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ANALYSIS

Analyzing the economic cost of the Kyoto protocol

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Abstract

This paper examines the cost of meeting the Kyoto Protocol commitments under alternative assumptions regarding technology and technical change. Real GDP is modeled as a function of the capital, labor, and energy inputs. The analysis is based on data for 23 Annex 1 countries from 1965 to 1999. Two important results emerge. First, the standard assumption of Hicks neutral technical change and time and scale independent output elasticities is not supported by the data. Second, when technical change is allowed to be biased in favor of the energy and capital inputs, and when the output elasticities vary with the level of factor use and over time, the loss in real GDP due to the Kyoto commitments rises substantially. On average, the loss in real GDP is one and a half times higher than obtained under the standard assumptions. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Technical change; Output elasticity; Bias; Annex 1; Translog production function; Cobb–Douglas production function; Linear homogenous

1. Introduction

In the past decade, a substantial body of literature has emerged analyzing the economic cost of reducing future carbon dioxide (CO_2) emissions. The range of model structures is quite varied. At one end, there are highly aggregate, top-down, regional dynamic models based on optimal control techniques. There are also multi-sector models in the tradition of the regional computable general equilibrium models, which allow for inter-industry differences and international commodity trade. Yet another model type are the bottom-up style models with a significant level of detail on the energy sector including several fuel types and technology options for energy supply. Not surprisingly, these models yield very different numerical results.

Recently, under the 16th Energy Modeling Forum (EMF-16) organized by Stanford University, some of the most prominent among these models were used to estimate the potential costs of the Kyoto Protocol. Under this Protocol, Annex 1 countries, that is developed countries included in Annex 1 to the UN Framework Convention on

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Climate Change, have agreed to reduce their overall net greenhouse gas emissions to 5% below their 1990 levels by the years 2008–2012. As in the case of previous such exercises, the great advantage of the EMF study is that it tends to highlight the differences in model results due to different model structures, rather than differences in scenario construction. Despite the generally uniform scenarios under which the models were operated, the carbon tax in 2010 required for USA to meet its Kyoto commitments through domestic emissions reductions alone, ranged from about $75 per metric tonne to more than $400 per metric tonne (as measured in 1990 prices). In the case of Japan and the European Union, this range is even wider.

However, there is one aspect in terms of which the model results are remarkably consistent. This relates to the estimated cost of the emissions reductions under Kyoto Protocol as measured by the loss in GDP in 2010. Table 1 summarizes the GDP impact on Annex 1 countries obtained under the no-trading scenario of EMF-16. The overriding conclusion that emerges from this Table is that the economic cost of the Kyoto commitments is small.

Table 1
GDP loss under EMF-16's no-trading scenario (as a percent of 2010 baseline)[a]

Model	Country			
	US	Japan	CANZ	EU
SGM	n.a.	n.a.	n.a.	n.a.
GRAPE	n.a.	0.18	n.a.	0.37
Oxford	1.91	1.88	n.a.	0.76
MERGE3	1.07	0.80	2.07	0.43
MS-MRT	1.90	1.73	1.82	0.27
G-CUBED	0.45	0.54	0.60	0.71
ABARE	2.14	0.83	1.59	0.42
CETA	1.98	n.a.	n.a.	n.a.
AIM	0.47	0.24	0.57	0.15
RICE	0.97	0.81	1.15	0.23
Average	1.34	0.88	1.30	0.42

[a] *Note*: these estimates are based on Figures 7 and 9 of Weyant and Hill (1999), since published versions of these models do not provide the data directly. In addition, GDP figures for 1990 were obtained from World Bank (1992). For CANZ, the sum of GDP in Canada, Australia, and New Zealand was used. For the European Union (EU), the 1990 OECD GDP was used. For detailed model results, see the 1999 special issue of the *Energy Journal*. n.a., Not available.

On average, the loss in 2010 GDP would be less than 1%. Even in the models with the highest estimates, the reduction in GDP is about 2%.[1]

One factor that could possibly explain this result is the structure of the production function embedded in these models, and the nature of technical change implicit therein. While the models included in this study differ widely in terms of overall structure, they uniformly assume Hicks neutral technical change and time invariant production or output elasticities. In addition, it is also assumed that the output elasticities do not vary with the level of factor use. The current analysis has a dual focus. First, it will be shown that these assumptions are not borne out by the recent empirical history of the Annex 1 countries. Second, and more important, relaxing these assumptions may significantly increase the estimated loss in GDP.

2. The econometric model

Since the focus of the paper is the impact of technology assumptions embedded in the aggregate production function on the costs of meeting the Kyoto commitments, the model used here abstracts from all other economic factors that might affect the results. An econometric model based on pooled cross-section and time series data from 1965 to1990 for 23 industrialized Annex 1 countries is used. Countries not included in the sample are Liechtenstein, Monaco, countries of the former Soviet Union and those in Eastern Europe, due to non-availability of data. Details on data and data sources are provided in the Appendix A.

Real GDP in each time period (GDP_t) is modeled as a function of the contemporaneous capital (K_t), labor (L_t), and energy (E_t) inputs. The trend variable (τ) captures technological change. Output elasticities for each factor input are estimated using a translog production function that is linear homogenous in factor inputs. Interactions between factor use and time are included to allow for biased technical change. This also allows the output elas-

[1] Another important conclusion is that USA is likely to bear the highest relative cost, followed closely by CANZ, an economic region defined by Canada, Australia, and New Zealand.