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Comment Meredith Fowlie

Policies designed to mitigate climate change are likely to have economy-wide impacts. Consequently, there is a strong case to be made for general equilibrium modeling that seeks to capture interactions between all sectors of the economy. A growing literature uses computable general equilibrium (CGE) models to quantify the economy-wide effects of greenhouse gas emissions regulations.

Kala Krishna begins her chapter with the observation that the CGE models commonly used in the literature tend to be nontransparent "black boxes." She provides a conceptual discussion of how greenhouse gas regulations imposed in one country can affect relative factor prices, trade flows, emissions, and emissions leakage in an open economy. The chapter provides useful insights into the inner workings of CGE models, emphasizing the value added vis-à-vis partial equilibrium approaches.

In this short comment, I first provide some context for Krishna's contribution. I then elaborate upon two of her key points. First, partial and general equilibrium models can yield very different predictions with respect to emissions leakage under incomplete climate change policy. Second, the extent of the emissions leakage predicted by CGE models will depend critically on the assumed structure of the model and the assumed values of some key model parameters.

Modeling Emissions and Emissions Leakage in an Open Economy

In her chapter, Krishna focuses primarily on general equilibrium modeling of emissions leakage. Leakage refers to any increase in emissions in one jurisdiction that occurs as a direct consequence of emissions regulation

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imposed in another jurisdiction. The potential for emissions leakage has been a major obstacle to regional climate change policies.

There are at least three related channels through which leakage can occur. Consider the simple example of a home country imposing a binding cap on domestic emissions while the emissions in the rest of the world remain unregulated. The introduction of the emissions cap is likely to increase the operating costs of domestic producers relative to their unregulated rivals. In the short run, this may result in a shift of production activity and emissions to unregulated foreign producers (the first channel). Over the long term, the extent of this direct leakage can be exacerbated as firms relocate to jurisdictions with less stringent emissions control policies (the second channel). If demand for carbon intensive inputs in the home country is sufficiently large to affect world energy prices, indirect leakage can also occur. More precisely, as domestic demand for carbon-intensive fuels decreases, fuel prices fall, and producers in unregulated jurisdictions substitute toward these inputs (the third channel).

Ideally, an analysis of the potential for emissions leakage under a particular policy or program would account for all three channels. This is easier said than done! For the sake of tractability, partial equilibrium models typically hold factor prices constant. This shuts down the third channel. General equilibrium models can, in principle, capture both direct and indirect leakage effects. However, assumptions commonly invoked in CGE modeling limit the extent to which leakage can be realistically represented.

Theoretical Foundations of CGE Models

Theoretical general equilibrium models formalize the mutual interdependence of markets and serve as essential foundations for the CGE modeling of climate change policy impacts. In her chapter, Krishna offers a parsimonious and intuitive discussion of the underlying theory. She begins by describing a simple partial equilibrium modeling framework. Consider a competitive industry that produces an emissions-intensive good. If the home country imposes a price on emissions, this will increase the cost of domestic production which will lead, unambiguously, to an increase in the domestic equilibrium product price. Demand for imports from unregulated jurisdictions will increase, leading to leakage through on or both of the direct channels described earlier.

Whereas partial equilibrium models consider the policy impacts on one industry or sector in isolation, general equilibrium analysis considers impacts on the economy as a whole. How do the theoretical drivers of emissions leakage differ as we move from a partial to a general equilibrium framework? In short, it depends on the details of the model. In a recent paper, Karp (2011) explains how an increase in the emissions permit price need not decrease domestic production of an emissions-intensive good in a general equilibrium setting. If the production function for the dirty good is not separable in emissions and other inputs to production (e.g., capital and labor), the impact of the policy on regulated producers is mitigated by changes in relative factor prices. Thus, general equilibrium effects moderate the partial equilibrium effect of the emissions policy, such that a partial equilibrium model will overstate the magnitude of leakage. However, this result can be reversed under alternative general equilibrium modeling assumptions (Karp 2010).

From Theory to Applied Theory

The CGE modeling applies general equilibrium theory in empirically oriented analyses. A natural starting point, in terms of theoretical foundation, is the canonical Heckscher-Ohlin (HO) model. This model assumes perfect competition in all markets, constant returns to scale technology, and perfect substitution between goods produced in different jurisdictions. Unfortunately, this workhorse theory model can have limitations when used as a basis for applied analysis. The model can yield extreme results in realistic cases where the number of goods produced exceeds the number of factors of production. Sectoral production can be very sensitive to small changes in world prices (the so-called overspecialization problem) or indeterminate. Moreover, the HO model is inconsistent with some stylized empirical facts including frequent "cross hauling" (which occurs when a country imports and exports the same good) and price differences across trading partners that cannot be explained by transport costs.

Most of the CGE models used to analyze the effects of climate change policies avoid the aforementioned complications by assuming that imported goods and domestic goods are imperfect substitutes. So-called Armington elasticities specify the degree of substitution between domestically produced goods and goods produced in foreign countries. It is common and convenient to assume a constant elasticity of substitution. These assumptions greatly simplify the parameterization of the CGE model. But, as Krishna notes, they significantly affect the extent to which leakage occurs in a CGE model (see, for example, Babiker [2005]).

Conclusion

In this chapter, Kala Krishna presents an intuitive conceptual introduction to general equilibrium analysis of emissions regulations. The general equilibrium approaches she describes serve to highlight how sensitive emissions leakage can be to the linkages and intermarket interactions that partial equilibrium models ignore. To keep applied general equilibrium analysis tractable, many simplifying assumptions must be made. It is important to be aware of these modeling assumptions because they can significantly impact the extent to which emissions leakage manifests in CGE modeling and analysis.

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