WARM: a European model for energy and environmental analysis

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This paper describes the structure of a newly developed econometric, imperfectly competitive, general equilibrium model for the medium term study of energy and environmental problems. The geographical coverage of the model regards twelve European countries as well as the European Union as a whole. Compared to existing quantitative E3 (economy-energy-environment) models, the WARM model is characterized by a few novel and relevant features. Firstly, in contrast to multicountry interlinked models, it copes with the international dimension by integrating differences from a common European denominator within a unified and homogeneously designed framework. A panel data estimation approach is used to achieve this objective. Secondly, in contrast to the traditional market-based philosophy of many econometric models, it adopts a perspective focused upon economic agents' decisions. Thirdly, in contrast with the practice of modelling technical progress as an exogenous and deterministic phenomenon, it incorporates an explicit attempt of modelling the sources and effects of endogenous technical change. A Kalman filter latent variable approach is the methodology from which statistical information on the dynamics of technical progress can be obtained. Finally, all markets in the model are imperfectly competitive, including the labour market where the wage bargaining process is explicitly modelled and estimated. This last feature is especially important in view of the European unemployment problem.

1 Introduction

The study of the impact of economic activity on the environment and the increasingly important constraints that the latter places upon the former has received new impetus in recent years, both at the theoretical and quantitative levels.

The threat of climate change, possibly generated by the growing accumulation of carbon dioxide in the atmosphere, has become a major economic and political issue: as a consequence, an increasing number of empirical economic models has been developed in recent years to deal with questions related to the effects on the economy of policies designed to control the global environment. In particular these models have attempted to provide a quantitative analysis of future trends in energy consumption and other economic variables, and to assess the economic costs of reducing carbon and other emissions. However, most of the existing computable or econometric models used for environmental policy analysis do not appear to satisfactorily address some relevant aspects of environment-economy linkages.

There are at least three key elements that ought to be entertained by a reliable model suitable for environmental policy analysis: the international dimensions of environmental problems, the uncertainty surrounding many environmental phenomena, and the role of technical progress. Global environmental problems have several international dimensions. First, from global warming to acid rains, they are by their very nature super-national (emissions in one country affect other/all countries). Moreover, national problems can have far reaching effects through international trade and redeployment of production activities. Third, environmental policy can be used as a strategic variable in international negotiations. Uncertainty has several dimensions too: not only is there scientific uncertainty about the characteristics of environmental phenomena, preventing a precise assessment of the impact of economic activities on the environment, but also there is volatile knowledge of the quantitative effect a deteriorating environment has on the economy, and of the economic cost of related policies.

Finally, there is the issue of the appropriate treatment of technical progress. The available empirical evidence appears to increasingly show that a reduction or stabilization of emissions at desired levels can hardly be attained through price-induced substitution effects, but rather through technological substitution and innovation. As stressed by Grubb [32], when modelling the effects of technological progress on GHG (greenhouse gas) emissions, it is not sufficient to compare the "environmental efficiency" of different technologies. It is rather necessary to assess the incentives that the market provides to the adoption of environment-friendly technologies, and the impact that policy decisions, taken by

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one country or internationally coordinated, can have on firms' innovation strategies. Moreover, the existing contrast between "top-down" and "bottom-up" methodologies in the assessment of the economic cost of reducing GHG emissions reveals that the issue of technological change is the most important one and deserves the greatest attention when developing an environmental-economic model.

To the above three key elements (international dimension, uncertainty, technical progress) one should add that the impact and effects of environmental phenomena and related policies are intrinsically long-run problems: hence, models should be designed to capture the long-run dynamics of environmental and economic variables. Even if this is certainly a necessity, it constitutes also a great limit of environmental modelling in that "the further into the future that we attempt to extend our model, the greater the uncertainty of our assumptions and, thereby, our conclusions becomes" [57, p. 253]. Moreover, impacts and effects of environmental policies crucially depend on the prevailing market structure [16] which cannot be assumed to be perfectly competitive in all markets. In particular, in Europe, energy and labour markets are certainly non-competitive.

In this paper we present a new model, called WARM (World Assessment of Resource Management) which addresses some of the above issues in a novel way, particularly with respect to the international dimension, the modelling of technical progress and the imperfectly competitive structure of all markets (with special reference to the labour market) 2. As opposed to many CGE models, WARM is internally consistent in the sense that the model used for simulation is also used for estimation (most other CGE models use outside estimates of key parameters). As opposed to most econometric models (e.g. the ones developed by the Department of Applied Economics in Cambridge), WARM adopts a sophisticated specification of the technology, of the preferences and of the changing composition of the capital stock. In particular, by using flexible functional forms, we do not have to estimate separate technologies or preferences for each country, as some of their key elements are variable functions and hence differ across countries 3.

After a brief review of some aspects of existing environment-economic models in section 2, the following sections 3 and 4 are devoted to the description of the structure and methodology characterizing the WARM model. Section 5 briefly mentions some of the initial applications of the model to relevant policy issues. The conclusions contain suggestions and directions for further development of the model.

2 Environmental-economic models: A brief review

A cursory view of the existing econometric and non-econometric environmental models evidences their failure to carefully describe the environment-economy linkages 4. Models are typically divided into two broad categories: top-down and bottom-up. Both classes of models have been used to answer the question of how much it would cost to limit GHGs emissions. Each yields very different results.

Bottom-up models aim at identifying alternative ways to provide energy services. The objective is pursued through a high level of disaggregation of the energy system, both on the supply and the demand side. Bottom-up models indicate that much can be done to significantly reduce GHGs emissions due to the existence of a wide range of technological opportunities and to the assumption that the economy will be able to exploit them immediately and at low cost. The main limit of this approach is that they generally neglect feedbacks on the economy and rebound effects through international energy markets. Moreover, they do not take into account the uncertainty concerning many environmental phenomena, the actual diffusion process of new technologies, and the effects of environmental policies. Finally, they generally cannot be used to provide an estimate of costs of reducing GHGs on a global scale [57].

In the top-down approach, the energy-economy interactions are modelled at the macro level, for a single country, for a group of nations, or for the world as a whole. These models aim at evaluating the economic impact of measures to reduce greenhouse gas emissions. They allow for varying degrees of disaggregation, particularly of the energy sector. The top-down approach assumes a world in which there is limited scope for technological improvement and cost effective opportunities. Hence substantive action to curb GHGs is only achievable through costly changes. There are many types of models following this approach. In particular, we may distinguish three major ones: the traditional macroeconomic models, the technical-economic sectoral models, and the computable general equilibrium models. The traditional macroeconometric models, such as DRI [52] and HERMES-MIDAS [39], follow a neo-keynesian theoretical approach: the assumed structure is "demand-driven" and under-utilization of productive capacity is possible in the short and medium term. Hence, they are not suitable for very long-run analyses

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2 Despite these theoretical improvements, we believe that some important issues are not appropriately dealt with. In particular, the model does not account for the role of uncertainty (in particular, its feedbacks on economic agents' decisions) and for the environmental feedbacks. These issues deserve further attention and an interdisciplinary effort.

3 We owe this point to an anonymous referee.

4 Some of the most recent and exhaustive surveys of environment-economic models can be found in Grubb et al. [33], Krause et al. [43], and Wilson and Swisher [57].