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# EXPLORING ALTERNATIVE SPECIFICATIONS OF TRADE PRICING IN ENVIRONMENTAL CGE MODELLING

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## ABSTRACT

Environmental computable general equilibrium (CGE) models have been widely used to support policy analysis of climate change mitigation and adaptation at different scales. The simulation results highly rely on the model structure, assumptions as well as parameter value inputs. Most single-region CGE models follow the traditional model settings, such as the agent-identical specification for import demand and price taker for exports pricing. This study aims to explore the importance of CGE model specifications on the simulation results and policy implications by means of alternative agent-specific specification for import demand and partial price pass-through for exports price, respectively. Singapore is chosen as the case study as its economic circumstance does not completely support the standard settings. It is found that, under both the carbon tax and border carbon adjustment scenarios, economic performance, emission reduction and average abatement cost vary substantially with different specifications. Policy implications are consequently discussed and compared.

**Keywords:** Environmental CGE model; Carbon pricing; Imports specification; Export pricing; Singapore

## 1. INTRODUCTION

Nearly 200 nations are making efforts together under the Paris Agreement to combat climate change, aiming to limit the global temperature rise to 1.5-2.0 degree Celsius above pre-industrial levels. Each county details its plan for climate change mitigation and adaption as well as the target for emission reduction in nationally determined contributions. Various types of energy system models, such as bottom-up technology-rich models, top-down macroeconomic models, and integrated assessment models (IAMs), have been widely used to evaluate the national mitigation potential and cost effectiveness of technical, operational and market-based measures. However, the simulation results could be fairly diverse due to model type, model structure, exogenous assumptions, parameter values, etc., which may greatly affect the implications for a given policy scenario (Calvin et al., 2012; Chaturvedi et al., 2012; Clarke et al., 2012; Jewell et al., 2018).

Generally, bottom-up models can provide important insights into energy saving and emission abatement potential with rich technical details, and top-down models can evaluate the economy-wide impacts of energy/climate policy instruments by considering interconnections among agents in the economy. CGE model, the most representative top-down model, is an important tool for quantitative assessment of policies and emerging issues. Building upon data availability in more countries, CGE modelling has developed mainly along two dimensions: (1) from single-region framework to multi-region framework and (2) from static model to recursive model and to dynamic model (Bergman, 2005). A recent trend is to apply single-region models to analyze sub-national or city level issues. After all, a region could be an economic zone, a province, a city, etc., not necessarily a country.

CGE models are traditionally used to analyze issues such as trade policy, infrastructure investment, tax/subsidy policy. With rising concerns on issues such as oil crisis, energy market deregulation and climate change in the 1990s, environmental CGE models that highlight energy usage and environmental impacts have been accordingly developed. Over the decades, even the environmental CGE families have been greatly expanded by incorporating new features/details or new forms of production function, consumption function, trade and macro closures. However, compared with the discussions about parameter values on CGE model validity, the importance of model specifications or assumptions have not been fully recognized or formally discussed in the literature.

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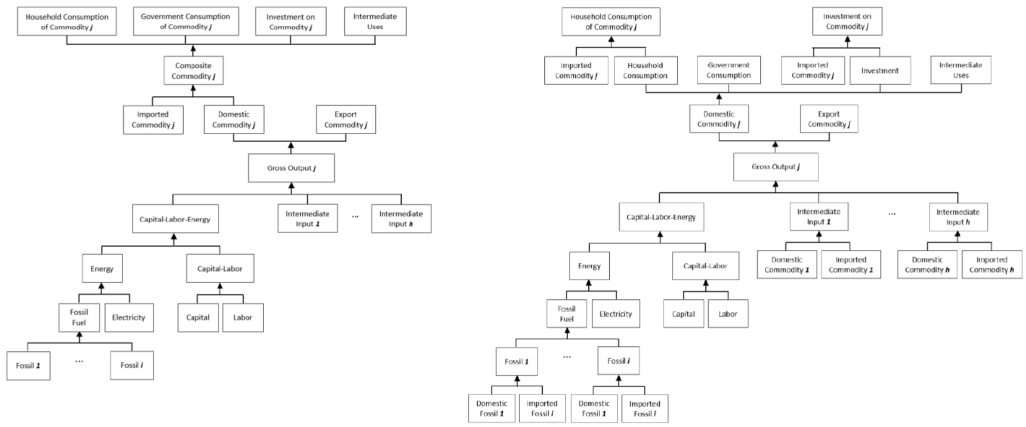

a. Model structure with agent-identical aggregation

b. Model structure with agent-specific aggregation

Figure 1. Model structures with two alternative specifications of import demand

This paper intends to fill in some gaps by investigating the impacts of the specifications of import demand and export pricing in a single-region CGE model on simulation results and consequent policy implications.

## 2. CGE MODEL SETTINGS

### *2.1 Model specifications*

Two static CGE models, a model with agent-identical specification of import demand (Model AI) and a model with agent-specific specification (Model AS), are built on the basis of Singapore's input-output (IO) tables for 2010 (DOS, 2014). Totally 114 non-energy sectors and 3 energy sectors (i.e. Refinery, Gas, and Electricity) are considered. The city state does not have any quarrying and mining sector, and generates around 95% of its electricity with natural gas. It is assumed that each sector has one representative producer. Figure 1 displays the main structures of two CGE models, with different treatments of imports highlighted.

Other general rules for CGE modelling apply to both frameworks. The producers maximize profits at each step subject to the production or transformation functions. The representative household maximizes utility subject to its budget constraint, with its total consumption a CES aggregate of consumption of each commodity. According to Singapore's IO tables, household income consists of labor income, capital income and transfer payment from the government.

The total government consumption is a composition of domestic commodities following a Cobb-Douglas function, which implies a fixed proportion of expenditure on each commodity. Government revenue is mainly from tax collection (i.e., labor and capital income tax, production tax on gross inputs, import duty and sale tax on household consumption and investment) and non-tax payment by households. The total investment, on which the expenditure equals to the sum of household savings, government savings and foreign savings at the local economy, is also a Cobb-Douglas composition of investment on each commodity. Foreign savings are mainly the current account balance with the rest of world. Singapore has a current account surplus and thus foreign savings are negative.

In both models, saving rates of households and the government are constant as in the base year. As Singapore's current account surplus increases slowly in recent years except for 2012/13 when the European debt crisis took place, foreign savings are assumed to merely float along with exchange rate. Local importers are assumed to have no bargaining power on the prices of imports, but two alternative assumptions are set for the prices of exports. Singapore is the major supplier of many manufacturing products (such as petroleum products, petrochemicals, semiconductors) and services (such as maritime and transshipment related services, banking and finance services) in the region, so has some degrees of pricing power on these exports in the international/regional market. As a result, in addition to the traditional price-taker specification, the other specification is experimentally set to the other extreme, assuming that all Singapore exporters can pass through the change in production cost except for direct carbon cost to export prices (i.e. partial pass-through).

### *2.2 Data*

Based on Singapore's IO tables for 2010 and Yearbooks of Statistics Singapore (DOS, 2010), two tailored social accounting matrixes (SAM) are prepared separately for Model AI and Model AS. In the base year 2010, the exported products accounted for around 50%

of Singapore's total outputs. The fairly high trade-to-GDP ratio indicates the importance of international trade to the Singapore economy and also the openness or globalization status of the country.

Sectoral consumption of fossil fuels and electricity were obtained from many sources, and the energy consumption data were further disaggregated to match the IO sector classification. Emission factors were selected following the IPCC (2006) guidelines to estimate $CO_2$ emissions from energy combustion. Parameter values of the elasticities of substitution/transformation in production, consumption and investment functions are the same as in Li and Su (2017), mainly following the MIT EPPA model (Paltsev et al., 2005) and the GTAP model (Huff et al., 1996).

### *2.3 Scenarios*

The modelling scenarios are combinations of alternative model specifications/assumptions discussed earlier, which are Agent-Identical import aggregation & Price Taker for exports (AI-PT), Agent-Specific import aggregation & Price Taker for exports (AS-PT), Agent-Identical import aggregation & Partial Pass-Through for exports (AI-PPT) and Agent-Specific import aggregation & Partial Pass-Through for exports (AS-PPT). The following scenarios are analyzed: (a) carbon tax on the Energy, Manufacturing and Land Transport sectors and (b) BCA on Singapore exports. The carbon tax scenario consists of three sub-scenarios: (a1) no tax revenue recycling (EMT); (a2) tax revenue is recycled to households (EMT_H); and (a3) tax revenue is recycled to producers (EMT_P). For each policy scenario, we will show the comparisons between AI and AS scenarios, PT and PPT scenarios, and AI-PT and AS-PPT, respectively.

In early 2018, the government of Singapore announced that a carbon tax of S$5 per ton of CO2 or equivalent (t-CO2e) will be imposed on facilities whose annual emissions exceed 25 kt-CO2e from 2019. The rate is supposed to be reviewed by 2023 and increase to S$10-15/t-CO2e by 2030. Taking into account the soaring price of the EU Emission Allowances and the settlement price of last California joint auction of greenhouse gases allowances, a middle rate of S$20/t-CO2 is selected for the simulation in this paper. The carbon tax is assumed to be levied only on the Energy, Manufacturing and Land Transport sectors, which covers 91% of Singapore total CO2 emissions in 2010.

The revenue generated from carbon pricing policies could be utilized in many ways, such as transfer payment or income tax reduction to households to alleviate their growing living burdens, industrial assistance or corporate income tax reduction to protect the competitiveness of domestic producers in international markets, investment in energy efficiency, clean technologies and adaption infrastructure. Therefore, recycling the carbon tax revenue to households and producers, which is expected to make the carbon tax more acceptable to the public and industries, is analyzed in this study.

Equivalent BCA at S$20/t-CO2 is also considered to assess to what extent the simulation results could be affected by specifications of import demand and export pricing. The comparisons are expected to provide insights to countries currently without carbon pricing policy, who are potentially exposed to BCA proposed to be levied on commodities exported by countries without comparable climate policy (Monjon and Quirion, 2010, 2011; van Asselt and Brewer, 2010; Weber and Peters, 2009). In this paper, BCA is assumed to be imposed on direct emissions from combusting fossil fuels in production and indirect emissions through electricity consumption that are embodied in exports. So in the base year 2010, exports embodied around 44% of Singapore's total carbon emissions.

## 3. RESULTS AND DISCUSSIONS

Under both policy scenarios, the change in GDP ranges from -0.03% to -0.25%, which is narrow in absolute level but wide if measured by times. The magnitude of carbon emission reduction mainly depends on the performance of the Refinery-Petrochemicals supply chain. As Singapore has a high GDP, even a slight difference in the simulated impact on GDP could lead to fairly distinct implications of economic cost of carbon pricing policies. It has been observed that, in either the carbon tax scenarios or the BCA scenario, Average abatement cost (AAC) tends to be the largest with AS-PPT specification and smallest with AI-PT specification. Compared to other three scenarios, the AS-PPT scenarios provide the smallest negative impacts on total exports and emission reduction but the largest negative impacts on household consumption and government consumption (or smallest positive impacts on government consumption in the EMT scenario). The impact on total imports are not clear-cut as too many factors can exert influence on it. At sector level, the changes in exports are overall much larger in AI-PT, AI-PPT and AS-PT scenarios, and the directions of some sectors' changes (increase or decrease) even change across the modelling scenarios.

The different estimates could provide fairly diverse implications. In the case study, the AI-PT specification is supposed to be most far away from Singapore's situation. Compare to other specifications, the AI-PT specification may lead the government and the public to underrate the costs and difficulties of achieving a certain emission reduction target through a carbon price. And the energy-intensive and trade-exposed sectors in Singapore (e.g., Refinery and Petrochemicals) may have an over-pessimistic expectation on their future and raise excessive opposition to carbon pricing policies, or lose potential investment opportunities for capacity expansion or new facilities. Besides, it has been shown that if the country would like to compare the relative effectiveness and efficiency of simply paying BCA or implementing domestic carbon pricing policies, models with different specifications could provide opposite directions. If GDP and AAC are the main criteria for policy making, BCA is suggested in models assuming pricing-taking for export prices (AI/AS-PT) and a carbon tax is favored in models assuming partial cost pass-through for export prices (AI/AS-PPT).

## 4. CONCLUSIONS

The comparison analysis in this study highlights the importance of adopting appropriate model specifications to better sketch the economy of interest, so as to avoid potential unnecessary biases. Generally, the specifications/assumption of agent-specific preference over imports and partial pass-through of changes in cost to the prices of exports (or AS-PPT scenario) are relatively more in line with Singapore's situation. But more exact specifications of differing pricing power of each producer in the international/regional market, ranging from 0 to 1, require the support of more detailed empirical work in the future.

It is important to note that specifications in environmental CGE models highly reply on data availability. Many economies, especially developing countries, may not have the resource and capacity to compile datasets that allow the model developers to take into account of agent-specific preference over imports and other detailed specifications. Better data collection and compilation are required to improve the model specifications in environmental CGE modelling. For example, Singapore's IO tables are already detailed enough in terms of sector classification and import disaggregation, but still does not separate the energy into energy use and non-energy use. When more detailed energy data become available, it is meaningful to update the simulations in this study and explore the factors that drive the discrepancies between the two sets of results. Besides, more detailed energy data could further allow research of other topics related to climate change mitigation, such as rebound effects of energy efficiency improvements.

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