Principles of Sustainability Economics

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Identifying the Gordian Knots

By

Jean-Marie Grether
and Inmaculada Martínez-Zarzoso

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To Aline, Eric and Yeleen

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FOREWORD

This short book is the result of more than a decade teaching courses on "environment and resource economics" and "sustainable development economics" at several publics and levels. The initial references were a selection of chapters of the excellent textbooks available at the time.[1] Over the years, a growing number of adaptations became necessary to answer the various needs of the audiences. The guiding principle has been to focus on the core contributions of economists in addressing environmental and sustainability issues. The result is the present textbook, which highlights the core principles, shows the relationships between them, and provides ad hoc problems to check their progressive understanding.

The first part presents the basic concepts used in the economic analysis of choices and their impact on collective welfare. Chapter 1 refers to a stylized case (the allocation of daytime between different activities) to illustrate under which conditions market-based decisions may be socially efficient. When they are not, societies have to deal with so-called "market failures", and the rest of the chapter exposes the major sources of market failures related to the environment. Chapter 2 presents the guiding principles to deal with these market failures. As the aim is to discuss sustainability, a particular attention is given to the estimation of future costs and benefits, and to the available methods for valuing the protection of environmental services and human lives.

These basic concepts are used in the second part of the book to address the major environmental challenges. Accounting for the sake of future generations is at the root of the sustainability concept. How economists propose to measure sustainable development in practice is detailed in chapter 3. Chapters 4 and 5 deal with the specificities of the two major types of environmental resources, renewable and depletable resources, how to use them in a sustainable way and why markets and governments often fail to

[1] In particular Perman, Roger, Ma, Y., Common, M., Maddison D. and Mcgilvray, J. 2012. Natural Resource and Environmental Economics, 4th edition., Pearson, and Tietenberg, Tom and Lewis, Lynne. 2018, Environmental & Natural Resource Economics, 11th edition, Routledge.

do so. Chapter 6 deals with environmental policy in two steps. It starts with the problem of pollution control, comparing the various instruments, and with a particular interest in pricing carbon emissions. It concludes on a more general note by discussing how technological progress and changes in social preferences may help to achieve sustainability.

We wish to thank all the students for their questions, remarks and criticisms which strongly contributed to improve the content of the book. Another special thank goes to the assistants Benjamin, Benedikt, Joséphine, Marc and Niccolò, who helped us to revise and clarify the notes, and to Stefan Ambec, Rob Elliott and Nicole Mathys for their excellent comments and suggestions. Our special thanks go to Marion Monney for her outstanding work on revising the content and the correction of problems and for her crucial contribution to the final stages of the manuscript preparation.

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INTRODUCTORY NOTE

Aim and content of book. Even if sustainable development is a booming topic, the book has been kept deliberately short. Facts, theories and policy measures are presented in a selective and synthetic way, focusing on the major trends and the basic principles. The presentation is kept simple, consistent and accessible to the general audience, even for those who are not familiar with the economic literature. It is just an introduction to the domain from an economic viewpoint. A deeper understanding of specific issues certainly requires further readings.

Chapter structure. Each chapter is constructed in a similar way. It starts with an abstract and a summary of the main learning objectives, followed by the presentation of the concepts and the discussion of their practical relevance. A set of progressive problems is proposed at the end of each chapter to strengthen understanding. The corresponding synthetic correction guides appear in the Appendix, along with a short recap of basic mathematical tools. The sequence of chapters is progressive, with more advanced chapters pointing to previously introduced concepts.

Additional resources are available at https://www.sustecon.org/. Two categories of complements to the book are freely downloadable from the Sustecon.org website. First, the interested reader will find more detailed bibliographical references, along with extensive corrections of the problems, including diagrams and worksheets. Second, additional material relevant to the topic are made available regularly.

ABBREVIATIONS

ANS	Adjusted Net Savings
BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CDR	Consumption Discount Rate
CE	Choice Experiments
CEA	Cost-efficiency Analysis
CV	Contingent Valuation
EPA	Environmental Protection Agency
ETS	Emission Trading System
GHG	Green-house Gases
HEE	Human Energy Equivalent
IAM	Integrated Assessment Model
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ITQ	Individual Transferable Quota
IW	Inclusive Wealth
IWR	Inclusive Wealth Report
MAC	Marginal Abatement Cost
MB	Marginal Benefit
MC	Marginal Cost
MD	Marginal Damage
MEC	Marginal Extraction Cost
MNB	Marginal Net Benefit

MRS	Marginal Rate of Substitution
MSY	Maximum Sustainable Yield
MUC	Marginal User Cost
NPV	Net Present Value
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of Petroleum Exporting Countries
PVMNB	Present Value of Marginal Net Benefit
RCT	Randomized Control Trials
RP	Revealed preferences
SCC	Social Cost of Carbon
SMC	Social Marginal Cost
ST	Stated preferences
STC	Social Total Cost
TB	Total Benefit
TBM	Total Benefit Maximisation
TC	Total Cost
TCM	Total Cost Minimisation
TEV	Total Economic Value
TNBM	Total Net Benefit Maximisation
UN	United Nations
VSL	Value of Statistical Life
WB	World Bank
WBDR	Well-Being Discount Rate
WON	Wealth of Nations
WTO	World Trade Organisation

CHAPTER 1:
MARKETS AND SOCIAL WELFARE

Abstract
This chapter presents a simplified model to analyse the relationship between human activity and the environment. Although very schematic, it is useful for two reasons. First, it introduces marginal thinking, one of the cornerstones of economic reasoning. Second, it offers a stylized but consistent explanation of two related facts. One the one hand, the relative economic efficiency of market-based economies vis-à-vis alternative economic systems, which helps understanding why, despite its defaults, capitalism remains so widespread today. On the other hand, it shows why market mechanisms fail to address many environmental issues. It concludes on three major types of market failures which are analysed in greater details in the rest of the book.

Learning objectives

- Discuss the benefits and costs of economic choices, including opportunity costs
- Link the concepts of marginal costs, marginal benefits and scarcity rent to social welfare
- Explain how price levels and changes may work as a coordination device
- Discuss how the invisible hand parabola is far from (or close to) reality
- Identify the major sources of market failures regarding the environment

1.1 Introduction

Over the last two centuries, market economies have been quite efficient in increasing physical well-being for their citizens, relying on billions of individual decisions guided by market prices. At the same time, this material progress has drastically increased the pressure on the environment. Economic growth has led to the destruction of natural habitats, reduction in biodiversity and alteration of global flows such as the nitrogen or carbon cycles, at an unprecedented scale.

This chapter provides an introduction on how economists look at the nexus between economic activity and the environment. It relies on marginal reasoning, a much-used analytical tool by economists, to illustrate how market forces and economic incentives may be both remarkably efficient on the one hand (increasing the material welfare of humans) and dramatically destroying on the other hand (putting entire ecosystems at risk).

The basic objective of the chapter is to introduce in a few pages the major concepts that economists use in practice to analyse environmental (and other) issues. Very often, these issues are very complex (e.g. biodiversity or climate change). Their proper understanding goes far beyond economics, involving almost all other social and natural sciences. However, to keep the exposition of this chapter tractable, we make three choices:

- We focus on the welfare of human beings. This may be criticized on behalf of the welfare of all other living creatures that are affected by human activities. We understand that criticism, but we keep the focus on humans because it is their behaviour that we try to analyse and possibly influence.
- We treat the impact of human societies on their environment rather than the reverse, although we do acknowledge the influence of the natural conditions on economic development (see Frankopan 2023 for a historical perspective).
- We keep the exposition and models as simple as possible. This may be difficult to admit given the complexity of the issues at stake. However, the objective of this first chapter is to highlight a few core concepts. More discussions will follow in the rest of the book.

A specific illustration of the "keep simple" guideline is the assumption that people are rational in the sense that they optimize an objective function (e.g. maximizing benefits or minimizing costs). This is often referred to as the ***Homo economicus*** assumption in the economic literature. It posits that each individual behaves completely selfishly. But are people only driven by such narrow and egoistic motives? The short answer is: “No”. However, it still makes sense to keep that assumption as an analytical starting point.

There has been an important debate among economists about this question at the turn of the last century. Empirical studies suggested that *Homo economicus* behaviour was either absent (e.g. Henrich et al. 2001) or magnified by theoretical teaching in economic faculties (Frank et al. 1993). The general view today, shared by most economists, is that people behave according to a variety of different drivers, many of them unlinked to private efficiency, like social concerns, beliefs and emotions. In fact, people may be particularly kind to each other, as argued by Bregman (2021) and trust and cooperation within human communities may have been at the root of economic development (see Seabright 2010). We will come back to these important considerations repeatedly in the text.

However, the fact that humans are social and cooperative beings does not preclude efficiency issues from being relevant. People do face physical and economic constraints and have preferences over feasible alternatives. The approach developed by economists help to account for these constraints and analyse how they condition individual choices. One could even argue that, from a natural selection perspective, those individuals who made the most efficient choices may have prevailed in the long run (e.g. Frank 2011). Independently of this last argument, identifying the most efficient choice is a relevant question whether it is followed in practice or not, because it opens the way for corrective measures to improve our efficiency in using resources, whether natural or human made. Thus, in this introductory chapter, we will often keep the rationality assumption, not because it is an appropriate representation of how people behave, but because it constitutes a useful benchmark to discuss the social efficiency of actual human choices.

We will proceed in two steps and three sections. In the first step, we propose estimates of social welfare in human societies, and we look at the conditions for social efficiency, i.e., social welfare maximization. Social welfare is conceived here in a very broad sense, as the difference between all the benefits and all the costs generated by human activities. We start with the simplest possible setting in section 1.2, analysing a society with only one person. We generalize the perspective in section 1.3, considering societies with many individuals and many activities. We list the restrictive conditions under which a market-based economy can be expected to be socially efficient. These conditions are crucial for the "invisible hand" result, i.e., a situation in which decentralized and selfish individual decisions lead (surprisingly) to social efficiency. This concludes the first step, illustrating how market forces may contribute to efficiency and overall welfare.

The second step consists of showing how taking the environment more seriously into account leads to the reverse, i.e., market failures or situations where market forces do not lead to the most desirable outcome, even for humans. This is done in section 1.4, which considers three canonical cases of market failures: externalities, intergenerational dependences and common pool resources. It illustrates how economic incentives lead to a mismanagement of natural resources. It also indicates relevant ways to prevent this outcome.

As a matter of illustration of the theories outlined in the book, a female character, Mrs. Robinson, is created. She resembles Robinson Crusoe, who has appeared in numerous economics' textbooks and has been cited by many economists. The reason the profession loves Crusoe is because a "single man" economy is a brilliant simplification of reality and a powerful way to explain the logic of economic models (The Economist 2023).

1.2 Individual choices

Imagine Mrs. Robinson, alone on her isolated island. Apart from leisure, which consists of making ricochets on the beach, her unique other activity is collecting blueberries. This may sound over-simplistic, but it will help define how people deal with constraints, specifically the fact that available time per day is limited. Out of a maximum of $\bar{h}$ non-sleeping hours per day, how much time should Mrs. Robinson devote to blueberry collection ("work") rather than leisure ("play")?

This is a basic problem of allocation of a scarce resource, "time" in that case, between two alternative uses. The key dimension which is introduced to solve the case is the assumption that there are **decreasing returns** on each use i.e., satisfaction increases with use (the more blueberries or ricochets the happier she is), but at lower and lower rates (each additional hour on collecting blueberries or throwing stones on the water surface generates a smaller and smaller increase in happiness). As a result, some intermediate allocation between working all the time and playing all the time should be optimal. We provide three alternative ways to prove more formally the intuition and solve this basic problem; each approach being exploited later in the book (see also problems at the end of this chapter for simple numerical applications).

1.2.1 Leisure, blueberries and marginal benefits

In figure 1.1 time is read on the horizontal axis, with a total length of $\bar{h}$, and two origins: O on the left to read leisure time (h) from left to right, and $\tilde{O}$ on the right to read blueberry collection time ($\tilde{h}$) from right to left. By construction, each point on the horizontal axis represents a given allocation of time between leisure and fruit collection (as $\bar{h} = h + \tilde{h}$, we have both $h = \bar{h} - \tilde{h}$ and $\tilde{h} = \bar{h} - h$). Thus, we call figure 1.1 an *allocation box*.

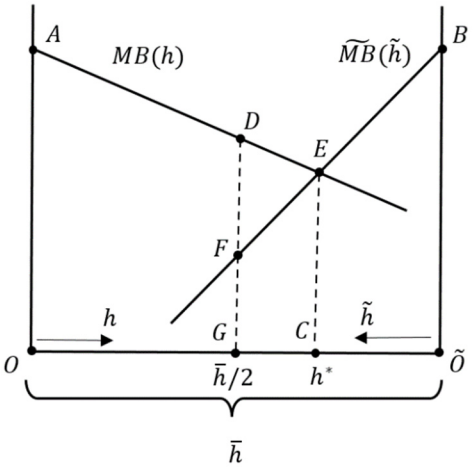

Figure 1.1: Optimality in the allocation box: marginal benefits

Welfare (or satisfaction) per additional time is represented on the vertical axis for each use. We assume that Mrs. Robinson has stable and well-known preferences over blueberries and leisure. We define extra perceived welfare for a small additional time (say a second) devoted to a specific use as the **Marginal Benefit** for this use, and we write it $MB(h)$ for leisure, $\widetilde{MB}(\tilde{h})$ for blueberries. How is welfare measured? In what follows, we will assume arbitrarily that welfare is expressed in terms of shells. That could be euros or dollars in a different context, and welfare measurement would certainly deserve further discussion. Here again the aim is to simplify. What we need for a start is just an accounting unit to aggregate (sum up) benefits or costs across different uses and also to compare benefits with costs. Shells will do for the moment.

More importantly, for each activity, we assume that **the marginal benefit is decreasing** with time. Each additional second spent on ricochets (or berries) procures less additional satisfaction to Mrs. Robinson than the previous units. In other words, the $MB(h)$ curve is downward-sloping going left to right, and the $\widetilde{MB}(\tilde{h})$ curve is decreasing going right to left. This property could be due to two reasons: a saturation effect on the consumption side or a decrease in the productivity of Mrs. Robinson's labour. For ease of interpretation, we will discard the latter and assume that labour productivity is constant.