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Substitutability and the Cost of Climate Mitigation Policy

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Abstract

We explore how and by how much assumptions about elasticities of substitution affect estimates of the cost of GHG emissions reduction policies in computable general equilibrium (CGE) models using G-Cubed, an intertemporal CGE model, to carry out a sensitivity and factor decomposition analysis. The results suggest that the average abatement cost rises non-linearly as elasticities are reduced. Substitution elasticities between capital, labor, energy and materials in production have a larger impact on mitigation costs than inter-fuel substitution does. There are notable differences in the effect of the elasticities on costs at the regional level due to interactions in international trade and capital flows in such a global model. Although the results in this study are derived from a particular model, the study, in a broader sense, suggests that there is a necessity for sensitivity analysis before making any conclusive policy recommendation using CGE models.

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1. Introduction

There has been extensive work on modeling the costs of climate change mitigation and adaptation using the tools of computable general equilibrium (CGE) models. Such models critically depend on research on the possibilities for technological change and substitution between energy and other inputs and among fuels. The parameters that govern these possibilities – the elasticities of substitution – “are the single most important parameters that affect the [ir] results.” (Bhattacharya, 1996, 159). Furthermore, “in the

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economic literature, there is little consensus about different elasticities for energy products” (Bhattacharya, 1996, 159).

In this study, we aim to test the effects of elasticities of substitution by carrying out a sensitivity analysis of the G-Cubed policy model (McKibbin and Wilcoxon, 1999). We assess the effects of variation in the following key parameters: (1) Elasticities of substitution in production between fuels; (2) Elasticities of substitution in production between capital and energy; (3) Elasticities of substitution in consumption between more and less energy-intensive goods and services. The costs of climate change mitigation globally and in the eleven G-Cubed model regions are assessed by changes in GDP relative to business as usual. We evaluate a number of possible absolute emissions reduction targets for each set of parameter values.

Our analysis is innovative in the sense that we use a global rather than national model to address a broader range of scenarios than previous work has covered (e.g. Jorgenson *et al.*, 2000). The decomposition analysis is also first used in such analyses.

2. Methodology and Experiment Design

The G-Cubed model is a global intertemporal CGE model that has been used for both climate policy and macro-economic analysis. A more detailed description of the model is documented in McKibbin and Wilcoxon (2013). The version of G-Cubed that we use in this study is version 110D, in which the world is divided into 11 regions, and each region has 12 production sectors. The default values of elasticities are estimates from the US time series.

In assessing a certain policy, the results are usually reported in deviations from the Business As Usual (BAU) such that the effect of the BAU scenario on the results can be reduced. In our exercises, the BAU scenario changes every time we change the elasticities of substitution. Despite some developing countries currently adopting emissions reduction targets relative to business as usual, absolute cuts remain the most relevant long-term policy goal. Therefore, unlike Jorgenson *et al.* (2000), we consider absolute rather than relative to BAU emissions reductions. We address the issue of the varying BAU effect by decomposing mitigation costs as explained in the following. For an absolute emissions target, given the vector of elasticities of substitution σ_i , the GDP losses relative to BAU can be decomposed as follows:

$$\frac{\Delta G}{G_{BAU}} \equiv \frac{\Delta G / G_{BAU}}{\Delta E / E_{BAU}} \times \frac{\Delta E}{E_{BAU}} \equiv \frac{\Delta G}{\Delta E} \times \frac{\Delta E}{E_{BAU}} \times \frac{E_{BAU}}{G_{BAU}} \quad (1)$$

where $\frac{\Delta G}{\Delta E}$ is the average cost of abatement, $\frac{\Delta G/G_{BAU}}{\Delta E/E_{BAU}}$ is the cost elasticity of abatement, $\frac{\Delta E}{E_{BAU}}$ is the

abatement relative to BAU, and $\frac{E_{BAU}}{G_{BAU}}$ is the emissions intensity in BAU. Defining $g = \frac{\Delta G}{G_{BAU}}$, $C = \frac{\Delta G}{\Delta E}$,

$A = \frac{\Delta E}{E_{BAU}}$, and $I = \frac{E_{BAU}}{G_{BAU}}$, then equation (1) can be rewritten as: $g = C \times A \times I$. Denote

$\Delta g_i = g(\sigma_i) - g(\sigma_{default})$ as the difference between the percentage GDP losses associated with a parameter set σ_i and those associated with the default parameter set $\sigma_{default}$ given a policy scenario (an absolute mitigation target).

We use the LMDI (additive) method (Ang and Liu, 2001) as the decomposition method to analyze the contribution of each of the three factors to the differences in percentage GDP losses between different parameter sets.

The simulation experiments involve several steps: first, we build a default model, which uses the standard assumptions used in G-Cubed for generating a BAU scenario; second, we impose a set of absolute targets and simulate the default model to find policy paths (a global carbon tax path that increases by 4% per annum) that achieve these absolute targets; third, we change the values of a set of parameters of interest by ($\pm$) 50% while keeping all the other assumptions unchanged to build a new model and corresponding BAU time path; finally, we simulate the new model to achieve the same absolute targets that we impose in the default model. The last two steps will be repeated for various perturbed sets of parameters. A discount rate of 4% is used to pin down the policy path and to calculate the present value of costs.

We look at the consequences of policies up till 2030 only as the G-Cubed model is more useful for shorter-term analysis. The absolute global emissions targets in 2030 are set as follows: (i) 20% below the 2010 global emissions level; (ii) 10% below the 2010 global emissions level; (iii) Constant emissions at the 2010 global level; (iv) 20% above the 2010 global emissions level.

3. Results and Conclusion

In the full-change model, the average abatement cost on the world level increases (decreases) by 61% (38%) if the world economy is 50% less (more) flexible. We find that GDP losses are generally more sensitive to top tier (labor, capital, energy and materials) substitution than inter-fuel substitution. The flexibility in the capital producing sector is also important for developed (capital-intensive) economies.

In terms of the average abatement cost and the marginal abatement cost, the results are qualitatively consistent with Jorgenson *et al.* (2000). The cost of emissions reduction is generally higher when substitution is more restricted. However, the average abatement cost (ΔC) increases more when the elasticities of substitution are lowered than it decreases when the elasticities of substitution are increased by the same percentage. This implies that overestimation of mitigation cost due to underestimating the elasticities of substitution is a more serious problem in CGE models.

However, our decomposition analysis shows that this is mainly due to the decreased level of BAU emissions in less flexible economies. Similarly, the higher GDP losses relative to BAU in a more flexible economy are due to a higher level of BAU emissions and economic growth. This needs to be taken into account when interpreting the results of model comparison exercises. Most model comparisons, such as EMF22 (Clarke *et al.*, 2009), show a wide range of mitigation costs across models for the common absolute targets. But each of these models has a different BAU emissions projection. It is then important to identify whether the variation of these mitigation costs is due to the varying BAU scenarios in each model or from the induced costs of mitigation policy. Therefore, our study suggests that there is a necessity for sensitivity and decomposition analysis to provide further policy recommendation using CGE models.

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Biography

Yingying Lu is a Post-Doctoral research fellow at the Crawford School of Public Policy of the Australian National University. She is an economist, interested in economic modeling, environmental economics, and energy and climate policy.