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Introduction

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Energy policy is one of the most important issues facing the world today. This can be easily explained by looking at three dramatic changes taking place on our planet: first, the explosion of human population – in the last century, world population has more than tripled from approximately 1.7 billion people in 1900 to more than 6 billion people in 2000.[1] Even more impressive has been the increase in the pace of population growth. World population has grown from 3.5 billion people at the beginning of the 1970s to 6.5 billion people in 2005. In just 35 years, world population increased by more than 3 billion people – a quantity more than the growth in the previous 35 thousand years! Second, the dramatic economic growth that took place in the last century, leading to the process of globalization of the economy. As remarked by the Millennium Ecosystem Assessment,[2] technological progress has been able to handle pretty well this dramatic increase in the size of human societies:

> *Since 1960, while population doubled and economic activity increased 6-fold, food production increased 2½ times, food price declined, water use doubled, wood harvest for pulp tripled and hydropower doubled.*[3]

And third, an increasing stress on the environment and natural resources, which has been generated by the simultaneous skyrocketing of both population and affluence. Again quoting the findings of the Millennium Ecosystem Assessment:

> *Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.*[4]

In considering the combined effects of these changes, it is clear that the economic problem associated with the need of satisfying the rapidly increasing demand for energy while respecting the environment is more and more becoming a mission impossible. In fact, if we admit that increased consumption of natural resources associated with an increasing consumption of energy, specifically fossil fuels, is required to produce and consume more goods and services per capita for more people, then we have also to admit that, sooner or later, economic growth will have to face the unavoidable existence of biophysical constraints. As Daly has stated, economic growth nowadays is taking place in a 'full world' (Daly, 1996).

In the field of energy policy, the discussion has been dominated by the debate of two key issues: first, peak oil (since fossil energy is not renewable – it is not produced, but extracted from stocks – the finiteness of these stocks and the continuous increase in the pace of consumption entails that sooner or later the reserves of oil and natural gas will be depleted). Peak oil indicates the point on the curve at which the pace of discovery of new reserves becomes lower than the pace at which existing reserves are depleted. This is analogous to a situation in which a bank account starts to be depleted because spending (withdrawal) surpasses earnings (deposit). And second, the global warming associated with the greenhouse effect (the accumulation of CO_2 and other gases generated by the metabolism of the global economy is affecting the normal functioning of Gaia[5]).

There are two ways to deal with the huge predicament associated with the acknowledgment of the unavoidable existence of biophysical constraints affecting the feasibility of 'perpetual economic growth' on a finite planet:

1. considering the option that humans should start looking for alternative patterns of development no longer based on the maximization of GDP; or
2. remaining tied to the ideological statement that the exponential growth of both population and consumption per capita can go on for ever thanks to a continuous supply of 'silver bullets' provided by technological progress.

As a matter of fact, traditional economic theory suggests that the problem represented by the existence of biophysical constraints on the expansion of the global economy will be solved by the markets. The theory states that:

> *as demand for energy increases and the supply of natural resources to produce energy diminishes, the price of energy will increase. These price signals will encourage investment in energy-efficient technological advancements.* (Hicks, 1932, pp124–125)

Policymakers around the world have clung to Hicks's 'induced innovation' hypothesis and made it one of the central components of their national energy and environmental policies. Technology will create environmental improvement with the least effect on the economy (Foster, 2000).

This confidence in the power of progress and technology provides the justification for refusing to consider the hypothesis of looking for alternative paths of development. Indeed the great achievements of human progress (the first quote of the Millennium Ecosystem Assessment) seem to justify such ideological intoxication. In the 20th century, technological progress provided humankind a power never dreamed of in the past. However, this technical progress was driven by a huge increase in energy consumption – fossil energy. In other words, since the industrial revolution the success of human technology has depended on a continuous increase in the rate of consumption of fossil energy. What then would happen if fossil fuels run out?

This is why, to save the dominant civilization from a possible decline or from the stress of re-discussing existing priorities, many believe that another type of silver bullet is needed: 'energy-efficient technological improvements'. This, it is claimed, is the type of solution that progress has to provide against energy shortages and, by extension, environmental degradation. Indeed many policymakers, traditional economists and members of the general public believe in this solution. With this book we want to challenge this belief.

Certainly, one would think that improvements in energy efficiency will reduce energy consumption and increase the effect of a given supply. Yet the point we want to make in this book is that this is not always the case. We aim to show that increased energy efficiency leads to increased demand and consumption of energy. This hypothesis is an extension of the Jevons Paradox, which operates when an increase in efficiency in using a resource leads to a medium- to long-term increase in the consumption of that resource rather than a reduction (Giampietro and Mayumi, 2006).

As noted earlier, the growing appetite for energy is a product of many factors, most notably rising incomes, increasing population, better access to energy and increasing international trade. Thus the implications of the existence of the Jevons Paradox in the energy sector are numerous. Primarily, the Jevons Paradox would indicate that market-based solutions will not solve today's energy or related environmental problems. Currently over half of the world's population do not have access to commercial energy (Banerjee, 2005, p2). As those countries that are on the verge of developed country status continue to modernize, the demand for energy will further increase. Thus the energy/environment nexus is at a critical stage.

Nearly all the products consumed in the world today are produced using fossil fuels, which are not a renewable source of energy. The traditional school of thought would have you believe that technological improvements making energy use more efficient will be the solution. However, as you will see throughout this book, this is not the case. The Jevons Paradox is little known outside some academic circles, but we argue that a sound understanding of it is important not only for policymakers but also for other stakeholders and the general public.

We have written this book to provide a warning that relying on energy efficiency and technology as a solution is foolhardy. The book is organized so as to provide a complete introduction to the Jevons Paradox, from its origins, through a theoretical framework of the topic, to an applied empirical approach.

Chapter 2 provides a detailed historical background of the Jevons Paradox and frames the issue from a historical perspective. In it Blake Alcott provides a thorough and detailed introduction to the topic. Specifically, he reviews the historical roots of the Jevons Paradox, examines the theoretical case for the Jevons Paradox and then applies that to the modern version, known as the rebound effect. Alcott then explores Jevons's analogy with the employment effects of improved efficiency of labour and presents an analysis of these arguments. Finally, he debates how to incorporate Jevons's findings and the rebound debate into sustainable development policies.

Chapter 3 examines the issue from both an epistemological viewpoint and a thermodynamic viewpoint and then offers an alternative to the traditional economic method of modelling the interaction between the economy and the environment. Mario Giampietro and Kozo Mayumi build upon the background provided in Chapter 2 to present the epistemological challenges of modelling evolving metabolic systems. This chapter also presents a thermodynamic analysis of the Jevons Paradox. Such a discussion is important because social systems are evolving open systems that cannot escape the constraints set by the laws of thermodynamics. Within this larger whole, the energy market is just a subsystem. The main purpose of the chapter is to provide a general theoretical framework by which a comprehensive understanding of the paradox can be acquired. At the same time it is argued that the Jevons Paradox reflects a standard epistemological predicament associated with the analysis of evolving metabolic systems organized in nested hierarchical levels – social and ecological systems are typical examples of these systems. The Jevons Paradox is always with us when perceiving, representing and analysing these systems.

Chapter 4 provides an empirical analysis to provide evidence that the Jevons Paradox may exist at both national and regional levels. John M. Polimeni uses an analysis of various countries and regions to provide empirical evidence that the paradox may operate at a macro level for energy consumption. Specifically, he uses some of the primary variables thought to cause increases in energy consumption, as well as a proxy for energy-efficient technological improvements, to decipher whether energy efficiency is the primary factor in increased energy consumption. Previous empirical studies have shown that the Jevons Paradox operates for individual energy consumption uses or types of energy, but few have explored it from a macroeconomic perspective. Analysis of this kind is important because policymakers are relying on technology to counter the effects of increased energy demand, and hence increased consumption of natural resources.

The book ends with a summary of the findings and a discussion of the implications of the Jevons Paradox. Included in Chapter 5 is an examination of alternative energy policies that may be used to counter the path the world is on by relying on energy-efficient technologies as a solution.

NOTES

1 www.census.gov/ipc/www/wp98001.html.
2 Finding number 2 in the executive summary slide show presentation (see www.millenniumassessment.org/documents/document.360.aspx.ppt).
3 Finding number 1 in the executive summary slide show presentation (see www.millenniumassessment.org/documents/document.360.aspx.ppt).
4 www.millenniumassessment.org/documents/document.360.aspx.ppt.
5 The expression 'Gaia' refers to the conceptualization that the planet Earth should be viewed as a complex of autopoietic systems acting as a sort of integrated super-organism. This idea was proposed originally by Lovelock and Margulis (1974) and then elaborated in more detail in Lovelock (1979). The name Gaia refers to the concept of Mother Earth and it was used by the Greeks for indicating the relative goddess.

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