evidence highlighting such behavioral tendencies in individuals. For example, studies such as Green et al. (1994) have shown that people often prefer receiving $5,000 immediately rather than $7,000 in one year. However, those same individuals would choose $7,000 in six years over $5,000 in five years.

The adoption of this discounting method aims to acknowledge significant but distant impacts while avoiding placing the future in a position of absolute supremacy. Nevertheless, hyperbolic discounting can lead to time-inconsistent decisions. In the example above, after five years, the individual might regret the initial choice and wish they had opted for the immediate receipt of $5,000 rather than waiting an additional year to obtain $7,000.

17.4 In practice

Unfortunately, there is no consensus on the choice of the TAS, or even on the methodology used to determine it. In addition, several conceptual issues remain unresolved. Various organizations and jurisdictions have therefore adopted standards or recommendations for the TAS, as shown in Table 17.2. For example, the most recent update of the Cost–Benefit Analysis Guide for Canada recommends using a base rate of 7%, except for environmental and health projects, for which the rate may be reduced to 3%.

The U.S. Environmental Protection Agency recommends that the costs and benefits of a project first be presented as undiscounted time streams. The NPV is then calculated using two types of TAS: one reflecting the **opportunity cost of private capital**, and the other based on the intertemporal preference rate. This methodology is intended to provide decision-makers with a more nuanced assessment of the **social profitability** of a project. It is also essential to emphasize the importance of conducting a sensitivity analysis on the TAS in order to assess how changes in this rate affect the evaluation of the project.

Based on available assessments, the use of a 7% TAS, combined with a complementary analysis at 3%, appears appropriate for generational projects. For projects with a multi-generational horizon (over 50 years), an analysis using a TAS that declines over time may also be justified.

Table 17.2 The social discount rate used in practice

Jurisdiction and organization	Real TAS	Noticed
Canada – Cost-Benefit Analysis Guide for Canada	7%	3 % for environmental and health projects . Weighted average and Ramsey formula
US, Environmental Protection Agency (2010)	3 % and 7 %	For projects over 50 years old, use 3 % and use hyperbolic discounting .
US, Office of Management and Budget (2018)	3 % and 7 %	3 % corresponds to the average yield on 10-year government bonds and 7 % to the average pre-tax yield on private capital .
France, Gostner and Ni (2023)	1.2 %	Addition of a premium for systemic risk of up to 3 %
UK , HM Treasury Green Book (2018)	3.5 %	For projects with a duration of more than 30 years, the TAS is adjusted to 3% for the period covering 31 to 75 years and reduced to 2.5% for the period extending from 76 to 125 years.

17.5 Conclusions

Key takeaways

- The choice of the TAS can have significant consequences for a CBA. Unfortunately, there is no consensus on the appropriate value of the TAS, and several conceptual issues remain debated.
- The weighted average method takes into account the source of the invested funds—such as the crowding out of private investment, private consumption, or foreign borrowing—in order to measure the social opportunity cost of capital.
- The social intertemporal preference rate method is based on the analysis of society's trade-off between the present and the future.

- Very long-term discounting (T > 50 years) raises challenges related to intergenerational fairness, as it may either underweight future generations or, conversely, give them excessive weight. One proposed solution is to use a TAS that declines over time, although this approach raises issues of consistency.
- In practice, some jurisdictions have adopted standards for the TAS. In the absence of such standards, discounting using TAS values of 3% and 7% appears appropriate for projects with horizons of fifty years or less. For projects extending beyond fifty years, it may be useful to apply a TAS that decreases over time.
- A CBA should also present benefit and cost streams over time in undiscounted terms, in addition to performing a sensitivity analysis with respect to the TAS.

Back to motivation

If we use a social discount rate of 7%, the **net present value (NPV)** of a tramway project is negative, but it becomes positive when a rate of 4% is used. How should a recommendation be formulated in this context?

Resolution

Obviously, there is no precise answer to this question. The analyst must exercise judgment while being as transparent as possible in their recommendations. In this situation, the analyst should, in particular:

- Check whether the CBA sponsor has a reference value for the TAS;
- If this is not the case, take the project's lifespan into account. In the case of a tramway, the lifespan is generally less than 50 years, meaning that it is not truly a project with consequences spanning several generations;
- Consider the nature of the main benefits. A tramway may help reduce pollution, which could justify the use of a lower rate. However, this is probably not the project's primary impact. The main benefits are often related to time savings and improved comfort for users;

Exercises

1. Briefly explain why the capital market interest rate is not necessarily a good measure of the social discount rate.
2. Based on the concepts of the dictatorship of the present and the dictatorship of the future, explain the issues associated with discounting projects aimed at reducing greenhouse gas emissions.
3. What is hyperbolic discounting?
4. Please briefly explain the intuition behind Ramsey's formula.
5. Briefly explain the two main approaches to determining the social discount rate.

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18.

UNCERTAINTY, RISKS, AND BIASES

Motivation and learning objectives

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To address the deterioration of the materials of a monument, authorities can choose between two restoration approaches that guarantee the same quality of restoration. The first option relies on a traditional approach, for which the estimated cost of one million dollars is very reliable. The second option adopts a new approach that is still little used but is expected to allow the restoration to be carried out at half the cost. However, it carries a 40% probability of a 350% cost overrun. Which option would you recommend?

In Chapter 6, we presented the decision rules applied in the context of CBA. The primary rule is that a project should be recommended if its **net present value (NPV)** is positive, that is, if its social benefits exceed its social costs. When choosing between two mutually exclusive projects, the one with the higher NPV should be selected. However, these rules assume that the NPV is assessed with certainty, which is rarely the case in practice. The evaluation of a project's costs, benefits, and duration is most often uncertain and subject to many risks. How can these risks and uncertainties be documented? How do they affect project selection? Are there systemic biases in CBA? These issues are examined in this chapter.

By the end of the chapter, you will be able to understand:

1. The concepts of risk and uncertainty and their implications for project selection;
2. The different forms of sensitivity analysis;
3. The causes of the megaproject curse.

18.1 Uncertainty, risks and choice of projects

Risk refers to a situation in which the final outcome is unknown, but the possible outcomes and their probability distribution are known a priori. In contrast, uncertainty refers to a situation in which the final outcome, the set of possible outcomes, and their probability distribution are unknown a priori.

For example, in a game of heads or tails, the possible outcomes and their probabilities are known in advance, making it a risky situation. By contrast, a tunnel project in ground that has not been characterized represents an uncertain situation, since neither the range of possible outcomes nor their probabilities is known. It is conceptually easier to analyze risk than uncertainty.

A distinction is commonly made between specific risk and systemic risk. Specific risk, also referred to as idiosyncratic or diversifiable risk, arises from random factors specific to a given project. For instance, the NPV of a vaccination campaign depends on the population's vaccination rate, which may be affected by widely publicized adverse effects. Systemic risk, or non-diversifiable risk, arises from general factors that are not specific to the project, such as overall economic conditions. The NPV of a new highway, for example, will be lower than expected if economic growth turns out to be weaker than anticipated.

The NPV of a project therefore depends on both specific and systemic risks and is subject to uncertainty. How should this affect project selection rules?

Project risks and choices

The expected utility theory developed by von Neumann and Morgenstern provides a framework for analyzing decision-making under risk. Applied to CBA, this theory posits that the choice between two risky projects depends not only on their expected NPVs, but also on the magnitude of the risks involved and the decision-maker's attitude toward risk.

These ideas can be illustrated with a simple example. Table 18.1 presents the NPVs of two mutually exclusive

projects. Project A is risky: with a probability of 0.2, its NPV is −$1 million, and with a probability of 0.8, its NPV is $6.5 million. The expected value of this project's NPV is the probability-weighted average of its possible outcomes:

Expected value of the NPV of Project A = 0.2 × (−$1 million) + 0.8 × $6.5 million = $5 million.

Project B is risk-free, and its NPV is also $5 million.

Table 18.1 Outcomes and probability of the two projects

Project	**Low NPV (probabilities)**	**High NPV (probabilities)**	**Expected VAN**
HAS	-$1 million (0.2)	$6.5 million (0.8)	$5 million
B	—	$5 million (1)	$5 million

In this context, the expected NPV is the same, while one project is risky and the other is not. The decision therefore depends on the risk attitude of the decision-maker. If the decision-maker is risk-neutral, the two projects are considered equivalent, since they yield the same expected NPV. By contrast, under risk aversion, Project B will be preferred because it offers a certain outcome. Project A will be preferred in the case of risk-seeking behavior, since it offers the possibility of obtaining more than $5 million.

In practice, CBA is typically conducted under the assumption of risk neutrality. Under this assumption, the selection rules in the presence of risk become:

- Non-mutually exclusive and unconstrained projects: recommend projects for which the expected NPV is positive;
- Mutually exclusive projects: recommend the project with the highest expected NPV;
  Projects subject to a budget constraint: recommend the project or set of projects that maximizes the sum of expected NPVs, provided that the sum of expected costs remains within the budget.

The assumption of risk neutrality in CBA is generally justified by two main arguments:

1. The possibility of eliminating a project's specific risk through diversification across a portfolio of projects. With a sufficiently large number of projects, those that perform better than expected are assumed to offset those that perform worse;
2. The idea that the systemic risk associated with a project is low.

The validity of these justifications has nonetheless been questioned (see Atkinson et al., 2018). Complete

diversification is not always feasible, and systemic risks may be significant. Moreover, the widespread demand for individual insurance highlights the presence of risk aversion, suggesting that collective choices should, at least to some extent, reflect such preferences. It may also be unwise to underestimate low-probability risks that could lead to catastrophic and irreversible outcomes, a concern that arises when focusing exclusively on expected values.

In practice, there is no uniform or widely accepted method for explicitly incorporating risk attitudes into the project selection process. Most often, risks are analyzed using quantitative or qualitative **sensitivity analyses** (see Section 18.2). The results of these analyses are then taken into account in an ad hoc manner when formulating recommendations.

More formal approaches are sometimes adopted by certain authorities. For example, French authorities account for systemic risk when determining the **social discount rate** (see Chapter 17). It is also possible to require that project costs include a contingency reserve to reduce the likelihood of cost overruns. To the extent that the size of this reserve depends on the level of risk and uncertainty, it may influence project selection (see Section 18.3).

Uncertainty and project choice

Uncertainty, by its nature, is difficult to address through quantitative sensitivity analysis, since neither all possible outcomes nor their probabilities of occurrence are known. Uncertainty is therefore most often assessed using qualitative approaches.

In an environment characterized by uncertainty, flexibility—the ability to accelerate, postpone, modify the scope of a project, or even abandon it—becomes particularly important. In other words, project flexibility provides a distinct advantage, often referred to as "quasi-option value"[1]. This flexibility allows decision-makers to adapt to changes and newly available information, thereby improving project outcomes as the context evolves.

For example, when choosing between implementing a bus rapid transit system and a tramway, the former is distinguished by its greater flexibility, largely due to lower initial costs. This flexibility is especially valuable in the face of uncertainty about public transport demand, as bus routes can be adjusted more easily and more quickly than tram lines. This characteristic of flexibility should therefore be taken into account in the CBA of these two options.

It is possible to assess the benefits of such flexibility using financial real options analysis techniques, but applications of these methods in CBA remain relatively limited (e.g., Kind et al., 2017, for an application in the field of flood control).

18.2 Sensitivity analysis

The most common way to document risks and uncertainty in CBA is to perform quantitative and qualitative sensitivity analyses.

1. This is actually the same concept as real option value used in finance.

18.2.1 Quantitative analysis

Quantitative sensitivity analysis aims to document how the NPV of a project evolves depending on the values of the main CBA parameters. As we mentioned in Chapter 2, three types of analysis are possible:

1. By parameter;
2. By scenario;
3. By simulation.

Analysis by parameter

The simplest and most widely used approach is to document how the NPV changes when the value of one parameter is modified at a time. For example, this may involve illustrating how the NPV changes when the social discount rate is varied. If the base rate is 5%, the parameter-based sensitivity analysis would recalculate the NPV using a lower and a higher rate, such as 3% and 7%, which are the two values recommended by the Government of Canada (see Chapter 17, Section 4). The analysis should focus on parameters that are both uncertain and likely to have a significant impact on the NPV. The results are often presented in the form of a tornado diagram (see Chapter 2 for an example).

It is also possible to show how the NPV evolves over a range of values for a given parameter. For instance, Figure 18.1 illustrates the evolution of the NPV of a project to develop a reserved lane for a bus route as a function of expected annual ridership. In some cases, this approach makes it possible to identify the break-even point or profitability threshold of the project with respect to a given parameter, that is, the value at which NPV = 0. In this example, slightly more than 30,000 users per year are required for the project to be socially profitable. It is assumed that the values of all other parameters are held constant at their baseline levels.

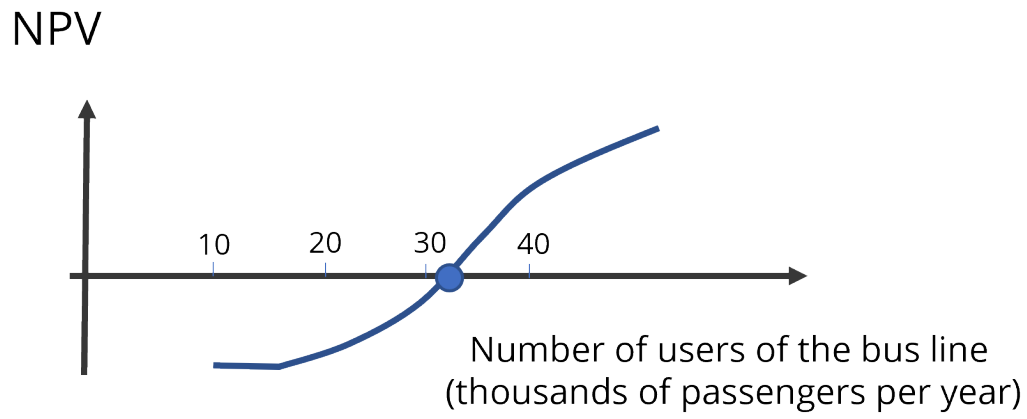


Figure 18.1 The evolution of NPV as a function of traffic

Parameter sensitivity analysis has the advantage of being simple and easy to interpret. However, it does not always provide an accurate assessment of the risks surrounding a project, particularly when the values of several parameters are correlated. For example, in the case of a bus line, ridership depends on regional economic

growth, which also affects the value of time. If economic activity in the region turns out to be weaker than expected in the baseline scenario, not only will ridership be lower, but the value of time savings per user will also decline. This is precisely the type of situation that the scenario-based approach is designed to analyze.

Scenario analysis

In this approach, the analyst constructs different scenarios corresponding to combinations of parameter values. In addition to the baseline scenario, they may develop an optimistic scenario (for example, lower costs, higher traffic, a lower discount rate) and a pessimistic scenario (cost overruns, low economic growth, a reduced value of time, and so on).

Like the parameter-based approach, the scenario approach is relatively easy to implement. However, it relies on the analyst's choices, which introduces an element of subjectivity. The simulation approach seeks to systematize and make explicit the assumptions regarding risk.

Simulation analysis

Under this approach, the risk associated with key parameter values is represented using statistical distribution functions, such as uniform, triangular, or normal distributions. The choice of these distributions should be based on historical data, empirical analyses, or expert judgment.

Once the statistical properties of the parameters have been specified, a very large number of simulations are performed algorithmically, that is, repeated random draws of parameter values (for example, a draw may yield a discount rate of 5.45% and an **elasticity of demand** of 0.5). Each draw of parameter values generates a corresponding NPV. By conducting a large number of draws (for instance, 10,000), each producing a different NPV, it is possible to simulate the statistical distribution of the NPV, as illustrated in Figure 18.2. In this example, there is approximately a 40% probability that the NPV is negative. It is also possible to calculate the expected value and its standard deviation, which is a measure of dispersion[2].

2. For more details on this method, see Boardman et al. (2018).

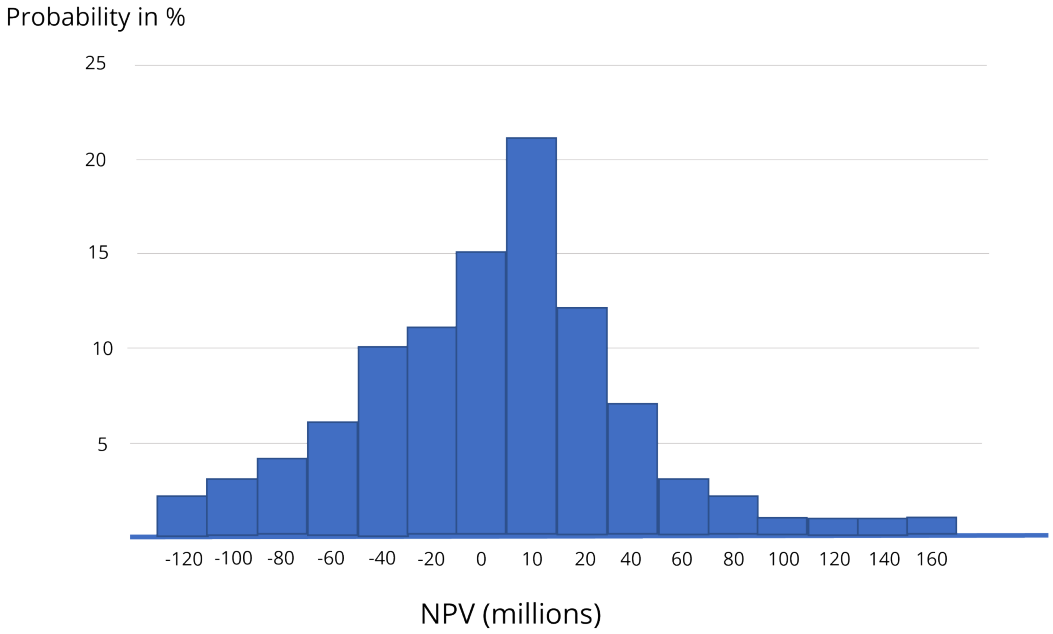


Figure 18.2 Histogram of the distribution of the NPV of a project obtained from a Monte Carlo simulation

18.2.2 Qualitative analysis

Qualitative analysis aims to broaden the perspective, particularly by addressing uncertainty or risks that cannot be examined through quantitative analysis. This may include discussion of more diffuse effects that are not captured by CBA but that decision-makers may nonetheless wish to take into account. Some of the common issues faced by projects are discussed in the next section.

18.3 The curse of megaprojects

There is no official definition of a megaproject, but according to Flyvbjerg (2017), a megaproject typically has the following characteristics: it is complex, spans several years, usually costs more than $1 billion, involves many partners, and has significant impacts.

Flyvbjerg and Bester (2021) analyzed the performance of 2,062 public projects from 104 countries over the period 1927–2013, covering eight investment categories (bridges, buildings, bus rapid transit systems, dams, power plants, railways, and tunnels). A comparison of forecasts with actual outcomes reveals a strong tendency to underestimate costs by an average of 40% and to overestimate benefits by an average of 10%. The benefits of bus rapid transit and railway projects appear to be particularly overestimated (by about 60% and 35%, respectively). Moreover, these large projects are typically delivered with substantial delays.

These findings led Flyvbjerg (2017) to propose a principle known as "The Iron Law of Megaprojects," which can be stated as follows: "Over budget, over time, under benefits, over and over again." In French, the

curse of large projects can be summarized by the expression: "Cost overruns, delays, overestimated benefits, over and over again"[3].

The curse of major projects: the Montreal Metropolitan Express Network.

This light rail project, launched in 2015, ultimately envisions 67 km of track and 26 stations. In 2016, the initial cost was estimated at $5.5 billion, with the first section scheduled to open in 2021. After additional stations were added, the estimated cost rose to $6.3 billion. By 2023, the projected cost had increased to $7.95 billion, representing a 45% increase over the initial estimate, which corresponds to the average cost overrun observed in the rail sector. The first section, comprising five stations, opened in the summer of 2023. It is still too early to assess the benefits of this project.



Source: Lea-Kim Chateauneuf, CC BY-SA 4.0, via Wikimedia Commons

The study of project performance by Marcellis-Warin et al. (2014) and Flyvbjerg (2011) identifies a series of risk factors associated with project cost and schedule overruns, as detailed in Table 18.2.

3. This curse likely also affects smaller projects; see Marcellis Warin et al. (2014).

Table 18.2 Project risk factors

Risk factors	Example
Project Features	• Size • Duration
Project complexity	• Innovative • Non-standard technology
Changes made during implementation	• Changing the magnitude • Changes in objectives
Insufficient planning process	• Inadequate needs assessment • Top-down approach • Lack of collaboration with the performers
Project governance	• Non-competitive award process • Capture effect following an irreversible choice early in the process
Political instability and regulatory uncertainty	• Change of continuity following political change • Pressure group with divergent interests
External factors	• Geology • Climate • Archaeological
Economic factors	• **Inflation** • Exchange rate • Recession

Frauds	• Conspiracy • Rigging the offer • Collusion • **Market Power**

However, the question arises as to why these risks are so often underestimated in CBAs. According to Flyvbjerg et al. (2007) and Flyvbjerg (2011), optimism bias and strategic manipulation are the root causes of the recurring drift observed in large projects. As described in Chapter 3, optimism bias is a **cognitive bias** that leads to an underestimation of risks. Strategic manipulation refers to the deliberate presentation of a project in an overly favorable light. This phenomenon is particularly pronounced in competitive environments where multiple projects compete for funding. In such contexts, developers, entrepreneurs, analysts, and politicians have strong incentives to embellish project presentations. Flyvbjerg (2011) summarizes this idea with the following equation:

Underestimation of costs + Overestimation of benefits = Project approval.

To counter this curse, Flyvbjerg proposes adjusting project assessments based on experience accumulated from similar projects. Reference class forecasting therefore consists of adjusting a project's internal forecasts using external historical data. This approach is used in the United Kingdom, the Netherlands, Denmark, and Switzerland.

It involves three steps, illustrated here using a cost estimate:

Identification of the reference class, that is, the selection of a set of completed projects of a comparable nature;

Estimation of the probability distribution of cost overruns within the reference class;

Adjustment of the project's internal cost estimate based on this external distribution and the level of cost overrun risk deemed acceptable.

To illustrate this procedure, consider a light rail project for which the probability distribution of total costs has been estimated in a CBA (see Figure 18.3). The expected cost of the project based on the internal estimate is $800 million. However, sensitivity analysis indicates that at this level, the probability of a cost overrun is 50%. To adopt a more conservative stance, suppose the analyst adds a $26 million contingency, reducing the probability of a cost overrun to 30%.

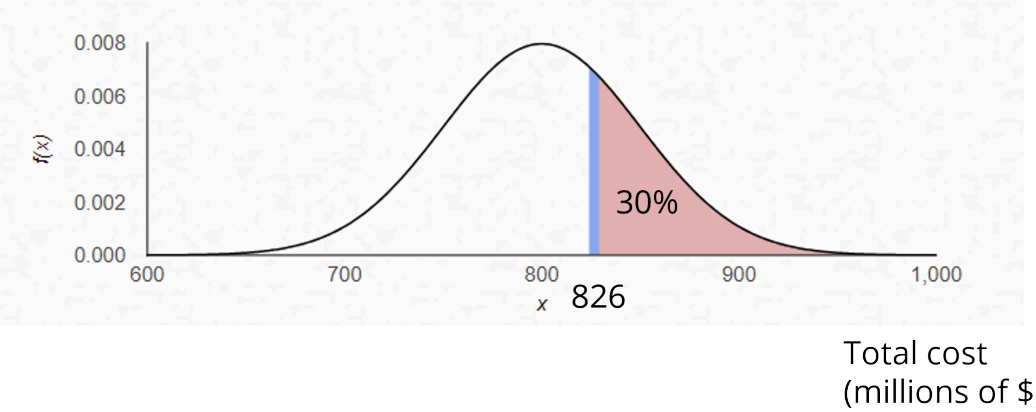


Figure 18.3 The probability distribution of project cost (internal assessment)

The external analysis of cost overruns for comparable projects yields a probability distribution as shown in Figure 18.4. The average cost overrun for this type of project is therefore 40%. This implies that the contingency reserve would need to be increased to 40% of the original project cost, bringing the total project cost to $1.12 billion. With this adjustment, however, the probability of a cost overrun would still be 50%. To reduce this risk to 30%, the internal cost adjustment would have to be increased to 50%, resulting in a total project cost of $1.23 billion.

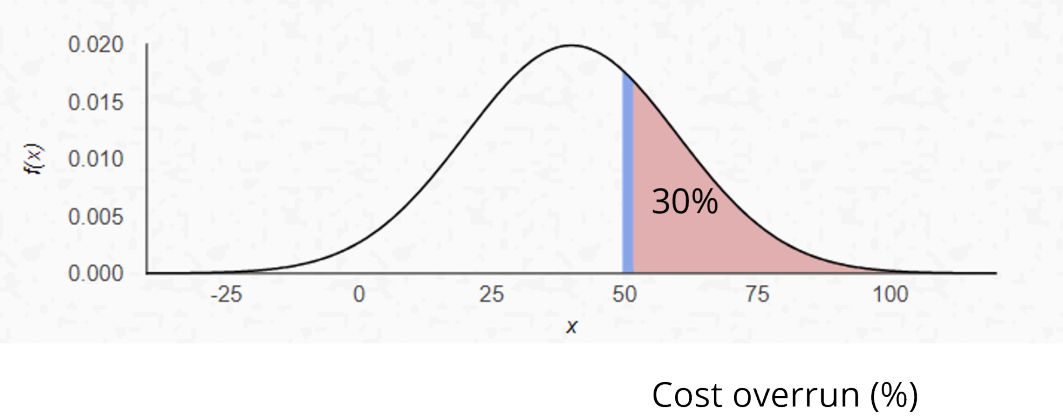


Figure 18.4 Probability distribution of cost overruns in the reference class

18.3 Conclusions

Key takeaways

- The costs, benefits, and schedule of a project are subject to risks and uncertainties that must be documented in a CBA through quantitative and qualitative sensitivity analyses.
- Risks are characterized by a set of possible outcomes and an associated probability distribution, whereas uncertainty refers to situations in which the possible outcomes and their probabilities are unknown.
- A distinction is made between project-specific risks and systemic risks arising from the broader economic environment.
- In practice, there is no uniform way to account for risk and uncertainty in the project selection process.
- Decision rules based on the expected value of the NPV implicitly assume risk neutrality, an assumption whose validity is often questioned.
- Systemic risk is sometimes taken into account through adjustments to the discount rate.
- Risk can also be addressed by including contingency reserves to reduce the likelihood of cost overruns; the size of these reserves should depend on the level of risk and uncertainty associated with the project.
- Quantitative sensitivity analysis can be conducted by parameter, by scenario, or through Monte Carlo simulation.
- Performance analyses of major projects reveal a recurring pattern of significant cost underestimation, benefit overestimation, and delivery delays.
- These patterns cannot be explained by random errors alone; they are more plausibly attributed to optimism bias and strategic manipulation of estimates.
- Reference class forecasting has been proposed as a way to improve the evaluation of large projects. It involves adjusting a project's internal estimates based on experience drawn from comparable projects.

Back to motivation

To address the deterioration of the materials of a monument, authorities can choose between two restoration approaches that guarantee the same quality of restoration. The first option relies on a traditional approach, for which the estimated cost of one million dollars is very reliable. The second

option adopts a new approach that is still little used but is expected to allow the restoration to be carried out at half the cost. However, it carries a 40% probability of a 350% cost overrun. Which option would you recommend?

Resolution

In this decision-making context, characterized by a defined risk in which the possible outcomes and their respective probabilities are clearly identified, adopting a risk-neutral stance leads public authorities to base their decision on the expected cost of the two restoration options.

The traditional approach: This option is associated with near-zero risk, with an estimated cost of $1 million, thereby offering complete financial predictability.

The new approach: The expected cost under this option is calculated as follows: 0.6 × $0.5 million (no overrun) plus 0.4 × [0.5 × (1 + 3.5)] million (in the event of an overrun), which yields an expected cost of $1.2 million.

Under these conditions, the traditional approach appears to be the more judicious choice, as it offers a lower expected cost. This recommendation remains unchanged even if public authorities are risk-averse, since the traditional option eliminates financial uncertainty while also being less costly in expected terms.

Exercises

1. (*) A biomethanization plant project aims to convert organic waste from a city's residents into natural gas. In your opinion, what are the main parameters and data that should be subject to sensitivity analysis for this project?
2. To illustrate the principle of the Monte Carlo method in a simple way, suppose that a project's costs vary uniformly between $5 million and $15 million, while its benefits vary uniformly between $1 million and $32 million. The two distributions are assumed to be independent.

   Using Excel, perform 100 random draws of costs and benefits. Then calculate the NPV resulting from each draw. Next, determine the mean and standard deviation of the NPV based on these 100 simulations.

   Finally, using the results of your 100 draws, determine the cost estimates such that the probability of a cost overrun is 50% and 25%, respectively.

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19.

WRITING THE CBA REPORT

Motivation and learning objectives

You have completed the CBA of a contaminated site remediation project. You now need to prepare the final report. How should this document be structured? What elements are essential to include? How can you ensure that the main message is clearly understood?

By the end of this chapter, you will have acquired the skills necessary to:

1. Structure your report effectively;
2. Write your report in a way that responds to the specific expectations of decision-makers and analysts;
3. Integrate a relevant critical assessment of your data sources.

19.1 The structure of the report

Writing a CBA report is a critical phase that requires a significant investment of time and thought. A poorly designed report can undermine the credibility of an otherwise rigorous analysis. It is therefore essential to consider several key elements:

1. **A report tailored to the target audience**: The report is primarily intended for two categories of readers: decision-makers and analysts. For decision-makers, a clear and accessible presentation, free of technical jargon, which summarizes the conclusions and explains the limitations of the analysis, is essential. For analysts, the details of the approach and the methodology adopted are essential for assessing the rigor of the CBA and, possibly, for reproducing its results;
2. **A neutral report**: It is imperative that the CBA remains impartial with respect to the project analyzed, thus avoiding reflecting the prejudices of its author. Recommendations must arise exclusively from the

results of the analysis, without being influenced by personal opinions;

3. **Hypotheses discussed**: A description and justification of the major hypotheses on which the analysis is based are necessary. They help to enlighten the reader on the foundations of the study as well as on the way in which the conclusions were drawn;
4. **A structured presentation** : The report must adopt an organized structure, clearly defined by numbered titles and subtitles, thus facilitating understanding and navigation within the document;
5. **Careful visual quality**: The CBA must reflect a professional level, both in formatting and in the choice of graphic elements, in order to optimize the reading and understanding experience of the proposed analysis.

The typical structure of a CBA report

Table 19.1 illustrates the recommended structure for a CBA report, based in part on the Government of Canada's guidance for regulatory impact analyses. It should be noted that this structure may vary depending on the specifics of the project and the requirements of the sponsor.

Table 19.1 Typical structure of a CBA

Components	Content
Title page (1 page)	• Project Title • Authors and affiliation • Mandatory body, if relevant • Date
Table of Contents	• Also includes a list of tables and graphs. • Tables and graphs must display a title, clear captions, notes, explanations and their possible sources.
Abbreviations and acronyms	
Executive Summary (From 1 to 5 pages)	• Summary of the project, its justification, the options analyzed, the benefits and costs • Summary table of benefits and costs • Effects on affected parties and distributive effects • Summary of the **sensitivity analysis** and the main limitations and determining assumptions of the analysis • Recommendations to decision makers in the form of a list (R1, R2, etc.)
Context	• Description of the needs targeted by the project • Project Description • Economic justifications for public authorities' commitment
Options considered	• Baseline scenarios and project scenario • Alternative scenarios for sensitivity analysis • Options considered but not retained
Stakeholders and identification of relevant impacts	• Identification of parties affected by the project • Description of costs and benefits • Analysis of unvalued impacts and justification

Methodology	• Conceptual framework • Review of literature and research on the subject • Main assumptions and parameters (justifications and anticipated impacts of the results) • Description of the sensitivity analysis • Description of the data and summary of the analysis of their qualities
Results	• Cost estimation • Estimation of benefits • Summary table • Analysis of results and external validation • Sensitivity analysis • Distributive effects
Recommendations and conclusions	• Recommendations based on the results of the analysis • Reminder of the limits
References	• List of references according to a recognized presentation standard • All items in the reference list must have been mentioned in the text. • All in-text citations should be detailed in the reference list.
Appendix	• Assessment of the quality of primary and secondary data and the values assigned to the parameters • Details of the methodology to enable reproduction of the results. • Table of impacts measured in natural units • Table of benefits and costs over time (without **updating** and with updating) • Summary table of hypotheses and parameter values
Source: Adapted from the Government of Canada (2023), section 9.3.	

The title page may alternatively be replaced by a summary sheet briefly outlining the content of the analysis, as illustrated in Appendix 1.

The executive summary requires particularly careful drafting, as decision-makers are very likely to read only this section. It is therefore advisable to adopt a clear, concise, and visually structured writing style (for example, by using numbered lists) to facilitate reading. The summary should focus on the core elements of the analysis, avoiding superfluous detail, while presenting as transparently as possible the limitations and uncertainties associated with the CBA. For instance, it is good practice to clearly identify in the summary table those relevant

impacts that are not monetized. When several recommendations are presented, organizing them in a numbered list is recommended, as this improves readability and allows each point to be clearly distinguished.

Particular attention must also be paid to the presentation of tables, figures, and diagrams. These elements should be accompanied by precise captions, explicit titles, and, where appropriate, sources and explanatory notes to facilitate interpretation.

An exhaustive list of bibliographic references is essential to support the credibility of the information and analyses presented. This list should follow a rigorous citation standard to enable readers to verify the sources used.

When identifying relevant impacts, the use of a summary table, such as Table 19.2, can be particularly useful. This table lists the various impacts and indicates their relevance in the context of the CBA. It helps clarify why certain effects are excluded from the analysis, either to avoid the risk of **double counting** or because they do not constitute additional impacts attributable to the project. The table also distinguishes between impacts that are quantified in natural units and those that are explicitly monetized in the analysis.

Table 19.2 Summary of relevant impacts

Impacts	Relevance	Quantifiable	Valued	Details
Costs				
Construction costs	**X**	**X**	**X**	
Psychological costs	**X**	**X**	Quantification by population survey (number of people who report a harmful effect of the project on their mental health). Difficult and controversial valuation	
Benefits				
Time savings	**X**	**X**	**X**	
Property prices are rising				Effect already taken into account by time savings
Structuring effects	**X**			Quantification and valuation outside the mandate
Economic benefits during construction				Impact not relevant, because not additional

Relevance: Should the impact be taken into account to measure the social profitability of the project (e.g., exclude impacts already measured elsewhere or those that are not additional)?
Quantifiable: Can the impact be measured in natural units? And if so, specify the unit.
Valued: Is the impact valued in the CBA?

In the methodology section, the level of detail required will vary depending on the complexity of the CBA. For a project considered "standard," for which the methodology is well established and widely accepted, a brief description may be sufficient. However, for projects in which the application of CBA is less common or raises specific methodological challenges, a more detailed explanation of the approach adopted is required.

In all cases, it is essential to provide readers with sufficient information to enable them to understand and, if necessary, reproduce the analysis. This entails clearly presenting the key methodological steps, the main assumptions, and the tools and data used. Such an approach ensures transparency and strengthens the credibility of the analysis.

19.2 Analysis of data validity

The reliability of the conclusions drawn from a CBA depends primarily on the quality of the data and estimates used. Given that data may sometimes be incomplete or of uncertain reliability, it is essential to conduct a rigorous assessment of data validity. This assessment should explicitly address issues related to data quality, covering both primary data and secondary sources.

Data quality analysis should be based on the following criteria:

1. Conformance: Verification that the available data meet the needs of the analysis. The use of proxies or substitute data must be justified when direct data are unavailable;
2. Accuracy: Assessment of how precisely the data measure what they are intended to measure, taking into account potential biases and errors;
3. Timeliness: Verification that the data are sufficiently recent to remain relevant. Where necessary, adjustments should be made to reflect changes in the economic or institutional environment;
4. Accessibility and clarity: Evaluation of how easily the data can be accessed and how clearly the data, variables, and data collection methods are described;
5. Consistency across sources: Examination of the compatibility of different data sources, particularly with respect to definitions and methodologies.

The results of the data quality assessment should be summarized in the main body of the report, while more technical details can be included in an appendix. This assessment may involve quantitative elements, such as variance analysis or tests of sample representativeness, but it often relies on qualitative judgment by the analyst or experts, as well as comparisons across multiple sources.

It may be useful to classify each variable or parameter according to a quality rating system, ranging from A (excellent quality) to D (very poor quality). This helps inform readers about the level of confidence that can be placed in different components of the analysis.

It is recommended that data quality analysis be conducted continuously throughout the CBA process rather than postponed until the final stage. This proactive approach allows methodological choices to be adjusted as needed and enables sensitivity analyses to be refined in light of data reliability.

19.3 Summary table of results

Table 19.3 shows an example of a CBA summary table in the environmental domain. This format can easily be adapted to suit other sectors.

Table 19.3 Summary of costs and benefits of an environmental quality improvement program

Benefits			
	For each option analyzed		Note
	Number	Millions $	
Improving human health			
Reduction of premature mortality	Estimate (fork)	Estimate (fork)	
Reduction of miscarriages	Estimate (fork)	Estimate (fork)	
Unquantified health impacts	Estimate (fork)	Estimate (fork)	
Environmental improvement			
Reduction of fish mortality	Estimate (fork)	Estimate (fork)	
Improving forest productivity	Estimate (fork)	Estimate (fork)	
TOTAL of the benefits valued	**Estimate (fork)**	**Estimate (fork)**	
Costs			
Initial costs	Estimate (fork)	Estimate (fork)	
Operating costs	Estimate (fork)	Estimate (fork)	
Other unquantified costs	Estimate (fork)	Estimate (fork)	
TOTAL of the costs valued	**Estimate (fork)**	**Estimate (fork)**	
TOTAL net benefits of valued costs	Estimate (fork)	**Estimate (fork)**	

- Specify the monetary units (for example, values expressed in 2021 Canadian dollars discounted at a rate of 3%).
- Also specify the units used to measure the effects in natural units (e.g., the average number of premature deaths avoided per year).
- Notes are useful for briefly describing the methodological approach, limitations or reasons why an impact is not quantified or valued.

Source: Adapted from US Environmental Protection Agency. (2016) p. 11-17.

19.4 Conclusions

Key takeaways

- The drafting of a CBA report is a crucial phase that requires meticulous attention. This process must ensure the clarity, accuracy, and relevance of the information presented.
- The report is primarily intended for two types of readers: decision-makers, who seek to quickly grasp the key results and limitations of the CBA, and analysts, who require a more in-depth understanding of the analysis in order to potentially reproduce the results.
- A thorough assessment of data reliability should be included in an appendix to the report.
- The main conclusions drawn from this assessment should be discussed concisely in the main text, with emphasis on their implications for the analysis.
- Recommendations presented in the report should follow directly from the CBA findings.
- They should also reflect an awareness of the uncertainties and limitations identified during the analysis, thereby ensuring that the resulting decisions are well informed and robust.

Appendix 1. Summary sheet of a CBA

<table>
<tr><td colspan="4">Incorporating Risk and Uncertainty in
Cost-Benefit Analysis</td></tr>
<tr><td colspan="4">September 2016</td></tr>
<tr><td colspan="3">Authors
S. Salci
G., Jenkins</td><td>Affiliation
Queen’s University</td></tr>
<tr><td colspan="4">Reference
74161.
MPRA Paper No. Online: https://mpra.ub.uni-muenchen.de/74161/</td></tr>
<tr><td colspan="4">Principal
Study funded by Environment Canada and prepared by Cambridge Resources International Inc.</td></tr>
<tr><td colspan="4">Summary
This report reviews the different approaches and practices for considering risks and uncertainties in cost-benefit analyses (CBAs). Based on this analysis, guidelines are proposed for conducting sensitivity analyses. The report applies these guidelines to a CBA of the imposition, in 2010, of a standard requiring that on-road diesel and fuel oil sold in Canada contain, on average, 2% biodiesel.</td></tr>
<tr><td colspan="4">Scenarios
S0: Reference without standard
S1: Standard and use of kerosene as an additive
S2: Standard and use of kerosene as an additive only for road diesel</td></tr>
<tr><td colspan="4">Important parameters</td></tr>
<tr><td colspan="2">Space Horizon: Canada except for GHG , with consideration of global damages</td><td>Base year and time horizon: 2007, 2011-2036</td><td>Discount rate: 3%</td></tr>
<tr><td colspan="4">Others (specify): demand growth, 1.7% per year; oil price, $49.45/barrel; social cost of carbon: $25/tonne.</td></tr>
<tr><td colspan="3">Main results
The imposition of the standard leads to a negative NPV of -$2.3 billion for scenario S1 and -$2.1 billion for scenario S2. Sensitivity analysis shows that it is unlikely that this standard will result in a positive NPV.</td><td>Main limitations</td></tr>
</table>

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20.

OTHER PROJECT EVALUATION METHODS

Motivation and learning objectives

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The C-17 Globemaster III (US AIr Force, Public domain, via Wikimedia Commons)

In the 1970s, the United States Armed Forces identified the need for a cargo aircraft capable of transporting heavy equipment over long distances while being able to land under difficult conditions. In the early 1980s, McDonnell Douglas's (now Boeing) proposal to develop the C-17 Globemaster aircraft was accepted, with an initial plan to deliver 120 aircraft. However, the development of this aircraft encountered numerous problems, including significant cost overruns, leading the U.S. Congress in 1993 to require an independent assessment to determine whether the C-17 program should continue or whether alternative options would be more appropriate.

How should such an assessment be conducted? A cost-benefit analysis is particularly challenging in this context, as measuring and valuing benefits raises major difficulties. How can a clear causal link be established between the acquisition of military equipment and improvements in national security? How should one value a reduction in the risk of attack or an increased sense of security?

In this chapter, we examine three alternative approaches to CBA, which were briefly introduced in Chapter 1. The chapter provides a general overview of these methods and refers readers to additional sources for further study.

By the end of this chapter, you will be able to:

1. Understand the mechanisms and limitations of economic impact analysis;
2. Describe the principles and steps required to conduct a cost-effectiveness analysis;
3. Explain the key concepts of cost-utility analysis.

20.1 Economic impact analyses

To begin this section, let us recall certain elements discussed in Chapter 1 concerning the analysis of economic impacts.

Economic impact analysis is a set of techniques based on input–output models that aim to assess the economic effects or benefits of a project. These effects can be measured in terms of employment, value added, tax revenues, or imports.

However, this approach does not allow us to determine the social profitability of a project, for two main reasons:

1. **Non-additivity of economic impacts**: The economic impacts measured using this approach are often not additional, since the funds invested in one project could instead be invested in another project that would also generate economic benefits. In other words, the observed impacts may reflect a reallocation of existing economic activity rather than net gains for the economy.[1];
2. **Lack of measurement of net benefits**: Economic impact analysis does not measure the net benefits of a project, that is, the difference between its social benefits and social costs. As a result, a project may generate substantial economic activity while still exhibiting negative social profitability.

1. As mentioned in Chapter 12, this argument does not apply to projects financed by entities outside the spatial horizon that generate additional impacts within the economy. The second argument, however, remains valid in that case.

Although economic impact analysis cannot be used to assess the social profitability of a project, it remains popular among decision-makers because it almost always yields positive-looking results, particularly in terms of job creation or retention and tax revenues. It is therefore essential to understand the mechanics of this approach and to clearly recognize its limitations.

20.1.1 The mechanics of economic impacts [2]

A project can be analyzed as a positive demand shock affecting direct suppliers. For example, the construction of a new highway increases demand in the construction and civil engineering sector by $1 billion. In economic impact analysis, spending on direct suppliers is referred to as **direct effects**. This spending can be broken down into several components:

- Purchases of intermediate goods and services: To build the highway, the construction and civil engineering sector must purchase bitumen, steel, and various support services from direct suppliers, known as first-tier suppliers;
- Imports (leakage): Part of the expenditures of direct suppliers is devoted to purchasing imported intermediate goods and services, such as a truck purchased abroad. These imports represent "leakage" from the national economy, as the associated spending leaves the country and does not generate additional domestic impacts;
- Taxes: A portion of project expenditures is paid to governments in the form of taxes and royalties;
- Value added: Part of the direct effect takes the form of value added generated by direct suppliers. Value added is defined as the difference between sales revenues and expenditures on intermediate inputs (including leakages and taxes). It therefore measures the value created by suppliers through the use of primary factors of production, namely capital and labor. In other words, value added provides remuneration to both labor and capital.

This decomposition of direct effects among suppliers is illustrated in Figure 1. By definition, these direct effects correspond to the total cost of the project, which is $1 billion in this example.

The component "purchases of intermediate goods and services by direct suppliers" constitutes a demand shock for first-tier suppliers. This shock is itself decomposed into leakages, taxes, value added, and purchases of intermediate goods and services from second-tier suppliers. The process continues at each stage of the production chain, as illustrated in the diagram below. These cumulative effects are referred to as **indirect**

2. For a more detailed presentation, see Graig (2007).

effects[3], reflecting the impacts on suppliers throughout the successive stages of the project's production process.

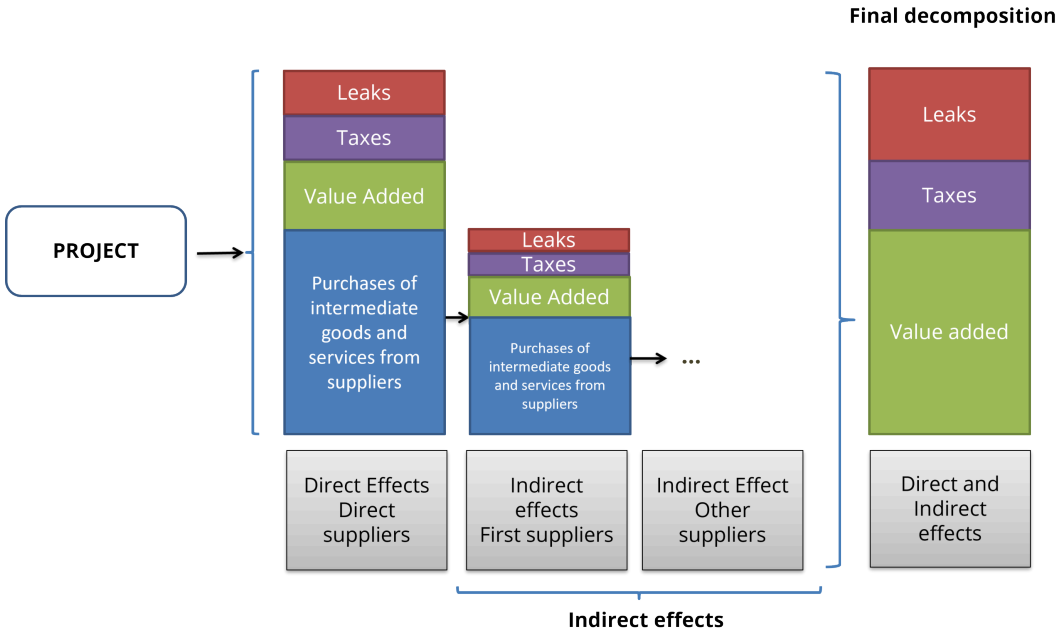


Figure 20.1 Direct and indirect effects of a project

From this process, it is therefore possible to translate the initial shock into leakages, taxes, and value added, as illustrated by the final decomposition in Figure 1. We observe that a billion-dollar project generates value added of less than one billion dollars, due to leakages (imports and savings) and taxes.

To generate greater economic impacts, it is necessary to consider **induced effects**. As illustrated in Figure 2, the value added generated by a project constitutes income for the primary factors of production, namely capital and labor. Part of this income is saved, which represents another leakage from the current economy, while another part is spent across various sectors of the economy. For example, a worker employed on the highway construction site may use their income to purchase groceries, a new television, or childcare services. This additional spending stimulates demand in these sectors, generating further income that is in turn spent, thereby amplifying the project's initial impact. These dynamics are known as multiplier effects.

3. The distinction between direct and indirect effects in economic impact analysis therefore differs from that used in CBA.

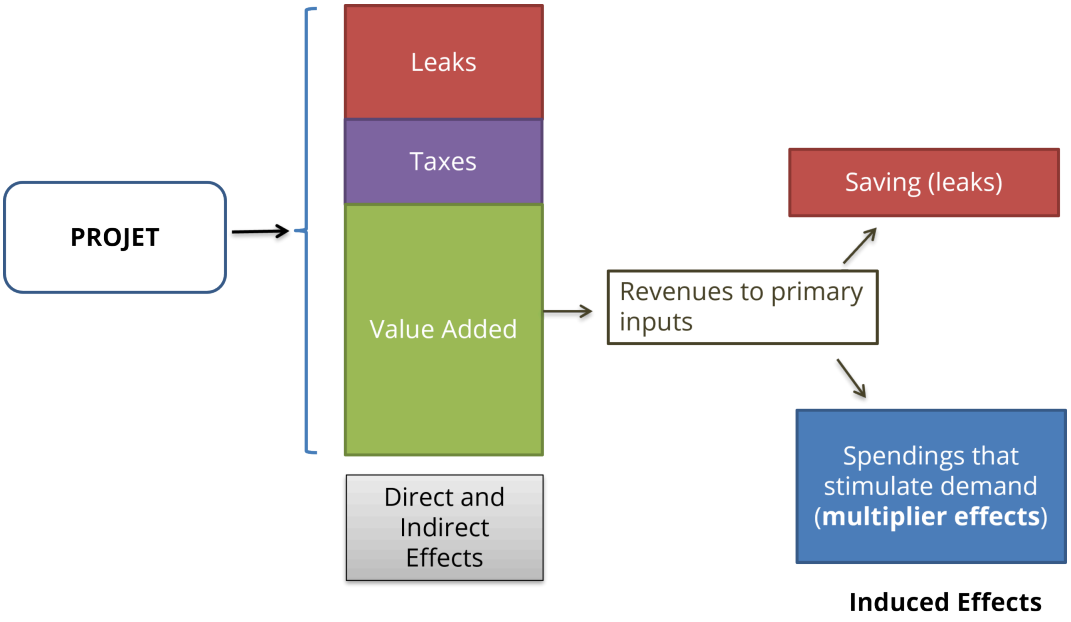


Figure 2. Induced effects

It is therefore through induced effects that the economic impacts can exceed the initial amount invested in the project. Proponents of the highway construction project often use formulations such as: "Every dollar invested in the highway will generate more than two dollars in economic benefits."

20.1.2 Limitations of impact analyses

The main limitations of this approach are as follows (see also Gunton *et al.*, 2020):

1. **Failure to screen projects**: All projects, even those that are socially undesirable, generate positive economic impacts. This can create an incentive to prioritize the project that, for a given size, generates the largest economic impacts (for example, the highest value added or tax revenues). This approach tends to favor projects in sectors with fewer leakages and higher multipliers. While this may be justifiable from the perspective of economic stabilization during a recession, it is also essential to consider the opportunity cost of financing the project, such as the negative economic effects associated with the taxes required to fund it. Moreover, this selection method does not ensure that the chosen project is socially profitable, since the impacts measured do not correspond to social benefits, as noted in the introduction to this section;
2. **Lack of price effects**: Economic impacts are often estimated using input–output models that assume significant underutilization of factors of production. Under this assumption, a project that stimulates demand has no effect on prices, as supply curves are assumed to be perfectly elastic, and therefore generates no crowding-out effects. However, in an economy operating near full employment, a positive demand shock is likely to increase prices, leading to a reallocation of activity across sectors rather than an

increase in total economic activity. By ignoring this mechanism, economic impacts are overstated;

3. **Static relationships**: Economic impact studies assume that intersectoral relationships are fixed and unaffected by the project, which can be restrictive. For example, a project that promotes automation in a given sector may alter labor requirements, thereby changing economic linkages across sectors;
4. **Validity of multipliers**: Induced effects are sometimes estimated using multipliers whose validity is questionable. In addition, when spillover effects are analyzed at the local or regional level, induced effects are often limited. Any spending that occurs outside the local or regional economy is treated as leakage, which reduces the potential magnitude of induced effects.

20.2 Cost-effectiveness analysis

20.2.1 Basic principles

Cost-effectiveness analysis (CEA) compares projects by calculating the ratio of a project's total cost (C) to a measure of its effectiveness (E), that is, C/E. Costs are expressed in monetary units, while effectiveness is measured in "physical" units, such as the number of lives saved in road safety projects. This ratio therefore represents the cost per unit of impact, for example, the cost per life saved.

CEA measures costs and effectiveness relative to a reference situation, which varies depending on the context of the analysis. The term **differential** is therefore often used to clarify that the analysis focuses on changes in costs and effectiveness relative to this reference situation.

Unlike CBA, CEA does not seek to value all of a project's benefits. It is therefore particularly well suited to comparing projects that share a similar primary benefit.

The analysis can also be conducted using the inverse ratio, E/C, which is referred to as cost-effectiveness. This E/C ratio measures the impact generated per dollar invested. In this chapter, we focus on cost-effectiveness analysis using the C/E formulation, although the same concepts apply when using the E/C ratio.

Table 1 presents a fictitious example of initiatives aimed at reducing household water consumption in an arid region. The initiatives are ranked in ascending order of total cost, with the baseline being the "do nothing" option. The table reports the estimated annual incremental cost of each measure, the incremental water savings, and the incremental cost-effectiveness ratios.

The analysis shows that installing flow reducers on taps is the most cost-effective measure per cubic metre

of water saved, followed by the installation of water-saving showerheads and dual-flush toilets. By contrast, installing rainwater collection systems is much more expensive per cubic metre of water saved.

Table 1. Cost-effectiveness analysis of measures to reduce household water consumption in an arid region

Measure	Estimated Incremental Cost* ($/year)	Estimated incremental water savings* (m3/year)	Incremental cost-effectiveness ratio* ($/m3)
A- Tap flow reducer	1,200,000	23,000,000	0.052
B- Installation of energy-saving shower heads	1,345,000	14,560,000	0.092
C- Dual-control flush	1,660,000	16,450,000	0.1
D- Rainwater collector	17,300,000	6,520,000	2.65

** Assessed relative to a baseline situation in which no action is taken.*

CEA is used in a wide range of fields, including education to compare initiatives aimed at improving learning outcomes (Yeh, 2010; McEwan, 2012), health and safety to evaluate life-saving measures (Vahidnia and Walsh, 2002), and the energy sector to analyze energy efficiency programs (Tuominen et al., 2015).

Advantages and limitations

CEA has the advantage of being less restrictive than cost-benefit analysis (CBA), as it does not require monetizing all of a project's benefits. Instead, it focuses on quantifying a single outcome without assigning it a monetary value. This feature is particularly useful when other effects of a project are diffuse or difficult to measure. For example, if a health intervention reduces the risk of surgical complications, it may be easier to measure effectiveness in terms of hospital days avoided than to attempt to value all associated benefits. That said, some benefits may be overlooked.

Another advantage of CEA is that it avoids certain ethical controversies, particularly those related to the monetization of intangible effects such as the value of a human life. However, this does not fully resolve the issue, since decision-makers must ultimately judge whether the results are acceptable. For instance, should a project that costs $15 million per life saved be implemented? Thus, while CEA simplifies some aspects of evaluation, it does not eliminate these difficult trade-offs.

A further limitation of this approach is that selecting a project solely on the basis of incremental cost-effectiveness does not necessarily ensure the choice of the option that maximizes social profitability (see Section 20.3.3).

20.2.2 Carrying out an CEA

Schematically, conducting a CEA involves four stages:

1. Establish the list of projects to be compared;
2. Estimate the cost and effectiveness of each measure;
3. Calculate the relevant incremental cost-effectiveness ratios;
4. Compare and select projects.

Step 1 depends on the context and objectives of the analysis, so it is difficult to provide further general guidance.

Step 2: Estimate the cost and effectiveness of each measure

Cost estimation should ideally follow the same principles as in CBA:

- Costs should be assessed based on the concept of opportunity cost;
- The total cost of a measure should ideally correspond to the sum of costs borne by all stakeholders within the reference society, that is, the social cost;
- Costs must be discounted before being aggregated, in order to obtain their total value in monetary terms for the base year.

In practice, however, costs are often defined more narrowly, taking into account only the costs borne by the entity that commissioned the analysis. For example, a CEA of public energy efficiency programs may consider only costs incurred by the government. This practice should be avoided or, at a minimum, explicitly acknowledged through appropriate caveats when formulating recommendations.

The **measure of effectiveness** should target the primary benefit sought. As noted earlier, CEA is particularly well suited to comparing projects that deliver the same main benefit.

Although effectiveness is measured in physical units, effects occurring over several years must be aggregated after discounting. For example, a project that saves 10 lives per year over five years is not equivalent to a program that saves 50 lives immediately. In CEA, this process is referred to as the **principle of "discounting consequences,"** which accounts for the lower value of effects that occur further in the future.

Step 3: Calculate cost-effectiveness ratios

As noted above, CEA compares incremental costs and effectiveness relative to a reference situation, which may vary depending on the context. This comparison yields the **incremental cost-effectiveness ratio** (ICER) of project j relative to project i. In what follows, we use the English abbreviation ICER (Incremental Cost-Effectiveness Ratio), as it is commonly used, even in French-language reports.

The ICER of project j relative to project i is defined as follows:

$$ICER = \frac{\Delta C}{\Delta E} = \frac{C_j - C_i}{E_j - E_i}$$

where C_j and C_i represent the costs of projects j and i, respectively, and E_j and E_i represent the corresponding measures of effectiveness.

Both the numerator and the denominator can be positive or negative, depending on the context. From a service improvement perspective, we typically consider projects that are more costly ($\Delta C > 0$) but also more effective ($\Delta E > 0$). From a budgetary constraint perspective, it may instead be necessary to identify an alternative that costs less ($\Delta C < 0$) while causing the smallest possible reduction in effectiveness ($\Delta E < 0$). It is also possible in some cases to reduce costs ($\Delta C < 0$) while improving effectiveness ($\Delta E > 0$), and the opposite situation may also occur ($\Delta C > 0$ and $\Delta E < 0$).

If project j is compared with the "no project" situation, then $C_i = 0$ and $E_i = 0$, and the ICER reduces to $\frac{C_j}{E_j}$. This particular ratio is sometimes referred to as the average cost-effectiveness ratio.

Example: New treatments for malaria

A pharmaceutical company has developed a new drug and a vaccine to prevent malaria in very high-risk populations[4]. The company would like to determine whether the new drug or the vaccine could effectively replace the current treatment. The malaria prevention methods cannot be used jointly because their combination would lead to excessive side effects. The projects are therefore mutually exclusive. The analysis thus focuses on comparing the costs and effectiveness of the two new options relative to the current treatment. Table 2 presents the three treatment options in ascending order of cost.

4. For simplicity, it is assumed that, in the absence of intervention, these very high-risk individuals will certainly develop malaria.

Table 2. Costs and effectiveness of malaria prevention treatments per person per year

Project	Cost ($/year)	Differential cost*	Efficiency	Differential efficiency*	ICER*
A – Current treatment	$350	–	90%	–	–
B-New drug	$500	$150	96%	6%	$2500
C- Vaccin	$620	$270	99%	9%	$3000

Column 2 of Table 2 reports the annual cost per person for each option, while column 3 shows the incremental cost of the new options relative to current treatment A. The new drug B costs $150 more per person, while the vaccine costs $270 more than the current treatment. Column 4 presents the effectiveness of each option relative to no treatment, and column 5 reports the incremental effectiveness of the new treatments relative to the current treatment. For example, the vaccine increases effectiveness by 9%, and the new drug by 6%. Finally, the last column reports the ICER, calculated as the ratio of the values in columns 3 and 5.

In this example, the ICER is interpreted as the cost per additional case avoided relative to the initial treatment, that is, $2,500 for the new drug and $3,000 for the vaccine. Indeed, in a population of 100 people, 10 individuals will contract malaria under treatment A, compared with 4 under treatment B. Total costs are $35,000 and $50,000, respectively. Treatment B therefore prevents malaria in six additional individuals compared with the initial treatment, at an additional cost of $15,000, which corresponds to a cost of $2,500 per additional case avoided.

Exercise

Determine the ICER of vaccine C relative to new drug B. Discuss the interpretation of this ratio.

Resolution

The ICER of C relative to B is $120 / 0.03 = $4,000. This value represents the cost per additional case avoided when using treatment C instead of treatment B. We therefore observe that the additional

cost increases as effectiveness rises. This provides another illustration of a pervasive economic reality: increasing marginal costs.

Step 4: Compare and select projects[5]

How should recommendations be formulated in a CEA? It is useful to represent the possible situations graphically using the cost-effectiveness plane. In Figure 3, the horizontal axis measures the difference in effectiveness, and the vertical axis measures the difference in cost relative to the reference situation, represented by point O. Points A, B, C, and D represent the projects under consideration.

The slope of the line connecting the origin to a given project corresponds, by definition, to the ICER of that project relative to the reference situation O. Indeed, the slope is equal to $\frac{\Delta C}{\Delta E}$.

Figure 3 allows us to distinguish four quadrants, each associated with different project selection rules:

1. **Quadrant I (Northeast)**: Projects increase effectiveness but at an additional cost ($\Delta C > 0$ and $\Delta E > 0$). Making a recommendation requires a value judgment, namely the determination of a critical threshold corresponding to the maximum amount one is willing to pay per unit of additional effectiveness. Budget constraints may also play a decisive role.

2. **Quadrant II (Southeast)**: Projects reduce costs ($\Delta C < 0$) while improving effectiveness ($\Delta E > 0$). These options are dominant, as they improve the situation relative to the status quo. The final choice will depend on the specific context, as discussed later in this section.

3. **Quadrant III (Southwest)**: Projects reduce costs ($\Delta C < 0$) but also reduce effectiveness ($\Delta E < 0$). Selecting projects in this quadrant requires a value judgment, that is, determining a critical threshold corresponding to the minimum cost reduction needed to justify a loss in effectiveness. Budgetary considerations may also be relevant.

4. **Quadrant IV (Northwest)**: Projects increase costs ($\Delta C > 0$) while reducing effectiveness ($\Delta E < 0$). These projects are dominated by the status quo and should be rejected.

5. This section is inspired by the Guide to Interpreting Health Economics, published by the Government of Canada (2024).

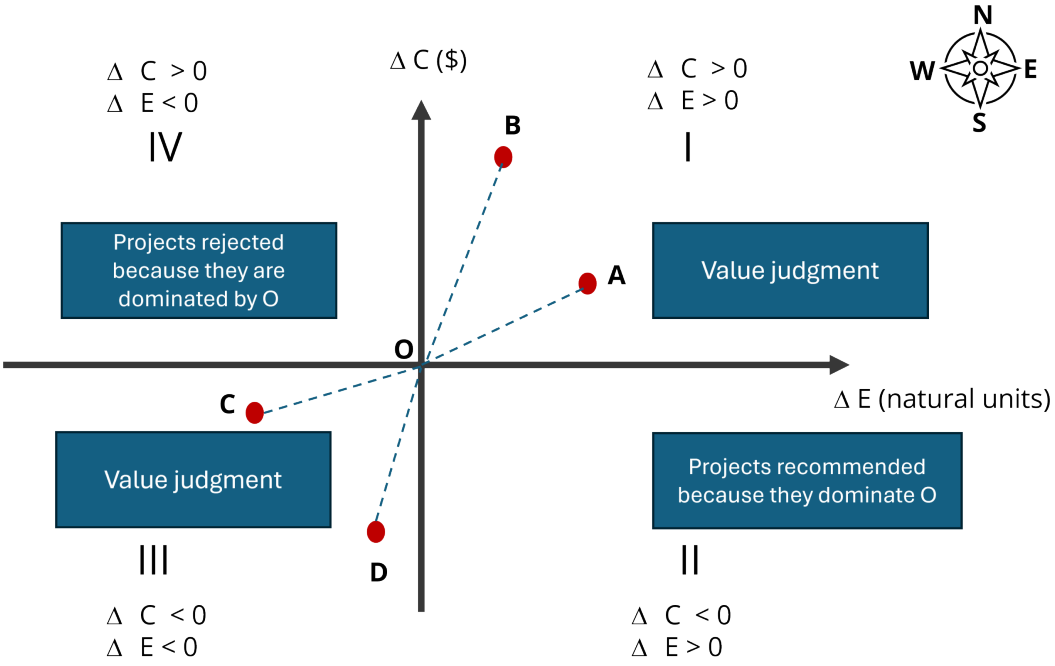


Figure 20.3 Decision rules according to the cost-effectiveness plan quadrant

In Quadrants I and III, once the critical cost-effectiveness threshold—also referred to as the **maximum willingness-to-pay threshold**—has been defined, it becomes possible to eliminate projects that do not meet this criterion. Graphically, this involves drawing a straight line through the origin with a slope equal to the critical threshold (see Figure 4). Projects located above this line have an ICER that exceeds the threshold and should therefore be rejected, whereas projects located below the line should remain under consideration. It is important to note that these recommendations are based on comparisons with the reference situation represented by point O. To proceed further, direct comparisons between projects may be required, as discussed below.

Exercise

Let us return to the example of water-saving measures presented in Section 20.2.1. Table 3 reports the cost-effectiveness data for these measures. Plot the projects listed in this table on the cost-effectiveness plane, using the absence of water-saving measures as the reference situation. Also plot the critical cost-effectiveness threshold, assuming that the maximum amount the municipality is willing to pay has been set at $\$1/m_3$. Assuming that these projects are not mutually exclusive, what would be your recommendation?

Table 3. ACE of measures to reduce the amount of water consumed by households in an arid region

Measure	Estimated Incremental Cost* ($/year)	Estimated incremental water savings* (m3/year)	Incremental cost-effectiveness ratio* ($/m3)
A- Tap flow reducer	1,200,000	23,000,000	0.052
B- Installation of an economical shower head	1,345,000	14,560,000	0.092
C- Dual-control flush	1,660,000	16,450,000	0.1
D- Rainwater collector	17,300,000	6,520,000	2.65

** Assessed relative to a baseline situation for which no action is taken.*

Resolution

All projects improve effectiveness but involve additional costs, so they all fall within Quadrant I. Figure 4 shows these measures plotted on the cost-effectiveness plane, along with the cost-effectiveness threshold represented by a line with a slope of 1. Since the projects are not mutually exclusive, measures A, B, and C should be recommended, while measure D should be rejected.

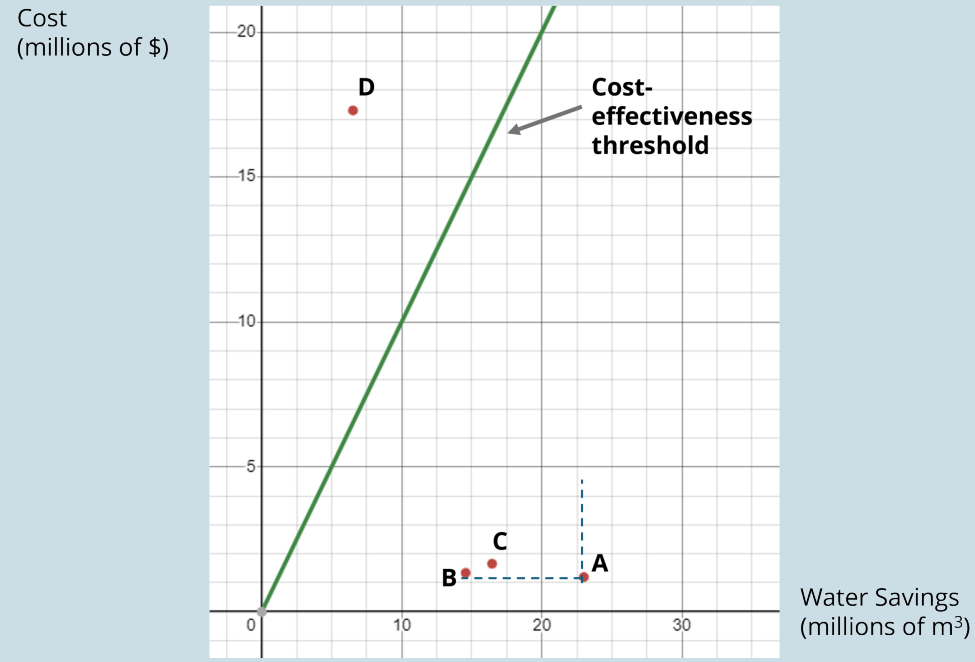


Figure 20.4 Representation of water-saving measures in the cost-effectiveness plan

In the case of mutually exclusive projects, a sequential analysis makes it possible to refine recommendations.

Sequential analysis of mutually exclusive projects

When projects are mutually exclusive, they must be compared not only with the status quo, but also with one another. To do so, projects must first be ranked in ascending order of total cost.

It then becomes possible to eliminate certain projects because they are dominated by others. A distinction is made between strong dominance and weak dominance (or extended dominance).

Strong dominance

Project i is strongly dominated by project j if $C_j \geq C_i$ and $E_j \leq E_i$, with at least one strict inequality. In this case, we also say that j strictly dominates i.

Strict dominance implies that the ICER of j relative to i is either negative or undefined.

Mutually exclusive projects that are strictly dominated should be rejected.

Project i should never be chosen, since it either costs more than project j without offering greater effectiveness, or it does not cost less and has strictly lower effectiveness than project j.

Note that a negative ICER may indicate not only that a project is dominated, but also that a project is dominant. Consider the following example. Project A entails a cost of $3,000 relative to the "do nothing" option and yields an incremental effectiveness of 100. By contrast, Project B costs $2,000 and achieves an effectiveness of 150 relative to the same reference. Calculating the ICER of B relative to A yields −1/2, or −$1,000/50. In this case, the negative ICER clearly indicates that Project B strictly dominates Project A.

Returning to the example of water-saving measures (Table 3), if the projects are assumed to be mutually exclusive (for instance, if the municipality decides to implement only one measure), we immediately observe that Project A strongly dominates all the others. Indeed, the ICERs of the other projects relative to Project A are negative. For example, the ICER of Project B relative to Project A is −$0.017/m^3.

In the cost-effectiveness plane, a project is strongly dominated by another when it lies in the northwest quadrant defined with respect to that other project. In Figure 4, Projects B and C are therefore strictly dominated by Project A.

Exercise: Five steps to save lives

Table 4 reports the cost and effectiveness of five mutually exclusive life-saving measures. Plot

these five projects on the cost-effectiveness plane and determine whether any of them are strictly dominated.

Table 4. Cost and effectiveness of five life-saving measures

Measure	Cost (millions)	Effectiveness (lives saved)
HAS	75	50
B	100	50
C	125	70
D	150	100
E	175	90

Resolution

Analysis of Table 4 immediately shows that:

- Measure B is strictly dominated by measure A;
- Measure E is strictly dominated by measure D.

Figure 5 confirms that measure B is located in the northwest quadrant, defined from project A and E in the northwest quadrant of D.

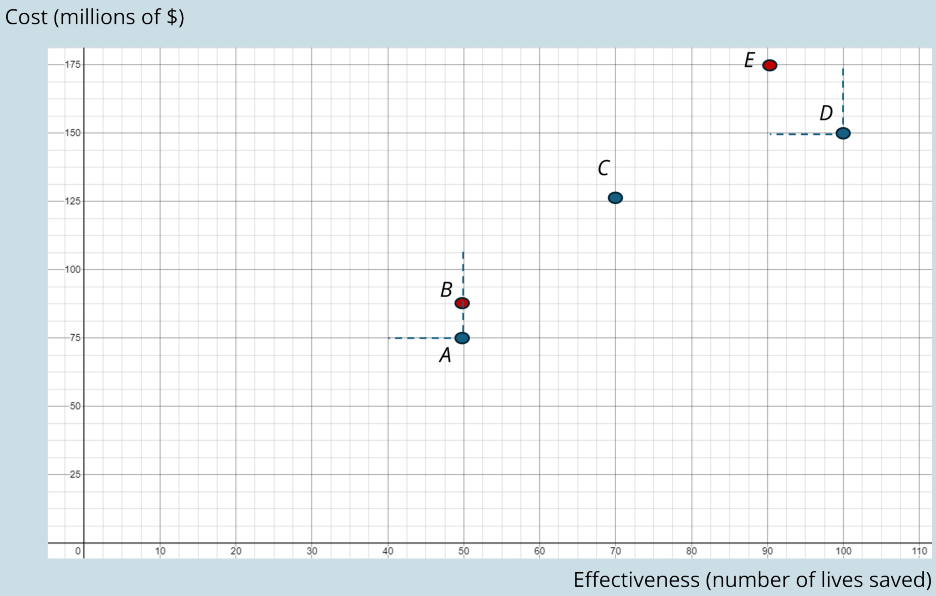


Figure 20.5 Illustration of strong dominance

It is also possible to eliminate some projects, because they are weakly dominated (or extension dominated).

Weak dominance (or by extension)

A project B is weakly dominated by projects A and C if the following two conditions are met:

1. $C_A < C_B < C_C$, with projects ranked in ascending order of total cost;
2. ICER (B relative to A) > ICER (C relative to B).

In other words, if moving from A to B costs more per unit of effectiveness than moving from B to C, then B is weakly dominated. Project B should therefore be excluded, since the resources used to increase effectiveness are better allocated to moving directly from A to C, which achieves additional effectiveness at a lower cost per unit.

In Figure 6, projects A, B, and C are ordered in ascending order of cost, so condition 1 is satisfied. It is further assumed that the maximum acceptable threshold is $5 million per life saved, meaning that projects A, B, and C all meet this threshold.

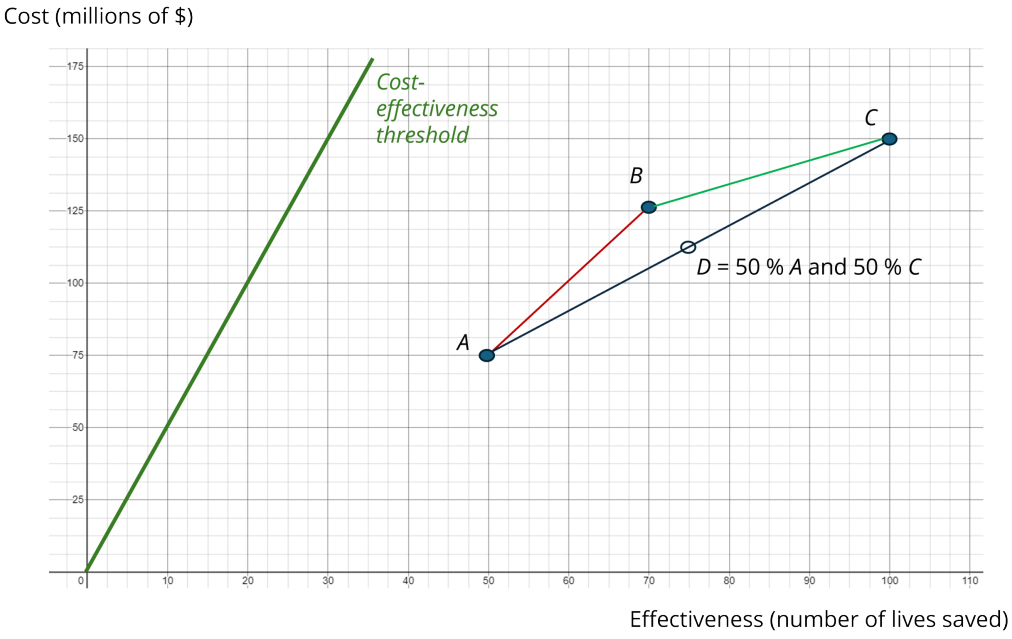


Figure 20.6 Illustration of weak dominance

Graphically, the ICER of a project relative to another project corresponds to the slope of the line that connects these two projects. For example:

- The ICER of *B* relative to *A* corresponds to the slope of the red line that joins *A* and *B*, i.e. (125 – 75) / (70 – 50) = $2.5 million.

- The ICER of *C*relative to *B*is equal to $0.83 million , which is the slope of the green line between *B*and *C*.

We therefore note that project *B*is weakly dominated by projects *A*and *C*since condition 2 is met (2.5 > 0.83).

Why should a weakly dominated project be rejected?

If the ICER of B relative to A is below the threshold set by public authorities, then the ICER of C relative to A will necessarily also be below that threshold, implying that public authorities will prefer C to B. Indeed, the ICER of C relative to A corresponds to the slope of the line connecting A and C (the blue line in Figure 6), which is, by construction, lower than the slope of the red line connecting A and B.

Another way to understand why Project B will never be chosen is the following. It is possible to construct a new project D that combines, in certain proportions, Projects A and C and that strictly dominates Project B. Project D is therefore a linear combination of Projects A and C and lies on the blue line AC.

For example, Project D could involve implementing Projects A and C, but only for 50% of the population originally targeted by these projects. Assuming that costs and effectiveness adjust proportionally, Project D would cost $112.5 million (i.e. ½ × 75 + ½ × 150) and achieve an effectiveness of 75 lives saved (½ × 50 + ½ × 100). This project saves more lives and costs less than Project B.[6]

Based on these concepts, it is recommended to follow the sequential analysis described below when comparing three or more mutually exclusive options.

Sequential analysis of mutually exclusive options

1. Rank the options in ascending order of total cost;
2. Eliminate options whose average cost-effectiveness ratio exceeds the critical threshold;
3. Remove options that are strictly dominated;
4. Calculate sequential ICERs, that is, ICERs comparing each option with the next least costly option, or with the “no project” option for the least costly alternative;
5. Eliminate options that are weakly dominated;

6. This section draws on the Government of Canada’s Guide to Interpreting Health Economics (2024).

6. Recalculate sequential ICERs for the remaining options;
7. Eliminate options whose sequential ICER exceeds the critical threshold.

The recommended option is the one with the highest sequential ICER among the options that have not been eliminated.

Graphically, the sequential procedure amounts to identifying the cost-effectiveness frontier in the cost-effectiveness plane. This frontier corresponds to the convex envelope drawn from the southeast of the set of points representing the different options that lie below the critical threshold, as illustrated in Figure 7.

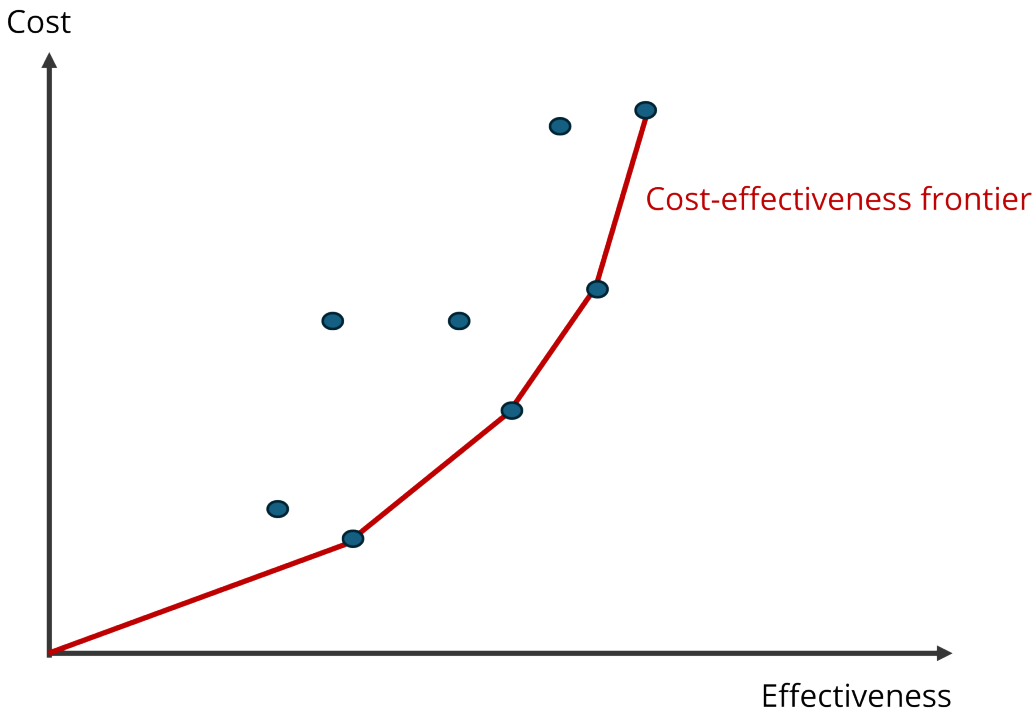


Figure 20.7 Determination of the cost-effectiveness frontier

Exercise: The CEA of 6 vaccines

Table 5 presents the costs and effectiveness of six vaccines in preventing severe disease in specific population groups. Public authorities have set a maximum threshold of $2,000 per case prevented. Only one vaccine can be administered per patient. Conduct a cost-effectiveness analysis of these vaccines.

Table 5. Costs and effectiveness of vaccines

Vaccine	Cost per dose ($)	Efficiency (%)
HAS	400	30%
B	700	45%
C	750	40%
D	980	65%
E	1250	70%
F	1430	72%

Resolution

All options fall within Quadrant I, as they improve effectiveness at an additional cost. Table 6 reports the average cost-effectiveness ratios, that is, the ICERs relative to the no-vaccine option, as well as the sequential ICERs.

Table 6. Cost-effectiveness analysis of vaccines

Vaccine	Average cost-effectiveness ratio ($)	Differential costs* ($)	Differential efficiency* (%)	Sequential ICER ($)
HAS	1,333	400	30	1,333
B	1,555	300	15	2,000
C	1,875	150	-5	– 3,000
D	1,507	230	15	1,533
E	1,785	270	5	5,400
F	1 986	180	2	9,000

** Compared to the previous scenario for vaccines B to F and compared to no vaccine for vaccine A*

First, note that all vaccines have a cost-effectiveness ratio below the critical threshold of $2,000. Second, Vaccine C is strictly dominated by Vaccine B. Its sequential ICER is negative because,

although it is more expensive, it offers lower effectiveness. This option should therefore be excluded from the analysis. Table 7 presents the sequential ICERs after the elimination of Vaccine C, such that Vaccine D is now compared with Vaccine B.

Table 7. Cost-effectiveness analysis of non-strictly dominated vaccines

Vaccine	Differential costs ($)	Differential efficiency (%)	Sequential ICER ($)
HAS	400	30	1,333
B	300	15	2,000
D	280	19	1473
E	270	5	5,400
F	180	2	9,000

From this revised table, we observe that Vaccine B is weakly dominated by Vaccines A and D, since the sequential ICER of B is higher than that of D. It is therefore necessary to eliminate this vaccine and recalculate the ICER of D relative to Vaccine A (see Table 8).

Table 8. Cost-effectiveness analysis of non-dominated vaccines

Vaccine	Differential costs ($)	Differential efficiency (%)	Sequential ICER ($)
HAS	400	30	1,333
D	580	35	1657
E	270	5	5,400
F	180	2	9,000

We observe that the sequential ICERs of Vaccines A and D are below the critical threshold of $2,000. Figure 8 illustrates this analysis in the cost-effectiveness plane. All points lie below the critical threshold, and the cost-effectiveness frontier is defined by Vaccines A, D, E, and F; as a result, Vaccines B and C will never be selected. Finally, we note that the slopes of the segments DE and EF on the frontier are greater than the slope of the critical threshold line, indicating that the sequential ICERs of Vaccines E and F exceed the critical threshold.

The recommendation should therefore focus on Vaccine D, as it offers the highest effectiveness among the vaccines whose average cost-effectiveness ratio and sequential ICER satisfy the threshold.

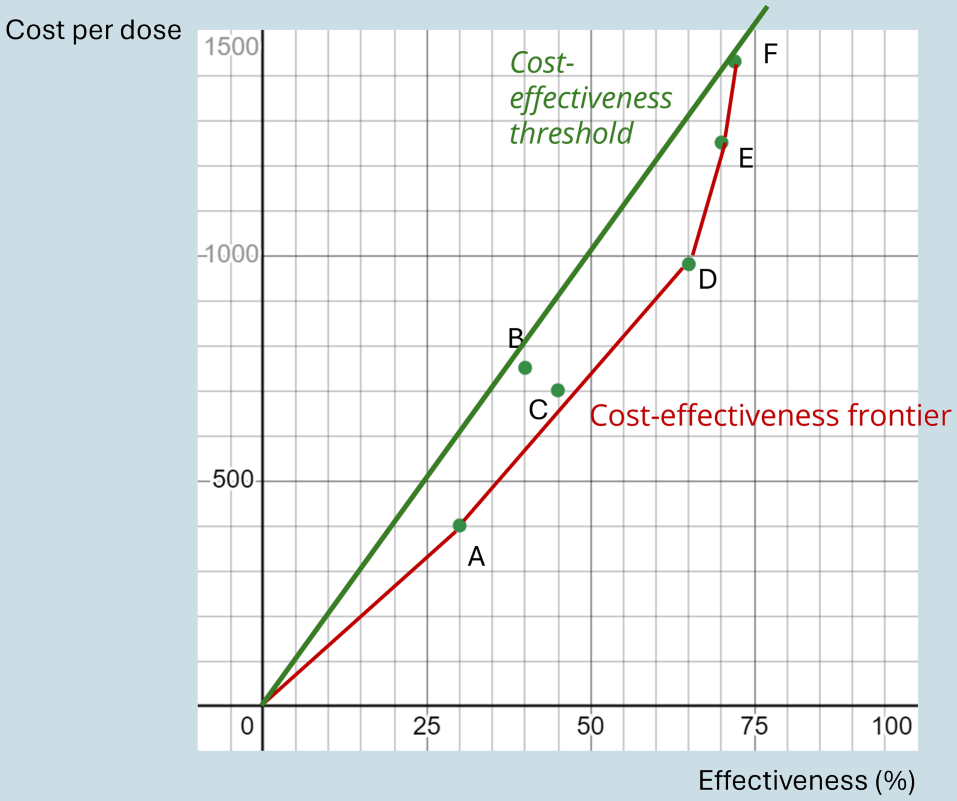


Figure 20.8 Cost-effectiveness frontier and cost-effectiveness threshold for vaccines

20.3 Cost-utility Analysis

20.3.1 Basic principles

Cost-utility analysis (CUA) is similar to cost-effectiveness analysis, but it is distinguished by the use of a composite effectiveness indicator designed to assess the impact of projects on the well-being (or utility) of their beneficiaries.

This method is used primarily in the health sector, and several national health technology assessment agencies—such as the National Institute for Health and Care Excellence in the United Kingdom, the Haute Autorité de Santé in France, and the Canadian Medicines Agency—recommend its use.

The measurement of effectiveness combines quantitative and qualitative dimensions. The quantitative dimension is typically expressed in terms of life years gained, while the qualitative dimension captures the quality of life associated with different health states[7].

The most commonly used effectiveness indicator is the number of quality-adjusted life years, known by the English acronym "QALYs" (Quality-Adjusted Life Years), which is widely used even in French-language documents. The following section provides a more detailed discussion of the QALY concept[8].

In all other respects, the determination of costs, the calculation of ratios, and the project selection procedures are identical to those used in CEA.

20.3.2 Effectiveness measured by QALY Gains

The concept of QALY accounts for both the impact of a project on life expectancy and the quality of life associated with a given health state. This composite indicator takes a value of 1 (QALY = 1) for one year of life in perfect health and a value of 0 in the case of death. It takes a value below 1 when a person lives a year with health problems that reduce quality of life. For example, a year lived with chronic, disabling pain might be assigned a value of 0.5, so that two years lived in this condition are equivalent[9] to one year of life in full health ($2 \times 0.5 = 1$). In some cases, health states involving intense and uncontrollable suffering may be assigned a QALY value below 0, corresponding to a state considered worse than death. Alternative indicators to the QALY have also been developed, such as the DALY ("Disability-Adjusted Life Year"), which is briefly presented in Appendix 1.

Using this indicator, it is possible to measure the effectiveness of interventions, treatments, or other types of projects that affect both the length and quality of life. For example, the effectiveness of a treatment designed to prolong the life of a person with terminal cancer would be measured by the total number of additional QALYs generated by the treatment.

More formally, the effectiveness of a project measured in terms of incremental QALYs (ΔQALYs) can be expressed as follows:

7. In English, Health-Related Quality of Life, abbreviated HRQoL.

8. Other indicators, such as the DALY (disability-adjusted life year), can also be used (see the National Collaborating Centre for Infectious Diseases, 2015).

9. Assuming a discount rate of zero.

$$\Delta QALY = \sum_{t=1}^{T} \frac{QALY_t}{(1+s)^t} = \sum_{t=1}^{T} \frac{1 \times u_t}{(1+s)^t}$$

where *T* is the number of additional years of life provided by the project relative to the reference situation, and *u* is a utility or quality-of-life score associated with the health state[10] during year t. The utility score satisfies $u_t = 1$ and $u_t = 0$, representing perfect health and death, respectively, and *s* denotes the social discount rate.

Exercise: Comparing two treatments for the pain of a terminal illness

Treatment A controls pain, but only to a limited extent, yielding a utility score of $u_A = 0.4$ and an expected life span of $T_A = 9$ years. Treatment B controls pain more effectively, yielding a utility score of $u_B = 0.9$, but it is associated with more severe fatal side effects, resulting in a life expectancy of $T_B = 5$ years. The present value of the cost of Treatment A is $60,000, while that of Treatment B is $100,000. The social discount rate is 4%. Determine the cost-utility ratios of the two treatments. Which treatment(s) should be recommended if the critical threshold is set at $20,000 per QALY by the organization responsible for determining the list of reimbursed drugs?

Resolution

Table 9 presents the costs, QALY gains, and cost-utility ratios of the two treatments relative to the option of doing nothing. Since the annual QALY gains are constant over time, they can be calculated by multiplying the annual gain by the appropriate annuity factor. For example, for Treatment A,

10. In medical analyses, the impact of a treatment is often simulated for a representative synthetic population. In this context, each individual has a probability of dying at the end of each year, depending on the treatment. The QALY gain of a treatment for an individual then takes the following form: $\Delta QALY = \sum_{t=1}^{T} QALY_t = \sum_{t=1}^{T} \Delta p_t \times \Delta u_t$, where *T* is the maximum duration of the analysis, i.e. the number of years until the entire population disappears, Δp_t is the change in the probability of death induced by the treatment, and Δu_t is the change in the utility score.

assuming that benefits accrue throughout the year, the annuity factor with $T = 9$ and s = 4% is 7.58, yielding a total QALY gain of 3.03. Treatment B is more effective than Treatment A but also more costly. Given the critical threshold, Treatment A should be recommended for reimbursement, whereas Treatment B should not, as it exceeds the willingness-to-pay threshold.

Table 9. Cost-utility analysis of the two treatments

Treatment	Actualized cost ($)	Updated QALY gain	Cost-utility ratio
HAS	60,000	0.4 x 7.58 = 3.03	19,802
B	100,000	0.9 x 4.54 = 4.08	24,473

Example: Quality of life trajectories related to chemotherapy

Chemotherapy provides a useful example for illustrating the sensitivity of QALYs to complex quality-of-life trajectories. Patients undergoing chemotherapy typically experience a substantial decline in quality of life during treatment because of side effects, but their quality of life and life expectancy may improve in the longer term. Figure 9 illustrates how the utility score evolves over time for a patient with a particular type of cancer, depending on whether chemotherapy is administered.

By calculating the difference between the two curves and applying discounting, it is possible to determine the QALY gain associated with chemotherapy treatment.

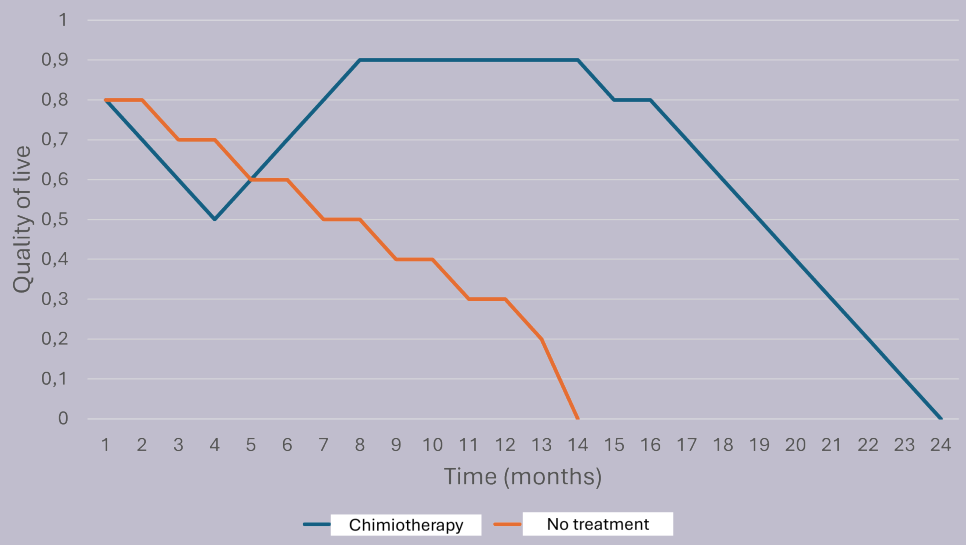


Figure 20.9 Quality of life with or without chemotherapy treatment in a patient with incurable cancer

Figure 9. Quality of life with or without chemotherapy treatment in a patient with incurable cancer

20.3.3 Estimation of QALY

Because it is a non-market good, the utility score associated with a given health state must be assessed using some of the techniques presented in Part III. A distinction can be made between direct methods and approaches based on value transfer.

Direct approaches

Direct, or stated preference, methods rely on questionnaires to elicit utility scores for different health states. Three main approaches are commonly used to reveal these utility scores.

1. **Visual Analogue Scale (VAS)**

Under this approach, respondents rank various health states on a scale from 0 to 100, ranging from "least preferable" to "most preferable" (see Figure 10). Surveys may target the general population, medical experts, or individuals affected by the health conditions being evaluated. Each health state is described, and respondents position it on the scale. This method is quick and simple to administer, but it has the drawback of providing an ordinal rather than a cardinal measure, since the distance between health states can differ across respondents. Moreover, the absence of an explicit time dimension means that only health states of similar duration can be

compared. For example, it is not possible to compare one month with a leg in a cast to five years with chronic headaches.

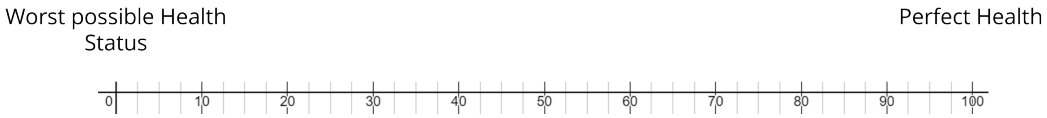


Figure 20.10 Visual analogue scale

2. **Time Trade-Off (TTO)**

The time trade-off (TTO) method asks respondents to choose between alternatives that involve a direct trade-off between health status and length of life. For example, an individual is asked to choose between living T years in an imperfect health state with utility $u_j < 1$, or living X years in perfect health with utility $u_i = 1$, where $X \leq T$. If the individual expresses a preference, a new scenario is proposed with a different value of X, until the individual reaches indifference between the two options. At this point, the utility score can be derived as $u_j = \frac{X^*}{T}$. Figure 11 illustrates an example in which a person is indifferent between living four years in perfect health and ten years with disabling heart failure, yielding a utility score of 0.4 for the poorer health state.

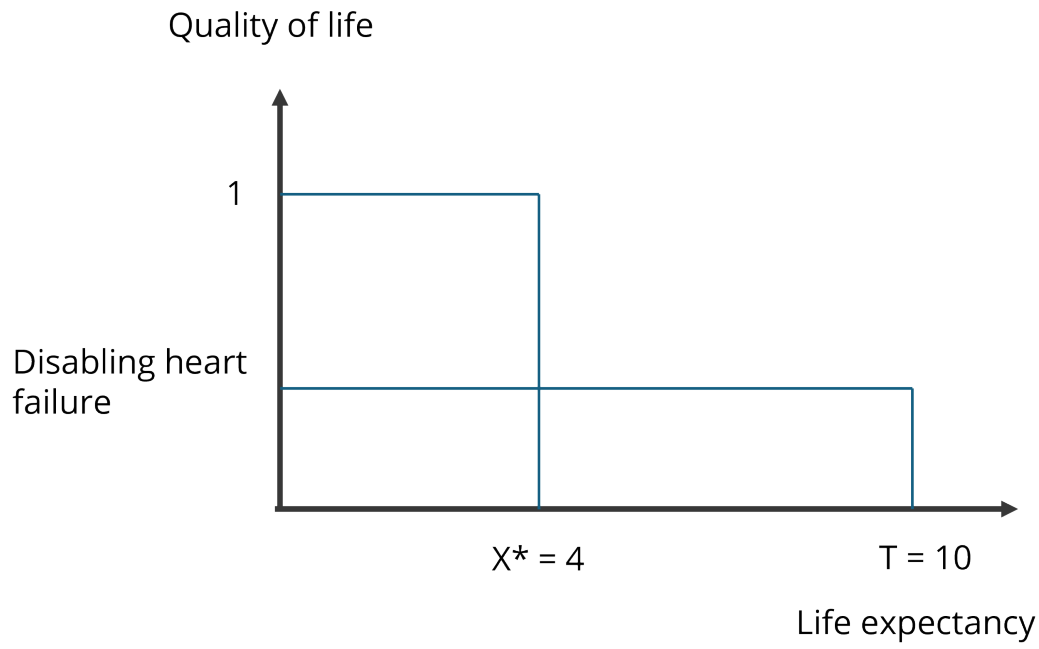


Figure 20.11 Example of response to a temporal arbitration choice

Although this method is relatively simple to administer, it becomes problematic when assessing health states considered worse than death, because the respondent would have to choose zero years in perfect health rather than living in a degraded health state.

Moreover, empirical evidence suggests that utility values derived using the TTO tend to decline as the duration spent in a given health state increases (Brazier, Green, McCabe, & Stevens, 2003). For example, an individual might be willing to trade 15 years of life with diabetes for 12 years in good health, yielding a utility

value of 0.8. However, if the duration increases to 30 years with diabetes, the same individual might prefer 20 years in good health, implying a lower utility of 0.67. In this sense, utility reflects not only the quality of a single year in a given health state, but also the overall life trajectory.

Finally, the procedure generally ignores respondents' time preferences, that is, the discount rate they implicitly apply when weighting present versus future years (see Johannesson, Pliskin, & Weinstein, 1994). The method described to elicit utility scores implicitly assumes that individuals value a year in the near future in the same way as a year further in the future. Since this assumption is unlikely to hold, the resulting utility values are influenced by respondents' time preferences. This creates a risk of double discounting if these utility scores are subsequently used to calculate QALY gains by discounting future health benefits (see MacKeigan, Gafni, & O'Brien, 2002). Several procedures have been proposed to address this issue, notably by explicitly eliciting respondents' discount rates (see Lipman, Attema, & Versteegh, 2020).

3. The Standard Gamble (SG)

In this approach, respondents are asked to choose between two options (see Figure 12). The first option involves, for example, undergoing a risky medical procedure that leads to a lottery with probability p of achieving perfect health (u = 1) for n years and probability (1 − p) of immediate death (u = 0). The second option is the certainty of remaining in an imperfect health state, such as chronic disabling back pain, for n years. As with the TTO, a series of scenarios is presented until the point of indifference is reached, allowing the utility score to be derived as $u_j = p * 1 + (1 - p) * 0 = p$.

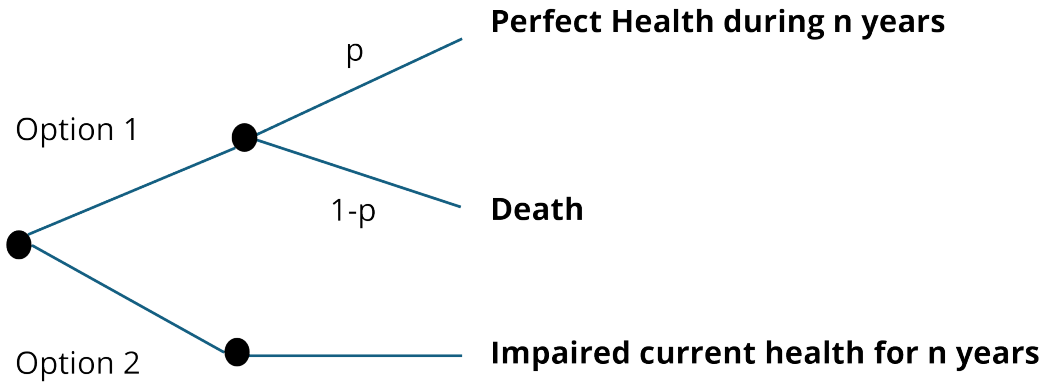


Figure 20.12 The decision tree of a standard bet

This approach has the advantage of being grounded in expected utility theory, but it also has several limitations. Respondents' choices are influenced by their attitudes toward risk, a factor that should be taken into account in the analysis. In addition, the scenarios presented are often unfamiliar, and some respondents may have difficulty understanding probabilities. Finally, as with the TTO method, this approach assumes that respondents assign equal weight to the present and the future (Gafni, 1994).

Approaches based on value transfer

In line with the principles described in Chapter 13, Section 2, value transfer approaches rely on utility scores

that have already been estimated in previous studies. These methods are therefore less complex and less costly to implement than direct elicitation methods.

Standardized tables are now available to assign utility scores to predefined health conditions. For example, a systematic review found that a woman experiencing severe menopausal symptoms has a utility score of 0.58, measured using the TTO method, compared with a score of 0.92 if she receives hormone replacement therapy. Such data exist for a wide range of diseases and treatments. In a cost-utility analysis (CUA), the transfer approach consists of using utility scores drawn from the scientific literature, with possible adjustments to reflect the context of the analysis (such as inflation, currency conversion, or differences in standards of living).

One variant of this approach involves the use of a Multi-Attribute Utility Index (MAUI). This method is based on standardized questionnaires that assess multiple dimensions of quality of life, such as pain, autonomy, mental health, and cognitive functioning. Subsequent studies have linked utility scores obtained through direct methods such as TTO or SG to these quality-of-life dimensions, thereby facilitating the transfer of utility values across contexts.

The EQ-5D algorithm

The EQ-5D is a health status classification system that assesses five dimensions—mobility, self-care, usual activities, pain/discomfort, and anxiety/depression—using a simple questionnaire. For each dimension, respondents select the level that best corresponds to their condition. For example, for the mobility dimension, respondents can choose from the following levels:

– **Level 1:**"I have no mobility problems.";

– **Level 2**: "I have some mobility problems.";

– **Level 3**: "I have a lot of mobility problems.";

– **Level 4**: "I can't move at all."

The combination of responses defines an EQ-5D health state (with 3,125 possible states), each associated with a utility score. For example, an individual who reports level 1 on all five dimensions is assigned a utility score of 1. For further details, readers may consult the video below or refer to Devlin, Parkin, and Janssen (2020).

Other algorithms are also used to assess health status and derive utility scores, including the SF-6D, which is applied in various contexts, as well as the HUI and the AQoL-8D. In addition, some instruments have been developed for specific populations, such as the CHU9D for children.

https://www.youtube.com/watch?v=jKc2jqjez2c

Determining utility scores is a complex and evolving field. For further discussion of these methods, see Brazier, Deverill, and Green (1999), Richardson, McKie, and Bariola (2014), and Fauteux and Poder (2017).

20.3.4 Advantages and limitations of CUA

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CUA shares the same advantages and limitations as CEA. For example, it generally does not account for project benefits that are unrelated to patients' health, such as impacts on relatives. However, compared with CEA, CUA has the advantage of using an effectiveness measure that integrates multiple dimensions of well-being.

CUA has been criticized for its weak connection to welfare economics, in the sense that project selection based on this method does not necessarily lead to an improvement in aggregate welfare or social well-being. In addition, utility scores can be subjective and vary across individuals, a heterogeneity that CUA typically does not capture. For instance, a loss of mobility may be perceived as more detrimental by a younger person than by an older one.

Moreover, QALY-based measures can sometimes lead to discriminatory outcomes. An intervention that prevents the death of a younger person will generate more QALY gains than the same intervention applied to an older person, due to differences in life expectancy[11]. Similarly, CUA may disadvantage people with disabilities whose baseline utility scores are lower.

As with CEA, final project selection requires defining a critical threshold. In the United Kingdom, the National Institute for Health and Care Excellence recommends a threshold between £20,000 and £30,000 per QALY ($35,000 to $53,000). The World Health Organization recommends values between one and three times GDP per capita. There is no explicit threshold in Canada, but values between $50,000 and $100,000 per QALY are commonly used in research.

Another limitation of CUA is its low sensitivity to large but short-term benefits. For example, anesthesia for a tooth extraction lasting one hour and costing $50 might be considered not very cost-effective. Assuming that utility is 0 without anesthesia and 1 with anesthesia, the resulting ICER would be $438,000 per QALY, well above the thresholds mentioned above. As a result, an intervention that prevents extreme pain at a relatively modest absolute cost may not be considered cost-effective because of the short duration of its effect.

11. This is why some U.S. legislation, such as the Patient Protection and Affordable Care Act (Obamacare), explicitly prohibits the use of this approach.

20.4 Conclusions

Key takeaways

- Complexity of CBA: In some circumstances, CBA may be impossible to apply or too complex to implement. In such cases, alternative approaches can be used.
- Economic impact analysis: This method measures the effects of a project on different sectors of the economy in terms of employment, value added, or tax revenues.
- Distinction of effects: The analysis distinguishes between direct effects on the project's primary suppliers, indirect effects on secondary suppliers, and induced or multiplier effects.
- Limitations of economic impact analysis: Economic impacts do not measure the social benefits of a project. As a result, the findings of this type of analysis should not be used to justify or select a project.
- Analytical models: Impact analyses are often based on models that assume generalized underutilization of productive resources, thereby neglecting the displacement of economic activity through price adjustments.
- Cost-effectiveness analysis: This method compares projects based on their incremental cost per unit of additional effectiveness. Effectiveness is measured in physical units of the primary benefit sought.
- Specific application: Cost-effectiveness analysis is particularly useful for comparing projects with a similar main benefit. The selection of mutually exclusive projects relies on a sequential procedure that includes the elimination of strongly or weakly dominated options.
- Cost-utility analysis: Cost-utility analysis is a specific form of cost-effectiveness analysis, used mainly in the health sector. Effectiveness is measured using a utility-based indicator, most commonly the QALY (Quality-Adjusted Life Year), which combines life expectancy and quality of life.

- Assessment of quality of life: Quality of life, as a non-market good, can be assessed using various stated preference methods or through value transfer approaches.

Back to motivation

In the 1970s, the United States Armed Forces identified the need for a cargo aircraft capable of transporting heavy equipment over long distances while being able to land under difficult conditions. In the early 1980s, McDonnell Douglas's (now Boeing) proposal to develop the C-17 Globemaster aircraft was accepted, with an initial plan to deliver 120 aircraft. However, the development of this aircraft encountered numerous problems, including significant cost overruns, leading the U.S. Congress in 1993 to require an independent assessment to determine whether the C-17 program should continue or whether alternative options would be more appropriate.

Resolution

An economic impact analysis could have been used to compare the economic impacts of the different options considered. However, it is important to recall that such impacts do not measure the benefits of a project and do not account for opportunity costs. Despite these limitations, this type of analysis is often used to promote defence programs (see, for example, *PwC Strategy &*, 2024, on the economic impacts of the Eurofighter Typhoon fighter aircraft development program).

To assess whether it was appropriate to continue the C-17 program, the Institute for Defense Analyses conducted a cost-effectiveness analysis (CEA). The main steps of this analysis were as follows:

1. Identification of alternatives to the reference project: The options considered included extending the service life of existing aircraft (C-141), militarizing commercial aircraft such as the Boeing 747-400, developing new aircraft models, and reducing the number of C-17s ordered. A total of 27 fleet configurations, including the reference scenario with 120 C-17s, were analyzed. All configurations were designed to provide similar theoretical daily lift capacity.
2. Measurement of the effectiveness of the 27 configurations: Effectiveness was measured in

terms of the quantity of cargo (including oversized cargo) and troops that could be delivered within a given time frame to meet different mission requirements. Simulation models were used, taking into account the characteristics and constraints of each configuration, such as loading time, speed, range, refuelling requirements, and maximum daily flight duration.

3. Cost assessment: Costs were evaluated over a 25-year horizon and included development, acquisition, maintenance, and operational support. A discount rate of 4.5% was applied.
4. Comparison of alternatives using a cost-effectiveness plane: See Greer (2010).

Based on this CEA, the decision was made to continue the C-17 program in its existing form, as the analysis concluded that it was cost-effective relative to the other options considered.

Exercises

1. Following an earthquake, a government plans to deploy a clean-up crew. A crew of 32 workers can clean 1 km^2 per hour, at a cost of $15 per hour per worker (Project A). It is proposed to expand the crew to 48 workers, which would increase productivity to 1.8 km^2 per hour, at the same hourly wage (Project B). What is the ICER of Project B relative to Project A?
2. A health agency is conducting a cost-effectiveness analysis of four treatment strategies to prevent recurrent strokes. The costs and effectiveness reported in the table below are calculated for treating all individuals who experience a first stroke each year. All values have been appropriately discounted. Which option do you recommend if only one option must be selected and the critical threshold is $15,000 per recurrent stroke prevented?

Table 10. Updated cost and effectiveness of treatments to prevent stroke recurrences

Treatment	Cost ($)	Number of recurrences avoided
HAS	2,000,000	200
B	3,500,000	250
C	5,000,000	500
D	8,000,000	800

3. An environmental agency asks you to evaluate three new wetland protection projects. The present value of the costs per unit of protected area is reported in the table below. Project A represents the current

alternative (the status quo), and the projects are mutually exclusive. Determine which option should be recommended based on the critical threshold adopted by the public authorities.

Table 11. Cost and effectiveness of wetland protection projects

Project	Cost ($)	Protected area (km2)
A (status quo)	410,000	60
B	830,000	65
C	890,000	79
D	900,000	75

4. You are responsible for assessing whether a shingles vaccination program for people aged 50 and over would be cost-effective. You know that shingles can cause neurological damage and severe pain if not treated promptly, but that it rarely causes death. What type of analysis would you propose to use, and why?

5. Cardiologists are examining different drugs to prevent heart disease in at-risk patients. New drugs are added to those already taken by the patient because their effects are complementary. Table 12 presents the costs and the annual reduction in the risk of cardiac events associated with the different therapies. The interventions are listed in an order determined by medical considerations.

Table 12. Annual cost and effectiveness of heart disease prevention measures over one year

Order	Intervention	Cost	% risk reduction
1	A- Aspirin	$200	2.4%
2	B – Aspirin + antihypertensive	$600	4.1%
3	C – Aspirin + 2 antihypertensives	$1500	7.3%
4	Aspirin + 2 antihypertensives + hypocholesterolemic	$6000	10.3%

Inspired by Marshall (2003)

Assuming that the government applies a maximum threshold of $30,000 per cardiac event avoided, determine which intervention should be selected.

6. As part of a pre-budget consultation, a coalition advocating for the promotion of culture in Quebec commissioned an analysis of the economic and fiscal impacts of cultural spending (Paradis, Ruscio, and Dufresne, 2020). According to this study, there is "no valid economic reason not to invest in culture, even if the

only factor considered is economic development." The study therefore recommends increasing government spending on culture, based on the following arguments:

- *"Culture has a significant influence on the rest of the economy, through its purchases from various suppliers and the spending of workers in the rest of the economy.*
- *Every dollar of economic output (GDP) in culture is accompanied by $0.70 to $0.90 in additional production in the rest of the economy (industry average: $0.70).*
- *Each tranche of $100 million spent on culture (excluding telecommunications) represents 1,540 jobs, significantly more than the average for Quebec industries (1,030 jobs).*
- *"Tax revenues from economic activities associated with culture compensate for the subsidies received by cultural organizations."*(Paradis, Ruscio and Dufresne, 2020, p. 4).

Provide a critical analysis of these arguments.

Appendix 1. The concept of DALY

The Disability-Adjusted Life Year (DALY) is a measure used to assess the burden of disease in a population by combining years of life lost due to premature mortality (YLL) and years lived with disability (YLD). Developed by the World Bank in the 1990s, this indicator is widely used to quantify the impact of diseases on public health.

The components of DALY

1. **Years of life lost**: This component measures the years of life lost as a result of premature death. It is calculated as the difference between the age at death and the average life expectancy. For example, if a person dies at age 50 while life expectancy is 80, this corresponds to 30 YLL.
2. **Years lived with disability**: This component captures the years lived with disability due to a disease or health condition. It takes into account both the prevalence of the condition and the severity of the disability, which is expressed through a weight ranging from 0 (no disability) to 1 (complete disability).

The DALY is a key tool for evaluating health interventions, particularly in the context of cost-effectiveness analyses. By incorporating both mortality and morbidity, it provides a comprehensive measure of the health impact of diseases and interventions. Public health decision-makers can use DALYs averted to compare the effectiveness of different interventions. For instance, a vaccination campaign may reduce the DALYs associated with an infectious disease, while a chronic disease prevention program may also yield substantial reductions in DALYs.

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PART V
CASE STUDIES

In this section, we present CBAs for different types of projects. Each case study is based on data drawn from specialized reports or scientific research. At this stage, the applications are primarily rooted in the Canadian context. We nonetheless plan to gradually expand this collection with additional examples from other jurisdictions. The purpose of these practical cases is to illustrate the concrete application of the theoretical concepts and best-practice rules introduced earlier, through the CBA of real-world projects.

21.

ENERGY AND ENVIRONMENT - CBA OF A DIESEL AND HEATING OIL STANDARD

This case study was developed from a Regulatory Impact Assessment (RIA) conducted as part of the amendment of a renewable fuels regulation of the Canadian Environmental Protection Act (Environment and Climate Change Canada, 2011). It also draws on work by Salci and Jenkins (2016).



Concepts used	Reference chapter
Increase in production costs due to the project	8
Side effects	12
Social cost of carbon	16
Sensitivity analysis	18

1. The context

The need: Canada is committed to reducing its greenhouse gas emissions, including by increasing the use of renewable energy, notably biofuels;

The project: In 2010, the Government of Canada implemented a standard requiring that road diesel and heating oil sold in Canada contain, on average, 2% biodiesel starting in 2012;

The objectives targeted:

1. Reduce GHG emissions;
2. Encourage national production of biofuels;
3. Providing new opportunities for Canadian farmers;
4. Accelerate the commercialization of new technologies in this sector [1].

The CBA:

- Is conducted as part of a regulatory impact study, taking **2007 as the reference year**;
- Adopts **Canada's spatial horizon**, while taking into consideration the global benefits associated with reducing greenhouse gas (GHG) emissions;
- Covers a period of 25 years, from 2011 to 2036;
- Uses a **social discount rate of 3%**.

2. The scenarios

The status quo scenario (reference scenario)

In the business-as-usual scenario, the Canadian 2% biodiesel standard for heating oil and diesel is not implemented. However, this scenario assumes that three provinces adopt the standard. Manitoba imposes a 2% biodiesel standard starting in 2009, Alberta imposes a 2% standard starting in 2011, and British Columbia imposes standards of 3% in 2010, 4% in 2011, and 5% in 2012. As a result, the incremental costs and benefits of the federal standard in these three provinces are virtually nil.

The regulatory scenario

This scenario assumes that the 2% standard is imposed across Canada, with implementation in 2012. To comply with this standard, fuel producers must adjust the composition of diesel and heating oil. Specifically, they must replace part of the fossil-based diesel and heating oil with biodiesel from plant and animal sources, as well as kerosene. Although kerosene does not reduce GHG emissions, as it is derived from fossil fuels, it is essential to prevent the freezing of the modified fuel.

3. Stakeholders and impacts

As illustrated in Figure 21.1, the main stakeholders involved in this project are:

- The government;
- Canadian consumers of heating oil and diesel;
- The Canadian fuel industry;
- Canadian biodiesel producers;

1. The study does not provide an explicit economic justification for the need for government intervention or for the choice of a standard over other policy instruments. However, intervention is justified by the presence of external costs caused by GHG emissions.

- Canadian farmers;
- The international community.

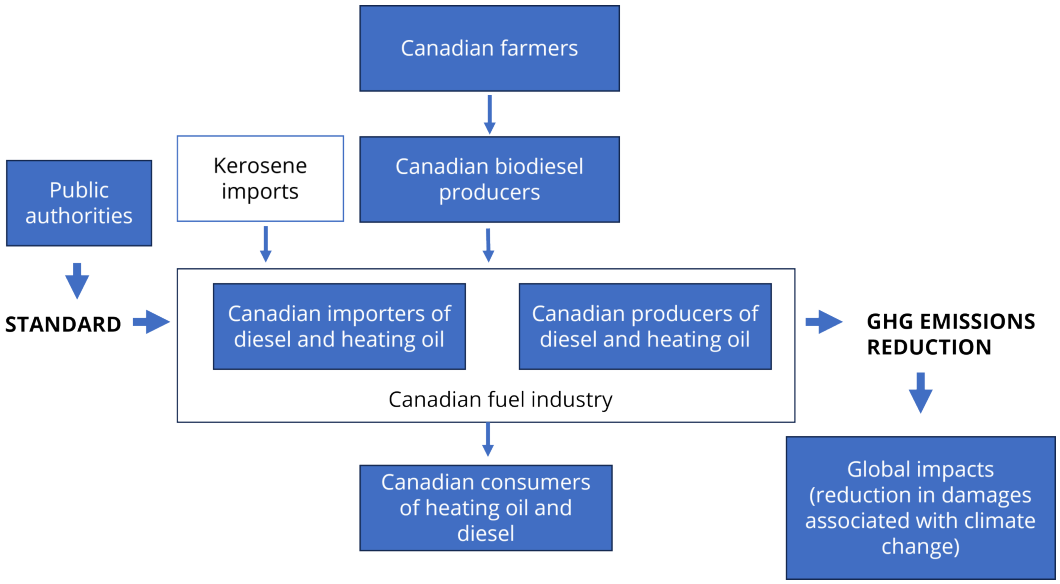


Figure 21.1 Simplified description of the fuel oil and diesel value chain

The government

Public authorities are responsible for implementing the standard and monitoring compliance, which involves personnel costs, among other things. However, these are considered negligible in the RIA.

Canadian fuel oil and diesel consumers

Consumers will face a price increase caused by the higher production costs of diesel and heating oil[2].

The Canadian Fuels Industry[3]

The standard must be met by the fuel industry – which includes Canadian producers of fuel oil and diesel – as well as importers of both products. To comply with the standard, the industry will have to:

- Make investments to adjust its production, transport and storage processes;
- Assume additional operating costs associated with replacing some diesel (and fuel oil) with biodiesel and kerosene[4], which are more expensive.

2. Kerosene has a lower energy content than diesel or fossil fuel oil, so the standard will reduce energy efficiency. Thus, diesel consumption per 100 km will increase somewhat as a result of the imposition of the standard. This effect is accounted for in the CBA, but it is very small, so we ignore it in the rest of the presentation of this case.

3. For simplicity of presentation, we include the distribution stage in the fuels industry, even though in pratice it is a distinct stage located downstream of production.

4. The RIA specifies that the additional kerosene will come from imports from the United States.

Canadian biodiesel producers

The standard creates an increase in demand for biodiesel. The RIA estimates that the additional demand will initially be met by imports, while domestic supply adjusts. This adjustment will occur through the commissioning of new biodiesel production units in Canada, resulting in additional capital and operating costs.

Canadian agricultural producers

Increased biodiesel production will increase demand for soybeans, canola and animal fats, which are inputs in its manufacture. These increased demands are expected to be met by Canadian supply, with the exception of hydrotreated vegetable oil, which will be imported, according to the RIA.

The international community

The standard will prevent the emission of a certain quantity of greenhouse gases over the analysis period, thereby helping to reduce damages associated with climate change at the global level.

Other impacts were analyzed in the RIA but were found to be too small to be considered relevant.

The imposition of the standard therefore triggers a series of impacts along the heating oil and diesel value chain. It is useful to construct an analytical framework to understand the impacts taken into account in the CBA and how they were assessed. This framework also helps to highlight certain assumptions that are maintained.

4. The analytical framework

The primary effect in the fuel market

In the fuel market, the imposition of the standard has a direct impact on the production and sale of diesel. To simplify the presentation, we focus on the diesel market, but the analysis would be identical for the heating oil market.

Figure 21.2 illustrates the supply (S0) and demand (D) for diesel in a given year under the baseline scenario. The RIA implicitly assumes that this market is competitive. In this context, the standard causes an upward shift in the supply curve, from S0 to S1, as it increases the production costs of diesel (see Chapter 8, Section 4).

To determine the impacts on producers and consumers, the effect of the standard on the price and quantity of diesel consumed (P_1 and Q_1) must be assessed. These impacts depend on the elasticities of supply and demand (see Chapter 4, Section 4). The net impact of the standard on the market is measured by the loss of gains from trade, represented by the area *abcd*. This area captures both the increase in diesel production costs and the reduction in gains from trade resulting from the decrease in the quantity traded.

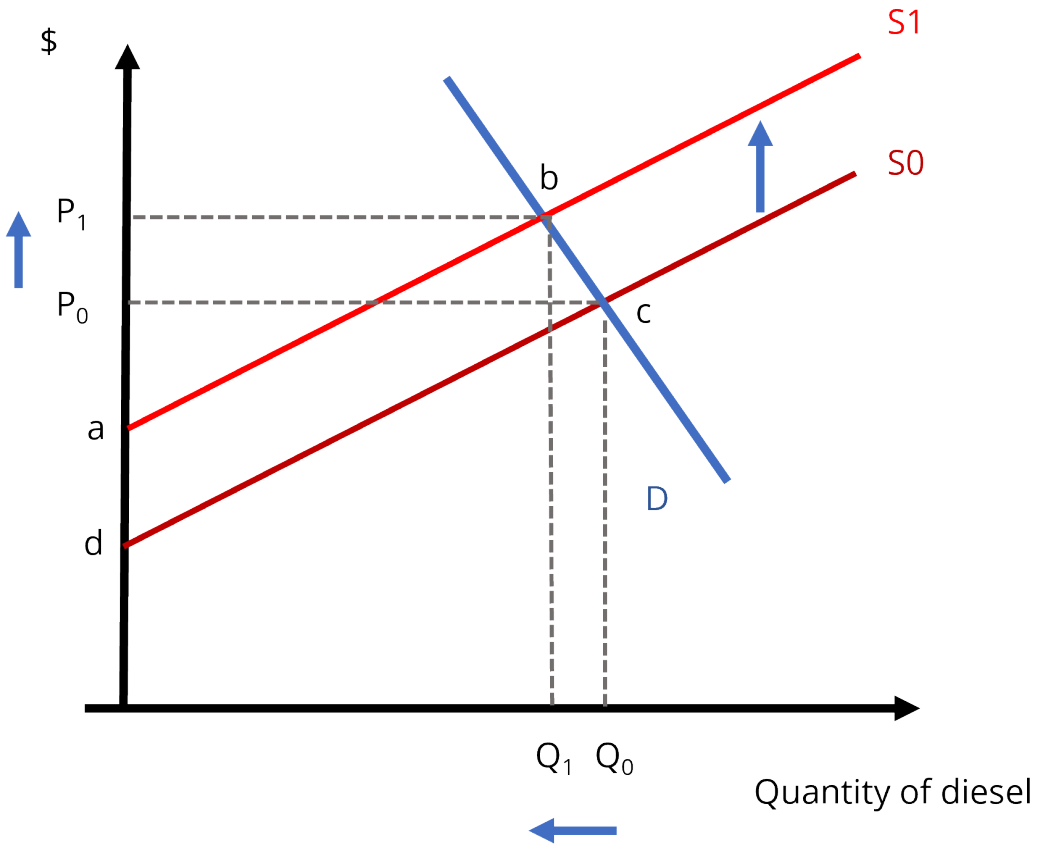


Figure 21.2 The impact of the standard on the wholesale diesel market

In this case, the analysis shows that the magnitude of the additional costs associated with complying with the standard is very small relative to the initial diesel price of about 60 cents in 2011. Indeed, the price would increase by less than one-third of a cent if these additional costs were fully passed on to consumers. In other words, the gap between S0 and S1 is very small. Under these conditions, the RIA concludes that the standard will have no significant effect on the quantity of diesel consumed (Q_1 equals Q_0).

An alternative way to view this result is to assume that demand is perfectly inelastic. In this case, the quantity traded does not change, and the increase in costs is fully passed on to consumers, as illustrated in Figure 21.3. The impact to be measured is represented by the area abcd in Figure 21.3, which corresponds to the additional cost imposed by the standard.

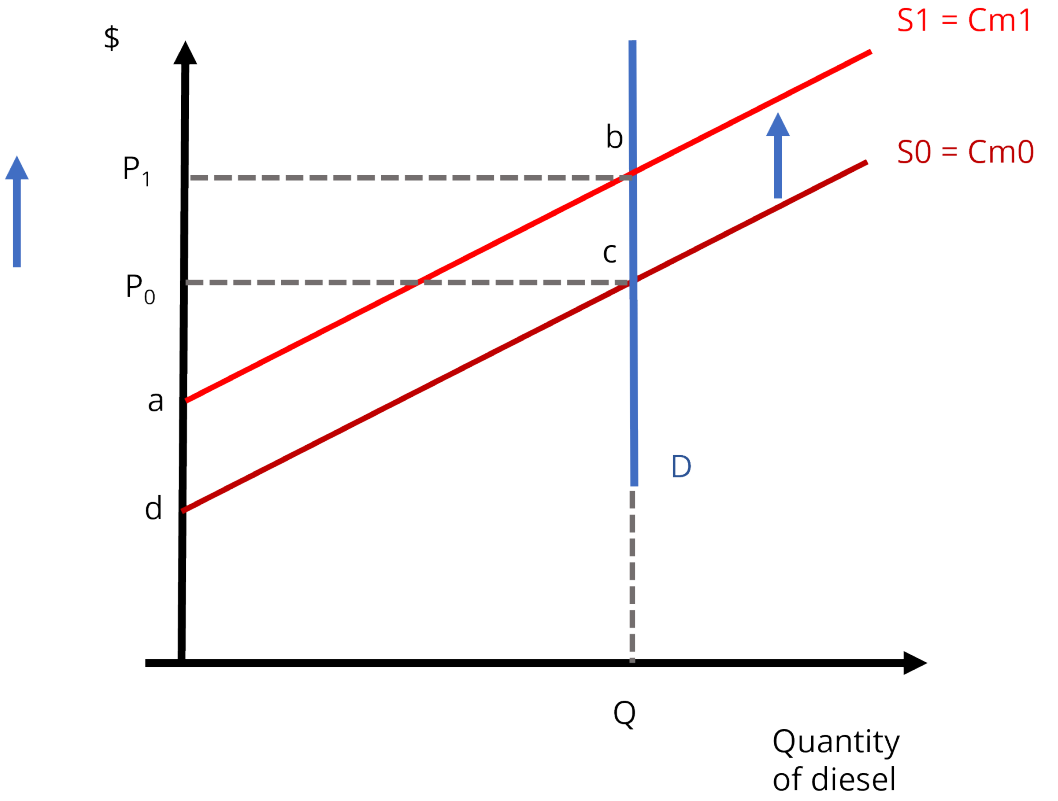


Figure 21.3 The impact on the primary diesel market with perfectly inelastic demand

The primary off-market effect

The reductions in GHG emissions resulting from the standard correspond to a primary non-market effect (see Chapter 9, Section 1). These reductions result from replacing 2% of fossil diesel with biodiesel, whose emissions, assessed over the full production life cycle, are significantly lower. This is, in fact, the main benefit of the project. The RIA estimates that GHG reductions will amount to approximately 1 million tonnes of CO_2 equivalent per year (0.17% of total Canadian emissions in 2007) and 23.6 million tonnes of CO_2 equivalent over the 25-year analysis period.

Side effects on the biodiesel market and agriculture

The standard leads to an increase in demand for biodiesel, as illustrated in Figure 21.4. The RIA projects an increase of approximately 40% in biodiesel production relative to the baseline scenario. No price effects are mentioned in the RIA, implying that supply is assumed to be perfectly elastic. The RIA also does not identify any distortions at this stage of production. All impacts in this market are therefore mirror effects of the primary effects (see Chapter 12). For example, the cost of the resources mobilized to increase production from B_0 to B_1, represented by the area *efgh*, corresponds to a portion of the area *abcd* in Figure 21.3.

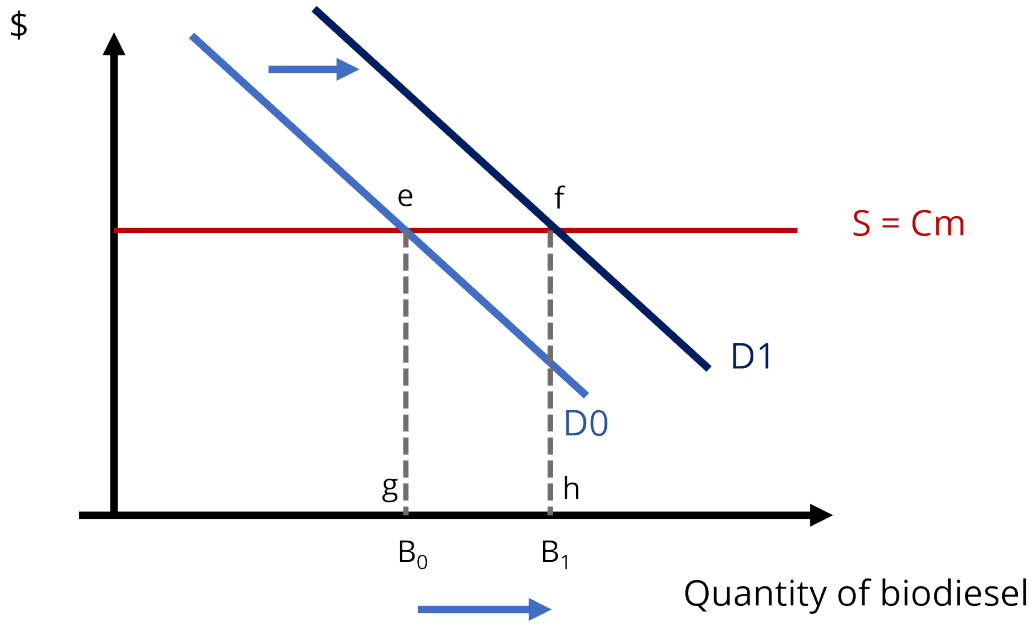


Figure 21.4 The impact of the standard on the biodiesel market

Further upstream in the value chain, the standard also leads to an increase in demand for certain agricultural products, such as soybeans. The RIA considers this increase in demand to be too small to trigger a rise in agricultural prices, particularly given that prices in agricultural markets are determined on international markets. The RIA also does not identify any distortions in these markets. The effects on agricultural markets are therefore mirror effects of the impacts identified further downstream in the value chain (a portion of the efgh area in Figure 21.4).

5. Estimation and valuation of impacts

Based on the analytical framework, the CBA of the standard requires determining:

1. The quantities of diesel and fuel oil traded in the reference scenario for each year over the period 2011–2035: These quantities are also assumed to apply to the scenario with the standard. The assessment is based on an extrapolation of past trends, with an annual consumption growth rate of 1.7%;
2. The quantities of GHG emissions avoided as a result of the standard: This estimate is based on technical analyses of the differential GHG emission rates of fossil diesel and biodiesel. The valuation of avoided emissions is conducted using the social cost of carbon, set at $25 per tonne (see Chapter 16);
3. The quantities of biodiesel and kerosene required to comply with the standard: Costs are calculated by multiplying the required quantities by the estimated unit costs. To obtain the net effect, the reduction in the cost of fossil diesel replaced by biodiesel must also be taken into account. Valuation is conducted at the price of conventional diesel and fuel oil;

4. The assessment of other costs that must be borne along the value chain to adjust to the standard, while avoiding double counting and excluding transfers or financial flows between parties: For example, payments from the fuel industry to Canadian biodiesel producers for the purchase of biodiesel are not included, as they represent financial transfers. In the CBA, only the resource costs associated with producing biodiesel are considered. By contrast, in the case of imports, the purchase cost represents an economic cost. These assessments are based on technical analyses and consultations with the industry.

The results are presented in Table 21.1. The present value of the costs of implementing the standard is therefore $2.6 billion. The largest cost component is the cost of importing kerosene, followed by the costs of domestic biodiesel production and additional transportation costs. The total gross cost of the standard amounts to $12.3 billion, but replacing a portion of fossil diesel with biodiesel generates savings of $9.7 billion. The resulting incremental cost is therefore $2.6 billion. The benefit associated with reduced climate damages is estimated at $0.47 billion.

Based on the monetized costs and benefits, the standard results in a net present value loss of $2.3 billion, corresponding to an average annual cost of $94 million.

Table 21.1 Baseline CBA results – present value of impacts from 2011 to 2035 in millions of 2007 dollars (3% discount rate)

Additional costs	
Cost of importing kerosene	6,408
Additional biodiesel production cost in Canada	4,693
Transportation costs	1,934
Costs of importing hydrotreated vegetable oil	775
Capital costs	157.2
Additional operating costs for fuel producers and importers	112.4
Costs of importing biodiesel	12.2
Administrative costs of fuel producers and importers	7.1
Retailer Adjustment Costs	3.1
Additional purchases of diesel and fuel oil related to the reduction in energy content by consumers	203
Avoided costs of diesel/fuel oil replaced by biodiesel	-9,725
Total costs	**2,636**
Additional benefits	
Social value of avoided GHG emissions (estimated at $25 per tonne)	470.3
Total benefits	**470.3**
Net present value	**-2,368**
Source: Environment and Climate Change Canada (2011).	

The RIA includes a qualitative analysis of other impacts that are likely to be minor. These include:

- Impacts on agriculture;
- Health impacts of reducing air pollutants;
- Job creation.

6. Sensitivity analysis by parameter

The RIA provides a parameter-specific sensitivity analysis examining the effects on the NPV of changes in the price of diesel and fuel oil, the social cost of carbon, the required volumes of kerosene, and the discount rate (see Chapter 19). In all cases considered, the NPV remains negative, even with a social cost of carbon of $100 per tonne. The NPV becomes positive only when the social value of carbon exceeds $121 per tonne.

Salci and Jenkins (2016) conduct an in-depth sensitivity analysis covering five key elements for which uncertainty or risk is present:

1. The price of crude oil;
2. The cost of producing biodiesel;
3. The cost of kerosene;
4. The evolution of demand for diesel and fuel oil;
5. The social cost of carbon;
6. The social discount rate.

In particular, they perform a Monte Carlo analysis. They assume a triangular distribution for the percentage change in diesel and heating oil demand relative to the main scenario, with a range from −10% to +10%. For the price of oil, the distribution is based on the evolution of actual prices observed between 1974 and 2015. The distribution of biodiesel production costs is established by assuming that input prices (e.g., the price of canola) follow a normal distribution centered on the prices in the main scenario, with a standard deviation of 10% around this mean. The simulations also impose a correlation of 0.9 between biodiesel production costs and the price of diesel. Finally, the distribution of the social cost of carbon is based on a meta-analysis of values reported in the relevant literature. Approximately 1% of the estimates in the documents available at the time of the analysis place the social cost of carbon between $100 and $110 per tonne. The simulation involves 100,000 draws. The results confirm that the probability of a positive NPV is very low.

7. Recommendations

Although the NPV was negative, the standard was implemented. The following excerpt from the conclusions of the RIA provides insight into the reasons that led to the adoption of the standard despite a negative NPV:

> "While the amendments impose costs on industry and consumers, these costs are likely to be manageable (for example, one-third of a cent per litre of diesel for consumers). They will also provide benefits in terms of reducing GHG emissions, and in conjunction with other Government of Canada programs, would help create jobs in rural areas and provide opportunities for rural Canada to participate in biodiesel production."
> Environment and Climate Change Canada (2011).

From an *ex post*perspective , the benefits of the standard are likely to be higher, as more recent assessments of the social cost of carbon are significantly higher than the minimum value needed to make the project cost-effective. For example, according to Environment Canada (2023), the social cost of carbon in 2020, expressed in 2007 dollars, is $200, which is well above the minimum value of $121 required to make the standard cost-effective. However, it would also be necessary to determine whether the implementation costs have been higher or lower than those anticipated in 2007.

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22.

CULTURE AND ECONOMIC DEVELOPMENT – CBA OF TAX CREDITS TO PROMOTE FOREIGN FILM PRODUCTION



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This case study was modeled after Lester (2013). Here, we present a somewhat simplified version[1] for pedagogical purposes.

Concepts used	Reference chapter
The impact of a grant	8
Importance of the spatial horizon	2
Ex post analysis	1
Marginal cost of public funds	5

1. The context

- **The need:** To support the Canadian film and television industry by attracting foreign productions , mainly from the United States.
- **The Project:** In 2010, the Government of Canada and provincial governments provided $470 million in

1. We use linear supply and demand curves, whereas Lester (2013) uses constant elasticity curves.

tax credits to Canadian businesses for the filming of foreign films in Canada.

- **The objectives:**
  - Promote production and employment in the Canadian audiovisual industry;
  - Generate economic benefits, particularly tax benefits, for Canada and the provinces;
  - Maintain competitiveness relative to incentives offered by other jurisdictions.
- **The CBA:**
  - Lester (2013) conducts an assessment of the social costs and benefits for Canada resulting from the tax credits for the year 2010. This year therefore constitutes the reference period for this study, with Canada as the spatial horizon and an analysis duration set at one year.
  - Since the programs are already in place , the CBA adopted by Lester is characterized by its *ex post aspect*.

2. The scenarios

The reference scenario

The baseline scenario considered represents an assumption that , in 2010, no tax credits would have been allocated to foreign productions. In the context of this *ex post* ACA, the baseline scenario therefore does not reflect the status quo, but rather a counterfactual scenario in which the project would have been withdrawn.

The scenario with the project

This scenario considers maintaining the status quo, namely the allocation of Canadian and provincial tax credits totaling $470 million to foreign productions made on Canadian soil by Canadian companies. The conditions of this financial support vary depending on the jurisdiction. For example, Quebec proposes a refundable tax credit corresponding to 20% of expenses related to labour costs and the purchase of eligible goods made in Quebec, as specified by SODEC (2023).

3. Stakeholders , impacts and state of knowledge

The stakeholders are as follows :

- Canadian film and television companies;
- Foreign producers of films and television programmes;
- Public authorities;
- Professionals working in this industry.

Canadian companies

Canadian companies operate on the supply side of the "filming market ". Subsidy programs create several impacts on this industry:

- Tax credits allow Canadian companies to offer competitive rates to foreign producers, which helps attract an international clientele. Despite these competitive rates, subsidies help increase the revenues of Canadian companies;
- The increase in production within the industry contributes to the improvement of the efficiency of companies, thanks to a better exploitation of economies of scale. This growth also stimulates external advantages, such as agglomeration and specialization effects, for example, the development of companies in the niche of special effects;
- The implementation of these programs is accompanied by certain administrative costs.

Foreign producers

Foreign producers represent the demand side of the filming market. The existence of tax credits reduces the cost of filming in Canada for these producers, making Canada a more attractive option. It is important to note, however, that the welfare of these international clients is outside the spatial horizon , since they are not part of the geographic area studied. Nevertheless, understanding their behaviour is essential to anticipate the effects of these programs on the industry.

Governments

The impacts of subsidy programs on governments include:

- Direct expenses associated with the grants awarded, representing an immediate monetary cost to the government ;
- Additional tax revenues generated by expenditures made in Canada by foreign persons or entities, such as expenditures by foreign film crews, which thus contribute to increased tax revenues;
- The cost of public funds on net tax expenditures;
- Administrative costs incurred in the management and execution of grant programs.

Industry professionals

Subsidies help increase the number of film shoots , which in turn promotes job creation in the sector. However, this stimulation of employment does not necessarily lead to an increase in collective prosperity, if we consider that the salaries paid to professionals do not involve an economic surplus (or rents). In other words, in the event that these subsidies were withdrawn, it is assumed that the workers affected would find equivalent opportunities in other industries where remuneration levels were comparable.

State of knowledge[2]

Based on this framework, it is possible to determine the impacts of the grant programs to be evaluated and to identify the data needed for this evaluation.

The reference scenario

In the baseline scenario, in which subsidies are not in place, the equilibrium in the foreign filming market is at the point of intersection between the supply and demand curves, as illustrated in Figure 22.1 . At this equilibrium, the quantity of filming made is Q0, and the corresponding price is P0. However, these values are not directly observable in reality, which requires finding a way to evaluate them.

The scenario with subsidy

The effect of subsidy programs on the industry can be examined using the approach described in Chapter 8. As illustrated in Figure 22.1, subsidies cause the quantity of filming to increase, bringing it to Q_1. This is because the price paid by buyers (P_b) decreases, while the price received by sellers (P_s) increases. The disparity between these two prices reflects the average amount of subsidy provided per filming, symbolized by *s*.

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2. See Lester (2013) for a more detailed description of the knowledge acquired on this sector and on the impact of subsidy programs . [/footnote]

Studies on the economic impact of foreign filming in Quebec have been conducted. According to the Quebec Film and Television Office (2016) , in 2015, 16 foreign productions generated approximately $313 million in direct spending , supporting more than 4,800 jobs. E&B Data (2004) reveals that for every $10 million spent on foreign productions in Quebec, 155 jobs are created and the Quebec government benefits from net tax revenues, that is , after the reimbursement of tax credits , of $1.17 million.

However, these analyses do not take into account the negative economic consequences resulting from the taxes raised to finance these subsidy programs. Furthermore, they assume that all foreign filming in Quebec is directly attributable to the existence of these subsidy programs. It is also important to note that these studies calculate the economic impacts and not the net social benefits of these programs.

4. The framework of analysis and the valuation of effects in the filming market

The main market affected by the subsidy programs is that of foreign filming in Canada. Although this market does not meet all the conditions of a perfectly competitive market (for example, the services offered by Canadian companies may vary in terms of quality and specialization), it remains relevant to use this analytical framework to assess the effects of subsidies. In this market, demand comes from foreign producers, particularly Hollywood producers, who own the rights to scripts and must choose their location for filming. Cost is a decisive criterion in this decision, leading to an increase in the quantity demanded when filming prices decrease.

When these clients choose to shoot in Canada, they hire a Canadian production company to deliver the finished product, whether it is a film or a television show. Thus, in our analysis, Canadian firms represent the supply. The quantity supplied tends to increase with price, which indicates that the marginal cost of production increases as the volume of shooting increases .[3]Note that this assumption contradicts the notion of "external economies," according to which total production tends to improve the efficiency of the industry.

3.

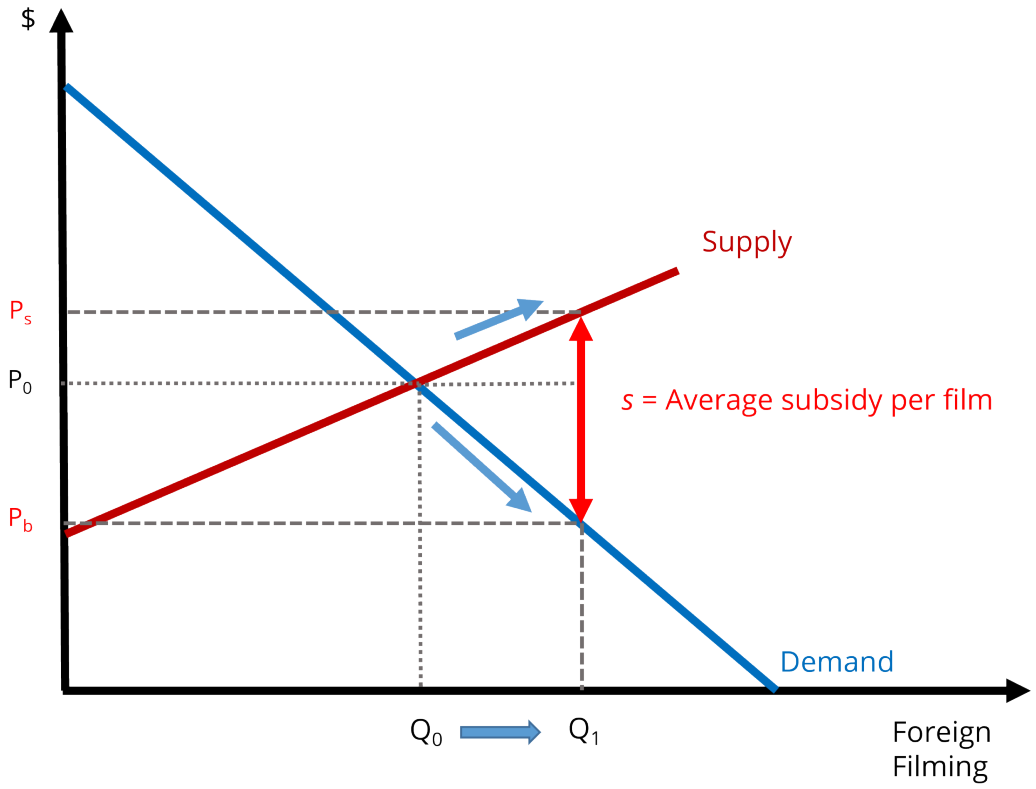


Figure 22.1 Impact of the subsidy in the foreign filming market

It is possible to determine the important impacts to be assessed on this market , by adopting the stakeholder approach. Figure 22.2 and Table 22.1 illustrate this procedure in detail.

It is important to emphasize that, given the delimitation of the chosen spatial horizon, the increase in consumer surplus for foreign customers cannot be considered an advantage. Thus, the net loss on the market is measured by the sum of the deadweight loss and the amount of the subsidy granted to foreign customers.

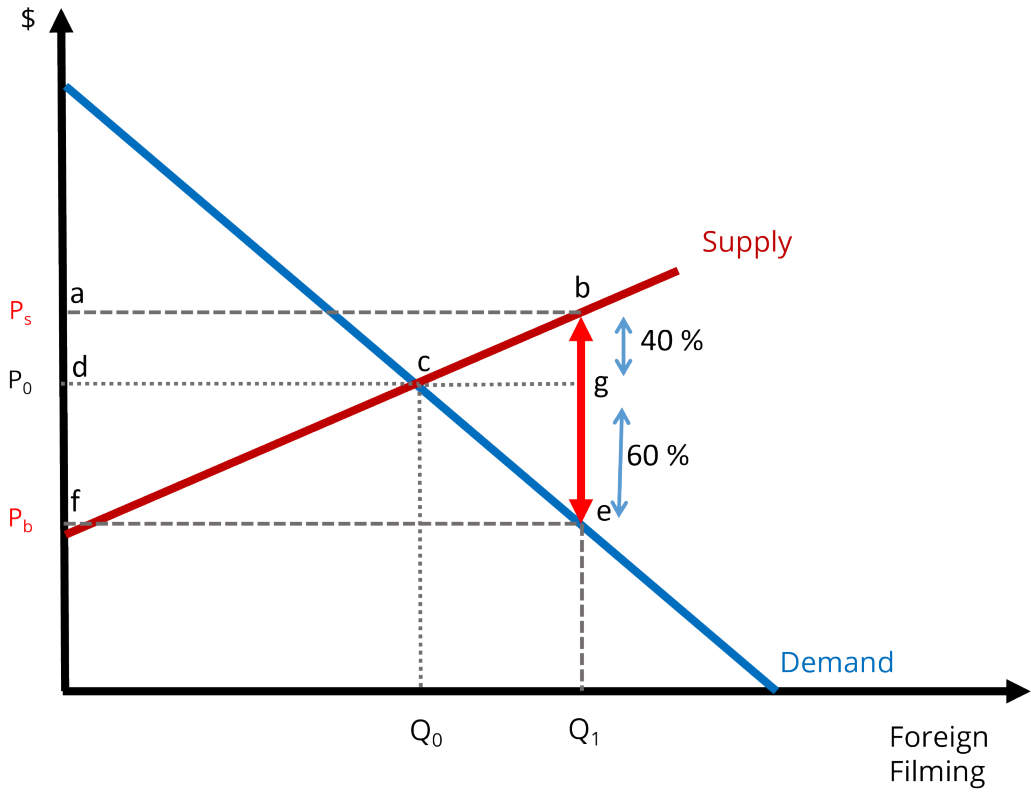


Figure 22.2 Determination of the net effect

Table 22.1 Impacts of subsidy programs on the foreign filming market in Canada based on the parties approach

Stakeholder	**Description of the impact**	**Surface s in Figure 22.2**
Canadian companies	Advantage: Increase in producer surplus following the increase in price from P_0 to P_s	abcd
Governments	Cost: Reduction in surplus caused by tax expenditure	- abef
Foreign clients (outside the horizon)	*Advantage: Increase in their surplus following the drop in price from P_0 to P_b (not to be considered)*	*dcef*
Net effect		**- dcbef**

To assess the effects of subsidy programs , Lester (2013) uses available data and determines the values of certain parameters from a review of existing literature :

- The price elasticity of demand (η_D) is estimated at 3.4;
- The price elasticity of supply (η_S) is 5;

- The grant program would increase the number of shoots by about 52%, which corresponds to an opportunism rate of about 66%;
- The total amount of subsidies awarded to Canada in 2010 reached $470 million .

To calculate the share of subsidies passed on to foreign customers, the incidence formula in Chapter 8, Section 2 is applied:

Share of subsidies passed on to consumers = $\frac{\eta_S}{\eta_D + \eta_S}$ =0.6 ou 60%.

Therefore, the value of the area *dgef* is equivalent to 60 % of the total amount of subsidies, or $282 million. It is now necessary to determine the value of the area of the triangle *cbg* . The height of this triangle, that is , the vertical distance between points *b* and *g* , represents 40 % of the average subsidy per shoot, s. In addition, the base of this triangle is formed by the difference between Q_1 and Q_0, which is 0.52 Q_0, assuming that the subsidy program resulted in a 52 % increase in the number of shoots. Thus, the area of the triangle *cbg* is calculated as follows :

Area of triangle *cbg* = ½ x 0.4 x *s* x 0.52 x Q_0.

Although we do not directly know the value of s or Q_0, we know that the area of the rectangle *abef* is given by:

Area of rectangle *abef* = *s* x 1.52 x Q_0 = $ 470 million .

Comparing these two formulas, we deduce that the area of triangle *cbg* is :

Area of triangle *cbg* = ½ x 0.4 x (0.52/1.52) x area of rectangle *abef* = $32.1 million .

The net effect of the subsidy program is therefore a net loss of $314.1 million, consisting of $282 million, plus $32.1 million.

5. Other impacts to be taken into account in the CBA

The analysis conducted above quantifies the efficiency losses induced by the subsidies and the cost to Canada resulting from the transfer of resources to entities outside the horizon of analysis. As noted in Section 4, these subsidy programs also have other impacts that Lester (2013) has estimated. The tax revenues generated by non-resident spending are estimated at approximately $13.8 million. This amount represents a net benefit, rather than a simple transfer, since these individuals are not included in the horizon of analysis. Furthermore, Lester estimates the increase in industry efficiency resulting from the subsidy programs at $50 million.

In terms of incremental costs, Lester estimates the administrative costs associated with administering the subsidy programs, for government and industry, at about $6.5 million, based on available administrative data. He also considers the marginal cost of public funds, estimated at $0.26 per dollar spent, based on findings from other research. Thus, the total cost of public funds is $120 million, which is $0.26 times ($470 million - $18.8 million + $6.5 million). Table 22.2 presents the CBA results.

Table 22.2 CBA results of grant programs

Category	Amount (in millions of 2010 dollars)
Benefits	
Taxes collected from foreigners	13.8
Improving industry efficiency	51.1
Total Profits	*64.9*
Costs	
Subsidies that go to foreigners, plus dead loss	314
Administrative costs	6.5
Costs of public funds	120
Total costs	*440.5*
Loss n and you	***-375.6***
Source: Adapted from Lester (2013)	

6. Sensitivity analysis

As part of his sensitivity analysis, Lester (2013) explores an optimistic scenario to assess the impact of subsidy programs with modified conditions. In this scenario, the price elasticity of demand for filming is assumed to be double that originally estimated, increasing from 3.4 to 6.8. This change reduces the proportion of subsidies that flow out of the country, thereby retaining a greater share of the value generated within national borders. Furthermore, a decrease in the supply elasticity from 5 to 1 further favours the Canadian industry, by increasing the share of subsidies that directly benefit Canadian producers. In addition, the efficiency benefits from increased production are increased by 50%. Despite these optimistic adjustments, Lester (2013) concludes that subsidy programs still result in a net loss to the economy.

7. Recommendations

According to Lester's CBA, subsidy programs generate a net cost that exceeds their benefits. Thus, their elimination could potentially improve collective wealth. This raises questions about the motivations of governments to maintain such programs. As we explain in Chapter 3, this policy benefits only a narrow group of stakeholders, while its costs are spread across a broad range of taxpayers. An initiative to abolish these subsidies would likely encounter far more organized resistance than the level of support it could garner.

Moreover, Lester's analysis is not without its limitations. One may question the realism of a baseline scenario in which all Canadian jurisdictions would coordinate to eliminate subsidies. These subsidy programs are indeed probably partly the result of a dynamic of tax competition between jurisdictions, as suggested by Sewordor and Sjoquist (2016). Elimination by a single jurisdiction would probably be less socially profitable.[4]

The assumption that supply increases with price, while allowing for efficiency improvements as production levels increase, presents some theoretical contradictions. Lester also does not examine the potential impact on the secondary market for domestic filming, where the increased presence of foreign productions could put upward pressure on the costs of local filming (price effect) but also improve the quality of the services offered. It is also possible that subsidy programs have favourable dynamic impacts. The increase in the number of filmings today could promote demand growth in the future, through network effects or by improving the quality of the services offered. In addition, demand growth could eventually translate into price increases, which would increase producer surplus.

In conclusion, it is important to approach these results with caution, as they represent the outcome of a single study. Before making a final decision on the future of these programs, it would be wise to establish a scientific consensus on their costs and benefits.

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4. Lester shows, however, that the unilateral elimination of subsidies by British Columbia would also lead to a positive NPV.

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23.

EDUCATION – CBA OF AN UNDERGRADUATE RESEARCH INTRODUCTION PROGRAM



Main building at the University of Texas at Austin. © 2014 Larry D. Moore. CC BY 4.0

This case study was developed from Walcott *et al*., (2018) and Rodenbusch *et al*., (2016).

Concepts used	Reference Chapters
Impact analysis	1
Risk treatment	18
The decision tree	18

1. The context

The need

University education in science, technology, engineering, and mathematics (STEM) is considered crucial for the development of contemporary societies. However, university programs in these fields face major recruitment and retention challenges, particularly in North America. This is despite the fact that median salaries for STEM graduates are generally higher than those from other academic disciplines.

Barriers to attractiveness of STEM disciplines include:

- Lack of information among young people when choosing their university orientation;
- A tendency to favor the short term: STEM studies are often perceived as more demanding, requiring greater immediate effort for future benefits;
- A traditionally masculine representation in these fields, with few female figures as role models.

Furthermore, many of these university programs still rely on a traditional pedagogical approach, favoring theoretical methodology courses at the beginning of the curriculum, which can lead to a loss of meaning and decrease student interest. The CBA presented here focuses specifically on a modification of the approach of these methodology courses, aimed at strengthening student retention in STEM disciplines.

The project

The measure studied, implemented at the University of Texas at Austin and known as the Freshman Research Initiative (*FRI*), proposes an innovative pedagogical approach to teaching STEM disciplines. This initiative aims to transform the educational experience of new students, by replacing three traditional laboratory courses with courses focused on the research experience. In these courses, a group of 35 to 40 students work together on a single research project, supervised by a doctoral student. This method based on project-based learning aims to lead students to produce original scientific contributions.

To succeed, participants are encouraged to master the laboratory techniques necessary to advance their research project. This educational framework aims not only to enrich their theoretical understanding through immediate practical application, but also to stimulate their interest and commitment to their field of study from the beginning of their university career.

The objective

- Improve retention and graduation rates from STEM study programs.

The CBA

The assessment focuses on the benefits and costs associated with a "typical student", i.e. an average student profile. Key aspects of this CBA include:

- **The period of analysis**: The impact of the FRI program is examined over the entire duration of a standard professional career;
- **The social discount rate**: A discount rate of 3% is used to calculate the NPV;
- **The spatial horizon**is restricted and asymmetrical:
  - For costs: Only costs incurred by the university are considered in the analysis. This includes, for example, expenses related to the implementation and maintenance of the FRI program, without taking into account possible costs for students or other stakeholders;
  - For benefits: The analysis focuses exclusively on tangible benefits for the student, in terms of additional salary, i.e. the potential increase in income attributable to participation in the FRI program. Other types of benefits, such as improved skills, increased employability or scientific contributions are not quantified in this evaluation.

2. The scenarios

The reference scenario

In this scenario, the typical student engages in a conventional educational path consisting of three standard laboratory courses during his or her first year of university studies. These courses emphasize traditional theoretical and methodological learning.

The scenario with the project

In this alternative scenario, the typical student replaces the three traditional laboratory courses with courses offered as part of the FRI program, which involve active participation in a research project under the supervision of a doctoral student.

3. Stakeholders and impacts

The actors involved in this initiative include:

1. Students, whether they opt for the traditional curriculum or the FRI approach;
2. The university that implements the FRI program;
3. The society that benefits from the contributions of a university graduate, particularly in STEM fields;

4. Other higher education institutions.

The impacts are briefly summarized in Table 23.1.

The benefits of the FRI program

- The FRI decreases the risk of dropping out of college and increases the chances of obtaining a STEM degree. These effects therefore increase expected earnings over the course of a career;
- The FRI is likely to improve the university's reputation, thereby increasing its tuition revenue and possibly reducing its recruitment expenses (e.g., by reducing advertising requirements). However, these benefits have not been quantified due to lack of data;
- Increasing the number of STEM graduates through FRI can also lead to benefits such as technological progress and enhanced economic growth, although this impact is diffuse and difficult to measure.

Costs associated with the FRI

- The FRI requires more human resources (teaching assistants) and more intensive use of laboratories, representing costs borne by the university. It is assumed that these costs are not passed on to students through an increase in tuition fees;
- The FRI program may require a greater investment of study time from students, although there are no data on this. However, the authors estimate that this difference should be minimal;
- In the absence of data, the analysis also excludes transition costs related to adapting courses to the new teaching approach;
- Other universities maintaining a traditional curriculum could suffer a negative impact resulting from the loss of students attracted to the university offering the FRI. However, this displacement effect is considered too diffuse to be quantified.

Table 23.1 Summary of impacts in the FRI CBA

Impact	Relevance	Quantifiable	Valued	Details
Additional benefits				
Salary increase during career	X	X	X	
Increase in net income of the University which sets up an FRI	X			Lack of data
Impact on innovation and economic growth of having more STEM graduates				Diffuse effects
Additional costs				
FRI costs (auxiliaries and additional laboratories)	X	X	X	
Implementation costs (course planning and reform)	X	X	X	
Costs of additional student effort in the FRI	X			Lack of data and probably weak
Negative impact on net income of other universities	X			Diffuse effect

4. The methodology

Cost valuation

The cost assessment is based on a detailed estimate of additional costs (*micro-costing*). The elements considered are: faculty resources, teaching assistants, equipment and use of buildings. In total, the cost of the three FRI format courses is estimated at $3,375/student, while in the traditional format, the cost rises to $2,136. The additional cost is therefore $1,239[1].

Valuing the benefits

Accurately assessing the benefits of the program requires an analysis of its causal impact on graduation rates. The CBA builds on the study by Rodenbusch *et al*., (2016), which examines the impacts of the FRI. A major challenge in assessing the causal impact of the FRI is that enrollment in the program is not randomly determined. The choice between the traditional pathway and the FRI depends on the student's decision.

This selection method introduces a risk of bias: students opting for the FRI could present stronger intrinsic

1. The initial results of the source study are expressed in 2014 US dollars. To make them more concrete, they have been adjusted to 2021 Canadian dollars, taking into account inflation from 2014 to 2021 and using the 2019 purchasing power parity exchange rate of 1.2.

motivation or higher previous academic successes, thus influencing their success rate, independently of the program.

To mitigate this problem, Rodenbusch *et al*. (2016) use a propensity score-matched control group. This technique[2] aims to predict the probability of choosing the FRI program based on various criteria such as gender, ethnicity, parental education and income, prior academic achievement, and the number of mathematics credits earned in high school. This prediction model is then used to match FRI participants with non-FRI students with similar characteristics, thus ensuring an equivalent probability of FRI selection between the two groups.

The impact analysis of the program shows that it increases:

- The probability of graduating from university (all programs combined) from 66% to 83%;
- The probability of graduating from a STEM program is 71% to 94%.

The valuation of this advantage is based on the differential in the median salary discounted over the entire career. The analysis also examines the impact on the median salary at the start of the career. Table 23.2 shows the salary differences according to the situation.

Table 23.2 Median salary by degree in 2021 Canadian dollars

	No college degree	**STEM University Degree**	**Non-STEM University Degree**
Starting annual salary	$17,150	$44,100	$32,950
Salary over entire career*	$1,014,420	$2,007,600	$1,422,990
* Updated at 3% Source: Walcott et al. (2018), Table 3, CC BY NC SA.			

The evaluation of the a priori expected benefits is then carried out using a decision tree characterized by the different possible paths, with the costs, the probabilities of graduation and the salaries associated with them (see Figure 23.1).

2. For a simple overview of this method, see the video https://www.youtube.com/watch?v=lwDcXH8kXds

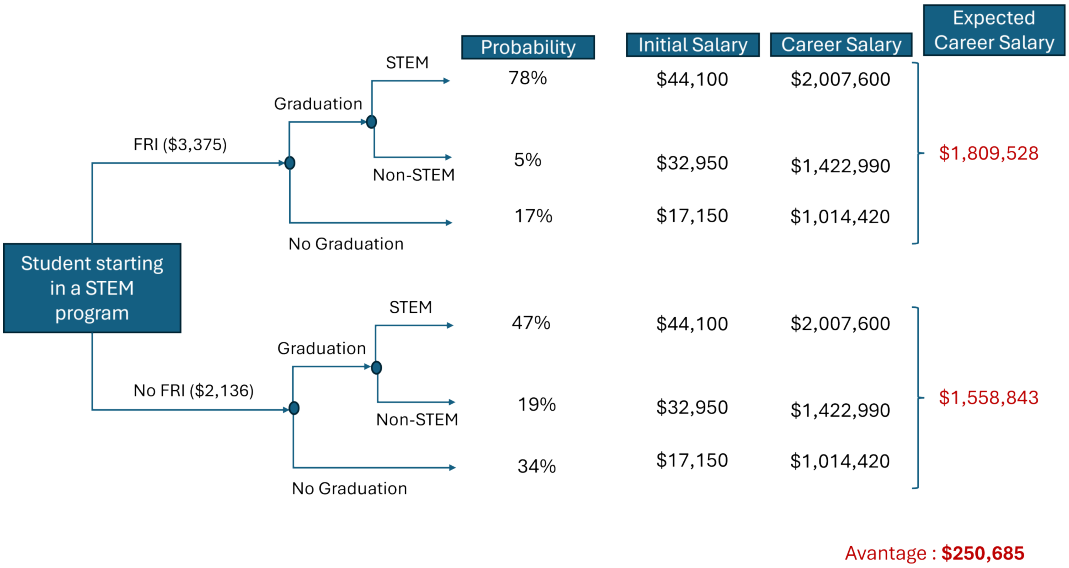


Figure 23.1 The decision tree. Source: Adapted from Walcott et al. (2018), Figure 2, CC BY NC SA .

5. The results

The results are unequivocal, as Table 23.3 illustrates: benefits overwhelmingly dominate costs. This is the case even when only the early-career wage differential is considered.

Table 23.3 The FRI CBA

Additional costs per student	$1,239
Expected benefits in terms of initial salary	$6,142
Expected career salary benefits	$250,685

A sensitivity analysis is performed on two aspects, namely the additional cost per student taking a low value and a high value. The second aspect concerns the fate of students who do not obtain a degree. In the base scenario, the student leaves the university and does not obtain a university degree. In an alternative scenario, it is assumed that 10% of the students who leave obtain a university degree elsewhere. None of the alternative scenarios changes the cost-effectiveness of the program.

6. Recommendation and limits

The CBA shows that the program is very cost-effective. However, it is important to highlight some limitations of the analysis:

1. Several impacts are not valued (see Table 23.1);

2. The impact of the program is based on the results of a single impact study and not on the results of a scientific consensus;
3. Although the impact analysis attempts to correct for the presence of selection bias, it is possible that other unobservable factors (e.g., psychological or initial motivational factors) differentiate those who choose the FRI curriculum;
4. The sensitivity analysis is quite summary.

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24.

TRANSPORT – THE CONSTRUCTION OF A TRAMWAY OR BRT IN THE QUEBEC CITY REGION



Quebec City. Source: Martin St-Amant, CC-BY-SA 3.0 via Wikipedia

This case analysis is based on a collection of reports[1] developed in 2014 by a Consortium Tramway Québec-Lévis and commissioned by the Ministère des Transports du Québec, as well as the cities of Lévis and Québec. Following this evaluation, the project underwent significant modifications before being temporarily suspended pending a revised proposal from the Caisse de dépôt et placement du Québec, expected in June 2024.

Concepts used	Reference chapter
The residual value	6
The project reduces the overall cost of transportation	7
Valorization of inputs	9
Valorization of inputs	11
Side effects	12
The social cost of carbon	16

1. The reports are available online https://tramwaydequebec.info/ressources/documentation/#

1. The context

The project aims to establish a heavy public transit system to connect the main activity centres of the cities of Québec and Lévis. It evaluates two options: a high-capacity bus rapid transit (BRT) service running on dedicated lanes with priority at intersections, as shown in Figure 24.1a, and a tramway, illustrated in Figure 24.1b.



*Figure 24.1a BRT in Xiamen.*Source: Dew1107, CC BY-SA 3.0, via Wikimedia Commons



Figure 24.1b Tramway in Antwerp. Source: Willem_90, CC0, via Wikimedia Commons

The project envisages the establishment of two main axes: an east-west line extending over 30.9 km and a north-south line of 6.9 km. The specific routes of these lines are detailed in Figure 24.2. The tramway is designed to carry up to 260 passengers per train, while the BRT can accommodate 150 passengers per vehicle. The frequency of services during peak hours varies depending on the section used, with intervals ranging from 3 to 6 minutes.



Figure 24.2 Proposed route for the project (reproduced with the kind permission of the City of Quebec, all rights reserved)

1. The justifications for the project

The project pursues the following objectives:

1. Meet the projected increase in daily travel needs, which are expected to increase from 1.9 million in 2011 to over 2.3 million in 2041, representing a growth of 22%;
2. Encourage urban densification and downtown revitalization, making these areas more accessible and attractive;
3. Create efficient connections between the region's main activity hubs through the introduction of a heavy public transport mode;
4. Overall improve the public transport offer in terms of capacity, frequency, comfort and reliability, in order

to make the system more attractive to current and potential users.

2. The scenarios

The **reference scenario**envisages the continued operation of the public transport networks of the two cities by bus, with an adaptation of the offer to meet the expected increase in demand for travel.

The scenario integrating the projectincludes the construction of a heavy public transport mode on a dedicated site for the two lines envisaged. As mentioned previously, two options[2] are under study:

Option 1: The deployment of a tramway, offering a sustainable and high-capacity mode of transport.

Option 2: The installation of a reliable BRT, i.e. with underground infrastructure (water, gas, electricity, sewer) previously moved to minimize service interruptions during road works.

The project's **time frame**extends over 35 years, from 2015 to 2050, including an eleven-year phase dedicated to studies, design and construction (from 2015 to 2026), a three-year period of partial network operation (from 2023 to 2025), and twenty-five years of operation (from 2026 to 2050).

The spatial horizonof the study covers the province of Quebec, but takes into consideration the global benefits of reductions in greenhouse gas emissions.

The reference yearfor the evaluation of the project is set at 2014.

The social discount rateof 4% is applied to assess the social profitability of the project.

3. Stakeholders and impacts

The main stakeholders involved include public authorities (the provincial government, and the cities of Quebec and Lévis), current bus users, motorists, public transit operators in both cities, and residents of the region.

Table 24.1 summarizes the impacts considered in the analysis. The main benefits fall into the following categories:

Time savings

1. For existing bus users, who will benefit from a more frequent and faster service[3] on the routes affected by

2. In the analysis carried out for the authorities, four versions of the BRT are analyzed, namely an unreliable BRT, a reliable BRT, a reliable and scalable BRT with platforms compatible with a tramway and a reliable and electric BRT rather hybrid (diesel-battery). To simplify the presentation, we are only considering the reliable BRT option which is the recommended option..

3. Some users may experience time losses if, for example, the new service requires additional transfers.

the project.

2. For new users of public transport, encouraged to abandon the automobile in favour of the new mode of transport, thus promoting a modal shift.
3. For motorists following a reduction in road congestion caused by reduced car travel.

Security gains

The reduction in car traffic should lead to a reduction in the number of accidents.

Reduction of automobile operating costs

New transit users will reduce their expenses related to the use and maintenance of their car, such as gasoline costs.

Reduction of bus operating costs

The introduction of the new mode of transport will reduce the costs associated with operating traditional buses.

The gains associated with reducing the number of parking spaces required

Reduced car traffic will reduce demand for parking, freeing up space for other uses.

Environmental gains

Reducing the use of cars and buses will lead to lower emissions of air pollutants and greenhouse gases, helping to combat smog and climate change.

The residual value

Some project assets will have a life that exceeds the analysis period, requiring the inclusion of their residual value as a benefit.

Other unvalued benefits

Other benefits are mentioned but not valued, such as the reduction of noise pollution, the positive impact on health linked to greater physical activity, the improvement in the comfort and reliability of public transport, and the structuring effect on economic activity and the built environment along the route of the new mode of transport.

The main cost categories are:

Capital costs

These expenses include preliminary studies, project design, necessary road works such as earthworks, purchase of rolling stock (trams or buses for the BRT), as well as construction of the infrastructure necessary for the operation of the system, such as maintenance centres.

Operating costs

These recurring costs include everything necessary for the proper daily operation of the new mode of transport, including the operation and maintenance of rolling stock and associated infrastructure.

Loss of parking

The implementation of the system will result in the removal of parking spaces along the routes, generating

an indirect cost for the businesses and residents affected, as well as potentially loss of revenue for the municipalities concerned.

Other costs

Although not directly quantifiable in financial terms, other impacts should be taken into account. During the construction phase, significant disruptions are expected, affecting traffic, commercial activities, and the daily lives of residents. These inconveniences, although temporary, may have consequences on the local economic fabric and quality of life. The CBA does not mention these costs.

Table 24.1 Considered impacts of the project

Impact	Relevance	Quantifiable	Valued	Details
Additional benefits				
Travel time savings	X	X	X	
Bus users				
Users switching from cars to public transport				
Motorists				
Reduction of accidents	X	X	X	
Reduction of vehicle operating costs	X	X	X	
Reduction of air pollutants	X	X	X	
Parking spaces freed up	X	X	X	
Reduction of bus operating costs	X	X	X	
Residual value	X	X	X	
Reduction of noise pollution	X	X	—	Not quantified
Revitalization effects along the route	X	X	—	Not quantified
Improved health of new users	X	X	—	Not quantified
Improving the reliability, comfort and brand image of public transport	X	X	—	Not quantified
Additional costs				
Tram operating costs	X	X	X	
Capital costs	X	X	X	
Loss of parking spaces along the route	X	X	X	
Disruptions during the construction phase	X	X	—	Not mentioned in the study

4. The analytical framework

The project has impacts on the primary market for public transport travel. It is analyzed as an improvement in the quality of a transport service (see Chapter 7, section 2). The new mode will be faster, which will reduce the generalized cost of transport for most users. However, some users could experience an increase in travel time

following changes in certain routes, the location of stops or the need to make transfers. Thus, the analysis is carried out at a disaggregated level by individual (see section 5).

For current transit users, the assessment focuses on changes in the generalized cost, which primarily translates into time savings or losses. This calculation includes walking time to the stop, waiting time, and time spent commuting. The value assigned to time varies depending on the purpose of the trip (work or leisure) and is adjusted to reflect an increased value during periods of walking and waiting.

For **traffic induced**by the modal shift from the automobile to the new public transport mode, the social gain corresponds to the sum of the time savings generated by the modal shift and the avoided costs of using the automobile (see Chapter 12, section 5). Avoided costs include fuel costs, depreciation, tire wear and parking fees.

The project also has repercussions in the secondary market for car travel. Indeed, **people who continue to use cars**benefit from a reduction in car congestion (time savings and reduction in car usage costs). Since these are impacts associated with a change in the level of a distortion (see Chapter 12), they must be taken into account in the analysis. In other words, this is not a mirror effect. The same is true for the reduction of pollutants, GHGs and accident costs.

5. Quantification and valuation of impacts

The forecast analysis of public transit and automobile traffic is carried out using a four-step methodology (Consortium Tramway Québec-Lévis, 2014c). The four steps[4] are:

1. Trip generation: This step consists of estimating the number of trips generated and attracted in different geographical areas. For this, data from the 2011 origin-destination survey, which documents trips by mode, reason, and departure time, are used. These data are adjusted to reflect sociodemographic, economic, urban, and motorization rate changes expected during the analysis period.
2. Distribution of trips: This step consists of distributing trips according to origins and destinations.
3. Modal share: The objective is to determine the distribution of travel between the different modes of transport for each scenario. For this project, the forecasts are made from the results of a multinomial logit econometric model estimated on the data from the 2011 origin-destination survey. This model takes into account various determinants such as travel time, monetary travel costs, and the socio-demographic characteristics of users. The results of this model then make it possible to simulate the evolution of modal shares in the scenarios considered.
4. Trip Allocation: This step identifies the routes that trips will take on the road network and the public

4. See the video produced by The Wichita Area Metropolitan Planning Organisation, the link to which is available at the end of this chapter.

transit network, depending on the travel period. This includes forecasting ridership for the tram or BRT, expected reduction in car volume, changes in parking demand, and time savings resulting from the project.

The valuation of these impacts is then carried out using reference prices such as the value of time, the average cost of an accident, the social cost of carbon or the price of gasoline. Table 24.2 shows the values of some reference prices.

Table 24.2 Values of the main parameters used

Setting	**Value**
Value of time (see Chapter 16)	
For work reasons	$31.68/h
For study reasons	$11.79/h
For leisure, shopping and other reasons	$21.11/h
Average cost per accident	$60,174 per accident
Social cost of air pollutants and GHGs*	
For light vehicle	0.030 014 $/km
For bus	0.088 090 $/km
Cost of using motor vehicles**	$0.3378/km
Value associated with a parking space***	$74 per seat per month

* CO_2 emissions are valued at the social cost of carbon of about $80 per tonne (see Chapter 16).
** Automobile operating costs are calculated excluding taxes (e.g., gasoline taxes or maintenance taxes), which implicitly assumes that the supply of these resources is considered perfectly elastic (see Chapter 11).
*** This value is based on the market value of a parking space.

The valuation of the residual value is carried out by applying linear depreciation rates to the expected life of the project's fixed assets, beyond the period analyzed. It is important to remember that this method is open to criticism (see Chapter 6, section 5).

Capital costs are based on technical forecasts provided by the Consortium Tramway Québec-Lévis (2014a and b). Operating costs are calculated by assessing the volumes of inputs required (such as the amount of electricity or the personnel required to operate, maintain, and manage the operations of the metro trains) and multiplying them by their unit costs (for example, the electricity rate or the gross salary of employees, including benefits). This approach implicitly assumes that the employees hired will already have equivalent employment

(see Chapter 11), and that the prices of other inputs are established in undistorted markets. In addition, the analysis also assumes that the project will have no impact on input prices (see Chapter 11).

Cost forecasts also include a contingency allowance and an estimate of accuracy. For capital costs, a Monte Carlo analysis using triangular probability densities achieved an estimated accuracy of ±30%, and suggested a 15% reserve to cover possible contingencies (see Chapter 18).

6. The results

Table 24.3 presents the CBA results. It can be seen that the tram exhibits a negative NPV, while the BRT leads to a positive NPV. In fact, the BRT offers similar benefits to the tram, but at a lower cost. However, it should be noted that the analysis does not include an examination of the sensitivity of the results.

Table 24.3 CBA Results (Net Present Value in Millions of 2014 Dollars)

	Tramway	BRT made reliable
Total time savings	524	530
Reduction of accidents	78	81
Reduction of vehicle operating costs	279	287
Reduction of air pollutants	34	28
Parking spaces freed up	55	54
Reduction of bus operating costs	523	550
Residual value	139	79
Noise reduction	–	–
Revitalizing effects along the way	–	–
Improving the health of former motorists	–	–
Improved network image and increased user satisfaction	–	–
TOTAL of the benefits valued	**1632**	**1609**
Tram operating costs	542	488
Capital costs	1595	938
Loss of parking spaces	12	13
TOTAL of the costs valued	**2149**	**1439**
TOTAL net benefits of valued costs	**-517**	**170**
Source: Transport Québec, Lévis and Ville de Québec (2014), Table 8 p. 63. Reproduced with the kind permission of the City of Québec. All rights reserved.		

7. Recommendations

The limitations of the CBA are not addressed, and the recommendations made in the final reliability study report are based not only on the results of the CBA, but also on technical and financial considerations. These recommendations are as follows:

1. Promote the adoption of an BRT.
2. Undertake additional analyses to determine the most advantageous solution between the different BRT

options.

3. Establish the different phases of project execution.
4. Establish a project office responsible for coordinating all the work required to prepare the project.

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One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.pbuq.ca/introduction-cost-benefit-analysis/?p=243#oembed-1

WAMPO is the Metropolitan Planning Organization (MPO) https://www.youtube.com/watch?v=e0eno7MbrPk

PART VI

SOLUTIONS AUX EXERCICES

CHAPTER 1 SOLUTIONS

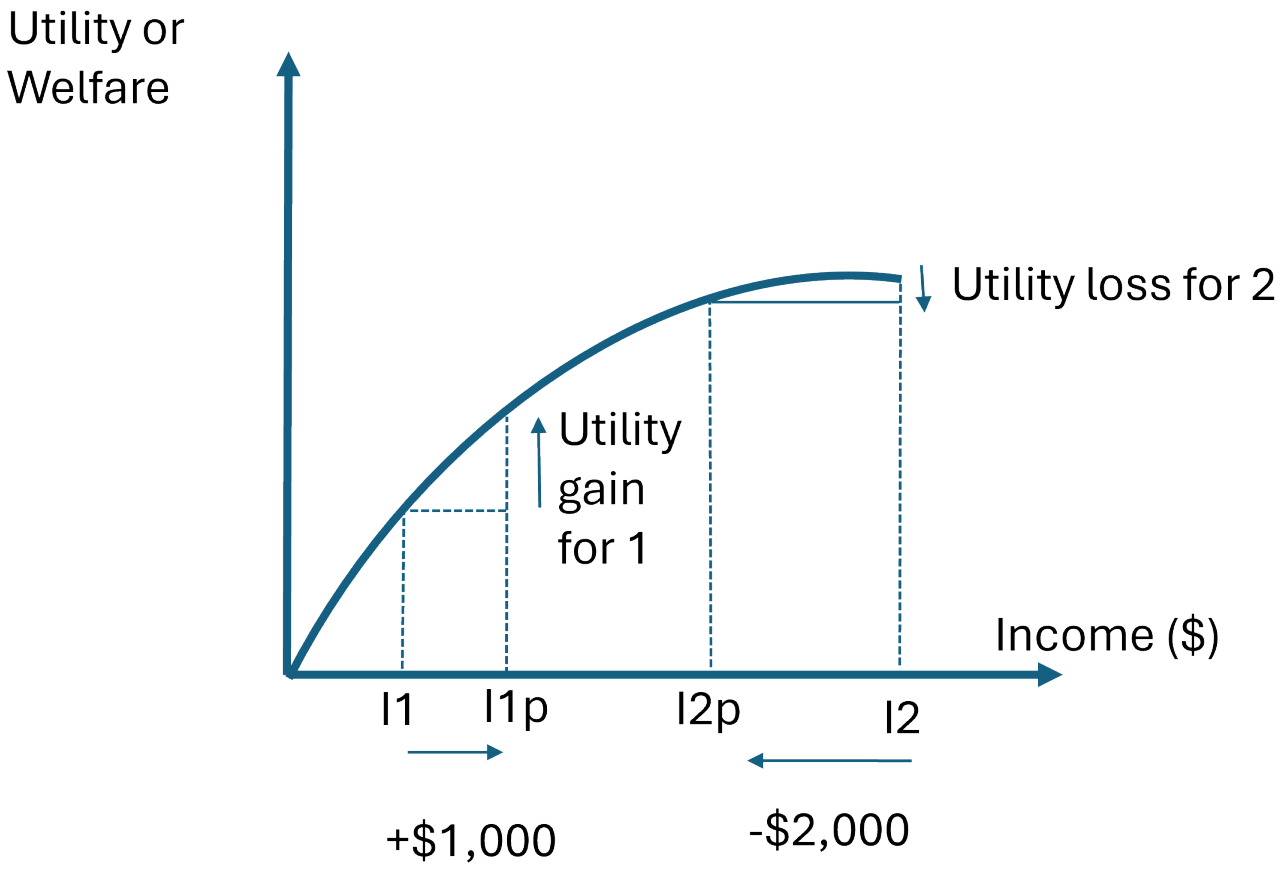
Question 3

Question 3

Given a graph and a project involving two people, develop an example of a project that reduces collective wealth but increases collective well-being.

Answer

Consider a project where individual 1 receives a benefit of $1,000, while individual 2 incurs a cost of $2,000. This is as if individual 1's income increases from I1 to I1p on the graph below, while individual 2's income declines from I2 to I2p. However, individual 2 is wealthier than individual 1, so the impact of this $2,000 loss of income has a lesser effect on his well-being than the impact of $1,000 on individual 1's well-being. We can see from the graph that the loss of utility of 2 is more than offset by the gain in utility of 1. Based on a CBA, this project should not be adopted, since its net value is negative. Yet, this project improves total well-being.


Utility or Welfare
Utility loss for 2
Utility gain for 1
Income ($)
I1
I1p
I2p
I2
+$1,000
-$2,000

CHAPTER 2 SOLUTIONS

Question 3 Question 4
Question 5 Question 6

Question 3

A project aims to improve the public transit offering in a transportation corridor, which would result in time savings for users. These time savings are taken into account in the project's CBA. The project would also result in increased property values along the corridor. Should this impact be included in the project's CBA? Justify your answer.

Answer

Adding this impact is probably not justified, as it probably results from the time savings that have already been taken into account. Indeed, the relative increase in property prices is probably caused by the increase in demand for these properties, due to their proximity to improved public transport. In other words, the time savings of residents are "capitalised" in the price of the properties considered. Adding the increase in property values and the value of users' time savings would amount to counting the same impact twice.

On the other hand, if the project reduces the nuisance of public transport on nearby dwellings (for example, by reducing vibrations or noise), then the increase in the price of residences caused by this impact could be a way of valuing this impact in the CBA. Chapter 12 provides a more detailed analysis of whether or not to include the secondary effects of a project.

Question 4

A project involves moving all of a city's citizen support services to a new building. The city will have to pay one million dollars to a local company that will be responsible for constructing the building. You are tasked with performing a CBA of this project with a colleague. She suggests ignoring this million-dollar amount in the CBA, since it is a transfer between stakeholders: the municipality bears a cost of one million dollars, while the contractor receives a benefit of one million dollars. What do you think of your colleague's argument?

Answer

The amount paid to the contractor is indeed a cost to the municipality and a benefit to the contractor. However, your colleague's mistake is that the payment is made as compensation for the costs of the resources mobilized to build the building. There is a counterpart to the payment. The building is therefore not free, its cost must therefore appear somewhere in the CBA. As illustrated in the table below, the contractor can simply be ignored in this CBA if the income he receives corresponds to his economic cost and the cost of the project is borne by the municipality.

Stakeholder	**Advantage**	**Cost**	**Net effect**
Municipality		100	-100
Entrepreneur	100	100	0

Question 5

The bridge project to replace the ferry system will result in job losses for employees of ferry operator. Using Table 2.3, examine how this impact should be taken into account if we add "ferry workers" as a stakeholder.

Answer

Table 1. List of costs and benefits of the bridge project (Stakeholders approach)

Benefits	Costs
Users : • Value of travel time savings • Reduction of vehicle operating costs • Reduction of accident costs (partly)	**State :** • Construction and land costs • Shuttle maintenance and operating costs
State : • Residual value • Reduction of accident costs (partly)	**Nearby residents :** • Transition costs
Third party : • Reducing the costs of polluting emissions	**Third party :** • Negative environmental impacts
Ferry company : • Elimination of ferry capital and operating costs	
Ferry workers • Salaries in the best alternative jobs	**Ferry workers** • Wage losses in current jobs

Since the analysis did not consider the impact on workers, the implicit assumption is that laid-off workers will be able to find new jobs with similar wage conditions, so the left and right columns cancel each other out. This would be different if workers received a rent in their current job (for example, high wages because of union protection). The loss of this rent should be included in the CBA (either the current wage – or the wage in the best alternative). But it would also be necessary to determine who paid this rent to determine whether its benefit should also be included in the CBA.

Question 6

A regional health organization is considering setting up a home care service for seniors. The organization will receive a government grant of $2 million per year for this service. Personnel costs are estimated at $3 million per year. In addition, there are $200,000 per year in expenses for supplies and equipment. Beneficiaries will have to pay part of the cost of the services, their contributions being estimated at $300,000 per year. The remainder is covered by the organization's budget. The gross benefits for users, or their maximum willingness to pay (MWP), are estimated at $4 million per year. Complete:

1. A financial analysis from the perspective of the regional health organization;
2. An analysis which adopts the sole point of view of the interests of the elderly;
3. A CBA with a regional perspective;
4. A CBA with a national perspective.

Answer

Analysis from different perspectives (in millions of dollars)

	Financial analysis for the organization	**Analysis from the perspective of older people**	**CBA** Regional	**CBA** National
Benefits	2 (grant) 0.3 (beneficiary contributions)	4 (benefits to users)	4 (benefits to users) 2 (grant)	4 (benefits to users)
Costs	3 (personal cost) 0.2 (supplies)	0.3 (user contribution)	3 (personal cost) 0.2 (supplies)	3 (personal cost) 0.2 (supplies)
Effect n and	**– 0.9**	**3.7**	**2.8**	**0.8**

CHAPTER 3 SOLUTIONS

Question 1 Question 2

Question 1

For each of the projects below, discuss the economic justifications for government intervention:

1. Smoking prohibited in public places;
2. Investment in new combat helicopters;
3. Grants for R&D activities;
4. Construction of a bridge ;
5. Public transport subsidy;
6. Ban on non-tobacco flavors in vaping products;
7. Provide social housing;
8. Certification of organic products;
9. Obligation to wear a helmet when cycling;
10. Tax on sugary drinks.

Answers

1. Smoking ban in public places: This is mainly to prevent a negative externality(external cost). Smoke has negative impacts on the health of people nearby.
2. Investment in new combat helicopters: National defense is a public or collective good. The purchase of helicopters is therefore part of the State's mission to provide a public good.
3. Subsidies for R&D activities: R&D activities generate positive externalities. Indeed, new knowledge will be useful not only to the person who produces it but also to other people. This is called knowledge spillover .Patents are intended to protect the innovator, but this is an imperfect protection. Without government subsidies, there is underproduction of new knowledge, because it is not possible for the innovator to appropriate all the benefits.
4. Construction of a bridge can first be justified by invoking the notion of an "essential good," particularly when the crossing provides a unique link. Moreover, the cost structure of such infrastructure is characterized by very high fixed costs associated with construction, while the marginal cost of an

additional crossing is negligible in the absence of congestion. From an efficiency perspective, this implies that the optimal usage price is zero. However, pricing at marginal cost does not allow fixed costs to be recovered, a situation analogous to that of a natural monopoly. As a result, a private operator would be willing to build and operate the bridge only if usage fees were set sufficiently high to cover these costs, leading to underuse of the infrastructure relative to the social optimum. We return to these issues later in the chapter.

5. Subsidy for public transport: here too we have high fixed costs and a very low marginal cost. There are therefore economies of scale. This is a situation comparable to that of the natural monopoly like the bridge in the previous point (see Chapter 10). However, there is another externality that is linked to the quality of the service, specifically to the frequency: the more public transport users there are, the more it is possible to increase the frequency of the service (i.e. to reduce waiting time and therefore travel time). Individually, people do not integrate this positive externality into their transport decision. This is the **Mohring effect**. Moreover, subsidizing the use of public transport is a (backdoor) way of reducing the social costs of car use (GHG, air pollution, land use, water pollution and congestion). Finally, we can also raise an argument of fairness: mobility is an essential good.
6. Ban on non-tobacco flavours in vaping products: Flavours appear to be particularly attractive to young people, creating nicotine addiction, leading to long-term adverse health effects. The ban may be justified by citing a lack of maturity among young people to make a rational decision (cognitive bias). There may also be an issue regarding risk-taking, since the additional health care costs associated with this behaviour are shared by the community as a whole rather than just by the individuals taking these risks.
7. Providing social housing: accessibility to an essential good (distribution function of the State).
8. Certification of organic products: presence of information asymmetry. Without certification, the consumer is never certain that the food has really been produced organically.
9. Mandatory helmet wearing when cycling: limited rationality of agents (underestimation of risks and potential costs) and problem of excessive risk-taking caused by collective health insurance. Victims pay only a tiny part of the health care costs incurred by an accident, so they may tend to take more risks.
10. Tax on sugary drinks: limited rationality of agents (present bias, self-control problem, addictive nature, underestimation of risks) and addictive nature of sugar. Increased risk-taking, since the costs of additional health care are shared by the whole community rather than by the individuals who adopt these risky behaviors.

Question 2

For each of the following goods and services, discuss its nature according to the Ostrom and Ostrom classification, the organization of its production (market, non-market) and possible distortions.

- Motor vehicles;

- A dose of flu vaccine;
- Oil;
- The information;
- Internet services;
- Film production;
- Pesticides;
- Medical care;
- Dental care.

Answers

Goods/ services	Private-Public	Organization	Distortions
Motor vehicles	Private	Merchant	• External costs related to production and use
Flu vaccine	Private	Mixed	• External benefits (reduction of transmission)
Oil	Private	Merchant	• External costs of production and use • Market power
Information	Rather a public good	Mixed	• External benefits
Internet service	Excludability/ Non-rivalry to a certain extent Well club/ congestible	Merchant, but with regulation	• External costs (pollution) • External benefits • Market power
Film production	Excludability increasingly difficult / No rivalry in consumption	Merchant, but with support from public authorities	• External advantages if excludability difficult • External benefits: cultural development
Pesticides	Private	Merchant with regulation	• External costs (pollution, health impacts)
Medical care	Private	Varies by jurisdiction.	• External benefits (contagious diseases) • Information asymmetry • Essential goods • Insurance aspect (risk sharing)
Dental care	Private	Varies by jurisdiction.	• Information asymmetry • Essential good • Insurance aspect (risk sharing)

CHAPTER 4 SOLUTIONS

Question 1 Question 3

Question 1

Canada applies a supply management system in the dairy and poultry sectors. This system combines domestic production quotas with customs tariffs that limit imports. It stabilizes prices and keeps them at higher levels than in the United States, where there is no supply management. You are asked to assess the impact of this system on Canadian butter consumers. An initial knowledge inventory has provided the following information on this market (2012 data):

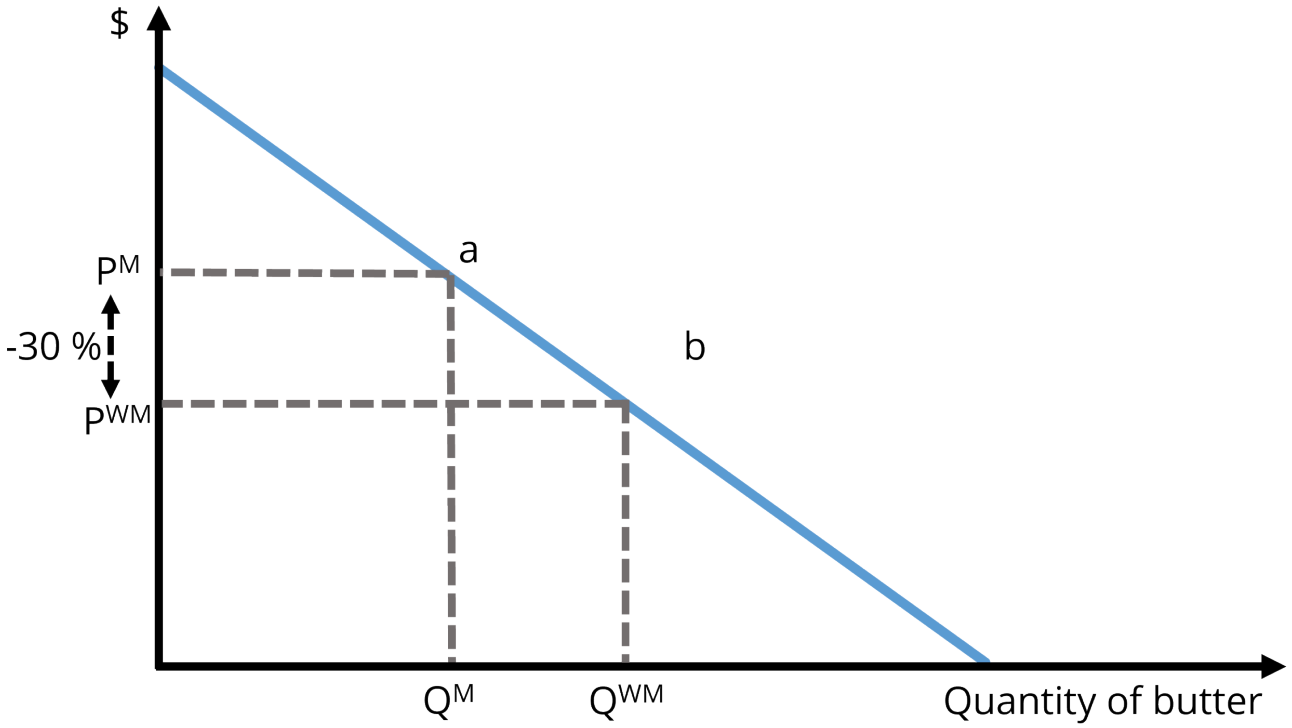
- The price of butter is on average 30% more expensive in Canada than in the United States;
- The price elasticity of demand for butter was estimated at 0.9.

Based on this information, can you determine the impact of the supply management system on consumers? What assumptions would you need to make? What additional information would you need? Find this additional information and calculate the impact. Clearly indicate the sources used to gather this information.

Answer

According to the available information, supply management would be responsible for a 30% higher butter price. The Figure below illustrates the impact that we would like to measure, namely the reduction in the CS due to supply management (the areas $P^{M}abP^{WM}$). P^{M} and P^{WM} correspond to the average prices with

and without supply management respectively, and Q^M and Q^{WM} are the corresponding quantities.



To calculate this area, we need data on the average price of butter and the quantity traded in Canada under the supply management system. Butter prices are available in Statistics Canada Table 326-0012 and average household expenditure in Table 203-0028. These tables indicate that the price of butter was $9.64/kg (in 2012) and the average household expenditure was $34/year, which gives an average quantity of 3.52 kg per household per year.

In the absence of supply management, the price would therefore be $6.75/kg (or $9.64 x 0.7), a price decrease of $2.89. At an average price of $6.75, the average quantity per household would increase to (1 + 0.9 x 0.3) x 3.52 = 4.47 kg, which means an increase of 0.95 kg per household per year.

The CS reduction for a household is therefore: 2.89 x 3.52 + ½ x 2.89 x 0.95 = $11.55/household.

As the number of households in Canada is 13.3 million, the impact on consumers is estimated at $154 million.

This exercise is inspired by:

Cardwell, R., Lawley, C. and Xiang, D. (2015). Milked and Feathered: The regressive welfare effects of Canada's supply management regime, *Canadian Public Policy*, *41*(1), 1-14. https://doi.org/10.3138/cpp.2013-062

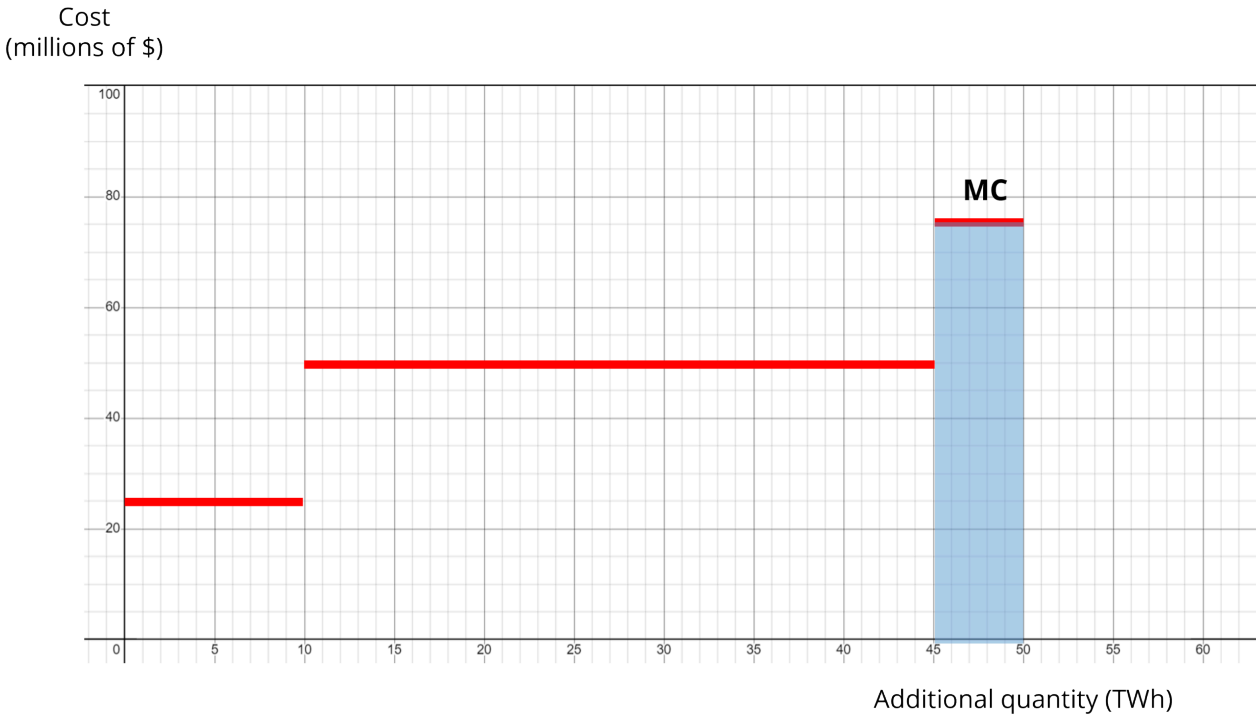
Question 3

Additional electricity needs are estimated at 50 TWh. The figure below shows the marginal cost curve for this additional production. An energy efficiency program would reduce these additional needs by 10%.

1. Determine the maximum amount that it would be justified to invest in the energy-efficiency program.
2. How would your answer change if you learned that the electricity production avoided by the energy-efficiency program would have created 200 jobs with an average annual remuneration of $55,000 per job?
3. Can you think of any other potential benefits that this program might generate?

Answer

1. Thanks to the program, the additional needs would only be 45 TWh, instead of 50 TWh. This would save the additional cost of producing 45 to 50 TWh. The benefit of the program is therefore measured by the area under the marginal cost curve between 45 and 50, or $375 million (shaded blue area). Thus, the program would be justified as soon as its cost was less than $375 million.



2. This does not change the answer. The gross benefit of $375 million actually corresponds to a reduction in the resources mobilized to produce this additional capacity involving the use of fewer workers. The project therefore frees up resources that will be used for another purpose, which will produce an economic value corresponding to $375 million. The gross benefit of the project is therefore indeed $375 million. As for the workers, they will receive a salary in their alternative employment equivalent to $55,000 per year.
3. There may be environmental gains associated with reducing electricity production. However, it is worth asking whether the energy efficiency programme does not also generate some environmental impacts.

CHAPTER 5 SOLUTIONS

Question 2 Question 3

Question 2

A project aims to modernize a railway line between Region A, which is remote and isolated, and the urban Region B. For each of the following effects, identify the nature of the impact; that is, determine whether it is a direct (primary), indirect (secondary), or induced effect.

E1. The project will increase mining production in region A by reducing transportation costs;
E2. The price of imported food in region A will decrease;
E3. Time savings for people travelling by train between region A and B;
E4. Decrease in revenues of air carriers connecting the two regions;
E5. Reduction in maintenance costs of the road linking the two regions, following the reduction in truck traffic;
E6. Increase in tourist activities in region A;
E7. Increase in the average salary of railway personnel;
E8. Increase in the price of railway tracks;
E9. Increased sales in bars in region A, thanks to workers employed by the project.

Answers

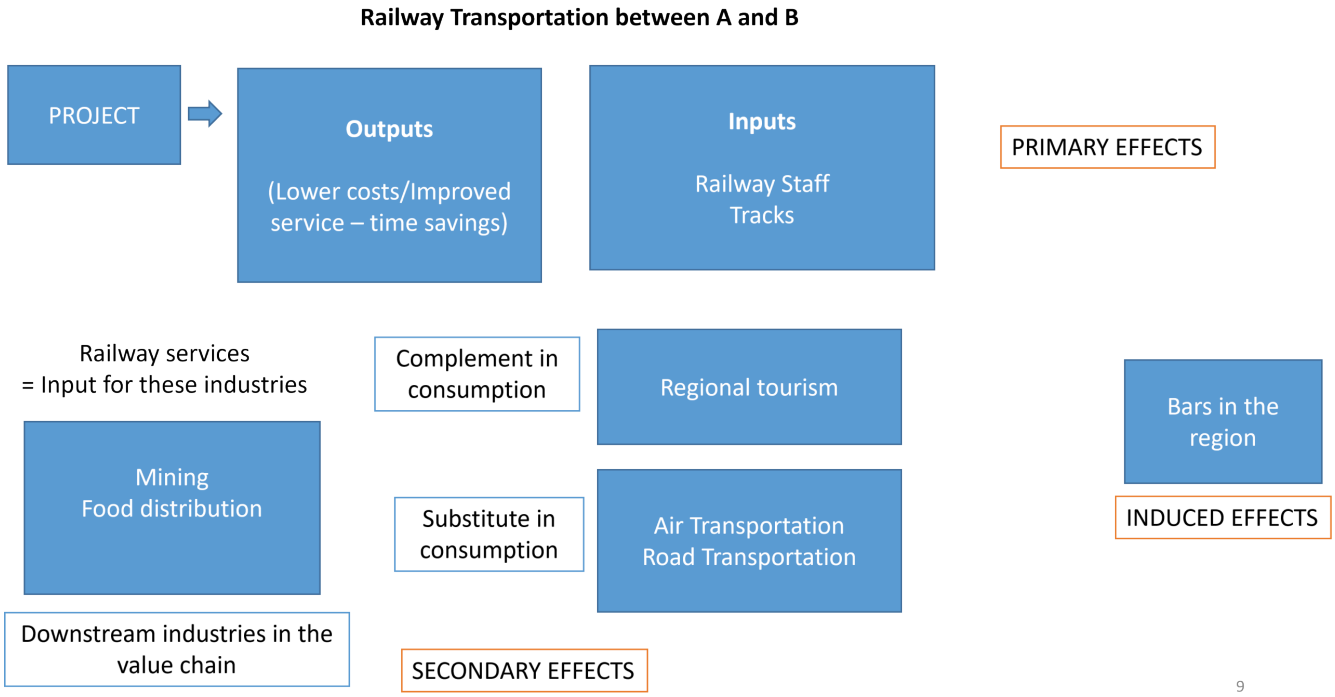
The primary market for outputs affected by the project is train travel between A and B.

Primary input markets include railway personnel and railway tracks.

Tourism in the region is a complementary service in consumption, while air and road transport are substitutes in consumption.

Rail transport is an input to the mining industry and food distribution, so both industries are further downstream in the value chain than rail transport.

The impact on bars in the region corresponds to an induced effect. The diagram below summarizes the situation and answers the various sub-questions



Question 3

(**Advanced**) The government has decided to produce 5,000 units of a good. Production requires only one input: low-skilled labor. With the existing technology, 6 units of labor are needed to produce one unit of output, and there are no **fixed costs**. The wage rate is $w = \$10$ per unit of labor, as determined by an undistorted competitive labor market. Alternatively, the government can make a one-time investment of $130,000 to adopt a new technology that doubles productivity.

1. Using the stakeholder approach, perform a CBA of the decision to invest in the new technology or not. Complete the table below. Then verify your results using the social approach.
2. How would your answers change if the wage paid included a $2 rent? In other words, workers are paid $10 per unit of labor, but their wage in the best alternative job is $8 per unit.

CBA of the adoption of new technology

Stakeholder	Advantage	Cost	Net effect	Description of impacts
State				
Workers				
NPV =				

AC A of the adoption of new technology with an annuity

Stakeholder	Advantage	Cost	Net effect	Description of impacts
State				
Workers				
NPV =				

Answers

Baseline : With existing technology, the production function is given by: Q = 1/6 L, with L representing the number of units of labor. Therefore, L = 30,000 is needed to produce Q = 5,000. The cost function is given by: C(Q) = $10 x 6 x Q = 60 Q, so that C(Q = 5,000) = $300,000.

Scenario with the new technology : the production function becomes Q = 1/3 L, and it takes L = 15,000 to produce Q = 5000. The cost function is given by C(Q) = $10 x Q + 130,000 = 30 Q + 130,000, so that C(Q = 5000) = $280,000.

CBA of the adoption of new technology

Stakeholder	Advantage	Cost	Net effect	Description of impacts
State	150,000	130,000	20,000	
Workers	150,000	150,000	0	
NPV = 20,000				

The government therefore avoids a personnel cost of $150,000 (15,000 x $10), but it incurs a fixed cost to adopt the new technology of $130,000. The net impact on the government surplus is therefore $20,000.

As for workers laid off because of the new technology, they will lose their wages, but they will find other jobs with the same competitive wage. The net impact is therefore zero, since there is no rent.

CBA of the adoption of new technology with an annuity

Stakeholder	Advantage	Cost	Net effect	Description of impacts
State	150,000	130,000	20,000	
Workers	120,000	150,000	30,000	
NPV = 10,000				

CHAPTER 6 SOLUTIONS

Question 1 Question 2
Question 4

Question 1

To implement a kindergarten program for four-year-olds, new buildings would need to be constructed. The average cost of these buildings is estimated at $800,000 per classroom. Assuming a 40-year service life and a social discount rate of 3%, calculate the equivalent annual cost of one classroom.

Answer

The annual cost is assumed to be spread out over the year, so that the annuity factor $a_{s=3\%}^{T=40} = 23.46$. The annual cost of a new class is therefore approximately $34,100.

Question 2

A project's net benefits are estimated at $450,000 at the end of the first year. These net benefits are expected to decline at a rate of 2% per year thereafter. The project lasts 20 years, and the social discount rate is $s = 7\%$. Calculate the NPV of this project.

Answer

Using the exact formulas, we obtain A = 450,000/(1 – 0.02) = $459,183 and i_0 = 0.09/0.98 = 9.1%, so the present value = $4,160,198, since the annuity factor is 9.06.

Using the approximation: A = 450,000 and i_0 = 9%, so the present value = $4,108,500 (annuity factor = 9.13).

Question 4

A project has a useful life of 50 years, but the CBA evaluates its costs and benefits over a horizon of only 20 years. In the final year of the analysis, the project's current net benefit (that is, undiscounted $A - C$) is estimated at $1.5 million. This net benefit is positively related to the size of the affected population. It is expected that, from $T = 21$ to $T = 50$, population will grow at 1% per year. Calculate the residual value to be included in the CBA as a benefit. The social discount rate is 7%.

Answer

The net benefit corresponds to an annuity spread over 30 years, with a growth rate of 1% from t = 21 to t = 50. The present value of this increasing annuity is determined as follows: $(1.5m/1.01) * a_{i0}^{30}$,with i_0 = 5.94% and $a_{i0}^{30} = 13.85$. The residual value at t = 20 = 20.57 million.

Thus, the residual value at t = 0 is VR (t = 0) = $20.57/(1+0.07)^{20}$ = 5.31 million. This is the amount that should be entered as a benefit in the CBA.

CHAPTER 7 SOLUTIONS

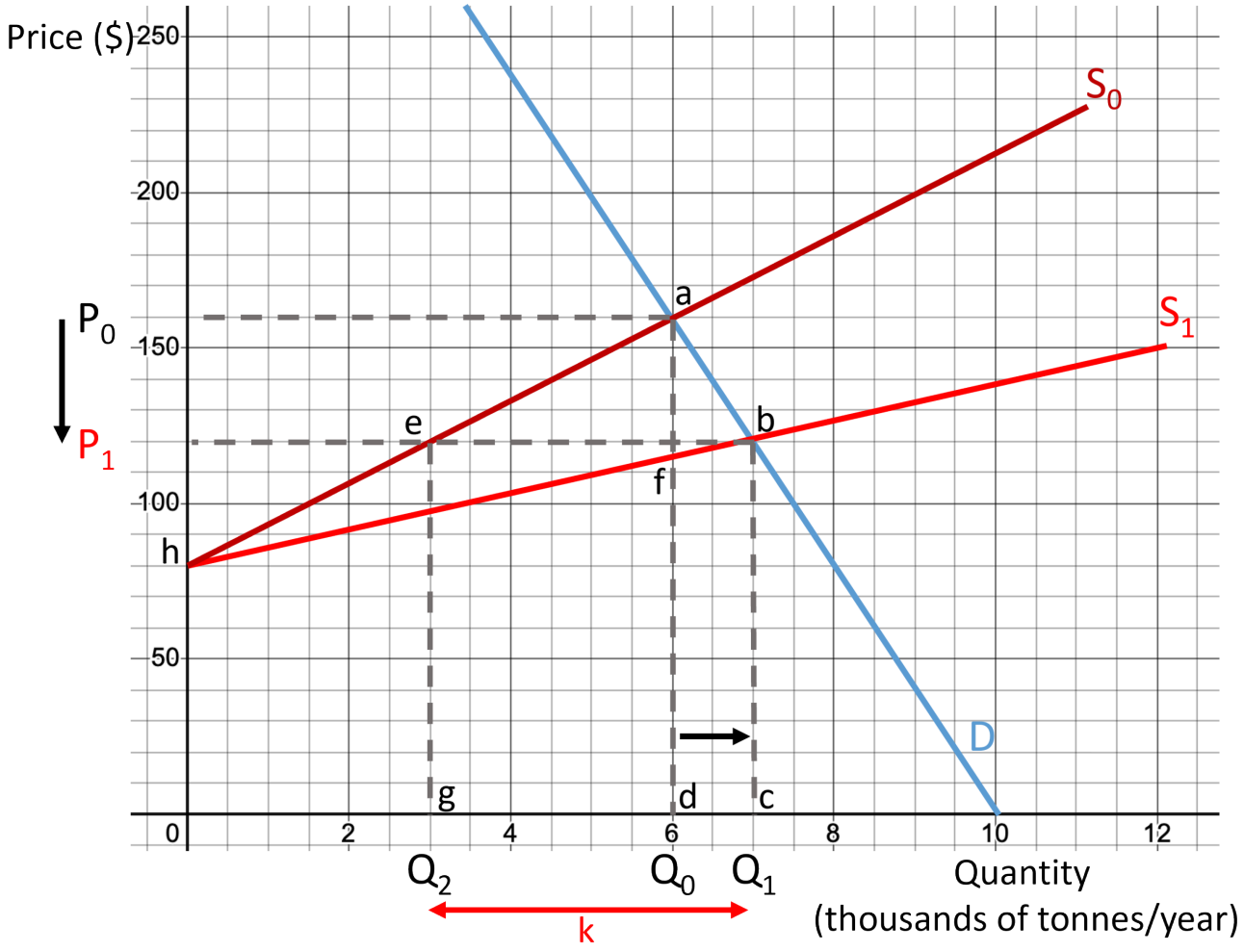
Question 1 Question 2

Question 4

Question 1

In the example of the new cement plant in Section 7.3.1, verify that the stakeholder approach also yields an NPV = $160 million. Distinguish the following stakeholders: consumers, established producers, and the new plant.

Answer



Stakeholder	Impact	Value
Consumers	Price decrease from $160 to $120, which increases the SC (P0abP1).	$260 million
Pre-existing producers	Decrease in their SP (P0aeP1)	-$180 million
New factory	Surplus = Profits = Sales – Costs (All costs are avoidable.) (Not visible on the graph.)	$120 x 4 m – $400 million = $80 million
	VAN	**$160 million**

Question 2

A commuter rail line carries an average of 75,000 riders per year between the suburbs and the city centre. The $15 fare per trip covers the average operating cost. A project is designed to improve the lines so that the travel time is reduced from 45 minutes to 25 minutes. The average value of the time of train riders is estimated to be $7/hour. In addition, the generalised price (or cost) elasticity of demand is estimated to be 0.7. The project will increase the average operating cost by 10%, but the fare per trip will not change. Assuming linear demand, determine the value of the impact on riders.

Answer

The value of the impact on users is approximately $182,597, as we show below.

The initial generalized price: $15 + $7 x (45/60) = $20.25

New generalized price: $15 + $7 x (25/60) = $17.91

That is a decrease of 11.55%[1], which should translate into an increase in traffic of 8.08%[2], so that ridership should be approximately 81,066 trips (1.0808 x 5,000).

The impact on users is measured by the change in surplus, which can be calculated as follows:

Variation in surplus = (generalized price reduction x existing traffic) + (½ x generalized price reduction x induced traffic) = ($2.34 x 75,000) + (½ x $2.34 x 6066) = $182,597.

Question 4

A fine arts museum is considering hosting an international-calibre exhibition of Alberto Giacometti's work. The exhibition would cost $1 million and run for four months. Based on outcomes observed in other museums, it is expected to attract 120,000 additional visitors relative to the attendance anticipated under the museum's permanent exhibition only. Additional revenue (tickets, parking, and gift shop sales) is estimated at $1.2 million. However, operating costs are expected to increase by $350,000. What must the average visitor surplus be for the exhibition to be justified on the basis of direct user benefits? Given the short duration of the project, discounting is not required.

---

1. Indeed, we have [20.25 – 17.91]/20.25, multiplied by 100.

2. 0.7 x 11.55% = 8.08%.

Answer

There are two parties: visitors and the museum. The table below summarizes the CBA with the party approach.

Stakeholder	
Use	Unknown consumer surplus: we must establish the break-even point X $
Museum	Operating profit = $1.2m – $0.35m = + $0.85m Fixed cost of the exhibition: – $1m
VAN	**= $0 (breakeven point)**

So the CS must be at least $0.15 million for the NPV to = 0. This corresponds to an average CS per visitor of $1.25, which seems reasonable.

CHAPTER 8 SOLUTIONS

Question 1
Question 4
Question 5

Question 1

A project plans to market 10,000 tonnes of a good whose tax-exclusive price is $100 per tonne. A 15% tax applies to this good. The project is expected to affect the market price, but for the purposes of this analysis, we will ignore this effect. The price elasticity of demand is 2, while the price elasticity of supply is 3. Before the project, the quantity traded in the market was 100,000 tonnes. Can you determine the social value of the output marketed by this project? Please explain your reasoning.

Answer

Initially, the tax-free price is $100, and the tax-inclusive price is $115 per tonne. The additional 10,000 tonnes on the market will cause an increase in the quantity traded, and also a crowding out of production by pre-existing producers (displacement of economic activities). Given the value of the elasticities, 2/5 of the production of the 10,000 tonnes of the project should serve new customers, and 3/5 should crowd out existing producers.

We must therefore value the production of the project using the following reference price:

Reference price = 2/5 x $115 + 3/5 x $100 = $106

The social value of the project's production is therefore **$ 1.06 million**.

Question 4

Create a fictitious example of a CBA involving the introduction of a unit subsidy of $s per unit in a competitive market where demand is more elastic than supply. Illustrate the impacts with a graph and perform the CBA using (i) the stakeholder approach and (ii) the social approach. Also explain how the opportunism rate would be calculated in your example.

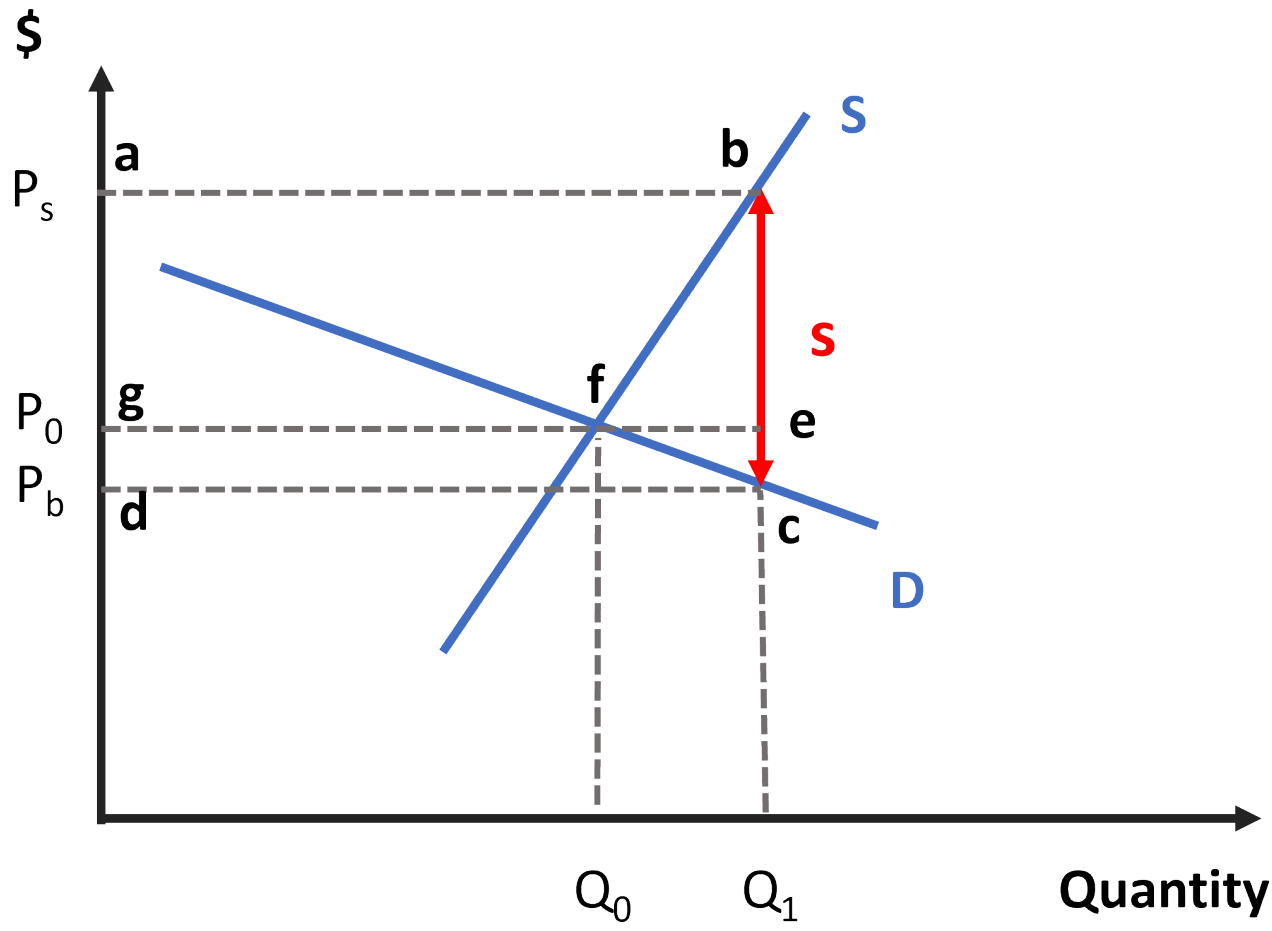
Answer

Figure 9 illustrates the introduction of a subsidy of $s/unit when demand is more elastic than supply. The initial equilibrium in the market (without a subsidy) is represented by (Q_0 , P_0). The introduction of a purchase subsidy of $ *s*shifts the market equilibrium to the right: trade increases because the price paid by buyers decreases. The new equilibrium is reached at the point where the difference between the price received by sellers (P_s) and the price paid by buyers (P_b) is equal to the amount of the unit subsidy *s*. Therefore, the quantity traded increases to Q_1.

Comparing with the initial equilibrium price P_0, we see that, in our example, it is mainly producers who benefit from the subsidy. The total amount of the subsidy corresponds to the area (*abcd*), and producers receive the portion represented by the area (*abeg*), while consumers ultimately only benefit from the area (*gecd*). On the other hand, if supply were more elastic than demand, buyers would receive a larger share of the subsidy than producers.

On the other hand, a subsidy also generates a deadweight loss corresponding to the triangle (*fbc*) in Figure 9. The subsidy allows for trades to be made for which the willingness to pay (according to demand) is lower than the marginal cost (according to supply), which harms allocative efficiency.

Finally, the opportunism rate in our example corresponds to the ratio Q_0/Q_1, since Q_0 refers to the quantity exchanged in the absence of a subsidy, and Q1 to the quantity exchanged with the subsidy.



Question 5

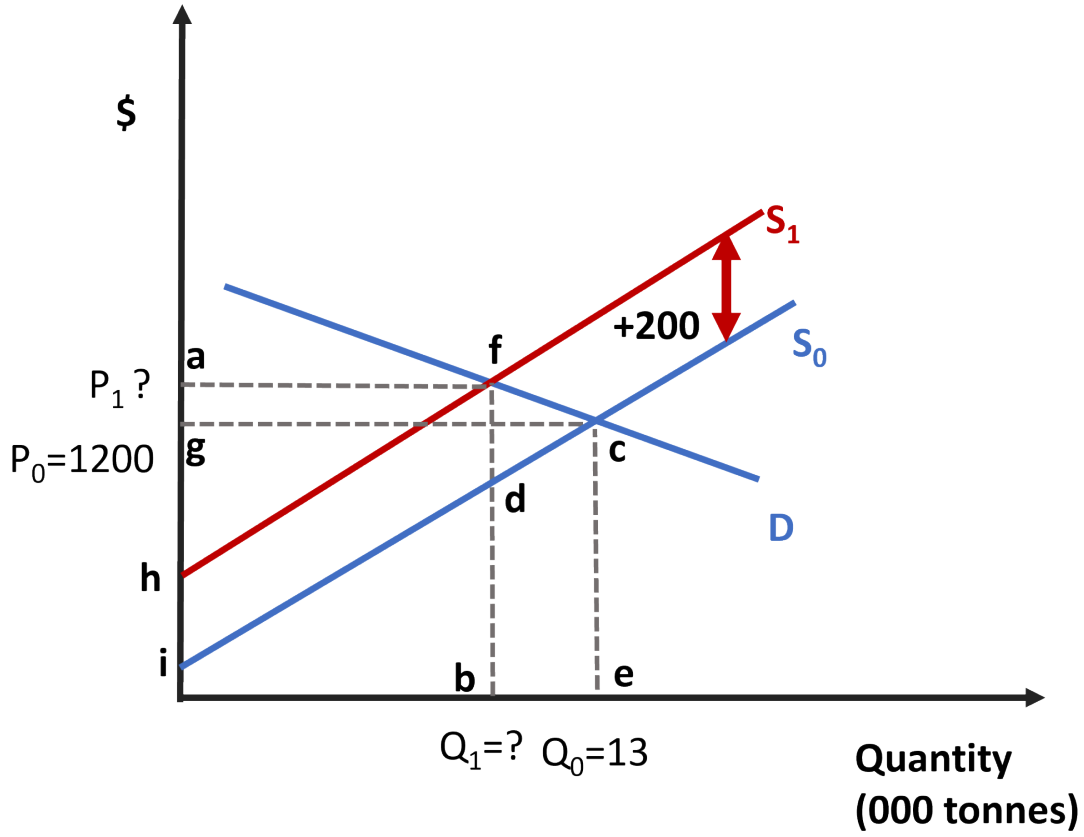
The government is considering regulations that would prohibit the use of certain pesticides in domestic apple production. These pesticides are associated with serious health risks for people who apply them. It is estimated that banning these pesticides would generate benefits of about $5 million, mainly through reduced health care costs. However, the regulation is expected to increase domestic production costs by approximately $200 per tonne. Demand for domestic apples is highly elastic because domestic producers face strong competition from imported apples; the price elasticity of demand is estimated at 6. Before the regulation, annual sales of domestic apples are 13,000 tonnes at an average price of $1,200 per tonne. The price elasticity of supply is estimated at 1.2. Perform a CBA of this project.

Answer

Reference situation: Q_0 = 13,000 tonnes/year, P_0 = $1,200/tonne

Project status:

The project increases the cost by $200/tonne, which implies a parallel shift upwards in the supply curve, as illustrated in Figure 10.



The equilibrium price (P_1) of the project and the quantity traded (Q_1) must be determined. As Figure 10 suggests, part of the cost increase is absorbed by producers and the other part is passed on to consumers. The share of the cost increase passed on to buyers and that absorbed by sellers depends on the price elasticities of supply and demand.

In the exercise, ηo=1.2and ηd=6,so that 16% of the cost increase is passed on to consumers, and 83% is absorbed by producers. We therefore have P_1 = $1200 + 0.16 x $200 = $1,233. From the price elasticity of demand and taking into account that the price increases by 2.75%, we can estimate that Q_1 = (1 – 0.0275 x 6) x 13,000 = 10,855 tonnes per year. Using this information, we can perform a CBA using the collective approach:

- The social value of the reduction in the quantity exchanged: -Surface (*fceb*);
- Social cost of resources mobilized: -Surface (*hfdi*) (i.e. the additional cost of $200/tonne x the quantity produced after the project);
- The social value of the resources saved: +Surface(*dceb*).

The net effect of these impacts is negative and corresponds to the surface area (*hfci*), i.e. -[$200 x 10,855 + ½ x $200 x (13,000 – 10,855)] = -$2,385,500.

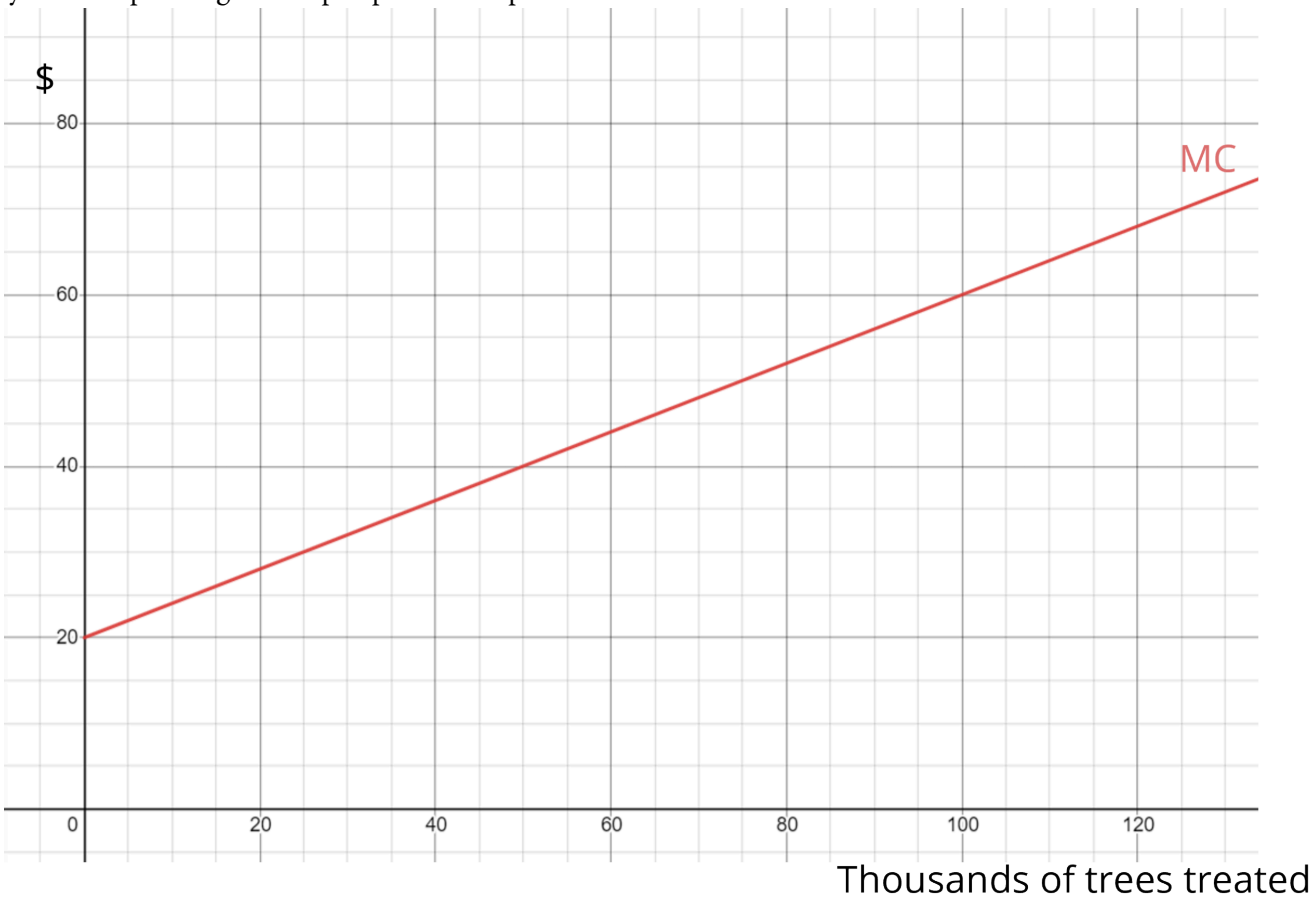
The health benefit of the ban is $5 million, from which we subtract the negative net market impact of $2.385 million, so the NPV of the project is $2.6145 million.

CHAPTER 9 SOLUTIONS

Question 1 Question 2

Question 1

A city is considering implementing a program to control Dutch slippery elm disease. The graph below shows the marginal cost of the program as a function of the quantity of trees treated (MC). The value of each tree treated is estimated at $40. In addition, the program is expected to reduce infestation in neighboring cities, creating an external benefit valued at $10 per tree treated.Conduct a CBA of this program, first from a municipal perspective and then from a universal perspective. Note that the optimal number of trees treated may differ depending on the perspective adopted.

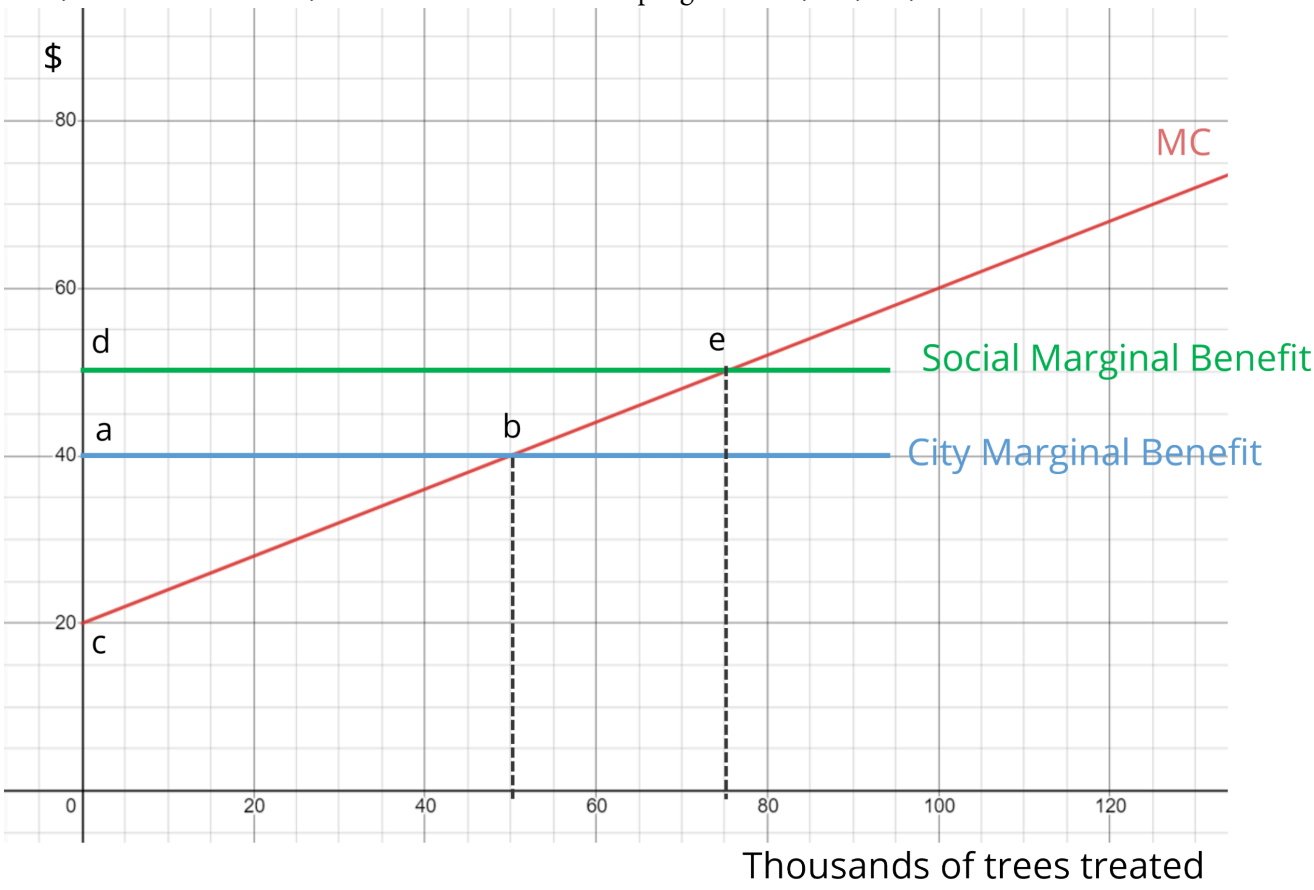


Answer

The figure below shows the marginal benefit from the city's perspective and the social marginal benefit that takes into account externalities. The number of trees treated is 50,000, if the city only takes into account its benefits. On the other hand, the number of trees treated is 75,000, if all benefits are taken into account.

The net benefit to the city of treating 50,000 trees is the area of triangle *abc* ,or $500,000. This program also generates an external effect of $500,000.

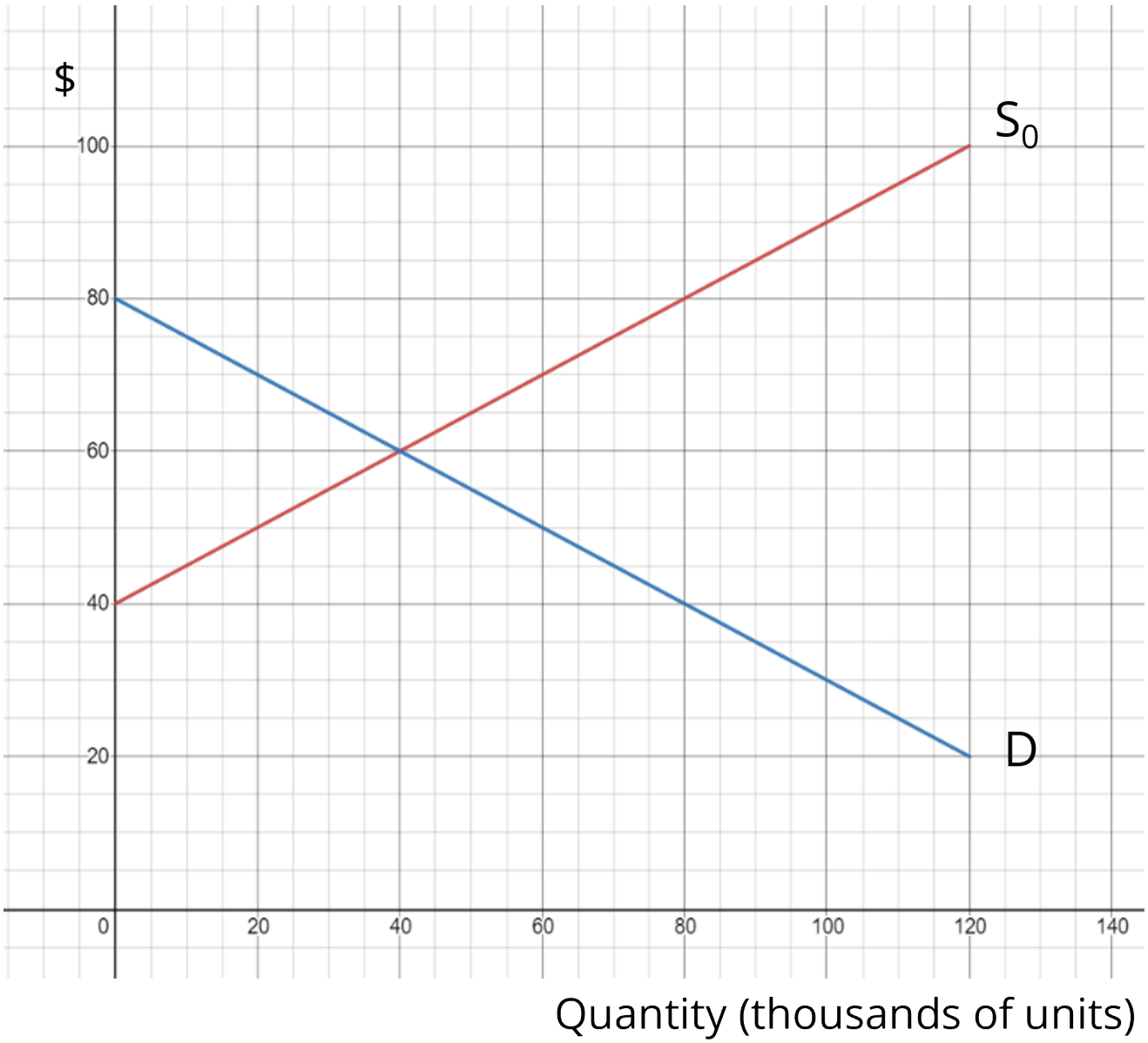
If 75,000 trees are treated, the net social effect of the program is $1,125,000, or the area of the surface of *dec*.



Question 2

In the graph below, we can observe the supply and demand in the competitive market for a material commonly used in the construction industry. The government is considering implementing regulations to reduce the flammability of this material. This regulation would increase the cost of producing the material by $10 per unit. In addition, producing this material, in accordance with the new flammability regulations, would generate an external environmental cost estimated at $5 per unit.

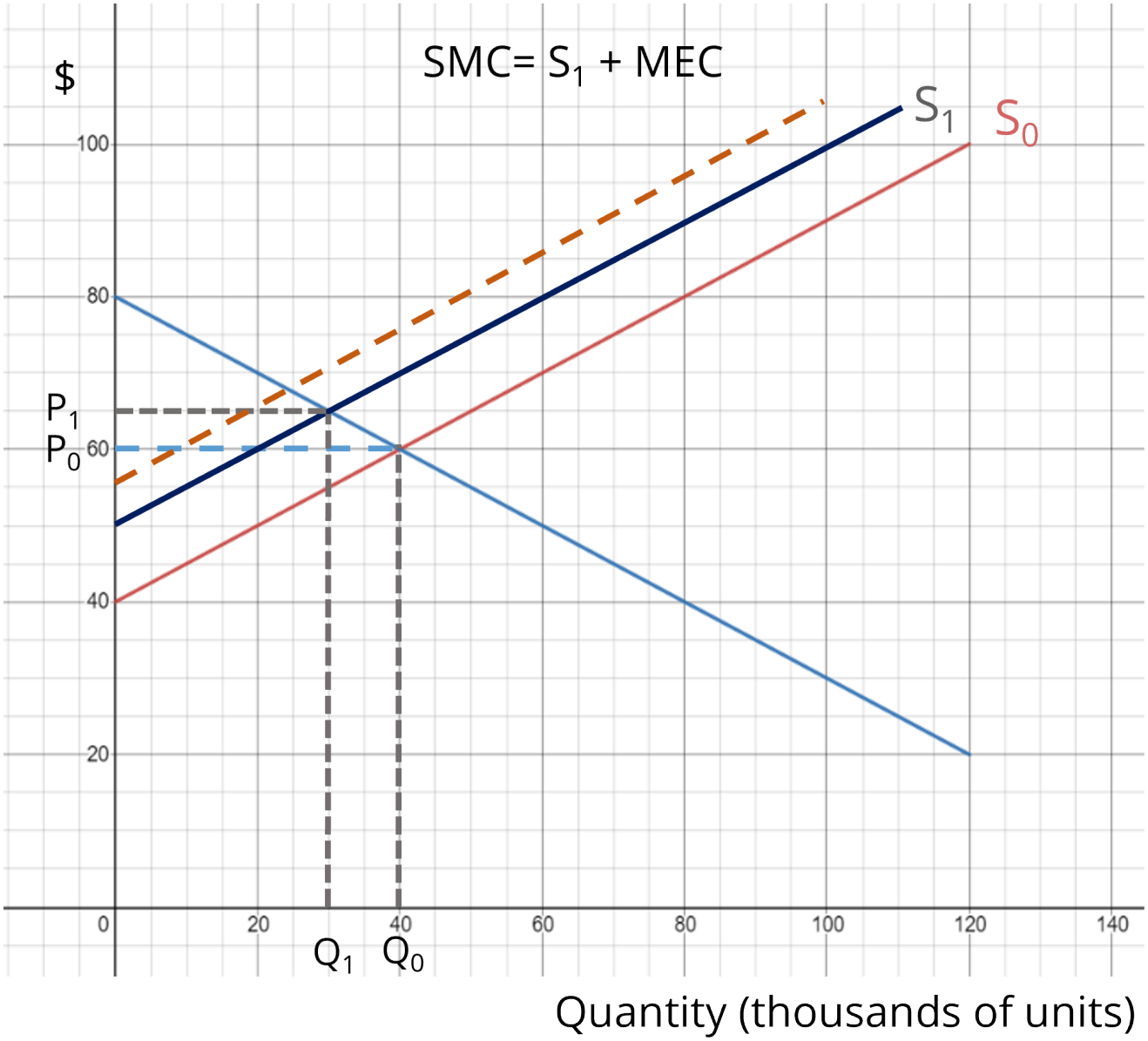
What should be the minimum benefit generated by this regulation for it to pass the CBA test?



Answer

The reference scenario(without the project): the market price is P_0 = \$60/unit, and the quantity traded is Q_0 = 40,000 units.

The scenario with the project : the project shifts the supply curve upwards (+\$10/unit), i.e. from O_0 to O_1 on the graph. Thus, with the project, the price of the material rises to P_1 = \$65, and the quantity exchanged falls to Q_1 = 30,000 units. Note that with the regulation, an external cost of \$5/unit also appears, so that the social marginal cost corresponds to the private marginal cost (O_1), plus the external cost of \$5, i.e. the dotted curve. In addition, the project reduces the damage caused in the event of a fire.



The project stakeholders are:

1. Consumers of the product, who will experience a price increase and therefore a decrease in the SC **;**
2. **Fire victims**: reduction of their damage, given the better performance of fire-fighting equipment;
3. Producers **,** who will experience an increase in production costs, which will cause a drop in the SP **;**
4. Third **parties**who are victims of environmental damage associated with the new production process.

The table below assesses the impacts that can be quantified. The result is that the reduction in fire damage must be at least $500,000/year for the project to pass the CBA test.

Part	Description	Value $/year
Consumers	SC Drop: -($5 x 35,000)	-$175,000/year
Victims of fires	Damage Reduction	+ X $/year
Producers	SP Drop: SP1 – SP0 = $225,000 – $400,000	-$175,000/year
Third party	External cost: $5 x 30,000	-$150,000/year
	Net effect =	$0

CHAPTER 10 SOLUTIONS

Question 1 Question 2

Question 1

(*) In a given country, coffee production is carried out by a large number of small producers. However, all harvests are purchased by a single buyer authorized by the government. A project is currently being considered to liberalize this market, which would lead to a substantial increase in the number of buyers.

To assess the potential impacts of this project on the coffee market, you are provided with the following information:

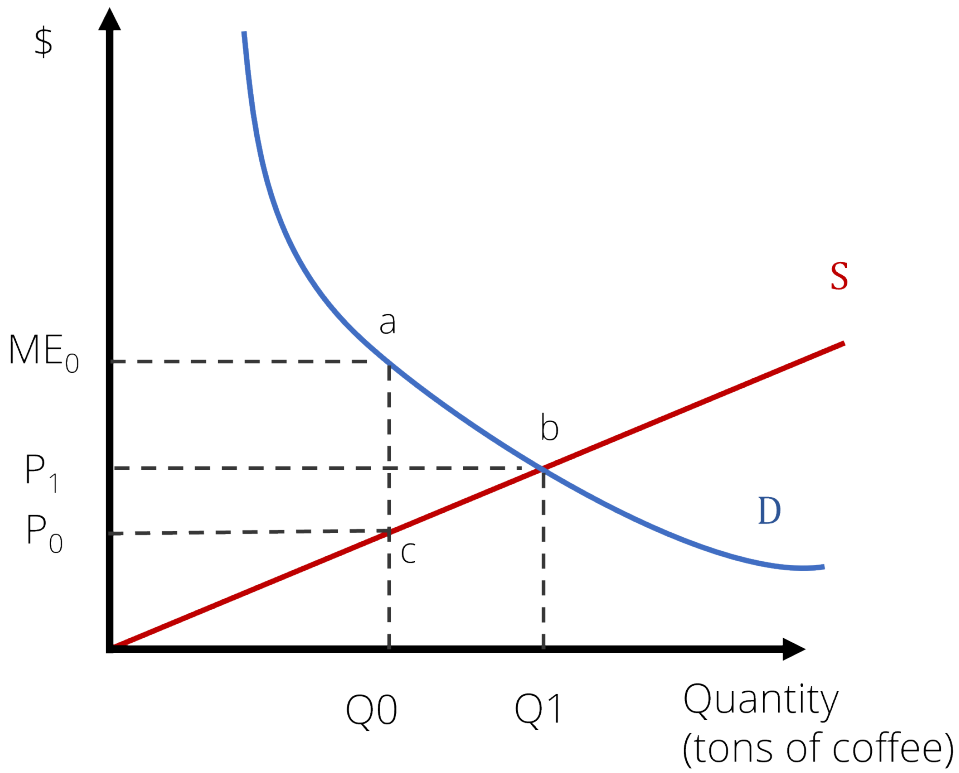
- The current market price is $2,000 per tonne;
- The quantity traded is 10 million tonnes;
- The price elasticity of supply is estimated at 2, while the price elasticity of demand is estimated at 1.

Develop an analytical framework to identify and value the impacts of this project on the coffee market. Explain how the price elasticities of supply and demand influence the net effect in the market. In addition, discuss other effects that may need to be taken into account in a comprehensive cost–benefit analysis of this project.
[The resolution should be based on the concepts developed in Appendix 2.]

Resolution

Figure 13 illustrates the analysis framework for this project.

The bulk coffee market



Reference scenario (monopsony):

Q_0 = 10 million tonnes

P_0 = $2000 per ton

Scenario with liberalization:

In the best case, the market becomes perfectly competitive. It is therefore necessary to determine what the quantity (Q_1) and the price (P_1) will be in a competitive context.

The net effect that we aim to evaluate is the dead loss *abc*caused by the monopsony. To do this, we must also evaluate Vm_0, i.e. the marginal value of the monopsony.

As Appendix 2 illustrates, the monopsony maximizes its surplus when:

$$L = \frac{Vm_0 - P_0}{Vm_0} = \frac{1}{\eta_O}$$

With P_0 = $2,000 and $\eta_O = 2$, we can deduce that Vm_0 = $4,000. It then turns out to be possible to estimate P_1, the price in perfect competition, using the formulas for the incidence of a tax, since we are in a similar context, where a gap exists between the demand price and the supply price (see Chapter 8, Section 1.2). Thus, the percentage of the $2,000 gap that reduces the price for producers relative to the competitive price is estimated at 1/3, from the application of the following formula $\frac{\eta_D}{\eta_D + \eta_O}$%.

Thus, P_1 = $2,000 + 1/3 x $2,000 = $2,666, which is a 33% increase in price, meaning that the quantity produced would be 66% higher under perfect competition, since the elasticity of supply is 2. Therefore, Q_1 is

expected to = $16.6 million. Thus, the deadweight loss avoided by the project is approximately $6.6 billion, or ½ x $2,000 x $6.6 million.

Question 2

A project aims to reduce alcohol addiction. The typical demand of an addicted individual is represented in Figure 10.8 by curve DD, while the typical demand of a non-addicted individual is represented by curve D. The average price of alcohol is $10 per litre.

Discuss the challenges involved in valuing the effects of this project from the perspectives of expenditure and consumer surplus.

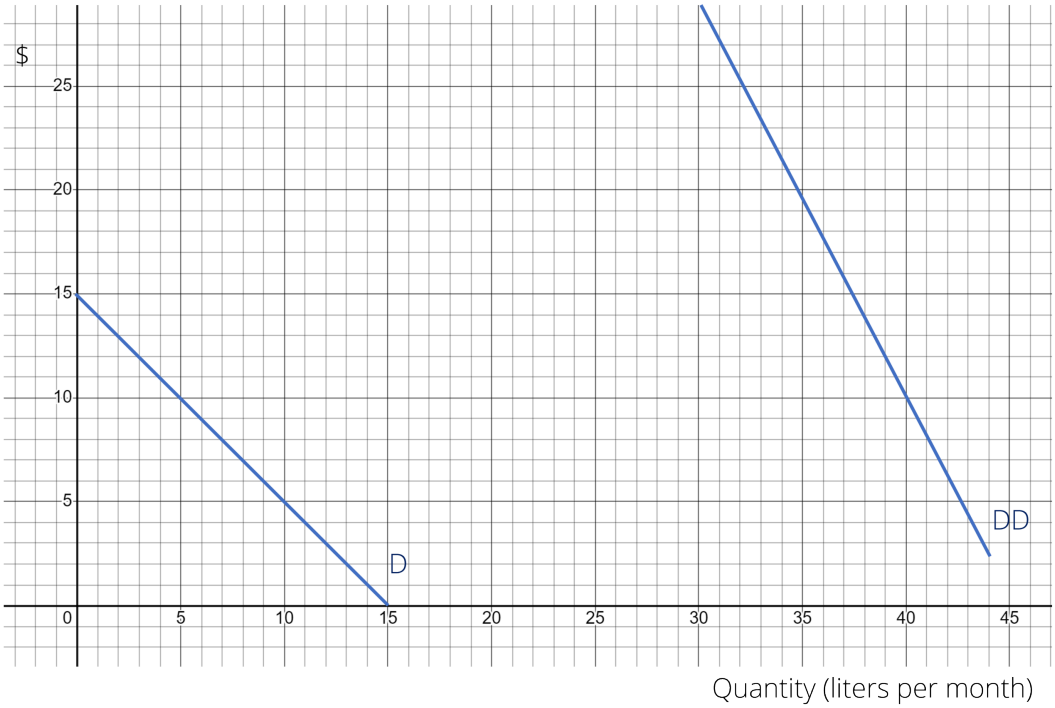


Figure 10.8 Typical request from an alcohol dependent and non-alcoholic person

Resolution

If the program is successful in combating an individual's alcohol dependence, one of its benefits is that the individual's monthly alcohol expenditure is reduced from $400 to $50 (assuming average consumption for a non-dependent individual). However, it is important to consider the reduction in the benefit associated with alcohol consumption, represented by the area under the demand curve between 40 litres and 5 litres. Using the DD demand curve, the reduction in consumption results in a significant welfare loss for the individual. However, this approach has a drawback in that alcohol dependence influences the DD curve. It can therefore be argued that the DD curve does not adequately capture the benefit associated with alcohol consumption for this individual.

An alternative is to use the demand curve D to estimate the loss of benefits resulting from the reduction in

consumption. Thus, a decrease in the quantity consumed from 40 liters to 5 liters would result in a reduction in benefits corresponding to the area of triangle *abc*, or $50 per month. Therefore, the net effect would become positive, with a net gain of $300 per month.

It is also important to consider the external costs avoided by reducing alcohol consumption, such as reduced health care costs.



CHAPTER 11 SOLUTIONS

Question 1
Question 2
Question 3
Question 4
Question 5

Question 1

A major infrastructure project requires 2 million tonnes of cement, which is about 10% of current market production. The elasticity of demand for cement is estimated to be 0.2, while the elasticity of supply for cement is estimated to be 2. The current price of a tonne of cement is $200. Determine the social cost of this input to be considered in a CBA.

Resolution

Based on the problem data, the expected percentage change in price is 4.54%, or 10% divided by (2 + 0.2). Therefore, the price is estimated to reach approximately $209.

The reference price is the average of the prices before and after the project, which is approximately $204.5. Therefore, the social cost is estimated at $409 million, equivalent to $204.5 multiplied by $2 million.

Question 2

A project requires the use of a fleet of trucks and is expected to consume 50,000 litres of diesel per year. The price of diesel is $1.20 per litre, including $0.30 in taxes. The supply of diesel is assumed to be sufficiently elastic so that this additional demand does not affect the market price. What is the social cost associated with the use of this input to be included in a CBA? How would your answer change if the supply of diesel were perfectly inelastic?

Resolution

With perfectly elastic supply, there is no crowding out of initial demand so the quantity must be valued at the

tax-free price. However, it is imperative to add to the social cost the value of the externalities caused by diesel, such as increased greenhouse gas emissions, if these impacts are not already internalized in the price.

If supply is perfectly inelastic, there is a complete crowding out of initial demand, which requires an assessment of the valuation of the price, including taxes. Furthermore, in this scenario, the total amount of pollution would not increase since the project only displaces economic activities. However, there could be implications in the valuation of external costs due to changes in local pollution levels.

Question 3

The government is considering a shingles vaccination program for people aged 65 and over. It is estimated that 100,000 doses will be required in the first year. The vaccine is produced by a firm holding an exclusive patent and is sold at a price of $120 per dose. Discuss the issues involved in the social valuation of these vaccines.

Resolution

First, it is necessary to determine whether the monopolist is included or excluded from the sphere of the reference company. If the monopolist is not taken into account in the analysis, the cost of a dose of vaccine is equivalent to its price. It is then necessary to assess whether the additional demand can lead to an increase in the price and whether the vaccine is subject to taxes.

On the other hand, if the monopolist is part of the reference society, it must be considered that it sells its product at a price higher than the marginal cost, thus generating a profit on each dose. In this context, the social cost corresponds to the marginal cost of production for the additional units and to the selling price for the doses resulting from the crowding out of the initial demand.

Question 4

A government intends to set an example in the electrification of transportation by requiring that a certain percentage of the government vehicle fleet be converted to electric vehicles. If a CBA of this project is to be carried out, what inputs should be considered and how should they be valued?

Resolution

When purchasing electric vehicles by the government, it is necessary to determine whether the additional demand will lead to an increase in prices. It is also worth considering whether there will be crowding out of the initial demand. In the event of crowding out, this part should be valued at the price actually paid by

buyers, which may be lower than the initial cost in the event of subsidies for the purchase of electric vehicles. For the rest, the purchase price can be used in the valuation, especially if the cars are produced abroad by a manufacturer outside the sphere of the reference company.

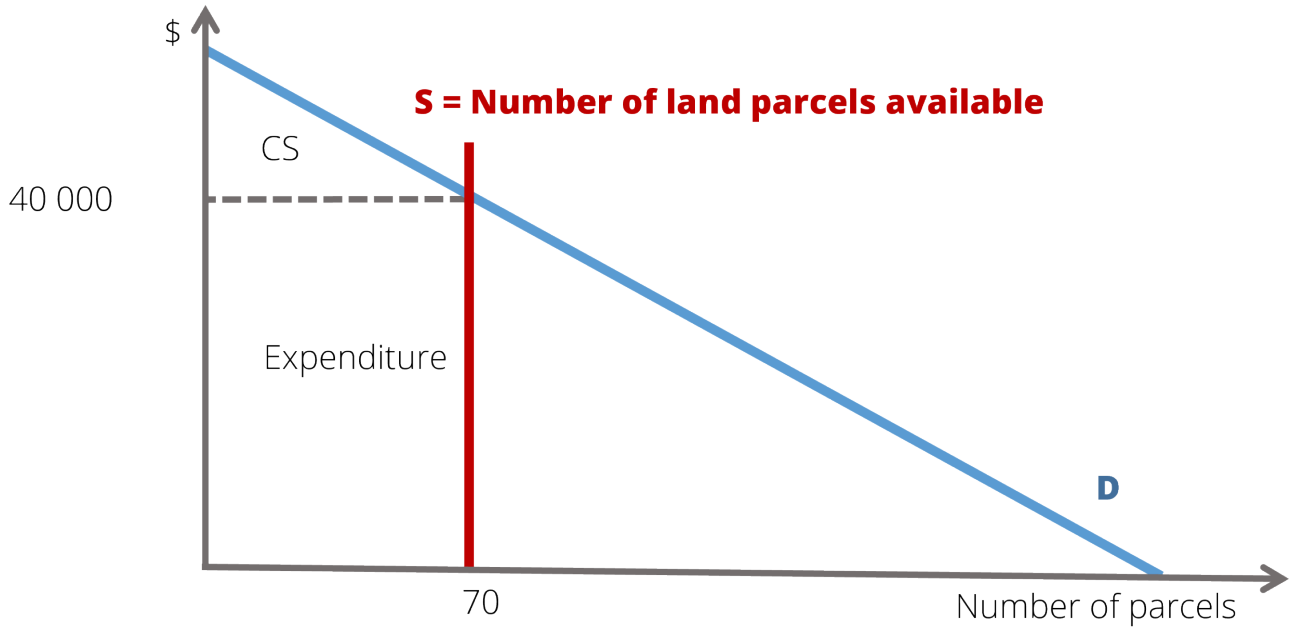
For other inputs, such as electricity, valuation may be at the marginal cost of production or at the opportunity cost (e.g. export price). It may also be appropriate to take into account the cost of public funds in the overall assessment.

Question 5

In a neighbourhood, there is a fixed supply of 70 building lots owned by several landowners. Private demand for land in this area is represented by a downward-sloping curve. The market price of a lot is estimated at P = \$40,000. The municipality plans to create a conservation area on this land in order to preserve water quality and intends to use its power of expropriation, offering each owner the market value of \$40,000 per lot. The project's budgeted expenditure is therefore 40,000 × 70 = \$2,800,000. Is this an appropriate measure of the social cost? If so, explain why. If not, determine the true social cost.

Resolution

The social cost includes the budgetary expenditure (\$2.8 million) as well as the surplus that owners will have to give up.



CHAPTER 12 SOLUTIONS

Question 1

Question 1

A project aims to promote the quality of national cheeses abroad in order to increase their export prices. Using a graphical analysis, examine the impact of this project on the primary cheese market and on the secondary milk market, which is a key input in cheese production. Then determine whether it is appropriate to take the impacts on the milk market into account in the CBA of this project.

Resolution

In the primary market (cheese), the project leads to an increase in the export price from P_0 to P_1 (see panel A of Figure 7). This increase translates into an increase in the surplus of domestic cheese producers. By assessing the elasticity of supply, it would be possible to predict the impact on quantity and on producer surplus.

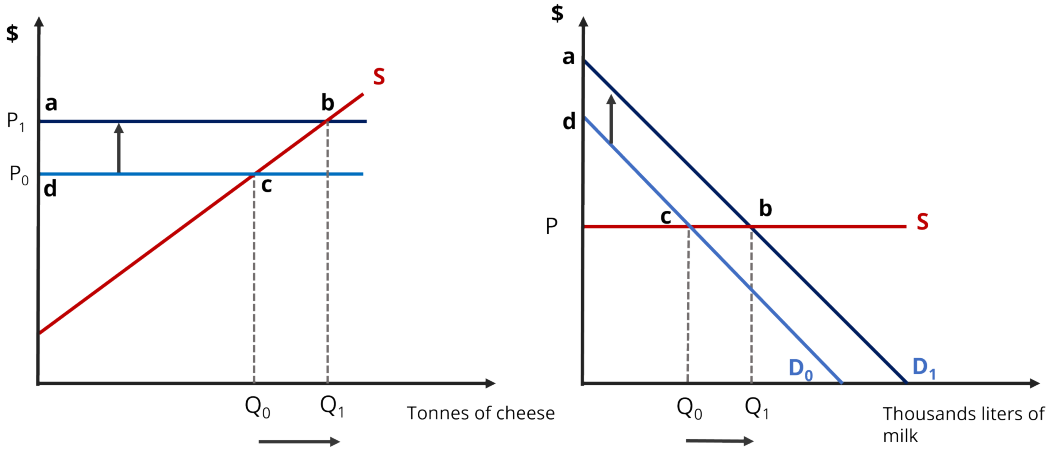
Milk is a key input in cheese production. In this secondary market, the project will indirectly increase demand for milk (see Panel B of Figure 7). It is important to recall that firms' demand for an input reflects its marginal productivity in value, calculated as $P \times \Delta Q/\Delta I$, where P is the price, Q is the quantity of the output (cheese), and I is the quantity of the input (milk). The increase in consumer surplus (*efgh*) in this market is therefore a mirror effect of the increase in producer surplus in the primary market (*abcd*). This **mirror effect**should therefore not be added to the primary effect.

If the supply of milk is not perfectly elastic and the increase in demand for milk is large, the equilibrium price of milk could also increase due to the project. In this case, the increase in the price of milk leads to a reduction in consumer surplus and an increase in producer surplus, measured from demand D_1. The net effect corresponds to a **price effect**that must be taken into account in the CBA.

However, this price effect can be ignored if the increase in producer surplus in the cheese market does not explicitly take into account the shift in the cheese supply curve caused by the increase in the price of milk.

Furthermore, the milk market may be distorted in several ways. Many jurisdictions impose production quotas, so that the price of milk is higher than its marginal cost. If milk production cannot increase because of quotas, the project will cause an increase in the production costs of cheese that will cancel out the benefit of the higher export price. In other words, all the benefits of the project will be transferred to milk producers. In this case, it is necessary to account for this effect in the CBA of the secondary milk market. Finally, since milk

production also entails external costs (e.g., methane emissions), this **effect associated with a distortion**must also be taken into account .



Panel A: Exportation Cheese Market

Panel B: Secondary Market for Milk

The market for cheese and a key input, milk

CHAPTER 13 SOLUTIONS

Question 2

Question 2

Radon is a colorless and odorless gas resulting from the natural decay of radioactive elements in the Earth's crust. This gas can accumulate at high concentrations inside homes, increasing the risk of lung cancer. In Canada, the maximum recommended standard for radon exposure is 200 becquerels per cubic meter (Bq/m^3). However, the World Health Organization (WHO) recommends a lower threshold of 100 Bq/m^3 to minimize health risks. Evidence shows that the higher and longer the exposure to radon, the greater the risk of developing lung cancer. To date, research has established a link between radon exposure and lung cancer, without identifying other significant health impacts associated with this gas.

As an analyst, develop a protocol to assess the costs associated with radon exposure in a given jurisdiction.

Resolution

Protocol for the assessment of health costs related to exposure to radon

1. Quantification of the health impact following exposure to radon

- **Identification of health risks:**Use epidemiological studies to determine the increased risk of lung cancer associated with different levels of radon exposure. Radon is the second most important risk factor for lung cancer after smoking.
- **Estimating Lung Cancer Incidence:**Using public health data to estimate the number of lung cancer cases attributable to radon exposure each year.
- **Lung cancer treatment costs:**Compile the average costs associated with the diagnosis, treatment (surgery, radiotherapy, chemotherapy) and follow-up of lung cancer patients. This includes direct health costs paid by public and private health systems as well as out-of-pocket expenses.

2. Assessment of indirect costs

- **Lost productivity:**Calculate the costs associated with lost productivity for individuals with lung cancer, including work days lost due to treatment and medical appointments as well as lost productivity due to

long-term disability or premature death.

- **Costs associated with long-term care:**Include costs of long-term care for terminally ill lung cancer patients, including palliative care.

3. Synthesis and report

- **Data Compilation:**Gather and analyze all data collected to provide a comprehensive assessment of health and indirect costs associated with radon exposure.
- **Final report:**Write a detailed report presenting the direct health costs, indirect costs and describe the impacts that were not valued as constituting a deterioration in the quality of life.

CHAPTER 14 SOLUTIONS

Question 1 Question 2

Question 1

A beach is accessible free of charge. A survey reveals that people living within 10 km of the beach visit it an average of four times per year. Their travel cost to visit the beach is estimated at $10 per visit per person. People living between 10 km and 20 km from the beach visit it an average of two times per year, with an average travel cost of $20 per visit per person. Approximately 10,000 people live within 10 km of the beach, and 25,000 live between 10 km and 20 km away. Based on these data, determine the surplus generated by the beach for the population living within 10 km. [Use linear extrapolation.]

Resolution

We have two points on the demand curve, namely ($4.10) and ($2.20). By linear extrapolation, we evaluate the reserve price at $30. From this reserve price, the calculation of the SC of people who live less than 10 km away is equal to:

$$\frac{(30-10)}{2} \times 4 \times 10,000 = 400,000\$$$

Obviously, this is a simplistic example. More observations would be needed and the heterogeneity of visitors would have to be taken into account to estimate consumer surplus more accurately.

Question 2

A hedonic study was conducted to assess the impact of nuisances created by proximity to wind turbines in a region. The econometric estimation of the hedonic function yields the following results:

$\log(PV) = a_0 + a_1 \log X - 0.03\ D[500_1000] - 0.07\ D[<500]$

where:

PV denotes property value;

X represents control variables;

D[500_1000] is a binary variable equal to one if the property is located between 500 meters and 1,000 meters from a wind turbine;

D[<500] is a binary variable equal to one if the property is located less than 500 meters from a wind turbine.

The coefficients reported above are statistically significant. The hedonic study also indicates that there is no statistically significant effect on properties located more than one kilometer from a wind turbine. Table 14.3 presents the average property value by area and the number of affected properties. Based on this information, value the nuisances associated with the presence of wind turbines in this region.

Affected areas	Average property value	Number of properties
500 to 1000 meters	$115,000	750
< 500 meters	$95,000	69

Resolution

The specification is semi-log, so that the coefficients on the variables D[500_1000] and D[<500]are interpreted as the % change caused by moving these variables from 0 to 1. In other words, proximity between 500 and 1000 meters results in a 3% reduction in property values, while proximity within 500 meters results in a 7% decrease. The table illustrates the impact of wind turbines on the nearby housing stock.

Affected areas	Average property value	Number of properties	Impact on a property	Impact on properties
500m to 1 km	$115,000	750	$3,450	$2,587,500
< 500m	$95,000	69	$6,650	$458,850

CHAPTER 16 SOLUTIONS

Question 1 Question 2

Question 1

To dissolve a blood clot during a heart attack, the drug currently used carries a risk of 5 in 100,000 cases of fatal allergic reactions. Health authorities are evaluating the use of a new drug that is more expensive but reduces the risk of fatal reactions to 3 in 100,000. For the rest, these two drugs are equivalent. The authorities use as a guideline in decisions to approve new drugs a statistical value of life of $5 million. Under these conditions, to be accepted according to the guideline, the additional cost of the new drug can be at most:

a) $40;
b) $55;
c) $75;
d) $100;
e) $150;
f) $175;
g) $250;
h) None of the above.

Resolution

The drug results in a reduction in the risk of mortality of 2/100,000.

The value of life is set at $5 million for a risk equal to 1.

Thus the maximum willingness to pay to reduce the risk by 2/100,000 is 2/100,000 x $5 million = $100, or answer d).

Question 2

In the United States, the first Trump administration (2017–2021) revised the methodology for calculating the social cost of carbon proposed by the Obama administration (2009–2017). The two main changes to this methodology were: (i) considering damages exclusively in the United States, rather than global damages; and

(ii) using a discount rate of 7–10%, instead of the 3% rate. Explain how these changes may have affected the value assigned to the social cost of carbon. Discuss the rationale for these changes.

Answer

These two changes go in the direction of reducing the value of the social cost of carbon. Indeed, by only taking into account national damages, we limit the amount of damages caused by an additional ton of carbon. This is all the more the case since the damages of climate change will be more significant for developing countries.

Furthermore, by giving less weight to the future by using a higher discount rate, the present value of future damages is reduced. For example, the Trump administration reduced the value of the social cost of carbon from US$45 to US$4. The Biden administration has eliminated these changes, restoring the average value of the social cost of carbon for the year 2020, first to US$51, and then, in 2023, this value was re-evaluated to US$230 (with a range between US$120 and US$340).

CHAPTER 18 SOLUTIONS

Question 1

Question 1

A biomethanization plant project aims to convert organic waste from a city's residents into natural gas. In your opinion, what are the main parameters and data that should be subject to sensitivity analysis for this project?

Resolution

The sensitivity analysis should examine the impact on the NPV of the change project for the values of the following parameters :

1. Quantity and composition of organic waste: Changes in the availability and variability of organic waste, including seasonality and composition, can affect gas yield.
2. Biomethanization technology: Analyze the different technologies available, their efficiency, their investment and operating costs and their adaptability to the types of waste treated.
3. Biomethane yield: Estimate the potential for converting organic waste into biomethane, taking into account possible variations depending on the technology and waste composition.
4. Infrastructure costs: To analyze how the cost of the plant affects social profitability.
5. Operational costs: To study how changes in the assessment of operating costs , including costs related to waste collection and transportation , can affect NPV .
6. Natural Gas Prices and Demand: Use different assumptions about how natural gas prices and market demand will change that will influence the profitability of the project.
7. Environmental impact: Evaluate the benefits in terms of reduced greenhouse gas emissions , using different values for the social cost of carbon and other environmental benefits (e.g., reduced landfill) .
8. Plant life : Consider different values for expected plant life and /or residual value .
9. Risks and Uncertainties: Identify the main risks and uncertainties related to the project, such as technological changes, variations in the supply of organic waste and regulatory changes.
10. Population growth and waste production scenarios: Examine the impact of different assumptions on population growth and waste production trends .

25.

CHAPTER 20 SOLUTIONS

Question 1

Following an earthquake, a government wants to send a clean-up crew. The crew of 32 people can clean 1 km^2/h, at a cost of $15 per hour per worker (project A). It is proposed to increase the clean-up crew to 48 people, who would then have a productivity of 1.8 km^2 per hour, at the same hourly wage (project B). What is the ICER (B relative to A)?

Answer

The ICER of B relative to A = ($720 – $480) / (1.8 -1) = $300 per additional km^2.

Question 2

A health agency is conducting a cost-effectiveness analysis of four treatment strategies to prevent recurrent strokes. The costs and effectiveness in the table below are calculated for treating all people who have a first stroke each year. All values have been discounted appropriately. Which option do you recommend if only one option must be selected, and the critical threshold is $15,000 per recurrent stroke prevented?

Table 10. Updated cost and effectiveness of treatments to prevent stroke recurrences

Treatment	Cost ($)	Number of recurrences avoided
HAS	2,000,000	200
B	3,500,000	250
C	5,000,000	500
D	8,000,000	800

Answer

A sequential analysis is performed to eliminate dominated options. Table 10.a presents the average cost-effectiveness ratio for each option, and it appears that all options are below the critical threshold. Inspection of Table 10 also shows that no option is strictly dominated by another. Table 10.a also displays the sequential ICER, revealing that Project B is weakly dominated, as its sequential ICER is higher than that of Project C. The sequential ICERs are then recalculated excluding Project B. The ICERs of the remaining projects are similar, indicating that they lie on the same line in the cost-effectiveness plane, this line representing the efficiency frontier (see Figure 13).

Table 10.a ACE of projects

Project	Average cost-effectiveness ratio	Sequential ICER	Sequential ICER without Project B
HAS	10,000	10,000	10,000
B	14,000	30,000	–
C	10,000	6,000	10,000
D	10,000	10,000	10,000

The cost-effectiveness analysis leads us to recommend project D, which meets the critical threshold, belongs to the cost-effectiveness frontier and offers the greatest efficiency.

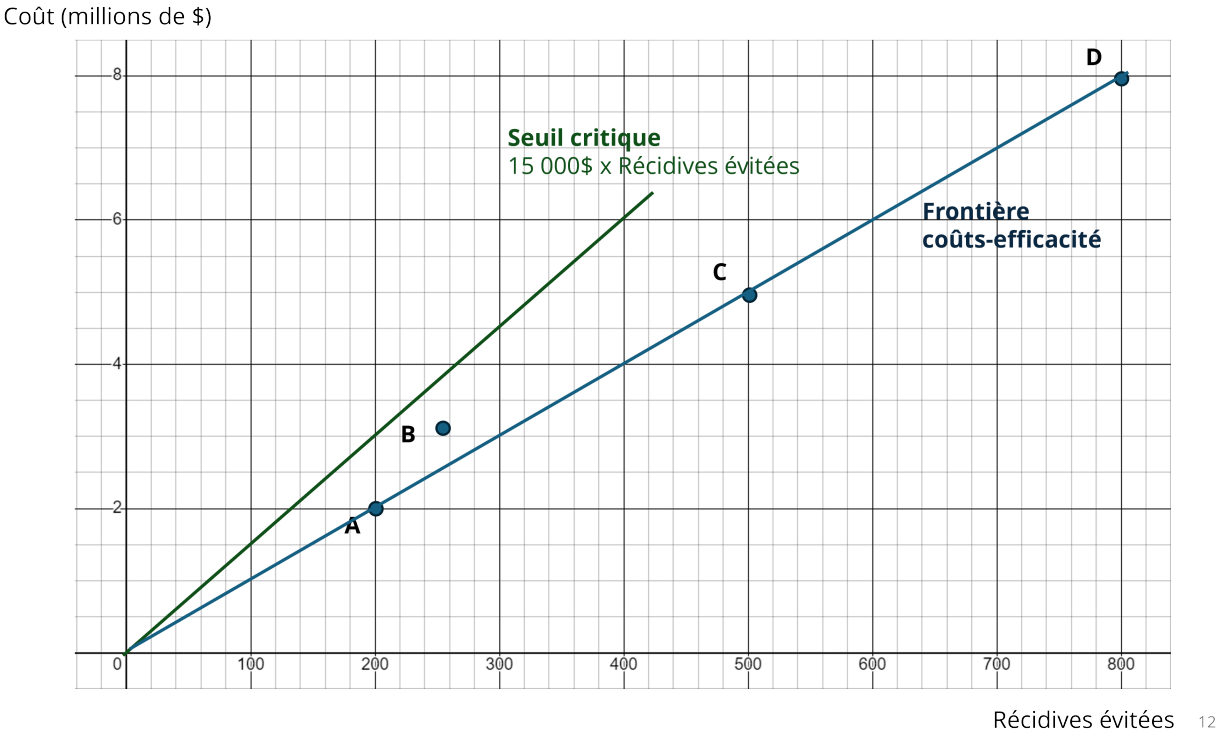


Figure 13. The cost-effectiveness frontier

Question 3

An environmental agency asks you to evaluate three new wetland protection projects. The costs per area of protected areas are listed in present value in the table below. Project A is the current alternative (the status quo), and the projects are mutually exclusive. Determine which option should be recommended based on the critical threshold that will be retained by the public authorities.

Table 11. Cost and effectiveness of wetland protection projects

Project	Cost ($)	Protected area (km2)
A (status quo)	410,000	60
B	830,000	65
C	890,000	79
D	900,000	75

Answer

A sequential analysis is performed to eliminate dominated options. Table 11 clearly shows that Project D is strongly dominated by Project C, as it is more expensive, while offering lower efficiency (the ICER of D relative to C is negative). Table 11.a presents the ICERs of the options relative to Status Quo A as well as the sequential ICERs, revealing that Project B is weakly dominated by Project C. The choice is therefore reduced to Status Quo A and Project C. If the critical threshold is lower than $25,263, the status quo should be maintained. If the threshold is higher, Project C should be recommended.

Table 10.a ACE of projects

Project	ICER vs. A	Sequential ICER
HAS	–	–
B	$28,000	$28,000
C	25 263	4,286

Question 4

You are responsible for assessing whether a shingles vaccination program for people aged 50 and over would be cost-effective. You know that shingles can cause neurological damage and be very painful if not treated promptly, but that it does not cause many deaths. What type of analysis do you propose to use and why?

Answer

Cost-utility analysis uses QALYs to measure the impact of the disease on quality of life. Vaccination, by preventing cases of shingles, allows QALYs to be gained. The cost of this intervention must then be determined in order to assess the cost-effectiveness of the vaccine.

Question 5

Cardiologists are looking at different drugs to prevent heart disease in patients at risk. New drugs are added to those already being taken by the patient because their actions are complementary. Table 12 shows the costs and annual reduction in the risk of cardiac events associated with different therapies. The interventions are listed in an order determined by medical considerations.

Table 12. Annual cost and effectiveness of heart disease prevention measures over one year

Order	Intervention	Cost	% risk reduction
1	A- Aspirin	$200	2.4%
2	B – Aspirin + antihypertensive	$600	4.1%
3	C – Aspirin + 2 antihypertensives	$1500	7.3%
4	Aspirin + 2 antihypertensives + hypocholesterolemic	$6000	10.3%

Inspired by Marshall (2003)

Assuming that the government uses a maximum standard of $30,000 per cardiac event avoided, determine which intervention should be selected.

Answer

Option 3.

RESTRICTED-ACESS SOLUTIONS

Chapter 1	Chapter 2	Chapter 5
Chapter 6	Chapter 7	

Chapter 1

Question 2

A municipality must decide whether to renovate its outdoor pool or build a new, larger one on the same site. In the current configuration, user benefits, assessed over the life of the infrastructure, are estimated at $1 million. The municipality expects to increase these benefits by 50% by building a larger pool. Renovating the existing pool would cost $350,000, while building a new pool would cost $1 million. Operating and maintenance costs for the renovated pool are estimated at $250,000, compared with $300,000 for the new pool. The municipality must also renovate the parking lot in front of the pool at a cost of $50,000.

a) Using this information, perform a CBA of the decision to build a new pool rather than renovate the existing one. Present your results in terms of additional benefits and additional costs for the new pool compared with the renovation.

b) How would your recommendation change if the provincial government agreed to cover 40% of the infrastructure costs (that is, the construction or renovation costs)?

Answers

Results of the CBA of constructing a new swimming pool versus renovating an existing swimming pool.

Advantage	
Additional benefit for users	**500 000 $**
Costs	
Costs of building a new swimming pool	1 000 000 $
Costs avoided from renovation	-350 000 $
Additional operating and maintenance costs	50 000 $
Total additional costs	**700 000 $**
NPV	**– 200 000 $**

Therefore, the new swimming pool project is not profitable compared to renovating the existing swimming pool.

With the provincial grant program, the project becomes profitable if the CBA is carried out from the perspective of the municipality, as indicated in the table below.

Results of the CBA of the construction of a new pool compared to the renovation of the existing pool with the provincial subsidy program and adopting a municipal perspective .

Advantage	
Additional benefit for users	**500 000 $**
Costs	
Costs of building a new swimming pool	1 000 000 $
Costs avoided from renovation	-350 000 $
Additional operating and maintenance costs	50 000 $
Additional subsidy	-$260,000 (i.e., -$400,000 + 0.4 x $350,000)
Total additional costs	**440 000 $**
NPV	**60 000 $**

However, the project remains unprofitable from a provincial perspective. We will see in Chapter 2 that this amounts to defining the spatial horizon (or the notion of status) of the CBA, either at the municipal or provincial level.

Chapter 2

Question 1

A municipality is considering building a biomethanization plant to treat its residents' organic waste. The construction cost is estimated at $100 million. The municipality will pay for the work, but will receive a federal government grant equal to 25% of the construction cost and an equivalent grant from the provincial government. The present value of the plant's operating costs, including the costs of collecting organic matter, is estimated at $80 million. The plant will produce natural gas that will be sold on the renewable natural gas market, generating expected revenues of $37 million. Redirecting organic waste to the biomethanization plant will save the municipality $13 million on its landfill bill. The plant will also help reduce greenhouse gas emissions, which represents a benefit estimated at $3 million. The inconvenience associated with sorting household waste for citizens has been estimated at $1.5 million. All values presented are discounted data over the duration of the project. For simplicity, it is assumed that there are no other impacts. Based on these data, perform a CBA of this project using the part-by-part approach and successively adopting the following spatial horizons:

1. Universal;
2. Provincial;
3. Municipal.

Answer

First and foremost, the relevant stakeholders must be identified. From a universal perspective, these are:

- The federal government;
- The provincial government;
- The municipality;
- Citizens who will have to sort their waste;
- Third parties who are affected by climate change.

Note that the following parts are ignored, since the net effect of the project can be considered to be zero:

- The eventual operator of the landfill site (which may or may not be the municipality), whose revenue loss caused by the project will be offset by a corresponding cost reduction, will be able to use the freed-up space to bury other waste and thus generate equivalent revenue. From a social perspective, the $13 million is therefore assumed to adequately represent the social value of the resources saved.
- The impacts on other participants in the renewable natural gas market are also unknown. It is therefore implicitly assumed that the project's implementation will have no significant impact on market

equilibrium (see Chapter 7 for an analysis of the case where this assumption is not valid).

The Stakeholder approach with the universal horizon

	Cost	Benefits	Explanation
Stakeholder			
Federal Government	25		Federal government grant paid to the municipality
Provincial Government	25		Provincial government grant paid to the municipality
Municipality	100		Infrastructure costs
		25	Grant received from the federal government
		25	Grant received from the provincial
		80	Operating costs
		37	Revenue from the sale of natural gas
		13	Landfill costs avoided
Tiers		3	Reduction of GHG emissions
Citizens of the municipality	1,5		Inconveniences related to waste sorting
TOTALS (excluding transfers)	101,5	53	
NPV	**– 128,5**		

In red, transfers between stakeholders.

From a **provincial perspective ,** the federal government is no longer a stakeholder, so its impacts (both positive and negative) are eliminated. However, the federal subsidy to the municipality still appears as a benefit for the municipality. The cost to the reference society has therefore decreased by $25 million (see the caveats below). Consideration of the impact of climate change on associated third parties depends on the existence of provincial commitments to emissions reduction. It is assumed here that such commitments exist, so this benefit continues to be considered. The results are presented in the following table.

The Stakeholder approach with the provincial horizon

	Cost	Benefits	Explanation
Stakeholder			
Provincial Government	25		Provincial government grant paid to the municipality
Municipality	100		Infrastructure costs
		25	Grant received from the federal government
		25	Grant received from the provincial
		80	Operating costs
		37	Revenue from the sale of natural gas
		13	Landfill costs avoided
Tiers		3	Reduction of GHG emissions
Citizens of the municipality	1,5		Inconveniences related to waste sorting
TOTALS (excluding transfers)	101,5	53	
NPV	**– 103,5**		

In red, transfers between stakeholders.

The principle is similar for the CBA with a municipal perspective.

	Cost	Benefits	Explanation
Stakeholder			
Municipality	100		Infrastructure costs
		25	Grant received from the federal government
		25	Grant received from the provincial
		80	Operating costs
		37	Revenue from the sale of natural gas
		13	Landfill costs avoided
Tiers		3	Reduction of GHG emissions
Citizens of the municipality	1,5		Inconveniences related to waste sorting
TOTALS (excluding transfers)	101,5	53	
NPV	-78.5		

WARNING REGARDING THE CONSIDERATION OF SUBSIDIES

With a provincial or municipal focus, the project cost appears lower, since part of the $100 million expenditure is covered by non-stakeholder entities (the federal government in the provincial analysis, and both the federal and provincial governments in the municipal analysis). However, it is important to consider whether these subsidies entail an **opportunity cost**. For example, does the $50 million grant to the municipality come at the expense of funding for other initiatives? If so, it would be preferable to exclude this grant: the project's opportunity cost to the municipality would then be $100 million. In other words, if the $50 million grant could also be allocated to other municipal projects, it is not additional to this project (it would be received regardless of whether the project proceeds) and should therefore not be included.

Key points to remember

Before treating a grant from outside the project's scope as a benefit, it is important to consider the opportunity cost of that grant. If the grant is awarded to this project, will it reduce the level of funding available for other projects? If so, the grant should be excluded from the project's cost–benefit analysis (CBA). In practice, the answer is often uncertain. In such cases, it may be advisable to present the CBA results both with and without the inclusion of the grant.

Chapter 5

Question 1

Annual production of greenhouse tomatoes in a region is 25,000 tonnes, generating revenues of $75 million for producers. This corresponds to an average price of $3,000 per tonne. Assume that Figure 5.5 illustrates the supply and demand curves in the wholesale market for greenhouse tomatoes.

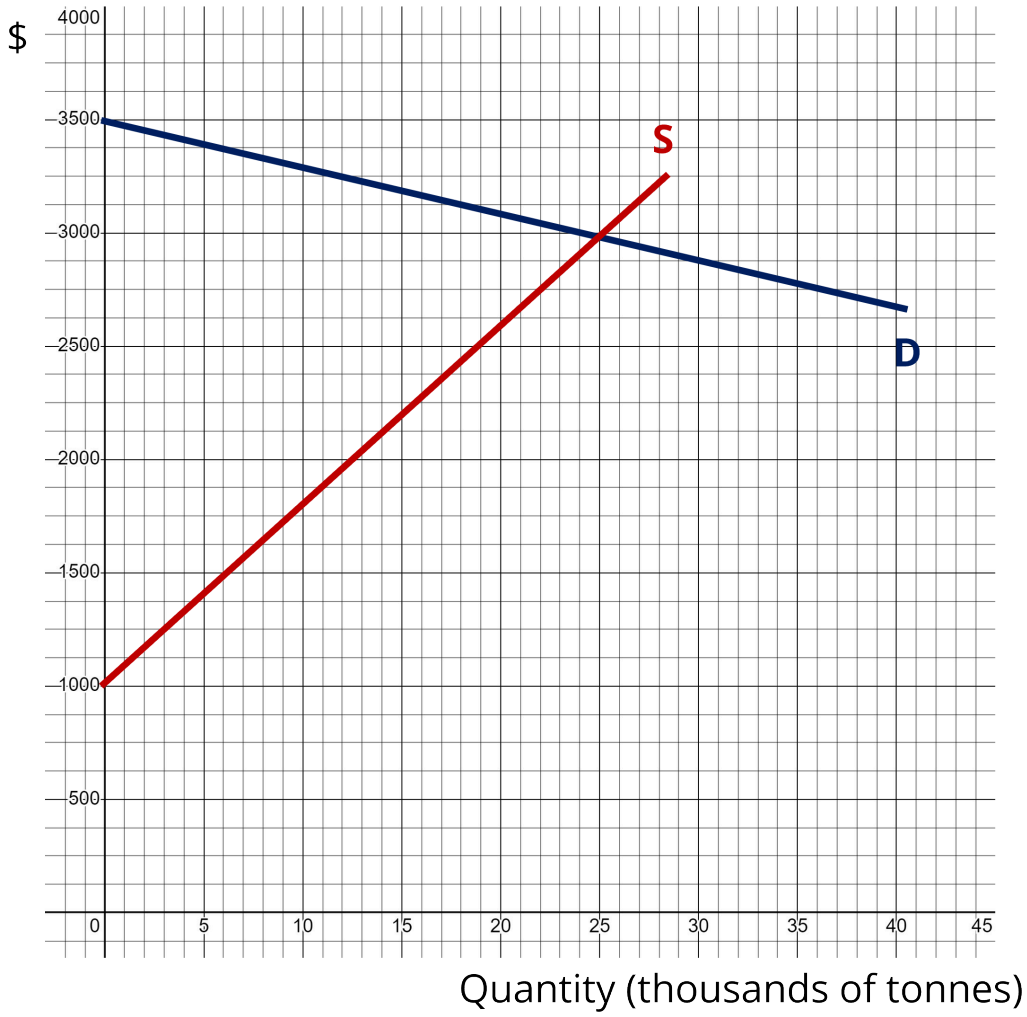


Figure 5.5 The greenhouse tomato market

Determine the value of the price elasticity of demand at market equilibrium.

Does that seem realistic to you?

To promote food self-sufficiency, the government is considering giving individuals access to the preferential electricity rate of 3 cents per kWh rather than the current rate of 5.8 cents per kWh. Assume that this decrease in the price of electricity results in a general decrease in the cost of $500 per tonne produced. Examine the impacts of this project on the greenhouse tomato wholesale market. Use both a social approach and a stakeholder approach (examine the impact on consumers first, then on producers in the wholesale market).

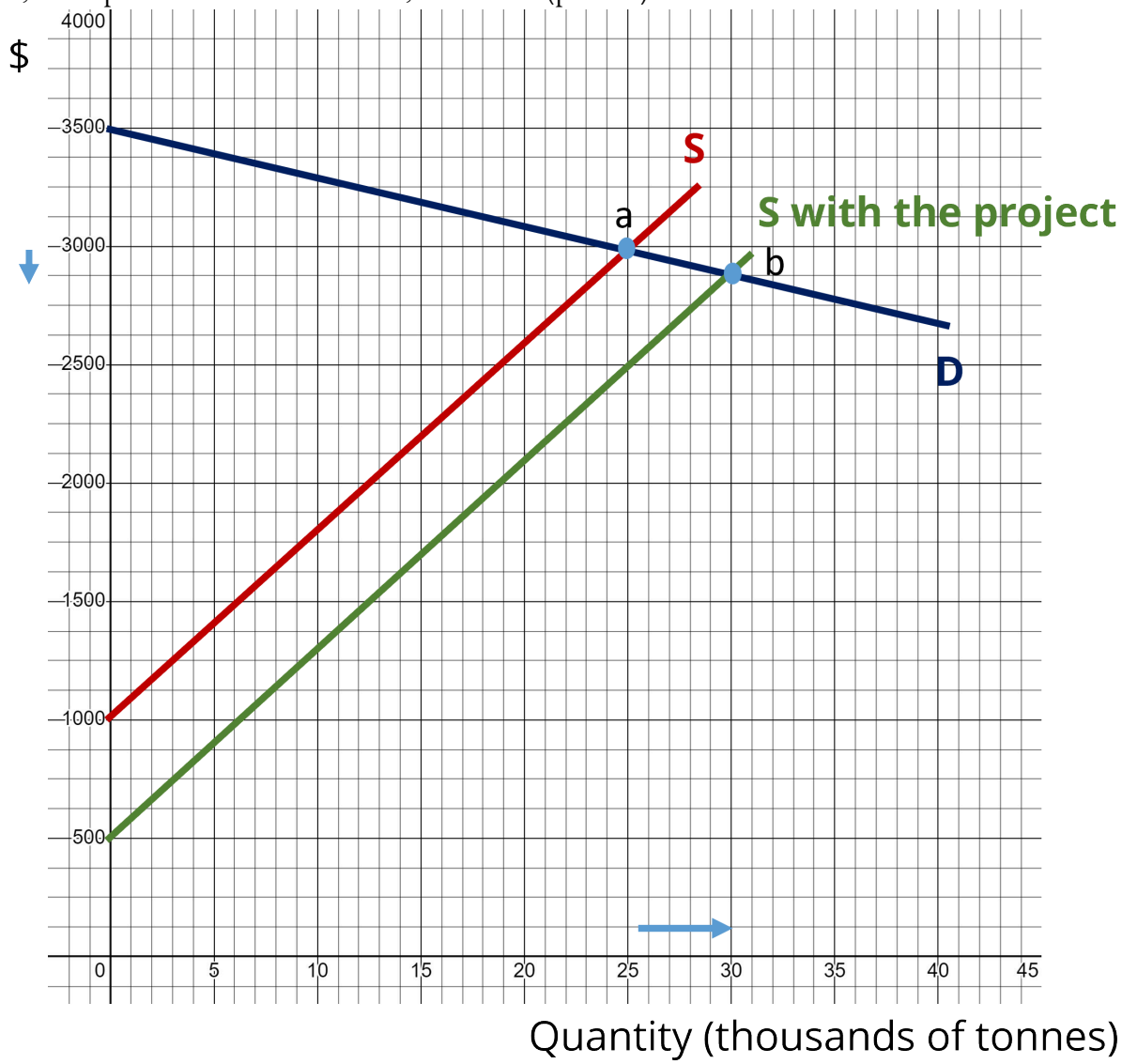
If we wanted to do a more complete ACA of this project, what other important impacts would you consider to be taken into account?

Answers

The initial equilibrium (a) lies within the elastic part of demand. We can even deduce from the graph that its value is 6.

The price elasticity of demand for greenhouse tomatoes is expected to be very elastic, since if the price of this category of tomatoes increases, consumers can easily turn to imported tomatoes (a very close substitute).

The project has the effect of shifting the supply curve downwards (the price of a variable input has decreased). From the graph, we observe that the project leads to a decrease in the market equilibrium price to $2,900/tonne, while production increases to 30,000 tonnes (point b).



In summary:

Reference scenario: P = $3000 and Q = 25,000 tonnes

Scenario with project: P = $2900 and Q = 30,000 tonnes

Social approach (quantitative reasoning)

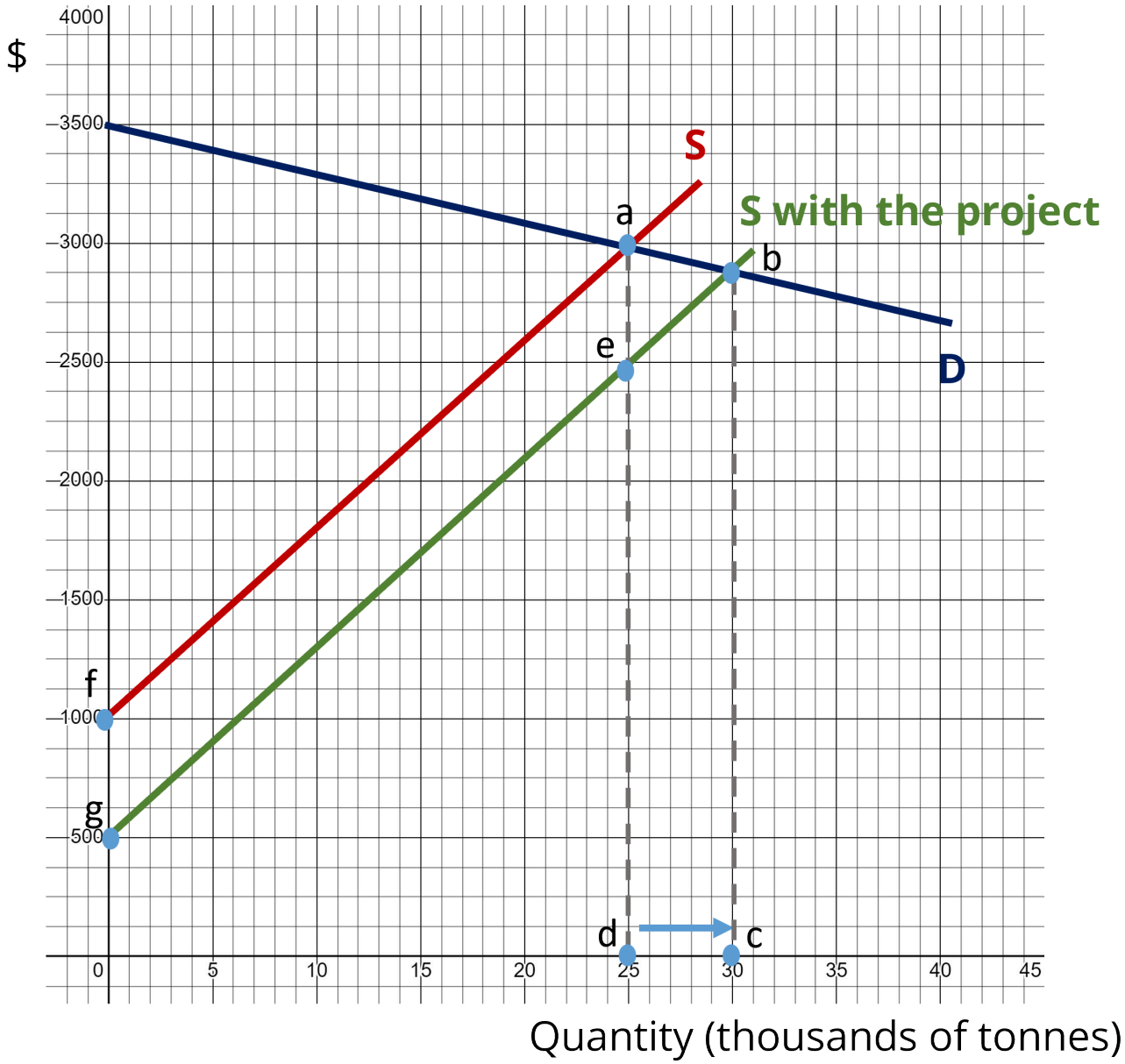
Reasoning in terms of quantity: the quantity changed increases from 25,000 tonnes to 30,000 tonnes .

1) Social value of the additional production? The area *abcd* = $14.75 million.

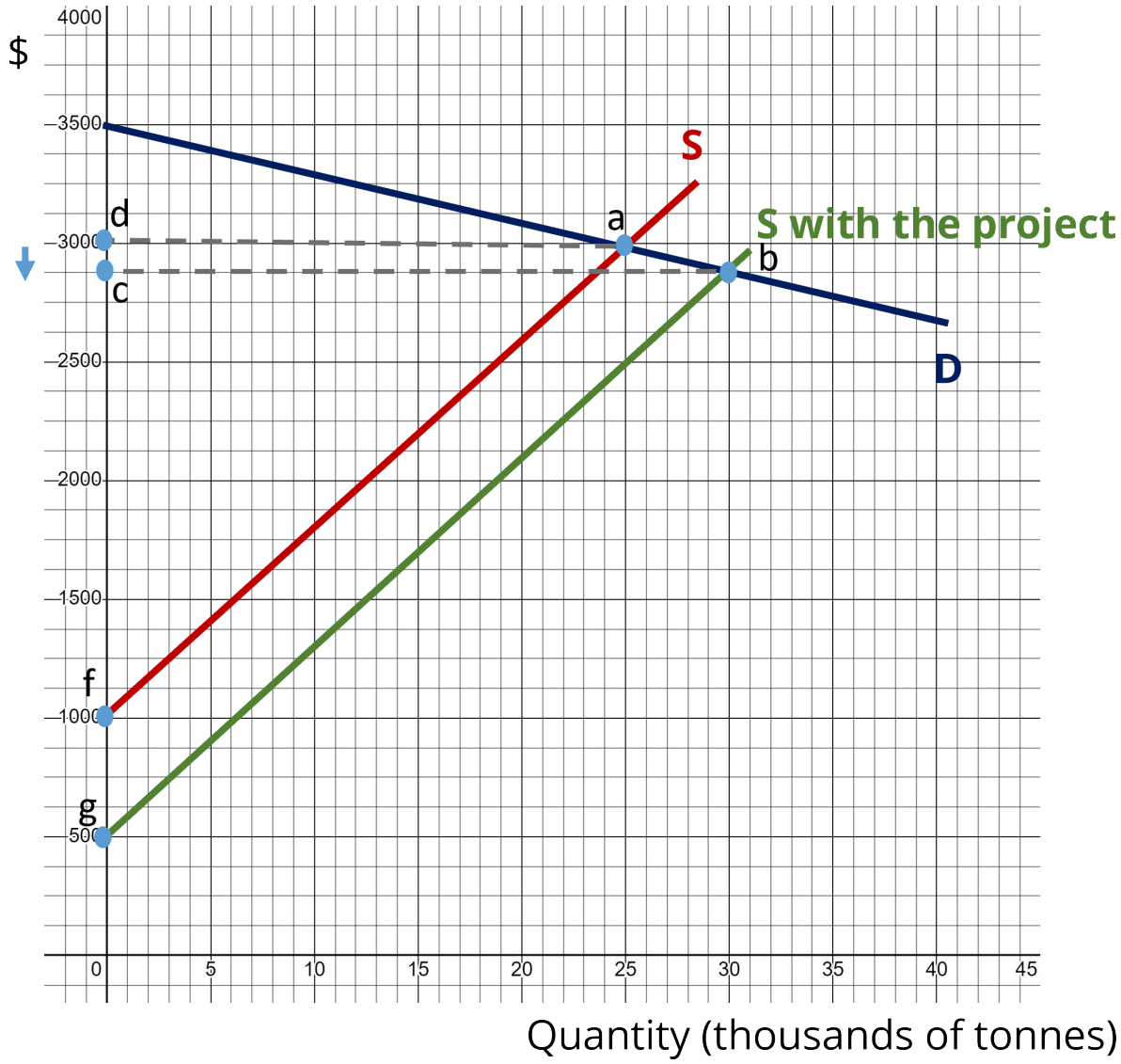
2) Value of resources saved by producers: The *faeg* area = $12.5 million.

3) Social value of the resources mobilized by the producers? The *ebcd* area = -$13.5 million.

The net value of the project (for consumers and producers only) = $13.75 million .



Stakeholder approach (price reasoning)



Vertical reasoning: the price drops from $ 3,000 to $ 2,900 .

Net impact on consumers: CS growth (*dabc* area) = $2.75 million.

Impact on producers: PS growth = PS (with the project) – PS (without the project) = *CBG* area – *DAF* area = 36 million – 25 million = $11 million.

Net value of the project: $ 13.75 million .

To conduct a more comprehensive cost-benefit analysis, we must consider the impact on the eletricity produceur. This project is being carried out at the expense of the electricity produceur operating profit and eventually at the expense of the government (i.e., taxpayers) if the operator is compensated. This project is thus equivalent to a subsidy, which we will examine in more detail in Chapter 7.

We should also calculate whether there is an advantage to reducing our food dependency (for example, a reduction in risks in the event of major global disruptions). We can also consider the environmental impacts of the program (reduced transport costs through local purchasing, but higher energy consumption during production).

Chapter 6

Question 5

A municipality currently sends all of its waste to a neighbouring municipality's landfill for a fee. It could continue with this option, but a CBA has shown that building its own landfill would generate an NPV of $3 million relative to maintaining the current arrangement. The new landfill would have a service life of 15 years. Alternatively, the municipality could build both a landfill and a composting facility. The NPV of this option is estimated at $4 million, and it would allow waste disposal for 30 years. Based on the information provided, and assuming a social discount rate of 5%, which option would you recommend?

Answers

The three scenarios are:

- The baseline scenario, which consists of continuing to bury waste at the site of the neighbouring municipality in exchange for a fee;
- The scenario with a clean landfill site, whose lifespan is T = 15: NPV = $3 million;
- The scenario with the landfill site and the composting center for a lifetime of T = 30: NPV = $4 million.

The two projects under consideration have different lifespans, making a direct comparison impossible. Here, we use the replication approach, calculating the NPV of the scenario with the site, but replicated once, so that this scenario will also have T = 30.

The NPV of the site replicated once = $3 + 3/(1+0.05)^{15}$ = $4.44 million. Project 1 is therefore the most profitable.

Chapter 7

Question 3

A medium-sized municipality is considering building a biomethanization plant for its organic waste. One of the project outputs is natural gas that will be sold on the market. In your view, at what price should this output be valued? Explain.

Answer

It is unlikely that the plant's production will be sufficient to significantly affect the price of natural gas , which is an international market. The current price can therefore be used to value the plant's output.

In addition, the project will produce 400 tonnes of ecological fertilizers. Given transportation costs, the market for ecological fertilizers is regional. The project is therefore expected to double regional production of ecological fertilizers. Demand for these fertilizers is estimated to have a price elasticity of 3, while the supply elasticity is 0.1. The current price is $250 per tonne. What social value should be assigned to the additional production of ecological fertilizers from the new plant? Explain.

Answer

We need to determine the market price for the project. We apply the formula

(k Qo) x 100ηo + ηd%

with

(k Qo) = 1, since the project doubles production. The price should therefore fall by 32.25%, with the addition of the project, to approximately $169.4. The reference price (average of the price before and after the project) is thus $209.7. The social value of the additional production of the organic fertilizer, which takes into account the impact on users, pre-existing producers, and the new producer, is $209.7 x 400 tonnes = $83,875.

Question 5

A project involves replacing a ferry service between two river banks with a bridge. The ferry service is operated by the Ferry Corporation. The crossing costs $3, and annual traffic is 100,000 crossings. Ferry operating costs are estimated at $150,000 per year. With the construction of the bridge, the ferry can be sold for an estimated $25 million. The construction cost of the bridge, incurred at $t = 0$, is $100 million. The bridge would be tolled at $5 per crossing. The monetary value of travel time savings is estimated at $12 per crossing on average. In addition, traffic is expected to rise to 145,000 crossings per year once the bridge opens and to remain stable thereafter. Bridge operating and maintenance costs are estimated at $100,000 per year. The bridge has an expected life of 75 years, and the social discount rate is 5%. For simplicity, assume that the bridge is built at $t = 0$ and that the ferry is sold at $t = 0$. Also assume that annual operating benefits and costs accrue continuously each year, starting in year 1. Perform a CBA of this project.

Answer

This project can be viewed as an improvement in the quality of the ferry service, which shifts the demand

curve. Alternatively, the analytical framework for this project can be framed as a reduction in the overall price of the ferry crossing. Indeed, the relevant primary market in this example is that of the crossing between the two banks. Demand for this service is inversely proportional to the overall price.

Thus, the generalized price of the crossing with the ferry (indexed by T) is:

$p_g^T = 3\$ + \theta \times t^T$.

And the generalized price including the bridge (indexed by P) is:

$p_g^P = 5\$ + \theta \times t^P$.

We do not have details on theta, t^T, or t^P . However, it is indicated that the value of the time saved by replacing the ferry with the bridge is $12. Therefore, we have theta × (t^T – t^P) = $12. Thus, the impact of the project can be analyzed as a decrease in the generalized price, which stimulates demand for crossings. The decrease in the generalized price is therefore:

$\Delta p_g = (p_g^T - p_g^P) = (3\$ - 5\$) + 12\$ = 10\$.$

The figure below illustrates the effect of the project on the demand for crossings.

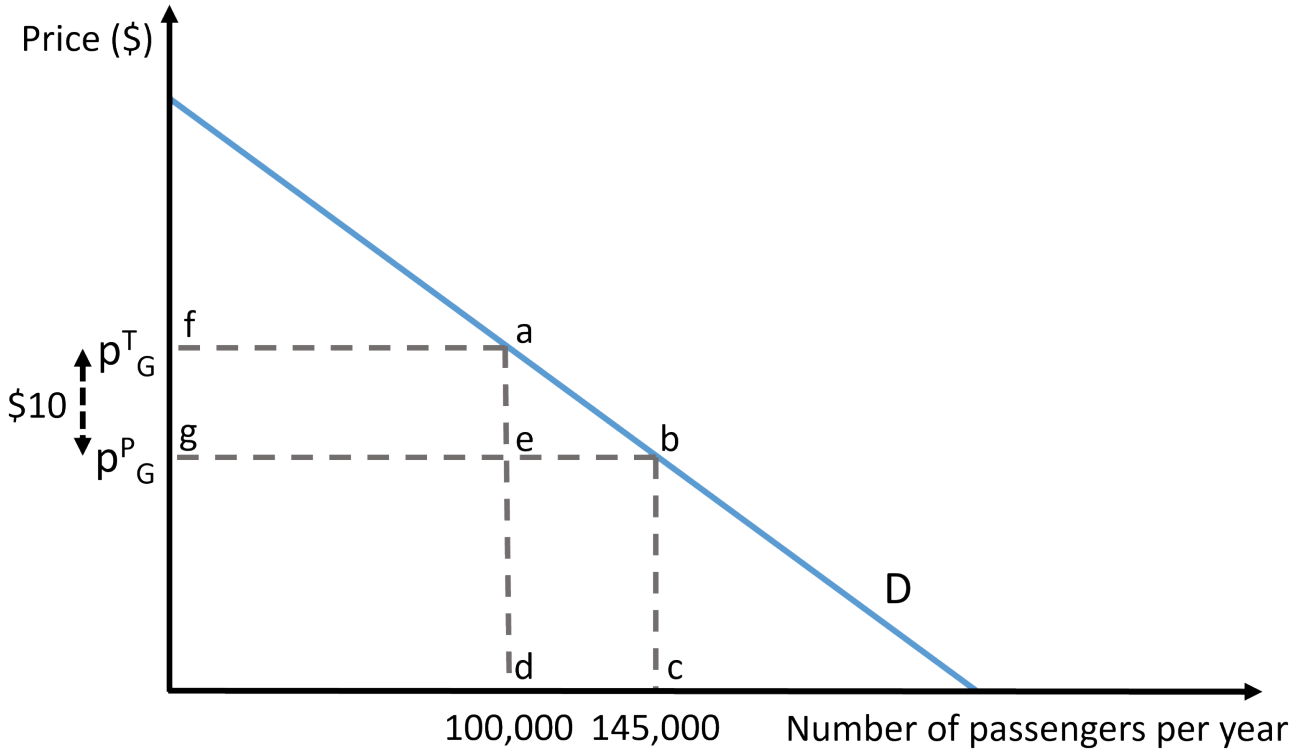


Figure . Representation of the project's impact on demand

As in the water park example, there is only one producer, so it is not appropriate to present a supply curve. However, it is possible to perform a cost-benefit analysis using the stakeholderapproach based on the Figure and the problem data. Among the parties involved, there are first the users, who can be divided into traffic diverted from the ferry to the bridge and traffic induced by the bridge. The gain from diverted traffic corresponds to the rectangle (*faeg*), which is the decrease in the generalized price of $10, multiplied by the diverted traffic of 100,000 crossings. For induced traffic, the gains from exchange are measured by the triangle

(*abe*), which is 1/2 x $10 (that is, the average valuation of a user crossing, which is $5), multiplied by the induced traffic of 45,000 crossings.

The second party affected is the ferry company. It loses revenue estimated at $3 x 100,000 = $300,000. It saves operating costs of $1.5 x 100,000 = $150,000 (i.e., resources freed up for other uses). The net effect is therefore a loss of operating profit of $150,000. The sale of the ferry must also be accounted for as a gain of $25 million.

Finally, there is the government, which must bear the cost of constructing and operating the bridge, but receives toll revenues of $5 x 145,000 = $725,000 [1]. These impacts are summarized in Table 2 and discounted according to the projected schedule.

Table 2. CBA of the replacement of the ferry by the bridge according to the Stakeholder approach

Stakeholder	Advantage	Cost	Present value
Users			
Tragic diversion	$1,000,000 (t = 0.5 to 74.5)		19,97 m $
Induced traffic	$225,000 (t = 0.5 to 74.5)		4,49 m $
Ferry Corporation	25 m (t = 0)	$150,000 (t = 0.5 to 74.5)	$22.01m
State	725,000 (t = 0.5 to 74.5)	100 m (t = 0) $100,000 (t = 0.5 to 74.5)	-87,52 m $
		NPV =	**-41,05 m $**

The annuity factor is 19.966

It is also possible to apply the social approach. However, not all the data are available to perform a specific evaluation of each component. On the other hand, sufficient information is available to calculate the NPV, since some components balance out, as shown in Table 3.

Table 3. CBA of ferry replacement by bridge according to the social approach

1. For simplicity, we assume here that the marginal cost of public funds is zero.

Social value of increased traffic	Triangle (abe) = ½ x 10 $ x 45,000 (t = 0.5 to 74.5) Rectangle (ebdc) = (5 $ + ∂xtP) x 45,000 (t = 0.5 to 74.5)
– Social cost of the resources mobilized	Bridge: 100 m (t = 0) Bridge operating cost: $100,000 (t = 0.5 to 74.5) Cost of induced traffic time: (∂xtP) x 45,000 (t = 0.5 to 74.5)
+ Social value of saved resources	Ferry: 25 m (t = 0) Ferry operating costs: $150,000 (t = 0.5 to 74.5) Time savings from diverted traffic: $12 x 100,000 (t = 0.5 to 74.5)
NPV =	**-41,05 m**

Source: Exercise inspired by Townley (1998), pp. 94-100.

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Chapter 1

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Chapter 2

Figure 2.2 Projections of the number of crossings over the Saguenay in the reference scenario and the scenario with the bridge (source: SNC-Lavalin/Genivar Consortium, 2009, p. 4-62, reproduced with the kind permission of the Ministère des Transports et de la Mobilité durable du Québec, all rights reserved), © Gouvernement du Québec.

Table 2.5 *Adapted from SNC-Lavalin/Genivar Consortium, (2009), pp. 5-14 and pp. 5-15, reproduced with the kind permission of the Ministère des Transports et de la Mobilité durable du Québec, all rights reserved,* © Gouvernement du Québec.

Chapter 7

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Chapter 16

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Chapter 18

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Chapter 23

Photo – Main Building at the University of Texas at Austin. © 2014 Larry D. Moore. CC BY 4.0, https://commons.wikimedia.org/wiki/File:University_of_texas_at_austin_main_building_2014.jpg

Table 23.2: Median salary by degree in 2021 Canadian dollars, Adapted from *CBE—Life Sciences Education* (*LSE*) ©2016 by The American Society for Cell Biology (ASCB) , CC BY NC SA.

Figure 23.1 The decision tree, CBE—Life Sciences Education (*LSE*) ©2016 by The American Society for Cell Biology (ASCB) , *CC BY NC SA*.

Chapter 24

Photo – *Quebec City*. Source: Martin St-Amant, CC-BY-SA 3.0 via Wikipedia

*Figure 24.1a BRT in Xiamen.*Source: Dew1107, CC BY-SA 3.0, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Xiamen_BRT_18m.jpg

Figure 24.1b Tramway in Antwerp. Source: Willem_90, CC0, via Wikimedia Commons, https://fr.wikipedia.org/wiki/Tramway#/media/Fichier:De_Lijn_Albatros_5-delig_Lijn_10.jpg

Figure 24.2 Proposed route for the project reproduced with the kind permission of the City of Quebec, © City of Quebec.

Table 24.3 CBA results (net present value in millions of 2014 dollars), Reproduced with the kind permission of the City of Quebec, © City of Quebec.

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