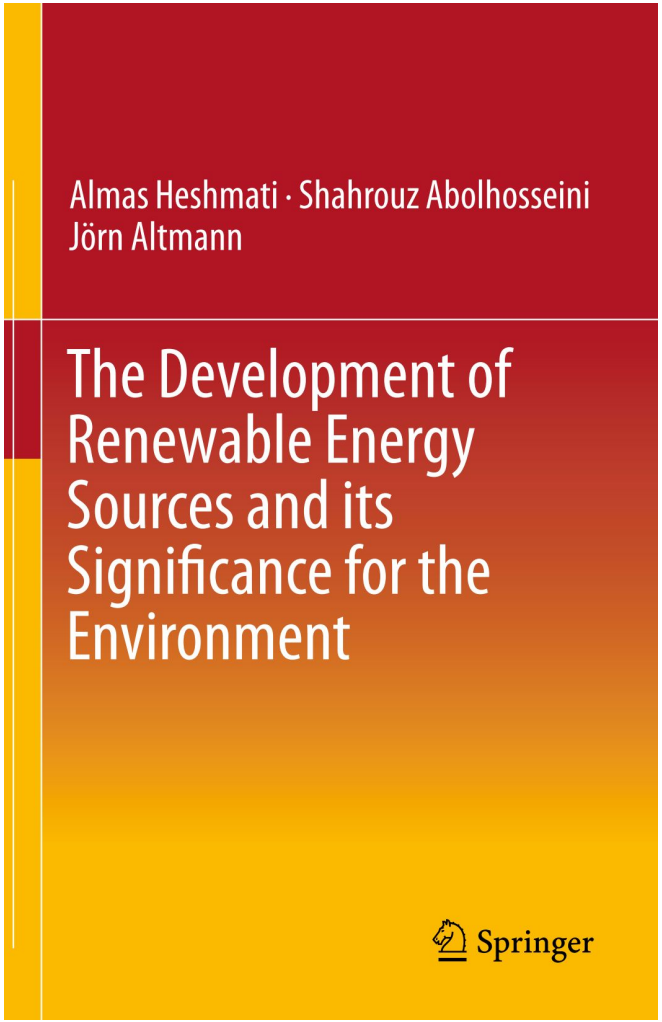

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The Development of Renewable Energy Sources and its Significance for the Environment

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Preface

The ongoing concerns about climate change have made renewable energy sources an important topic of research. Several scholars have applied different methodologies for examining the relationship between energy consumption, environment and economic growth of individual countries and groups of countries, in order to understand the effects of energy policies. In particular, previous studies have analyzed carbon dioxide emission savings made through the use of renewable energy from an individual source or in combination with traditional sources of energy by applying life-cycle analysis methods. This research has shown that after a certain period, economic growth leads to the promotion of the environmental quality. However, econometric critiques have opposed the results of these studies. Moreover, the effectiveness of governance-related parameters has been neglected in these studies. In this research, among others we analyze the impact of renewable energy development on carbon dioxide emission reduction.

In this volume, a number of issues are discussed that play a crucial role in enhancing the deployment of renewable energy, namely, the energy–environment relationship, alternative renewable energy production technologies, regulation frameworks for renewable energy sources, financing renewable energy development, and the market design for trading commoditized electricity generated by small renewable energy sources. Local power generation, which is the basis of renewable energy production, encourages the production of renewable energy resources, decreases transmission loss, increases saving energy, and enhances energy efficiency. Therefore, the integration of local, renewable energy sources and smart grids through local marketplaces that trade renewable energy in small units is a promising solution.

There are several points making this book unique compared to others. It analyzes important aspects of renewable energy development and its challenges. A model is developed to evaluate the effectiveness of renewable energy development, technological innovation, market for trade, and market regulations with respect to carbon dioxide emission reduction. For this purpose, a panel data model is applied to data from the EU-15 countries between 1995 and 2010. The effects of renewable energy on carbon emission reduction in EU-15 is investigated. The findings show that the effects of climate change can be mitigated by governance-related parameters in addition to regulations, economic incentives, and technology development measures. It proposes a marketplace for trading renewable energy sources and provides suitable and evidence-based policy recommendations to promote renewable energies to substitute fossil fuels.

The subject of this work is development of renewable energy sources and their significance for the environment. A number of issues of particular interest to the readers are raised. We present the development of different renewable sources in recent decades and forecasts for future illustrated in figures and tables. Some regression analysis is also used for establishing relationship between emission and use of renewable energies. The key features of this work is its deep review and analysis of technologies, finances, environment and trade markets for renewable energy sources. It provides an up-to-date review of the literature considering production and consumption of renewable energy sources at country, regional and global levels.

Deployment of renewable energy and technological innovations can be used to reduce carbon emissions. Tariffs, finances, tax policies, and energy efficiency are used by governments to develop renewable energy. State research and development support, innovation, finances, and regulations have impacted the market for renewable energies. The effects of different technology, regulations and financial support factors on emission reductions are estimated. The structure of a marketplace for renewable energy sources is proposed and the requirements for the marketplace to function are outlined. Suitable policy recommendations are provided to enhance the efficient operation of market for renewable energies. Researchers, professionals, decision makers, environmentalists, non-governmental organizations, graduate students, postgraduate students, and public and private utilities will benefit from reading this research.

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Chapter 1
Introduction

1.1 Background

Industry's electricity consumption will comprise an increasing share of the global energy demand during the next two decades. It is expected that the growth rate of electricity consumption will be more than that of the consumption of other sources of energy (e.g., liquid fuels, natural gas, and coal) (IEA 2012). The increasing prices of fossil fuels such as crude oil and the increasing concerns about the environmental consequences of greenhouse gas emissions have renewed the interest in the development of alternative energy resources. In particular, the Fukushima Daiichi accident was a turning point in the call for alternative energy sources. Renewable energy is now considered a more desirable source of fuel than nuclear power plants because of the absence of fatal risks.

Considering that carbon dioxide is the major greenhouse gas (GHG), there is a global concern about reducing carbon dioxide emissions. Different policies can be applied in this regard (e.g., enhancing renewable energy deployment and encouraging technological innovations). In addition, supporting mechanisms (e.g., feed-in tariffs, renewable portfolio standards, and tax policies) can be employed by governments to increase renewable energy generation and achieve energy efficiency. Many countries have started installing facilities for power generation that can use renewable energy sources. However, the share of a renewable energy supply differs by region and country. Europe is considered at the forefront of using renewable energy technologies.

The research literature on the relationship between energy consumption and economic growth is extensive. Many researchers have studied the effectiveness of conservative energy policies on economic activities. Some researchers (Fthenakis et al. 2008; Crawford 2009; Frick et al. 2010) have measured the amount of carbon saving by using the life-cycle analysis method. Other researchers have analyzed carbon emission saving by enhancing energy efficiency through cogeneration and advanced technology (Shipley et al. 2008; Kiviluoma and Meibom 2010; Wille-Haussmann et al. 2010). However, no previous study has measured the amount of carbon emission reduction and the interaction effects of different policy tools that support mechanisms to enhance renewable energy sources (generation and consumption), technological innovation, and market regulation.

The methodology used by early researchers to investigate the relationship between emissions and gross domestic product (GDP) per capita is not appropriate. Some researchers such as Stern (2004), Müller-Fürstenberger and Wagner (2007), and Wagner (2008) have cast doubt on the existence of an inverted U-shaped curve showing the relation between carbon emissions and GDP per capita. They argued that the results were obtained by commonly used estimation methods that have serious problems. For instance, the issues of causality and its direction are well established.

Furthermore, a study (Dasgupta et al. 2004) pointed out that this relationship is not as rigid as proposed as poor countries were mistakenly assumed to not have strong governance. The role of GDP growth in CO_2 emission reduction could be reduced by the regulations applied by the governments of such countries. In addition, other parameters such as technological innovation and environmental tax could play an important role in emission reduction. The direct impact of each parameter might change when it is affected by the impact of interactions between different variables.

1.2 The Objective

This research aims to analyze the effects of power generated by renewable energy sources, renewable energy production technology, energy efficiency, and market regulation on carbon emissions. These parameters have direct and indirect effects on carbon emission reduction. For example, environmental tax could reduce carbon emissions directly by decreasing fossil fuel consumption or stimulating energy savings through technological innovation. In addition, renewable energy sources could affect both economic growth and the environment. After analyzing renewable energy consumption, production technology, market regulation, and their relations in detail, we devised a model to measure the extent of their effectiveness and the result of interactions between these parameters. Based on these results, we proposed the structure of a marketplace for renewable energy sources and outlined the requirements for this market to function effectively.

As Europe is considered to be at the forefront of renewable energy deployment, this study selected the EU-15 countries[1] to examine the effects of renewable energy generation on carbon dioxide emission reduction. We examine the long-term effects of related policies on carbon dioxide emissions of individual countries and the group of EU-15 countries. We compare the effect of each variable over time and across countries. Three hypotheses are posed:

1. The power generated by renewable energy sources in the EU-15 has been able to affect carbon dioxide emission through the displacement of traditional capacity fueled by fossil fuels. Moreover, we expect a negative elasticity for renewable energy sources regarding carbon dioxide emission.
2. Technological advances are able to decrease carbon dioxide emissions by decreasing the costs of renewable energy sources and enhancing energy efficiency. Therefore, we expect a negative relation between technological innovation and carbon dioxide emission.
3. Environmental taxes applied by governments have a direct negative relation with carbon dioxide emissions. The size of this parameter could indicate its importance in comparing renewable energy development and technological innovation. We expect negative elasticity for environmental tax.

We review the relevant literature on the effectiveness of renewable energy development, production technology, and market regulation on reducing carbon dioxide emissions. Based on this, we derive appropriate variables for measuring their impacts on carbon dioxide emission reduction. The effectiveness of technological innovation will be determined by examining patent applications that adopt climate change mitigation and information and communications technology (ICT) patent applications. We apply the panel data method to develop our model in the form of the translog function to investigate the interaction effects of different parameters. After estimation of the model, the elasticity of carbon dioxide emission in relation to GDP, renewable energy generation, energy patent applications, ICT patents, and environmental taxation trends is calculated. In economics, elasticity is the measurement of how change in one variable affects another variable, assuming that all other variables are kept constant. We use this term to measure the effectiveness of the aforementioned variables on carbon dioxide emission.

Our results help identify the variables that have a greater impact on carbon dioxide emission reduction. In addition, the results indicate that policymakers should apply the policies that are the most effective in achieving targets.

The contribution of this research lies in defining three variables (i.e., renewable energy generation, technological innovation, and environmental tax) with regard to the Environmental Kuznets Curve and analyzing their effects on carbon dioxide emission per capita. For the analysis, we employ the number of patents and the amount of environmental taxes for measuring technology and market regulation impacts instead of research and development (R&D) expenditures, which were used by previous research. We also calculate the elasticity of carbon dioxide emissions per capita over time for each EU-15 country and for all EU-15 countries jointly. We also apply an estimation methodology to overcome the econometric issues neglected by the early researchers. Many researchers have estimated fixed-effect models without applying regression diagnostic tests (Cropper and Griffiths 1994; Shafik 1994; Horvath 1997; Moomaw and Unruh 1997; and Suri and Chapman 1998). Our

[1]The EU-15 comprised the following 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, and United Kingdom.

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estimation method differs from most studies in its use of feasible generalized least squares (FGLS) to correct heteroscedasticity and autocorrelation. The FGLS method is appropriate for this, as demonstrated by Stern (2002), Aldy (2005), and Luzzati and Orsini (2009) in their research.

1.3 The Outline

In the next chapter, we focus on the current situation of renewable energy consumption and the global outlook. We also review the roles of economic growth, energy security, and carbon dioxide emission reduction as the main drivers in the development of renewable energy. Chapter 3 provides a review of the literature on renewable energy supply technologies and energy efficiency technologies. While we analyze different regulations for increasing the renewable energy deployments in Chap. 4, we focus on financial supporting mechanisms and cross-national incentive policies for enhancing renewable energy deployment in Chap. 5. Based on these results, we propose the requirements and structure of a marketplace for trading small units of renewable energy in Chap. 6. In Chap. 7, we describe our model for evaluating the impact of renewable energy generation, economic growth, technological innovation, and environmental tax on carbon dioxide emission reduction in EU. The results of this model, which are discussed in Chap. 8, could be used by governments to make effective policies to achieve their targets of carbon dioxide emission reduction and climate change mitigation.

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Concerns about climate change have made Renewable Energy Sources (RES) an important research topic.

Of interest is the relationship between

- Energy consumption
- Environment
- Economic growth.

After some time, economic growth leads to the promotion of environmental quality (➔ Environmental Kuznets Curves, EKC).

Your textbook analyzes the impact of Renewable Energy (RE) development on the reduction of CO_2 emissions.

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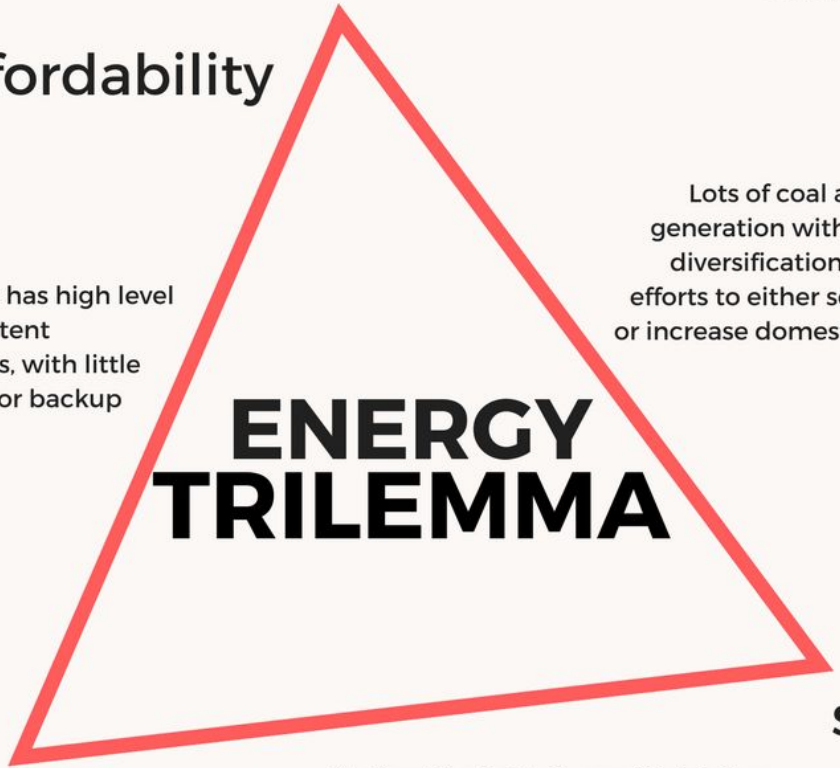


Issues that may play a crucial role in enhancing the deployment of RE:

- Energy-environment relationship
- Alternative RE production technologies
- Regulation frameworks for RES
- Financing RE development
- Market design for trading commodity electricity generated by small RES
    - And prosumers!

Basis of RE production = local power generation:

- Encourages production of RE resources
- Decreases transmission losses
- Increases energy savings
- Enhances energy efficiency.

Integration of local RES & smart grids in local marketplaces.

Your textbook concludes that the effects of climate change may be mitigated by

- Government regulations
- Economic incentives
- Technology development.

Evidence-based policy recommendations may help promote RE to replace fossil fuels.

The textbook also presents the development of different RES in recent decades & some forecasts (but remember that the book is published in 2015).

Who may benefit from this research:

- Researchers
- Professionals
- Decision makers
- Environmentalists
- NGOs
- Public & private utilities
- Graduate students.

Reasons for the increased appeal of RE:

- Industrial electricity consumption
- Growth rate of electricity consumption
- Increasing prices of fossil fuels
- Increasing concerns about environmental consequences of GHG (greenhouse gas) emissions
- Fukushima Daiichi nuclear accident (2011).

Supporting policies and mechanisms are employed by governments to

- Increase RE generation and consumption
- Boost technological innovation
- Regulate the market.

The European Union (EU) is at the forefront of RE technologies.

Research focuses on the relationship between

- energy consumption and
- economic growth.

Regarding EKCs:

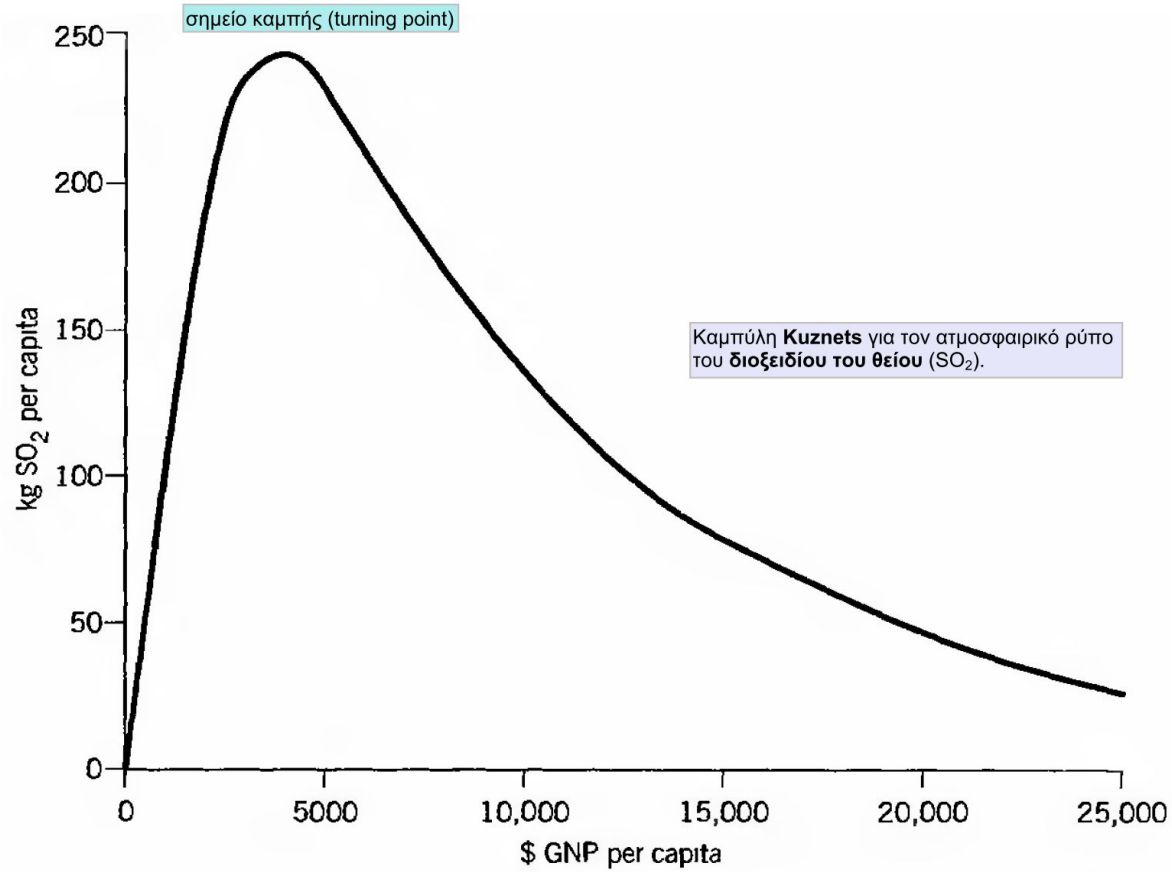
- Doubt on the existence of an inverted U-shaped curve showing the relationship between CO_2 emissions and GDP per capita (EKC)
- The role of GDP in CO_2 emissions may be reduced by regulations applied by governments.

Table 1
Water Pollution and Income

Pollutant	EKC Turning Point	
	1985 US$	2001 US$
Arsenic	$ 4,900	$ 8,000
Biological oxygen demand	7,600	12,500
Cadmium	5,000	8,200
Chemical oxygen demand	7,900	13,000
Dissolved oxygen	2,700	4,400
Fecal coliform	8,000	13,100
Nitrates	2,000	3,300
Lead	10,500	17,200
Smoke	6,200	10,200
Sulfur dioxide	4,100	6,700
Total coliform	3,000	4,900

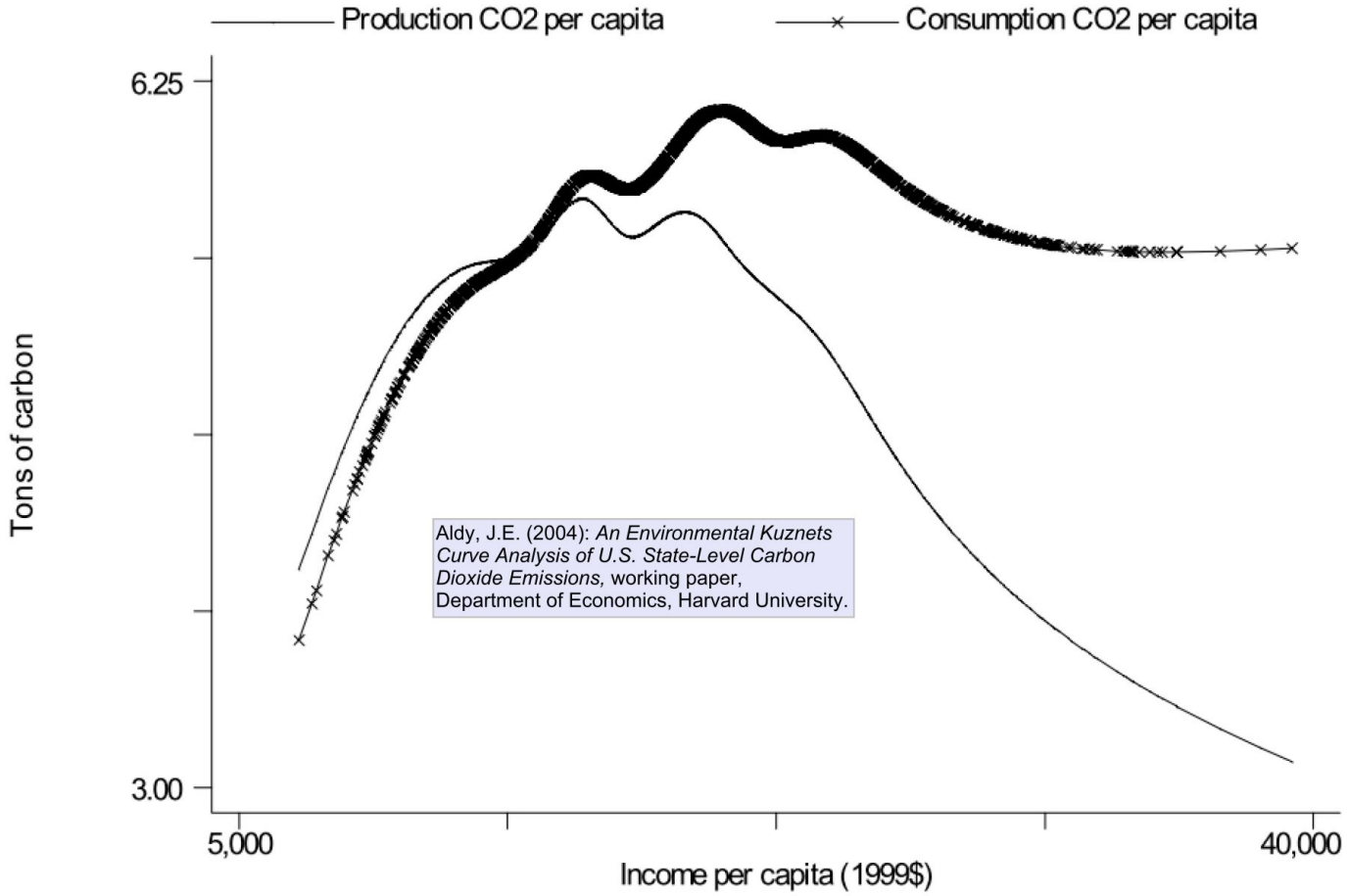
Note: The values for 2001 U.S. dollars are approximate.

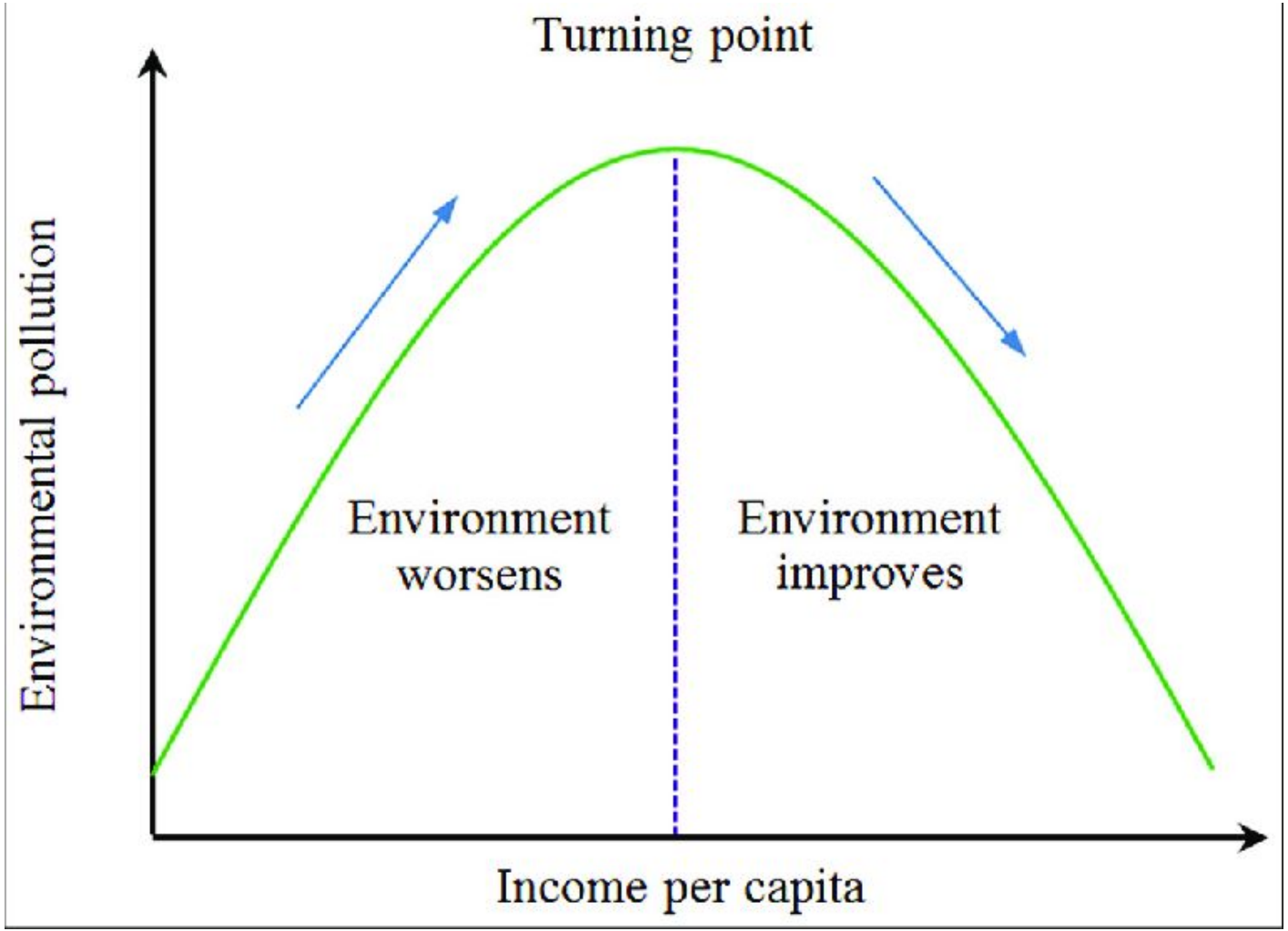
Source: Grossman and Krueger (1995).

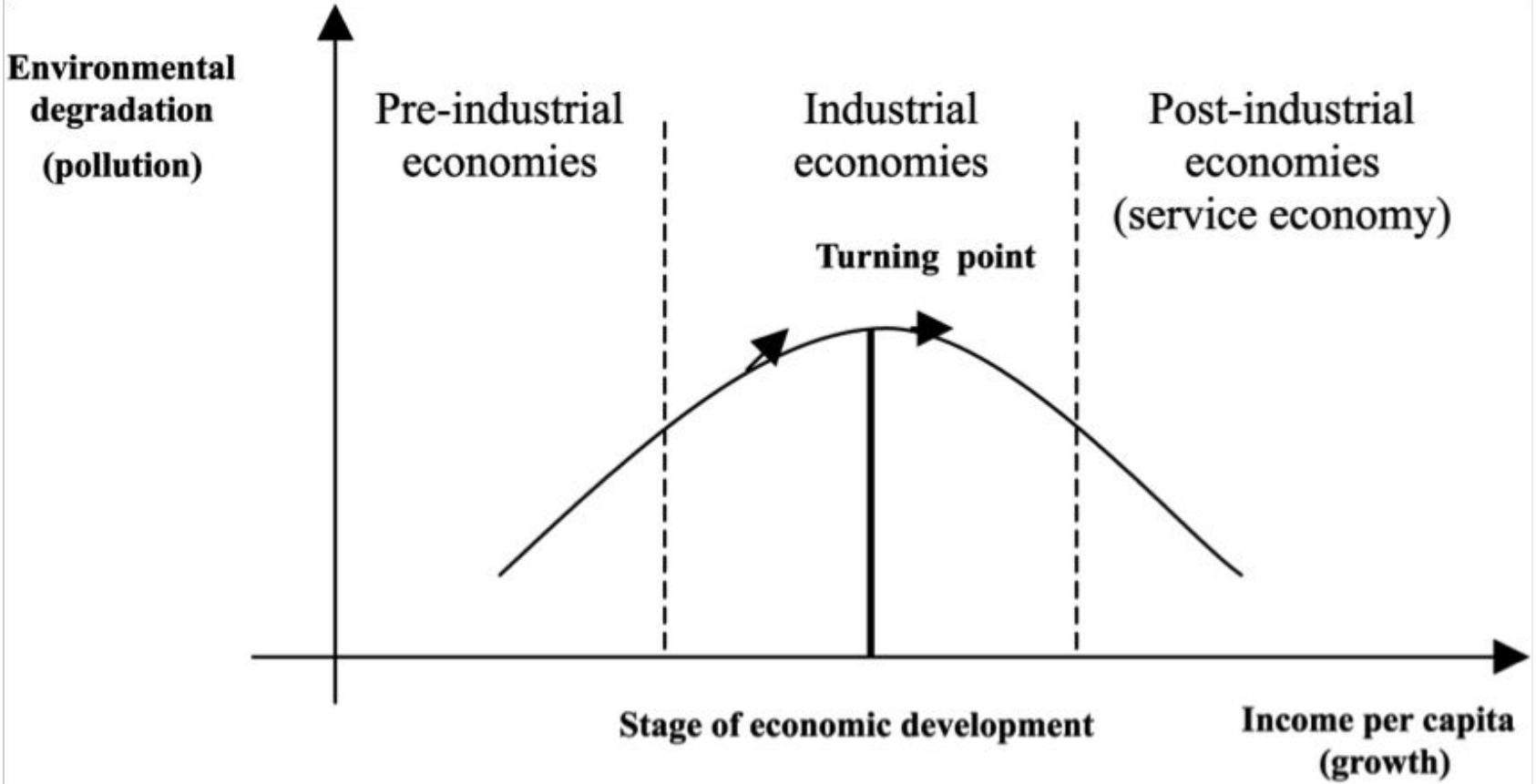


Καμπύλη **Kuznets** για τον ατμοσφαιρικό ρύπο του **διοξειδίου του θείου** (SO_2).

Figure 2.2 *An Environmental Kuznets Curve for Sulphur Dioxide*

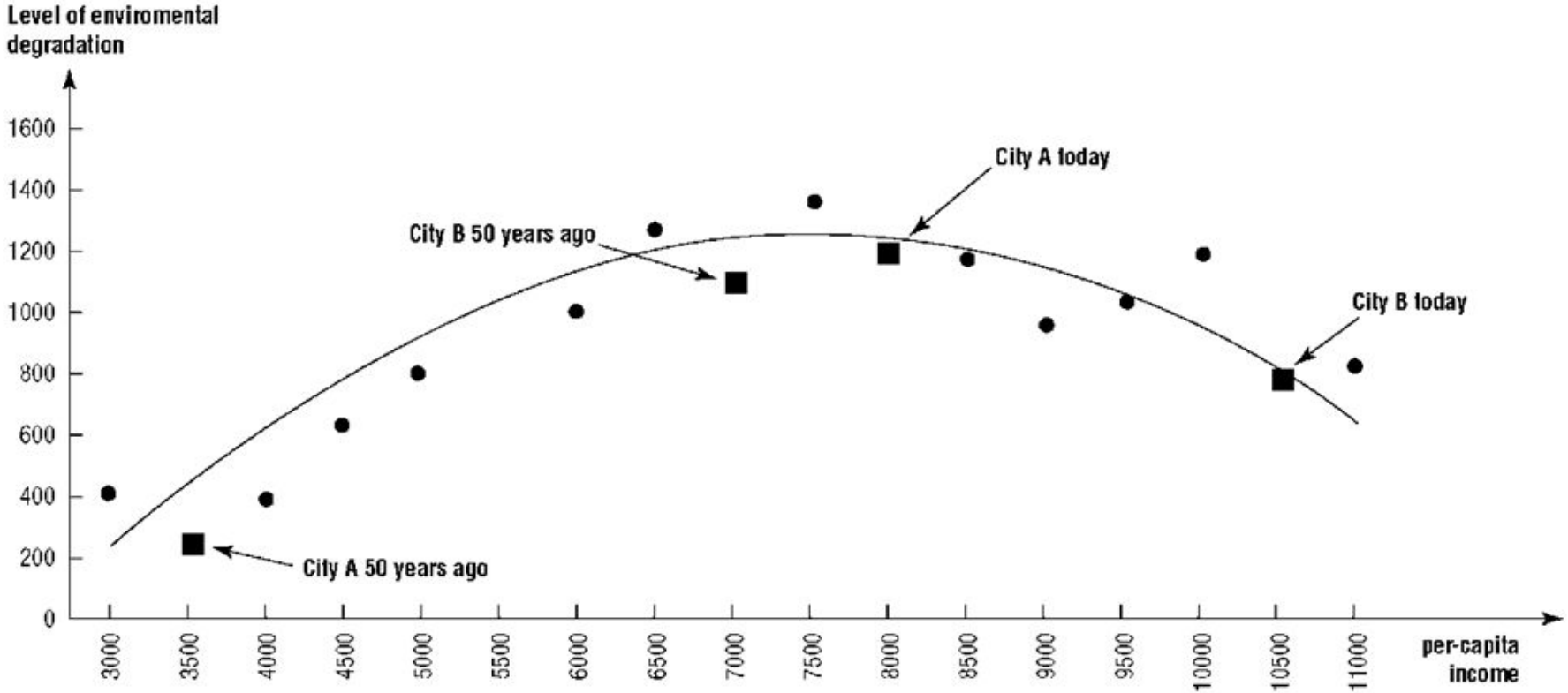

Production CO2 per capita
Consumption CO2 per capita
6.25
3.00
Tons of carbon
5,000
40,000
Income per capita (1999$)
Aldy, J.E. (2004): *An Environmental Kuznets Curve Analysis of U.S. State-Level Carbon Dioxide Emissions,* working paper, Department of Economics, Harvard University.


Turning point
Environmental pollution
Environment worsens
Environment improves
Income per capita

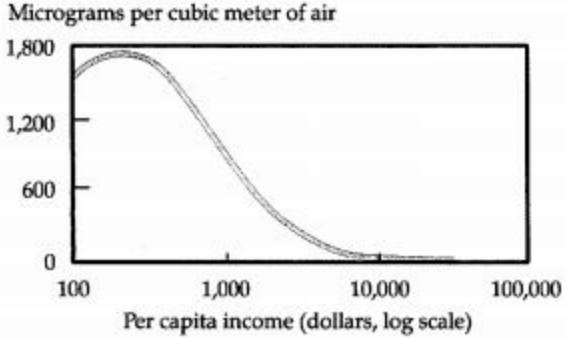


Source: Panayotou (1993)

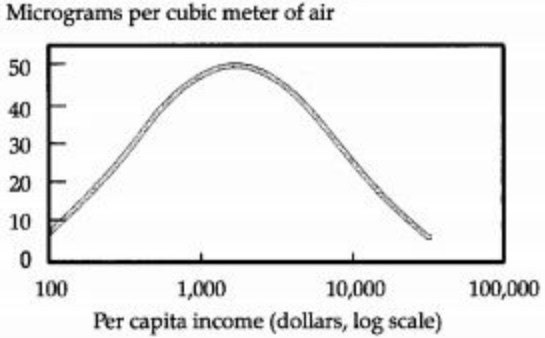
Graphical representation of the intuition behind the environmental Kuznets curve



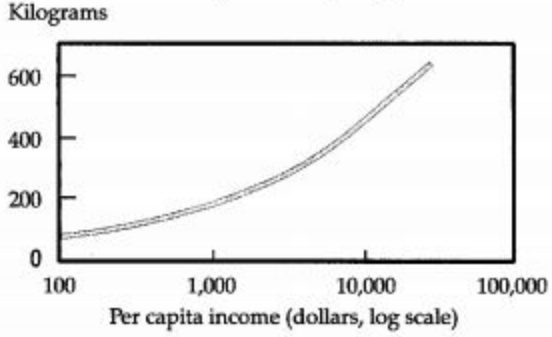
Urban concentrations of particulate matter



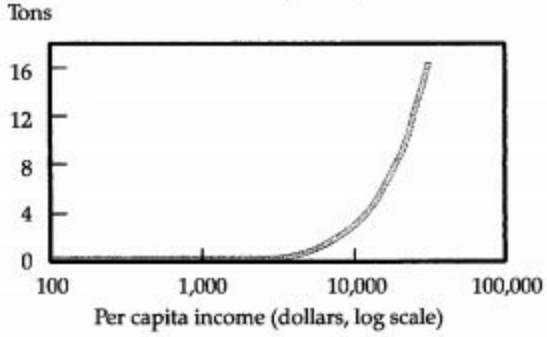
Urban concentrations of sulfur dioxide



Municipal wastes per capita



Carbon dioxide emissions per capita[a]



Note: Estimates are based on cross-country regression analysis of data from the 1980s.
a. Emissions are from fossil fuels.
Sources: Shafik and Bandyopadhyay, background paper; World Bank data.

Effects on carbon emissions of

- Power generated by RES
- RE production technologies
- Energy efficiency
- Market regulation.

For example, environmental taxation can reduce carbon emissions by

- Decreasing fossil fuel consumption (direct effect)
- Stimulating energy conservation through technological innovation (indirect effect).

Policy makers should apply the policies that are the most effective in achieving targets.

Your textbook is a research study analyzing the effect of the following on CO_2 emissions per capita (via EKC):

- RE generation
- Technological innovation
- Environmental taxation.

Elasticity of CO_2 emissions per capita over time

- For each EU country.

(Elasticity = measure of responsiveness to a change)

Your textbook focuses on

- Current situation of RES consumption globally
- Roles of following factors as main drivers of development of RES
  - Economic growth
  - Energy security
  - CO_2 emissions

Textbook focuses on

- Financial supporting mechanisms
- Cross-national incentive policies for enhancing RES deployment.

Textbook develops a model for evaluating the impact on the reduction of CO_2 emissions of the following factors:

- RE generation
- Economic growth
- Technological innovation
- Environmental taxation.