Economic Modelling of Climate Change and Energy Policies

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Contents

Figures

Tables

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Preface

Adam Smith famously remarked: 'Man is the only animal that makes bargains; one dog does not change bones with another dog.' Europe has mobilised this unique ability of our species to trade to address the challenge of global warming. Carbon dioxide is the main greenhouse gas. For the first time since history began, beginning in January 2006, you can call your broker and buy (and sell) as many tonnes of it as you like on the European Union Emissions Trading market. The creation of this market is the most important development bar none in the battle to combat climate change. While the US waffles about technologies and partnerships, Europe puts its faith in markets. And the great irony is this. The US invented the idea of emissions trading to solve environmental problems, and insisted - over European objections - that it be included in the Kyoto Protocol. But then revisionism took hold in the US, and handouts and capture by special interests took the place of markets as the solution to the climate change challenge.

The European scheme is disarmingly simple: 6.6 billion tonnes of carbon dioxide called 'allowances' with an asset Value (@ €20 per tonne) of €132 billion have been issued to each of about 11,000 installations in the power generation and heavy industry sectors in the 25 countries of the European Union; each installation was given free a quantum of tonnes called 'allowances.' In general, utilities were left short, while the rest of heavy industry got what it needed. And the total envelope allocated by countries in the 'old' EU fifteen Member States generally was less generous than allocations in the 10 new Member States. So we would expect selling from East to West, and from non utilities to utilities. Total trades documented over the counter and via exchanges amounted to about €5 billion in 2005.

The key rule in emissions trading is this; you can emit as much as you like, but at the end of the accounting period, you have to hold enough allowances to cover your emissions. If you get 500 tonnes of allowances and you emit 760 tonnes, then you have to buy an additional 260 allowances to achieve this obligation. If you get 500 tonnes, and reduce your emissions to 300 tonnes, then you can sell the surplus – 200 tonnes – in the market place and still meet your obligation. Trading produces a price per tonne of carbon dioxide which drives holders to see how they can reduce emissions and make money. This simple mechanism achieves the following; those polluters who can reduce at very low cost do so, and sell the reductions to those for whom it is relatively expensive. The overall target is achieved, and at minimum cost to the economy. The price signal releases the dynamic of innovation, as businesses everywhere try to find new and less expensive ways to reduce emissions. And it is fair – those who emit most, pay most, and vice versa, and the tax payer does not pick up the tab.

Business will always complain about price signals, but the best in business always responds with imagination and innovation. BP introduced its own internal emissions trading scheme in 1999; by 2001 it had reduced emissions by 10 per cent, and is now an active supporter of and participant in the European scheme. And leading US companies can see the advantage of trading, as evidenced in a recent advertisement from Chevron Texaco Corporation, one of the world's largest companies: 'seeking a Carbon Markets Team manager to work in our San Ramon Ca headquarters. This individual will coordinate carbon credits management activities to ensure that the company makes the most effective use of its carbon credit generating opportunities to satisfy its internal needs for carbon offsets.' Jeffrey Immelt, General Electric's (GE) chief executive, argues that the US government must create policies that foster renewables and address climate change: "America is the leading consumer of energy. However, we are not the technical leader. Europe today is the major force for environmental innovation" (IEEE Spectrum on line, 3 July 2005). GE's sales of power equipment exceed $17 billion annually. Because renewables are a growing segment of the power industry, it has decided to become a leader in wind energy for electricity generation and in solar cell technology, using innovation in technology to drive the achievement of this objective. But it is doing this in spite of US policy, and it is looking abroad for markets and its developmental platform. Carbon constraint will be a continuing part of our business future.' As the new generations of super carbon efficient houses, offices, cars, power stations, cement factories and associated materials and software come to market, US business will find itself at a competitive disadvantage.

The 'Vision Statement of Australia, China, India, Japan the Republic of Korea and the US for a New Asia Specific Partnership on Clean Development and Climate Change' represents the US view of the way forward. It proposes 'a new partnership to develop, deploy, and transfer cleaner, more efficient technologies and to meet national pollution reduction, energy security and climate change concerns… A non binding compact will be developed in which the elements of this shared vision, as well as ways and means to implement it, will be further defined, and the establishment of a framework for the partnership, including institutional and financial arrangements, will be considered'. This means either nothing at all, or the provision of subsidies and associated bureaucracy to develop and transfer technologies. And we know two things: market signals are much better than subsidies and bureaucracy as a way of moving any agenda forward, especially one requiring imagination and innovation, and the Iraq War and related commitments means the US tax payer is not going to have much money to spend on new subsidies for the foreseeable future. When it comes to climate change, to paraphrase Maynard Keynes, Europe chisels in stone, while the US knits in wool.

With the agreement in Montreal in December 2005 at the United Nations Climate Change Conference to continue the global efforts to fight climate change, there is a clear implication that the European Emissions Trading Scheme will continue after 2012; it is also likely to be expanded to embrace other jurisdictions. This makes it imperative that the nuances of this scheme be studied and lessons for the future learnt, and that the interface with energy policy and energy systems be seamless and well understood. This book takes up the challenge of providing these understandings and connections. It therefore comprises an important attempt to ensure that markets continue to be at the heart of addressing climate change in Europe and globally.

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1. Introduction and overview

Carlos de Miguel, Xavier Labandeira and Baltasar Manzano

The design and foundations of energy and (energy-related) environmental policies, together with a quantification of their effects, are very relevant from both positive and normative points of view for a number of reasons: the essential importance of energy in the functioning and survival of our societies; the growing concern caused by certain environmental problems and phenomena that are closely related to energy consumption (especially climate change); and, clearly linked to the former, the significant efficiency and distributional consequences that these policies hold for producers and consumers.

Knowing that this is a huge field, this book intends to provide an answer to only some of the previous questions and concerns. It does so by combining theoretical papers with empirical applications, policy-oriented chapters with basic contributions to the literature, and specific analysis of some policy developments with more abstract approaches. We have attempted to include some useful comprehensive papers on growth and the environment and environmental instruments, together with in-depth analysis of marginal questions related to a major interest of the book: the definition and design of public environmental and energy policies. Moreover, we stress the ex-ante assessment of some actual or hypothetical applications in the field. In sum, we present here a collection of papers that contribute to the literature in several ways and could help draw a picture of some relevant aspects for public intervention in the environmental and energy domains.

To this end, the book is organized in three parts and thirteen chapters. The first part deals with some fundamentals of energy and environmental policies, including this introduction and Chapters 2 and 3. Subsequently, Part 2 groups a number of papers (Chapters 4 to 8) interested in different aspects of the EU

Emission Trading System (ETS) already mentioned by **Frank Convery** in the Preface to the book. Finally, the third part of the book includes Chapters 9 to 13, covering a selection of specific advanced issues pertaining to climate change and energy policies. The rest of this introduction is devoted to highlighting the main objectives and results of each chapter.

In Chapter 2, **Sjak Smulders** examines the fundamental forces that shape the interaction between growth and the environment, trying to answer very relevant questions from both scientific and policy points of view. Among them are the issues of whether it could be expected that climate change policy and associated energy policies become more (or less) stringent when the world economy grows; whether technological change would reduce the cost of climate change policy, and whether a constant carbon tax could mitigate global warming in a growing economy.

In Chapter 3, **Juan P. Montero** discusses some aspects of the performance of existing permits programs (particularly the Acid Rain Program in the U.S. and the total suspended particulate program of Santiago), and proposals for implementation of new ones (in particular, carbon trading for dealing with global warming and a comprehensive permit program for curbing air pollution in Santiago). Furthermore, he extends the basic model of a permit market to accommodate several practical considerations such as the regulator's asymmetric information on firms' abatement costs, the uncertainty of benefits from pollution control, incomplete enforcement, incomplete monitoring of emissions, the possibility of voluntary participation of non-affected sources and market power.

In Chapter 4, **John Reilly** and **Sergey Paltsev** examine the EU ETS by using a computable general equilibrium model of the world economy, disaggregated to provide detail on most of the major EU-25 countries and sectors covered in the ETS. They find that a competitive carbon market clears at a carbon price of ~0.6-0.9€/tCO_2 (~2-3€/tC) for the 2005-2007 period in line with many observers' expectations, but in sharp contrast to the actual early history of trading prices which had settled in the range of 20-25€/tCO_2 (~70 to 90€/tC) by the middle of 2005. They examine possible reasons for this divergence, from faulty modelling to firms' expectations about future periods and how that could impact prices in this period. Reilly and Paltsev argue that the performance of the ETS, real or perceived, could well affect the political acceptance of emissions trading as an instrument for managing the environment and, as such, that economists must carefully evaluate the maturing EU ETS.

European Union countries have agreed to reduce carbon dioxide emissions by individual amounts relative to their emissions in 1990 to reach the Kyoto target for the EU as a whole, in what is known as the Burden Sharing Agreement (BSA). Given that the reduction requirements formulated within the BSA differ substantially among EU countries, in Chapter 5 **Tim Hoffmann**, **Andreas Löschel** and **Ulf Moslener** study the effects that this phenomenon may have on climate policy and compliance costs of EU Member States, particularly in the design of their National Allocation Plans to implement the EU ETS. They demonstrate that attempts to harmonize the free allocation of emission permits across countries may introduce significant efficiency costs, thus undermining the advantages of emissions trading, because it dramatically increases the variance of average costs per ton of reduced carbon dioxide within the sectors that are not subject to the ETS. The chapter shows that in some countries the average cost per ton of abated CO_2 increases substantially, so the use of the flexible mechanisms of the Kyoto Protocol (Joint Implementation and Clean Development Mechanism) is necessary to meet the target.

From 1990 to the end of 2005, Spanish carbon dioxide emissions grew by more than 45%, which is clearly incompatible with the EU allocation of Kyoto-mandated CO_2 reduction or BSA (+15% for Spain). The reasons for this situation are to be found in a combination of economic growth and an inefficient energy domain, coupled with a total absence of climate change policies. In chapter 6, **Xavier Labandeira** and **Miguel Rodríguez** use a general equilibrium model to assess the effects of a sudden and intense (i.e., with a limited time to carry out the requested abatement) CO_2 reduction by the Spanish economy. The results, which could be valid for other developed Mediterranean economies, show that the costs of immediate and medium-size reductions are not significant in the short run and thus the system is a cost-effective way to attain environmental improvements. However, the authors confirm that delaying action with a binding commitment means that the degree of CO_2 emission reduction is much higher and so economic costs are far more important.

Pedro Linares, **Francisco J. Santos** and **Mariano Ventosa** start Chapter 7 by indicating that the use of renewable energies in the European Union has increased considerably in recent years, especially in those countries where price-based mechanisms have been used. However, there is also a discussion on whether this type of support is too generous for renewable producers, particularly in view of the EU ETS, which is expected to become an additional incentive for renewables through higher electricity prices. In this context, their objective is to analyse this impact quantitatively by simulating the behaviour of the Spanish electricity sector with and without the EU ETS, and specifically to look at the combined effect of the ETS and different renewable support systems in Spain. The chapter shows that, contrary to the expectations of some, the EU ETS will not induce significant changes in the profitability of renewable energies and therefore renewable installed power will not grow very much. However, the EU ETS may reduce the efficiency of the support systems already in place when these are price-based.

In Chapter 8, **Frauke Eckermann** uses a method for the verification of firm data within the EU ETS that sets the audit probability in relation to the allowance allocation and to penalties for misreporting. The chapter shows how, due to cost efficiency, a scheme with random audits and penalties should be preferred to an audit probability of one for each firm. In particular, the expected penalty should equal the gain from misreporting. Since penalties are limited in the political context, the author characterises efficient verification schemes for different penalty structures. It is thus shown that in a scheme with linear penalties, the efficient audit probability is dependent on the form of the allocation function. For a regressive allocation of emission allowances, for example, the audit probability of an efficient verification mechanism is non-increasing in the reported values, while in the case of a proportional allocation of emission allowances, the audit probability should be the same for all firms. In a scheme with maximum penalties, the efficient audit probability is inversely related to the strength of the penalty and increasing in the reported emissions value for any allocation of emission allowances.

Following developments in the new growth theory, in Chapter 9 **Malte Schwoon** and **Richard S. J. Tol** start the third part of the book by presenting an analysis in which they include the costs associated with premature capital turnover by penalizing rapid changes in the level of abatement from one period to the next. The results suggest that the option to shift some abatement into the future, where it is less costly due mainly to discounting and also to learning, is more valuable than the option to increase current abatement so as to generate additional learning effects. Furthermore, the authors find that inertia is a much more important determinant of the optimal abatement path than induced technological change is.

In Chapter 10, **Rafaela Pérez** and **Jesús Ruiz**, in a second-best framework, analyse the dynamic properties of a general equilibrium model of endogenous growth with environmental externalities. In particular, they study the conditions for global and local indeterminacy and their implications for the control of pollution by governments. From a theoretical point of view, the existence of coordination failure between private agents and government can be explained through the indeterminacy of equilibria issue. As a consequence, the environmental policy implemented by government may not yield the effects on pollution levels that society wants. Therefore, the existence of this coordination failure can be explained through the indeterminacy of equilibria issue.

In Chapter 11, **Agustín Pérez-Barahona** and **Benteng Zou** study the effect of a tax on the energy expenditure of firms as a way to promote investments in energy-saving technologies. Fossil fuel is an essential input throughout all modern economies and thus the reduced availability of this basic input to production, e.g., due to climate change policies, would have a negative impact on GDP and economic growth through cutbacks in energy use. However, they show how this trade-off between energy reduction and growth could be less severe if energy conservation is raised by energy-saving technologies. To study such a hypothesis, the authors consider a general equilibrium model with embodied and exogenous energy-saving technological progress in a vintage capital framework, where the scrapping rule is endogenous and linear simplifications are eliminated.

In Chapter 12, **Carlos de Miguel**, **Baltasar Manzano** and **José M. Martín-Moreno** use a real business cycle model to analyse the consequences of oil price shocks on the characteristics of aggregate fluctuations and on welfare in a small open economy, as is the case of European economies. Their simulations indicate that oil shocks can account for a significant percentage of GDP fluctuations in many European countries, even though the explanatory power is quite smaller for others. In addition, the authors show that this model reproduces the cyclical path of the European economies in periods of oil crisis. Furthermore, it is shown that the increases in the relative price of oil have negative effects on welfare, which is particularly high in southern European countries.

Finally, in Chapter 13, **Adriaan van Zon** and **Tobias Kronenberg** present a cyclical growth model where the R&D sector is disaggregated, first into carbon and non-carbon R&D, and further into basic R&D and applied R&D. The authors argue that transitions from one energy system to the other can be better understood in a general purpose technology (GPT) framework because the energy sector relies on a small number of highly pervasive GPTs.