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CO_2, GDP and RET: An aggregate economic equilibrium analysis for Turkey

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ABSTRACT

There is a worldwide interest in renewable electricity technologies (RETs) due to growing concerns about global warming and climate change. As an EU candidate country whose energy demand increases exponentially, Turkey inevitably shares this common interest on RET. This study, using an aggregate economic equilibrium model, explores the economic costs of different policy measures to mitigate CO_2 emissions in Turkey. The model combines energy demands, capital requirements and labor inputs at a constant elasticity of substitution under an economy-wide nested production function. Growing energy demand, triggered by economic growth, is met by increased supply and initiates new capacity additions. Investment into RET is encouraged via the incorporation of (a) endogenous technological learning through which the RET cost declines as a function of cumulative capacity, and (b) a willingness to pay (WTP) function which imposes the WTP of consumers as a lower bound on RET installation. The WTP equation is obtained as a function of consumer income categories, based on data gathered from a pilot survey in which the contingent valuation methodology was employed. The impacts of various emission reduction scenarios on GDP growth and RET diffusion are explored. As expected, RET penetration is accelerated under faster technological learning and higher WTP conditions. It is found that stabilizing CO_2 emissions to year 2005 levels causes economic losses amounting to 17% and 23% of GDP in the years 2020 and 2030, respectively.

1. Introduction

As an EU candidate country, with which accession negotiations have started (in October 2005), Turkey shall adopt the community acquis. Under energy and environment chapters, the country's related legislation is currently being scrutinized within a detailed screening process. New and renewable sources of energy form an agenda item under the energy chapter. The Kyoto Protocol forms an agenda item under the environment chapter. The two agenda items in separate chapters are closely related as new and renewable forms of energy will contribute to greenhouse gas emission reduction. Turkey's renewable energy sources shall therefore become a focus of interest during the accession talks under both chapters. Economically feasible renewable power generation potentials have been estimated at 196.7 TWh/a for biomass energy, 124 TWh/a for hydropower, 102.3 TWh/a for solar energy, 50 TWh/a for wind power and 22.4 TWh/a for geothermal energy (Evrendilek and Ertekin, 2003). In electricity generation, renewables accounted for 30.7% (46.34 TWh) in 2004, of which hydroelectric energy was absolutely dominating (99.5%).

Official energy supply mix projections do not forecast a rapid expansion of new renewable electricity technologies (RETs), which can be explained by relatively high investment costs as compared to traditional fossil fuel-based technologies. Reducing greenhouse gas emissions at a low cost without harming economic growth appears to be a challenge for Turkey. Given this challenge for sustainable development, Turkey emerges as an interesting case study to explore energy–economy–environment interactions with particular focus on the diffusion prospects for new RETs. The adoption of new RETs is naturally subject to developments that bring down unit generation costs to a level where these technologies can actually compete with conventional ones. This might happen with increased exposure to RET due to experience accumulation, which typically improves the technical and economical performance, productivity and organizational efficiency. The learning effect, also referred to as 'technological learning', is indeed an empirical artifact as many applications have shown (e.g. Arrow, 1962; BCG, 1970; Lieberman, 1987; Argot and Epple, 1990; Barreto, 2001).

Intimate relationships between RET/non-RET energy prices and demand levels, pollutant emissions and economic growth necessitate an integrated framework for energy policy and planning.

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The literature covers various modeling techniques for numerical policy analysis, ranging from linear programming to mixed complementarity programming. There is a great variety of approaches and methodologies used in energy and environmental policy modeling. However, even though the approaches are quite different with respect to the structure and focus of models, there is a common core that inherits some optimization methodology.

There are two broad classes of models describing the relationships between the energy sector and the rest of the economy: top-down and bottom-up. The first category approaches the problem from a macro-economic perspective with an aggregate energy sector representation, whereas the second one adopts a technology-rich description of energy activities including cost structures, conversion efficiencies and technological limitations from primary to final energy. The top-down label derives from how modelers apply economic theory and techniques to historical data on consumption, prices, incomes and factor costs to model supply and final demand. Therefore, top-down models evaluate the system from an economic viewpoint, in contrast to bottom-up models which consider energy systems and conversions in detail from an engineering viewpoint.

In this study, a top-down policy analysis model computing an aggregate economic equilibrium (AEE) is developed and calibrated for Turkey. Accounting of the consumer willingness to pay (WTP) for CO_2 emission reduction and endogenized technological learning for new RETs are two particular strengths of the model. The impacts of various energy and environmental policy scenarios on CO_2 emissions, GDP growth and RET diffusion are explored. GDP losses are interpreted as the economic costs of emission reductions. Yet the corresponding benefits are considered to be beyond the scope of this study.

The theoretical background of the model is discussed in the next section introducing the AEE approach, the methodology for determining WTP and the theory of technological learning. Section 3 provides the model description. The empirical analysis and model results are presented in Section 4. Finally, Section 5 concludes the study.

2. Literature survey

2.1. The aggregate economic equilibrium approach

AEE models are classified under the top-down approach. They describe investment and consumption patterns, and emphasize short-run energy and environmental policy dynamics. Final demand determines the size of the economy, and the models work to balance quantity based on exogenous prices. Capital stock turnover and new technology penetration rates can be explicitly and endogenously formulated under this approach. However, the economy representation is aggregate. Typically, there is an economy-wide production function, generally in CES-form, relating capital (K), labor (L), energy (E) and other inputs (O) to produce gross output (Y), i.e. $Y=f(K, L, E, O)$. Gross output is further computed as the sum of energy costs (EC) and GDP, i.e. $Y = EC+GDP$. The addition of EC to GDP involves deliberate double counting (as GDP accounting typically already includes the cost of energy) in order to feature an accounting of energy–economy interactions. However, the effect of double counting is in a way penalized by the inclusion of energy as an explicit factor of production. That is, energy is treated as an intermediate good only (e.g. there is demand for transportation rather than gasoline) contributing to the ultimate production of final goods and services. Hence, energy costs enter only indirectly into gross production. Although this approach is not fully satisfactory from an economic point of view, it provides a fairly well representation of the two-way linkage between the energy sector and the rest of the economy. The production function parameters are determined from optimality conditions to maximize the profit of producers for a representative year. Consumer utility maximization, on the other hand, is envisaged in the overall objective function. That is how both parties are taken care of so that the model yields an AEE. The AEE accounting conventions are derived in Hogan and Manne (1979) where the theory is introduced under the metaphor of the fable of the elephant (the economy) and the rabbit (the energy sector).

The literature covers various macroeconomic models using the AEE approach for energy and environmental policy modeling. These include MERGE (Manne et al., 1995), CETA (Peck and Teisberg, 1992), MARKAL-MACRO (Manne and Wene, 1992), NEMS (Hoffman and Stephan, 1996), MEEET (Arıkan and Kumbaroğlu, 2001), GLOBAL 2100 (Manne and Richels, 1994), MIS (Kuckshinrichs and Kemfert, 1997), RICE (Nordhaus and Yang, 1996) and GRAPE (Kurosawa et al., 1999), among others. These models are widely used to reflect the economic effects of greenhouse gas emission reduction policies in a medium to long planning horizon. One of them, namely MERGE, considers the consumers' WTP for CO_2 emission reduction, which is also a major feature of our model. MERGE assumes an S-shaped curve for the relationship between WTP and per capita income. A theoretical WTP value is computed as a function of per capita income and temperature change, calibrated such that the WTP does not exceed 100% of GDP. However, there is lack of empirical evidence and a great deal of uncertainty involved that may induce misleading policy implications if consumer WTP is not truly represented.

2.2. Willingness to pay for CO_2 emission reduction

A central problem for an economic analysis with non-marketed goods (i.e. goods that are not sold or bought in the market) such as CO_2 emissions is the difficulty of placing a monetary value on them. WTP offers an approximation to this value. It is defined as the maximum amount of money an individual might want to pay to equalize a utility change. The maximum amount an individual is willing to pay is assumed to be an indicator of the value he/she places on the good or service. For direct measurement of WTP, the contingent valuation methodology (CVM) emerges as a generally favored survey technique that is widely used by economists to value non-marketed assets (Brookshire and Eubanks, 1978; Schulze and D'Arge, 1978). In this approach, individuals are directly asked the amount they would be willing to pay for a non-marketed good through survey questions (Mitchell and Carson, 1989; Bjornstad and Kahn, 1996; Bateman and Willis, 1999). Respondents display their feelings or choices in terms of WTP for the non-marketed good. To increase the possibility of valid and reliable answers, a typical CVM study starts by making the respondent familiar about the environmental good to be valued. Information on the proposed changes, implications and the financing procedures are clearly explained in a hypothetical scenario.

The questioning approaches employed in a CVM survey are basically fourfold:

- *Open-ended:* Respondents are directly asked the maximum amount they would be willing to pay for a specified change in the good to be valued.
- *Dichotomous choice:* The questioning is arranged in two parts. The first one investigates whether the respondents are willing to pay for a specified change in an environmental asset. If willingness exists, then a second question asks whether the WTP is equal to a specified amount.