CGE Modeling of Trade and the Environment

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Abstract

This chapter provides a description of CGE modeling and explains why it is used over other competing methodologies. Selected insights of early work are explained and a short survey of current and future developments is proposed.

This chapter is about CGE modeling, and is intended much more as a background to the modeling approach than as a telling of the future. In particular, I talk about where it came from, some selected policy insights and, as the title suggests, an important element of CGE analysis `sweating the details.'

Outline

This paper begins with a definition of a CGE model and motivates why one might want to use one. I'll then turn to some very early applications of CGE models to trade and environmental policy issues, noting some selected and highly idiosyncratic insights that emerged from early CGE modelling efforts. Finally, I will take moment to very broadly survey the direction of new research.

1 What is a CGE Model and Why Use One?

Computable General Equilibrium Analysis[1] is the use of computer simulation models of the economy. The models used are `equilibrium' models in the sense that there are markets for various goods and factors which are in equilibrium, sometimes in a limited sense. In other words, markets may not clear in the sense of a perfectly competitive market with full information. Finally the models are called `general' equilibrium models because a large number of interrelated markets are assumed to be in equilibrium at a given time. This differs from the `partial' equilibrium usually taught to undergraduates, where a single market is studied in isolation with the use of the ceteris paribus assumption. General equilibrium models dispense with most of the ceteris paribus assumptions and allow a large number of interconnections between markets. For example:

- Factor tax changes have direct impacts in the labour market but will have indirect effects in product markets. A higher tax on labour for example, might affect labour-intensive sectors and those which use relatively little labour input differently. Effects might be spread across time as well, if increased labour taxation leads people to do less investment in human capital, leading to less supply of skilled labour in the future.

- Trade policy changes may affect certain product markets, and in turn (depending on factor intensities) markets for capital and labour.

- Environmental policy changes can be expected to impact `dirty' and clean product markets differently as well. In turn, these environmental taxes can affect factor markets.

The interconnections are often extended to include international linkages through trade and even environmental

externalities.

The earliest CGE models were perfectly competitive in all sectors, and used simple `wedge' representations of all policies. In other words, quantity-based policies such as import quotas were represented as a constant tariff rate giving the same effect in the benchmark data. They still provided two things that competing models couldn't provide:

Welfare Analysis

> A well-conceived CGE model provides a sound basis for welfare analysis. In simple terms, the model should have one or more indicators that allow policies to be ranked in a meaningful way. The objective functions of the agents provide a basis for their endogenous responses (next item) and a means of deciding which policy proposals are good and bad.

Endogenous Response

> The earliest CGE models took account of the fact that firms and consumers' behaviour might be changed by policy in ways that are directly shaped by the technology (or technologies) available to them for producing goods and their preferences. The building blocks of CGE models were (and remain) agents minimizing costs and maximizing utility, rather than supply and demand curves. These things were not present in competing policy models of the time.

By my definition then, having both of these features distinguishes a CGE model from other policy models.

CGE models are preferred tools for both analysing given policies and choosing among alternative microeconomic policies.[2]

2 CGE Analysis of Trade

CGE analysis of trade came into use just about the time that the Tokyo Round of GATT talks was being negotiated. The alternative was either partial equilibrium analysis of tariff reductions (usually focusing on sectors expected to lose from liberalization) or macro analysis, where changes in tariff revenue were run through macro models with a very limited role for relative prices (like the relative price of imported to domestic goods).

As a research assistant for John Whalley in the early 1980's I can tell you that the idea of solving a general equilibrium model of global trade was viewed as more than a bit crazy.[3]

Such analysis was important partially because it contributed to a discussion of trade agreements on the basis of something other than mercantilist yardstick. As many authors have stated before, tariff reductions are viewed as giving a concession and were viewed as losses, when in fact, they often contributed significantly to welfare gains. The welfare calculations presented by the models highlighted the consumer gains and gains by firms that were not protected, relative to the losses of protected firms.

An insight from this early work concerned early tariff-cutting proposals for the Tokyo Round. Early discussions focused on various tariff cutting formulas proposed by the EEC, US, Japan, Switzerland and Canada. Whalley[4] found that the proposal made by the US was the worst of the major proposals for the US in overall welfare terms; the EEC proposal was very nearly the worst for the EEC; and the Japanese proposal was indeed worst for the Japanese.

I will avoid reading much more into it than that it may have revealed the real motivation for formula design wasn't what a neoclassical economist would suggest it should have been.

2.1 Sweating the Details: Imperfect Competition

Another useful example of how getting the details correct can improve on earlier work concerned the effects of

Canada-US trade on the North American Auto industry.

Early CGE analyses had found that welfare gains for Canada from Canada-US free trade would either be modest or slightly negative. This result was attributed to adverse terms of trade effects.[5] Some very influential work by Richard Harris and David Cox Harris (1984), Harris and Cox (1984), Cox and Harris (1985), introduced imperfect competition to CGE models and captured the insights of an earlier generation of trade policy experts Eastman and Stykolt (1967), English (1964). They argued that Canada would be a huge beneficiary of Canada-US trade liberalization due to rationalization. This was the process whereby numerous short production runs in Canada would close and be replaced by fewer long production runs (supplying Canada and the US).

While this insight was valuable in itself there were some puzzles in the model's findings. In particular, the model found that the Canadian auto industry would be expected to expand significantly from free trade, even though virtually free trade had existed between Canada and the US for 20 years at the time. The Harris and Cox model had 2 crucial weaknesses in this respect. First, all industries were assumed to have the same degree and nature of imperfect competition, when it was clear that the steel industry was significantly different than the auto industry in terms of the degree of competition between firms. Second, the model effectively assumed that GM in Canada was a separate entity from GM in the US. A later paper Silanes, Markusen and Rutherford (1994) represented the structure of the auto industry much more accurately and gave results much more in line with industry analysts at the time. Notably, the changes expected in the North American auto industry were not as dramatic as implied by Harris and Cox.

2.2 Sweating the Details: Distance

The models we will be discussing will focus a lot on the treatment of transportation and distance as key elements of modeling. To show how important distance can be, let me reflect back on an argument made by Melvin that was incorporated into some early modeling work. It concerned the modeling of Canada-US trade liberalization (a topic which generated significant heat through much of the 20th century in Canada). The standard analysis of Canada-US trade effectively treated the two nations as two points separated by a (small) distance. As a result, international trade would naturally be impeded by distance. The conclusion reached was that this meant that small trade barriers between Canada and the US would be relatively innoccuous.

Melvin[6] argued that this mental map of North America was all wrong, and suggested a different mental map. The map in his mind is shown in the bottom frame of Figure 1. This map lead to an entirely different interpretation of the impacts of trade barriers, since instead of just discouraging trade between Canada and the US, it encouraged Western and Eastern Canada to incur very large transportation costs shipping goods across a continent. CGE modeling work to evaluate the importance of this analysis suggested that distance was indeed important to regional analysis of the tariff, but qualified some of the strong welfare stories.[7]

Figure 1: Alternative Maps of North America

Figure

This stylized representation of the spatial economy is a long way from that proposed by current models reviewed in later sections, but the exercise pointed out how having a better picture of the spatial economy could be important.

3 Trade and the Environment

Some very important and, in retrospect startlingly simple insights came from early CGE analysis of carbon taxes. In the late 1980's, there was renewed interest in the idea of global warming (as it was know then), and using carbon taxes to reduce greenhouse gas emissions. Much of the discussion was about how high the required carbon taxes would be.

Some early analyses of carbon taxes took place in the context of macro models which had a very limited role for relative prices, notably relative prices of energy-intensive goods or partial-equilibrium bottom-up models which had a very shematic representation of the non-energy economy.[8] The macro models gave hard to explain answers about consequences of carbon taxes. A case in point was the major modeling effort used to inform the Canadian position at the Kyoto Conference of the Parties in 1997. It found that some permit-based schemes would lead to significant *expansion* of energy-intensive sectors in Canada. The conclusion was driven by the nature of the macro model, where firms in a given industry were assumed to invest a constant share of their profits in their own industry. In the DRI results, the energy-intensive sectors were granted the emissions permits, yielding increased profits and, as a direct consequence expanded capacity to make energy-intensive goods. There is no mechanism in that model whereby returns to *investment* in the (e.g.) steel industry might fall in the presence of carbon restrictions.

Simple bottom-up models came to the conclusion (and in some circles still do) that just about any policy that would cut fossil fuel consumption would actually be significantly better than doing nothing (even ignoring any environmental benefits).

Why were they wrong? Macro models lacked the microeconomic structure to link the taxes to a wide array of micro-economic decisions that were very relevant to the policy issue at hand.

Bottom-up models, while having extensive details of alternative energy processes, failed to adequately incorporate the increasing cost of scrapping old energy infrastructure and installing new infrastructure. In the simplest sense they were really elaborate partial equilibrium models that assumed that all types of resources for energy-efficiency projects were available at constant cost. For small scale projects this is probably appropriate. For large scale projects (like reducing the whole economy's carbon emissions by 50 or more percent) the assumption is very inappropriate.

A detail that was either overlooked or ignored in the very early discussions of carbon taxes was that one could tax fossil fuel consumption or fossil fuel production. To the extent that the world as a whole is a closed economy this should make no difference, but from the point of view of specific countries, they are not at all equal. On average the world is neither a net importer or net exporter of fossil fuels. But specific countries are significant net exporters (OPEC nations) or significant net importers (Japan). In this case specific governments care a lot about whether taxes are collected on production of fossil fuels or their consumption, not least because of the potentially huge revenues involved. What was necessary was a model that had both trade in fossil fuels and carbon taxes with the revenue carefully traced. This is commonplace for CGE models.

3.1 Current and Future CGE Models

The current generation of global CGE models with linkages to environmental policy have a number of extensions and refinements over the early models.[9] I'll give a very quick survey of some of these extensions and hint how they relate to climate change policy.

3.1.1 Intertemporal Dimension

Intertemporal, or dynamic models explicitly represent investment decisions and choices between current and future consumption. In the case of climate change, the time scale of the problem is immense and the timing and order of decisions matters. Explicitly representing the time dimension is crucial to understanding the time path of response to a given policy. They will also be valuable in selecting among alternative policy approaches.

One of the key questions that emerges from this analysis is whether it makes more sense to reduce emissions know, or, instead devote additional resources to research and development of lower-carbon energy alternatives.

3.1.2 Transportation and Distance

I will not dwell on this topic here, but there is a lot of work to be done to go from the abstract representation of transportation common to most CGE models to more realistice representation of transportation activities.

Existing models (including the one discussed in Chapter ? by Johannes Broeckner) already represent existing

transportation networks and can be used to investigate the benefits of expanding those networks. Other challenges involve more careful representation of the dynamics of vehicle fleets in response to alternative policy approaches. Other challenges involve modeling choices between trips in a vehicle, on the bus or in a train.

To some extent, the improved microeconomic structure implied by these models follows the example given by the convergence of the bottom-up and top-down energy models.

3.1.3 Negotiation among Governments

In most CGE analyses, governments are assumed to be passive. The normal posing of the CGE experiment is ``What is the effect of policy regime A?" Some questions are not really amenable to this method of analysis. For example, Abrego, Perroni, Whalley and Wigle (2000) tries to see why developing countries seem to oppose linking trade policy negotiations to those on the environment. They ask how developing countries would fare under alternative institutional arrangements for negotiating international trade and environmental accords. This paper uses the Nash bargaining concept.

Earlier papers used Nash equilibrium concepts (see for example Markusen and Wigle (1989) and Harrison, Rutstrom and Wigle (1989)) and recent work has explored using a CGE model to reveal policy preferences to allow a broader range of policy options and institutional settings for negotiations to be considered.[10]

3.1.4 Emissions and the Environment

An area which I think is crucial for illuminating the public policy debate is the explicit linkage of realistic dose-response functions to economic models. The clearest case is for the study of climate change where we have some admittedly imperfect models of radiative forcing and greenhouse gases that could be linked to economic models. The important result here would be a better understanding of the dynamics of cost-effective policies and lowest-cost methods for achieving them.

4 Conclusion

The theme I have chosen is `sweating the details.' By this, I specifically mean getting the microeconomic setting correctly modeled and getting the policies modeled as precisely as possible. I might have augmented that to read ``Sweating the details while still watching the big picture." Watching the big picture is really a result of my definition of a CGE model. It means that CGE models should be driven by an economically sound yardstick for evaluating performance. No one says that welfare maximization is likely to suddenly inspire political decisions throughout the world, rather, policy-relevant models should never abandon the `welfare' yard stick as a unifying concept.

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Footnotes:

[1]CGE Analysis is also referred to as Applied General Equilibrium Analysis (AGE) or Numerical General Equilibrium Analysis (NGE).

[2]I would argue that a major avenue of advance in modeling has been the more accurate representation of policies in models. By degrees this effort has driven extensions and elaborations in the microeconomic structure of CGE models.

[3]The modeling project (eventually including Tom Rutherford and Glenn Harrison) constituted one of the most computationally-intensive projects at the University of Western Ontario at the time.

[4]Whalley, 1985 Chapter 8

[5]Because Canadian tariffs were initially much higher than US ones, bilateral free trade would be expected to generate terms of trade losses for Canada.

[6]See Melvin (1985).

[7]Jim Melvin will still tell you I just got it wrong. See Wigle (1992).

[8]See Howatson and Campfens (1997).

[9]See for example Weyant and Hill (1999).

[10]See Costa Pinto and Harrison (2000)
