The Coalition of Finance Ministers for Climate Action

Finance Canada CGE model

Canada—Department of Finance

A contribution to the 'Compendium of Practice from a Global Community of Ministries of Finance and Leading Organizations: Economic analysis and modeling tools to assist Ministries of Finance in driving green and resilient transitions'

Topic: Modeling tools relevant to Ministries of Finance

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Overview

Finance Canada has the lead role in macroeconomic analysis within the Government of Canada. To fulfill this obligation the organization has developed and maintains a suite of economic models for macroeconomic analysis. These include the following.

- A small, open-economy New Keynesian dynamic stochastic general equilibrium model (DSGE) used for simulating the macroeconomic consequences of industrial and social policies, as well as prospective policy responses to macroeconomic conditions (e.g., inflation, recessions).
- A forward-looking multi-country multi-sector computable general equilibrium (CGE) model with a finite time horizon and limited dynamics for analysis when sectoral or regional detail is important (e.g., trade agreements, industrial policy).
- The Heterogeneous Agent New Keynesian (HANK) model, which combines incomplete markets with idiosyncratic risk to generate an endogenous and continuous wealth distribution for making quantitative statements about the equity implications of monetary and fiscal policy (e.g., employment insurance take-up, progressive taxation).
- A semi-structural econometric forecasting model for medium-term economic and fiscal analysis.

Finance Canada uses these general-purpose economic models to analyze and quantify the potential economic impacts of a wide variety of different scenarios. It is seldom the case that there is enough lead time or policy specific knowledge to build the ideal model to explicitly capture the sector/policy being analyzed. For many projects, discussions between modelers and subject matter experts lead to decisions about how best to approximate the scenario within the existing structure of the models rather than creating a new purpose-built model.

In the early 2000s it was determined that Finance Canada would increasingly need to model the climate mitigation policies necessary for Canada to achieve its pledged emissions reduction targets. Environment and Climate Change Canada (ECCC) takes the lead on policies related to climate change and maintains its own suite of models. The investment to build a climate variant of the Department's CGE model was, however, deemed necessary because of the magnitude of the potential economic and fiscal impacts, the likelihood that a climate-specific model would be used repeatedly, and the absence of key variables (emissions) in existing models.

The climate CGE variant tracks combustion emissions associated with the intermediate and final uses of fossil fuels as well as the process emissions associated with production. The model features a nested production structure that allows substitution possibilities between energy types, energy efficiency improvements through the substitution with capital inputs, and abatement possibilities to reduce process-based emissions. With a full set of policy parameters to price emissions, this model has been a useful tool in discussions of the relative efficiency of different potential climate mitigation proposals.

Strengths and limitations

The climate CGE model has been a useful tool to quickly examine the economic channels through which climate mitigation policies might impact the Canadian economy. A key strength of the model is that since it was developed internally and is not overly complex, it can be customized quickly. For example, when studying alternative revenue recycling arrangements, it was possible to add a large final emitter system where allowances are related to output. The model can also be calibrated to a Global Trade Analysis Project (GTAP) aggregation or directly to a specific baseline provided by ECCC. Thus, when Finance Canada is supporting ECCC policy development, Finance Canada can align the model to match the ECCC baseline assumptions.

The climate GGE model has simplified dynamics and only considers the real economy.[1] When short-run impacts, or impacts on variables not in the model, such as inflation, interest rates, and government revenues, are required, this model would be used in coordination with other models. However, as Finance Canada does not specialize in climate science or engineering, parameterizing the climate CGE model to capture real-world technological possibilities represents a greater challenge than the parameterization of its other models. Finance Canada is therefore reliant on external estimates for baseline emissions and most identifying assumptions that determine how easily agents in the model can reduce emissions. The calibration of the model relies heavily on the GTAP Data Base and information provided by ECCC. Results from the model must always be interpreted as dependent on parameter assumptions, which can be challenging to verify and are subject to change.

Relevance to Ministries of Finance

Given the flexibility of the climate CGE model, it has many possible use cases. These include:

- The evaluation of alternative policy design choices during the design phase of new climate mitigation policies
- The sensitivity analysis of new climate mitigation policies under alternative demand and/or technology assumptions
- An exploration of how multiple climate mitigation polices might interact
- Quantification of the potential emissions impacts of non-climate-mitigation policies.

The climate CGE model is used to explore the economic channels through which climate mitigation policies might impact the economy. However, Finance Canada does not rely on this model to project or predict the future economic or climate impacts of the Government's mitigation policies.

Use in practice

In practice, the climate CGE model has been used extensively over the past 20 years to position internal Finance Canada assessments regarding climate mitigation policy. In the early years, the model was used to support briefings on the choice of economy-wide policies to achieve emissions reduction targets (carbon tax versus cap-and-trade versus non-pricing measures). This analysis included examining different revenue recycling options and emissions coverage to quantify the potential economic impacts of a "first best" policy and the economic trade-offs of potential deviations from this "first best." The climate CGE model is most useful in modeling the impacts of carbon pricing-type policies since they are directly incorporated into the model. However, because the model is very adaptable, non-pricing measures can be incorporated through distortionary shadow prices and non-distortionary revenue return if enough information about their direct impacts is understood.

The climate CGE model is an important tool for trying to understand policy interactions. For example, the implementation of a carbon tax in a region with a cap-and-trade system or a regulatory standard would lower credit prices in the cap-and-trade system or make standards less binding before lowering emissions. Being able to model and quantify the potential impacts with and without layering existing (or future) policies is a valuable addition to analysis on potential measures.

Most recently, Finance Canada has employed the model to conduct sensitivity analysis on how alternative assumptions about future demand or technology might change how policies under development by the ECCC will impact the economy.

The climate CGE model tracks how quantities and prices adjust between the baseline and other scenarios and can therefore report a wide range of metrics. Standard reporting would include macroeconomic metrics such as regional GDP components, industry metrics such as production and

1 The Finance Canada CGE model and its climate variant solve a forward-looking optimization over a user-defined finite time horizon, assuming a new steady state is reached in the last period. The model currently features only limited dynamics such that aggregate capital adjustment costs are the only constraint from the economy immediately achieving the new steady state. Sector-specific capital and labor adjustments are planned as future improvements.

prices, fiscal metrics such as revenues and transfers, and a detailed emissions accounting by source. Given the openness of the model code, the reporting file is customized to whatever set of results best supports the analysis.

Future work

Finance Canada has continually worked to improve the CGE model and its climate variant. Changes to the analytical structure of the model and the addition of policy levers have improved the model's ability to inform a diverse set of policy questions. However, improvements and access to global datasets have arguably been the largest driver of model progress. Because the CGE model is calibrated to the GTAP database, each release of the GTAP has represented an incremental improvement, with the release of GTAP-ENV and GTAP-POWER having been particularly important for the climate variant. One area of improvement that would be particularly beneficial to enhance the analytical capabilities of all climate CGE models would be peer reviewed data on available mitigation technologies by GTAP sector and region.

Specific to Canada, the most important analytical change that could be made to the climate CGE model would be sub-national disaggregation. Canada's economy wide carbon pricing policy allows different provinces and territories to maintain their own carbon pricing regime so long as it meets the Federal benchmark. Having Canada as a single region in the climate CGE model simplifies the model, however it has limited Finance Canada's ability to model the impacts of certain policy elements. While ECCC has a recursive dynamic sub-national CGE model, adding sub-national structure to our climate CGE model would be data intensive and require additional analytical work in areas where sub-national regions should behave differently than national regions (factor mobility, international closure rules, price arbitrage, etc.).

Lessons and challenges

The original analytical structure for Finance Canada's multi-sector, multi-region CGE models was developed internally with the involvement of Jean Mercenier, a Visiting Professor at the University of Ottawa. Finance Canada has benefitted from having a model developed and maintained internally because the expertise exists to quickly adapt the model to provide analysis on a diverse set of topics. Ensuring internal expertise is maintained within Finance Canada requires that resources are allocated for senior modelers to train new modelers. This is especially important, as it seems that CGE modeling has become less popular in academia and fewer students are graduating with CGE modeling experience.

Calibrating a multi-sector, multi-region CGE model is data intensive. Building the required global social accounting matrix is a nontrivial task, which explains why GTAP was originally formed. Building flexibility into the Finance Canada CGE model structure and the calibration routine so the model can be calibrated to any GTAP aggregation (so that specific sectors and regions are present) or to match a specific climate scenario provided by the ECCC has proven to be very beneficial.

Conclusions

The climate CGE model has provided Finance Canada with numerous insights about climate mitigation policies. However, it is not appropriate for every aspect of every climate-related question. Finance Canada's experience has been that acquiring the climate-specific expertise required to build a multi-country, multi-region CGE model that tracks emissions is within the capacity of a small team of experienced economic modelers. However, the climate science, engineering, and energy systems knowledge required to estimate all the parameters in such a model, or to build a more comprehensive climate-energy-economy model, would require dedicated resources with specialized expertise. For MoFs that do not have the lead in environmental policy, a multi-country, multi-region CGE model calibrated to external data will likely provide a good balance between the MoFs' needs and the allocation of scarce modeling expertise and resources within the public service.