PE VS. GE: MODEL PREDICTIONS OF INDUSTRY SPECIFIC SHOCKS

Ross Hallren
Richard Nugent
Caroline Peters

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Ross Hallren, Richard Nugent, and Caroline Peters
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Abstract

Using an industry-specific partial-equilibrium (PE) Armington model, we simulate several industry-specific shocks that have been previously simulated using an Armington-style computable general equilibrium (CGE) models. We draw on two Armington-style CGE studies that simulate an industry-specific policy shock in the steel and electricity industries using a single-industry PE framework. We evaluate the distance between the model predictions across output, quantities demanded, imports and exports, prices, and welfare. Generally, we find that the PE estimates are larger in magnitude that the GE estimates except in the case of welfare.

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Ross Hallren
Office of Economics
U.S. International Trade Commission

Richard Nugent (Corresponding Author)
Department of Economics
City University of New York
rnugent@gradcenter.cuny.edu

Caroline Peters
Office of Economics
U.S. International Trade Commission

1 Introduction

Policy analysts have two frameworks from which to choose for carrying out a quantitative assessment of the probable economic effect of a industry-specific shock: partial equilibrium and general equilibrium. Partial equilibrium (PE) is partial in that it sets aside all industries other than the particular industry being modeled. General equilibrium (GE) has the means of representing all industries in the economy and the way that they are linked. A modelers decision of which framework to use may depend on the industry receiving the shock, the nature of the shock, the outcomes of interest, and the time and resources at hand. Importantly, if these criteria have implications across industries, GE is preferred. On the other hand, if the outcomes of interest are measured at a level that is highly disaggregated, PE is preferred.

The comprehensive computable general equilibrium (CGE) models such as the Global Trade Analysis Project (GTAP) model may be ideal but incurs substantial set-up costs. In some cases, modelers refer to the industry-specific partial equilibrium framework as a sufficient compromise when faced with pressing time constraints (Hertel (1985)). Referring to a PE framework in lieu of a GE framework, analysts assume away the inter-industry general equilibrium effects that result from the industry-specific shock. The simulated responses for industry output, prices, and welfare will differ depending on the modelers choice of a PE versus GE framework (Hess and Von Cramon-Taubadel (2008); Robinson et al. (2014); Valin et al. (2014)). The question that we address is how much these outcomes will differ and whether this difference matters.

Using an industry-specific PE Armington model, we simulate several industry-specific shocks that have been previously simulated using an Armington-style CGE models. We draw on two Armington-style CGE studies that simulate an industry-specific policy shock in the steel, and electricity industries. We simulate the policy shock using the single-industry partial equilibrium framework and the General Algebraic Modeling System (GAMS). We evaluate the distance between the model predictions across output, quantities demanded, imports and exports, prices, and welfare. Generally, we find that the partial equilibrium estimates are larger in magnitude that the general equilibrium estimates except in the case of welfare.

The paper proceeds as follows. In the next section, we discuss the relevant literature. Following the literature review, we describe the industry-specific partial equilibrium Armington model that forms the basis of the simulations. In the fourth section, we describe each of the CGE studies that serve as the benchmark for the industry-specific policy shocks and characterize how different are the CGE outcomes from our estimates using the industry-specific PE framework. The final section concludes.

2 Literature Review

2.1 PE vs GE in the agricultural sector

There are several papers in the agricultural economics literature comparing the specifications of CGE and PE models. Robinson et al. (2014) examine the supply-side specifications of the AgMIP family of CGE and PE models, exploring how different specifications of technology and supply behavior under a GDP growth scenario impact the results of a global long-run food analysis. The authors conclude that depending upon the chosen specification of the PE and CGE model compared, results may end up being largely similar, despite major theoretical differences between the two model types. In the same journal issue, Valin et al. (2014) compare CGE and PE specifications on the demand side, looking at food demand projections among the AgMIP family of models under several different scenarios.

There are also a handful of studies that aggregate compare CGE and PE model results for similar policy experiments from pre-existing literature. Abler (2007) looks at the criteria for choosing model approaches to analyze trade agreements specifically, briefly comparing the findings of two studies using CGE (Kehoe (2005)) and ex ante PE (Carpentier (2001)) models to predict the effects of NAFTA on North American agricultural trade. Abler notes that although the PE model predictions were closer to realized trade over the time period than those of the CGE model, they also tended to underpredict increases in agricultural trade.

Gylfason (1994) explores the applications of PE and GE models to understanding the EUs Common Agricultural Policy by reviewing 14 studies measuring the cost of EU agricultural support in the 1980s, 9 of them were based on PE models, and five of them based on GE models. On average, the author found that GE estimates are about three times higher than PE estimates, a difference which, according to Gylfason (1994), is mostly explained by the larger price elasticities of agricultural supply typically assumed in GE models.

Several study authors undertake the modeling themselves, comparing the results of their CGE and PE policy experiments. Gohin and Moschini (2006) compare results of one PE and two CGE models using the GTAP database in their analysis of the phase-out of the EUs Common Agricultural Policy, finding similar market effects across all three models. The authors acknowledge, however, that welfare effects from their results depend on modeling choice, echoing findings in previous literature they have reviewed (specifically Gylfason (1994), Bautista et al. (2001), and Tockarick (2003), the latter two of which are summarized below).

Tockarick (2003) explores the impact of removing agricultural support subsidies in developed countries using PE and GE (GTAP) model frameworks. He suggests that some of the differences noted between the two models (particularly in regard to welfare effects) may be accounted for in the consideration of income effects and inter-sector factor mobility in the GE model that are absent in the PE model.

Bautista et al. (2001) compare results of CGE and PE models examining the impact of policy bias against agriculture in a hypothetical, agriculture-dominant economy characteristic of a developing country. They carry out four experiments to simulate the impact of introducing industrial protection and taxation of agricultural exports, with and without a fixed exchange rate. The authors find that compared to CGE models, PE measures miss much of the action operating through indirect product and factor market linkages and overstate the strength of the linkages between the changes in the exchange rate and price of traded goods on the agricultural terms of trade.

Stehfest et al. (2013) explore the environmental impact of reductions in livestock production via a PE (IMPACT) and CGE (LEITAP) model using the GTAP database. Both models suggested similar outcomes in terms of environmental gains falling short of theoretical outcomes. Significant differences between the model calculations resulted from each models assumptions regarding the implementation of international trade.

2.2 PE vs GE in non-agricultural sectors

In terms of comparisons between PE and GE models within a non-agricultural industry sector, the literature is more limited. Among the only examples is Narayanan et al. (2010), who uses data from the GTAP database to look at unilateral and multilateral tariff liberalization of the auto market in India, comparing the results of PE, GE and a PE-GE model. The authors find that the PE model does a poor job predicting the size and the price level in the industry following liberalization, but that the GE model overestimates substitution between regional suppliers due to false competition (i.e. countries that do not compete at a disaggregate level appear as competitors at the aggregate level) and underestimates welfare gain, both due to the problem of tariff averaging in the aggregated model.

Also outside of the realm of agricultural studies, Kokoski and Kerry Smith (1987) compare outcomes under PE and GE models simulating the effects of climate change, looking specifically at the limitations of partial equilibrium models to measure welfare change following a shock to the unit costs of producing commodities in several sectors in a developed economy. This shock is meant to represent a 50 percent increase in carbon dioxide levels. The study findings suggest that fairly large single-sector impacts can be reasonably measured using a single-market partial-equilibrium measure of compensating variation. Smaller multisector changes (in terms of the unit cost increases implied for each sector), however, can result in large errors in single-market PE welfare estimates.

Hess and Von Cramon-Taubadel (2008) conduct a meta-regression analysis of 110 studies simulating welfare changes from trade liberalization under the Doha Development Agenda using PE and GE models. The authors evaluate the experiment, databases, and model characteristics of each study, inversely weighting study results by the number of country-scenarios each produces. The welfare effects of trade liberalization were significantly positive under GE model specifications, while welfare under PE is significant and negative under weighted regressions and insignificant and positive in unweighted regressions. Long-run PE simulations appear to generate larger welfare gains than all but a few GE simulations, however, suggesting that the dampening impact of small elasticities in PE models tends to outweigh the dampening effect of GE linkages in GE models, as the latter become more apparent in comparisons when the former is removed. Among GE studies, the Johansen closure are always and high Armington elasticities are usually associated with higher welfare gains.

3 Partial Equilibrium Armington Model

The partial equilibrium simulations are based on an industry-specific Armington model that is readily adapted to the consumption and production structure of the case studies as previously simulated using CGE models. The partial equilibrium framework is a comparative static model that closely follows Hosoe et al. (2010) and Francois and Roland-Holst (1997). We assume that product varieties are imperfect substitutes and products are differentiated by source country/region. Buyers substitute between varieties at a constant rate of substitution, and consumers maximize utility. Further, we assume that firms maximize profits, markets are perfectly competitive, and markets clear in every market.

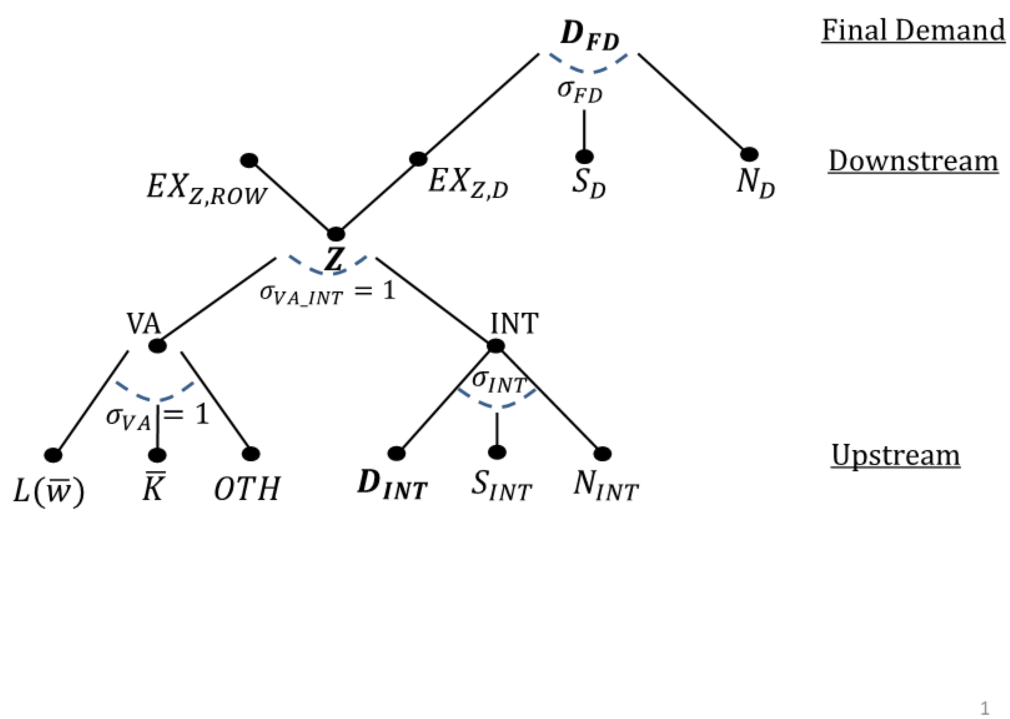

Figure 1: Nesting structure of industry-specific Armington model

Figure 1 illustrates the conceptual framework of the industry-specific Armington model. For illustrative purposes, we assume that a tariff is applied to the variety of imports in the industry from subject countries (S) but not to the variety of imports from non-subject countries (N). Domestic firms combine primary factors into a value-added composite and combine intermediate inputs into an intermediates composite. Value-added and intermediate composites are in turn combined to produce domestic output in the industry (Z). Domestic production consists of a variety for export to the rest of the world (ROW), and a variety that feeds into demand for final goods in the industry (D). Demand for final goods is also supplied by imports of varieties from subject and non-subject countries.

Demand for final goods (FD) in the industry follows from the Armington (1969) Constant Elasticity of Substitution assumption regarding consumer preferences, given by Equation 1:

$$q_{\text{FD,i}} = Q_{\text{FD}} b_{\text{FD,i}} (\frac{P_{\text{FD}}}{p_{\text{FD,i}}})^{\sigma_{\text{FD}}} \quad \forall \ i \ \in \ \{D, N, S\} \tag{1}$$

where Q is total demand for final goods and $b_{FD,i}$ are factors that shift the demand curve. The demand shift parameters are calibrated using initial market shares of each variety $i \in \{D, N, S\}$ and sum to one in the initial equilibrium.

The buyers' prices for each variety is p_i. The producers' prices for domestic and non-subject imports are equal to the buyers' prices. However, the producers' price of the imported variety of the final demand product from subject countries is $\frac{p_{\text{FD,S}}}{(1+\tau)}$, where τ represents the tariff rate. The model assumes that the supply functions for the imported varieties $h \in \{S, N\}$ are constant price elastic, given by Equations 2 and 3:

$$q_{\text{FD,N}} = a_{\text{FD,N}} * p_{\text{FD,N}}^{\varepsilon_{\text{FD,N}}} \tag{2}$$

$$q_{\text{FD,S}} = a_{\text{FD,S}} (\frac{p_{\text{FD,S}}}{1+\tau})^{\varepsilon_{\text{FD,S}}} \tag{3}$$

where the ε_h are constant price elasticities of supply, and a_h represent factors that shift the supply curves. The supply equations are calibrated to fit industry data, reflecting the level of production capacity and input costs.

The Constant Elasticity of Demand structure in the final goods market implies the following additive consumer price index in Equation 4:

$$P_{\text{FD}} = \left[\sum_{i \in D,S,N} b_{\text{FD,i}} p_{\text{FD,i}}^{1-\sigma_{\text{FD}}} \right]^{\frac{1}{1-\sigma_{\text{FD}}}} \tag{4}$$

Total industry demand adjusts to changes in the average of industry prices, reflecting movement in consumption between varieties. Total demand is given by Equation 5:

$$Q_{FD} = k_A P_{FD}^{\theta} \tag{5}$$

where k_A represents the initial national aggregate industry expenditure (Y_0) at the baseline calibrated price, P_{FD}=1, and θ represents the price elasticity of total demand in the industry.

Domestic firms combine a value-added composite and an intermediate composite with Constant Elasticity of Transformation (CET) technology to produce two varieties of the industry output (Z). One variety is produced for export to the Rest of the World (ROW) and the other variety supplies the domestic (D) final demand. The supply functions for the two varieties $k \in \{D, ROW\}$ are given by Equation 6:

$$q_{FD,k} = q_z \delta_k \left(\frac{p_z}{p_{FD.k}}\right)^{-\rho} \tag{6}$$

where q_Z denotes total domestic production of the final demand product. The parameter ρ represents the constant elasticity of transformation parameter which governs the rate that output can be converted between the two varieties $k \in \{D, ROW\}$. The shares of domestic production that are allocated to each variety k in the initial equilibrium are represented by the parameters δ_k, and sum to one. We denote $p_{FD,k}$ as the price of domestic output of each variety k, and p_Z is the producer price index of output. We assume that output q_Z is small relative to the rest of the world market such that it does not influence world price. It follows that world price can be fixed, assuming that the rest of the world demand is perfectly elastic.

The value-added (VA) and intermediate (INT) composites that are combined as described above are each produced domestically with constant returns to scale Cobb-Douglas technology. The resulting factor demand functions for the two composite inputs $j \in \{VA, INT\}$ are given by Equation 8:

$$q_j = \frac{\beta_j \, p_z}{p_j} q_z \quad \forall \ j \in \{VA, INT\} \tag{7}$$

where the β_j represent the cost share parameters for the value-added and intermediate composite inputs in the initial equilibrium and sum to one. Together with the zero-profit/perfect competition assumption, the demand equations imply that the price of domestic output is equal to its unit cost function:

$$p_{\text{z}} = p_{\text{VA}}^{\beta_{\text{VA}}} \; p_{\text{INT}}^{\beta_{\text{INT}}} \tag{8}$$

where the p_j are prices of the composite inputs.

Domestic firms produce the value-added composite by combining primary factors – labor (L) and capital (K)in fixed expenditure shares using constant returns to scale Cobb Douglas technology. The demand function for each value-added input $F \in \{K, L\}$ is given by Equation 9:

$$q_{\text{VA,F}} = \frac{\beta_{\text{F}} p_{\text{VA}}}{p_{\text{F}}} q_{\text{VA}} \tag{9}$$

where p_{F} and β_{F} represent the price and cost share of factor $F \in \{K, L\}$, respectively. The unit cost function for the value-added composite input is given by Equation 10:

$$p_{\text{VA}} = \Pi_{\text{F}} p_{\text{F}}^{\beta_{\text{F}}} \tag{10}$$

The intermediate composite input consists of a variety of inputs that are sourced from different countries: the home country, countries subject to the tariff, and countries not subject to the tariff. The varieties differentiated by source country/region are combined into the intermediate composite input using CES technology. The resulting demand function for varieties $i \in \{D, S, N\}$ of intermediate inputs is given by Equation 11:

$$q_{\text{INT,i}} = q_{\text{INT}} b_{\text{INT,i}} \left(\frac{p_{\text{INT}}}{p_{\text{INT,i}}} \right)^{\sigma_{\text{INT}}} \quad \forall \; i \;\; \in \;\; \{D, S, N\} \tag{11}$$

where the $b_{INT,i}$ are productivity parameters specific to the three varieties $i \in \{D, S, N\}$. The productivity parameters are calibrated to initial market shares and sum to one.

The assumption of perfectly competitive markets implies that Equations 2 and 3 determine the price of the composite intermediate input price in the place of an explicit supply equation. It follows that the unit cost of the composite intermediate input is the CES price index in Equation 12:

$$P_{\text{INT}} = \left[\sum b_{\text{INT,j}}\, p_{\text{INT,j}}^{1-\sigma_{\text{INT}}}\right]^{\frac{1}{1-\sigma_{\text{INT}}}} \quad \forall \;\; i \;\; \in \;\; \{D, S, N\} \tag{12}$$

where $p_{\text{INT,j}}$ are the consumer prices of the three varieties j of intermediate products. The producer prices are equal to consumer prices for the varieties of intermediate products sourced domestically and from non-subject countries. The imported varieties of intermediate products from subject countries are subject to a tariff, thus producer prices of this variety are $\frac{p_{\text{INT,S}}}{1+\tau}$. The intermediate inputs are supplied according to a constant price elasticity supply function:

$$q_{\text{INT,g}} = a_{\text{INT,g}}\, p_{\text{INT,g}}^{\varepsilon_{\text{INT,g}}} \quad \forall \;\; g \;\; \in \;\; \{D, N\} \tag{13}$$

$$q_{\text{INT,S}} = a_{\text{INT,S}} \left(\frac{p_{\text{INT,S}}}{1+\tau}\right)^{\varepsilon_{\text{INT,S}}} \tag{14}$$

where the $\varepsilon_{\text{INT,i}}$ denote the constant price elasticities of supply $\forall \;\; i \; \in \{D, S, N\}$ and the represent the $a_{\text{INT,i}}$ represents the factors that shift the variety i supply curve. The level of production in the industry and industry-specific input costs are used to calibrate the supply curve parameters.

Model calibration is completed by setting initial equilibrium conditions. Initial prices are set to one and demand shift parameters are set to initial market shares for each variety $i \in \{D, S, N\}$. The productivity terms are calibrated to initial cost shares in the value-added factor demand equations, and shift parameters in the supply equations are set equal to the relevant initial quantities supplied.

4 PE vs GE Model Predictions

In this section, we describe the simulation of two industry-specific shocks using a partial equilibrium Armington model. We draw on industry-specific policy shocks that have been previously been simulated using computable general equilibrium Armington models. We characterize the distance between the predicted outcomes and discuss the mechanisms behind the different model predictions.

4.1 U.S. Electricity Generation Industry

Barbe (2017) studies the effects of restricting coal consumption by the U.S. electricity generation industry on coal exports and greenhouse gas emissions. This is a narrowly defined shock to a strategic industry. Using a modified version of the GTAP-E model, Barbe (2017) restricts the ratio of the quantity of coal inputs used relative to the quantity of electricity generated by 10 percent below the baseline level. Emissions and exports are calculated based on simulations of restrictions on coal inputs at 10 percentage point increments. An important finding of the paper is that U.S. and foreign inter-fuel substitution would make coal-specific environmental policy less effective than comprehensive environmental policies.

The partial equilibrium model sketched in the previous section is modified to simulate the U.S. electricity generation industry with a 10 percent (and incrementally higher) relative reduction in the use of coal. The modification occurs primarily through adjustments in substitution elasticities for consistency with GTAP-E, re-organization of the value-added arm of the industry, and the restriction on coal use. The restriction is a 10 percent shock to demand, which is implemented as a mixed-complementarity problem using fixed supply equations. This restriction is not modeled as a tariff, but rather a fixed quantity restriction.

Table 1 contains the PE vs GE model predictions for coal, oil and gas emissions, as well as coal exports. The PE vs GE predictions of the change in coal emissions at the national level are a close match. At a restriction of 10 percent, the partial equilibrium framework predicts that greenhouse gas emissions attributable to coal will reduce by 246 million metric tons. Meanwhile, the general equilibrium framework predicts the same restriction reduces emissions by 204 million metric tons. The predictions are 42 million metric tons apart for the 10 percent restriction. The deviation is 20.6 percent of the change predicted by the CGE simulation. Put differently, the 42 million metric ton difference is 2.8 percent of total coal emissions in 2007. As the intensity of the coal restriction is elevated, the distance between the PE vs GE model predictions grow closer in relative terms. The PE prediction deviates by 123 million metric tons at the 50 percent restriction, which is 11.7 percent of the CGE prediction and 10.1 percent of 2007 coal emissions.

Two additional patterns emerge among the PE vs GE model predictions in Table 1. The change in U.S. oil and gas emissions and emissions in the rest of the world are not closely matched between

Table 1: Restriction on Coal Use for Electricity Generation

Coal Intensity Reduction (percent)	10	20	30	40	50
Change in U.S. Coal Emissions PE	-246	-477	-708	-940	-1171
Change in U.S. Coal Emissions CGE	-204	-427	-676	-958	-1294
Change in U.S. Oil and Gas Emissions PE	-190	-386	-602	-843	-1115
Change in U.S. Oil and Gas Emissions CGE	31	72	127	212	368
Change in ROW Emissions PE	13	28	46	69	96
Change in ROW Emissions CGE	-1	-2	-2	-3	-4
Change in Total World Emissions PE	-422.5	-835	-1264	-1714	-2190
Change in Total World Emissions CGE	-173	-357	-551	-750	-930
Percent change					
U.S. Coal Exports PE	12.5	26.7	44.1	65.3	91.4
U.S. Coal Exports CGE	3.3	7.7	13.9	23.2	39.4
Total U.S. Emissions PE	-6	-13	-17	-24	-31
Total U.S. Emissions CGE	-3	-6	-10	-13	-17

Source: Barbe (2017) and authors calculations. Emissions are given in millions of metric tons.

Table 2: Change in Welfare from Restricting Coal Consumption

Coal Intensity Reduction (percent)	10	20	30	40	50
Change in U.S. Welfare PE (billion USD)	-0.017	-0.017	-0.018	-0.019	-0.019
Change in U.S. Welfare CGE (billion USD)	-1.3	-5.6	-15.3	-36.6	-89.9
Marginal U.S. Welfare Cost PE (USD per MT CO2)	0.36	0.33	0.30	0.27	0.23
Marginal U.S. Welfare Cost CGE (USD per MT CO2)	15	35	73	166	678

the two frameworks. The partial equilibrium framework does not assess the extent of domestic and foreign inter-fuel substitution. This is a potential factor of the larger decreases in domestic demand for oil and gas and modestly larger increases in coal exports and emissions in the rest of the world than predicted by the GE model. Due to the many additional moving parts in a general equilibrium framework, this question is difficult to answer.

We simulate the changes in welfare that result from the incremental coal restrictions. As suggested in the literature, the differences between welfare estimates calculated from PE and CGE models can be quite large (Kokoski and Kerry Smith (1987), Hess and Von Cramon-Taubadel (2008)). Many modelers find welfare estimates from CGE models to be more believable, as changes to welfare from a policy shock in the real world are distributed across the economy due to factor scarcity, income effects, and intersectoral linkages. Our industry-specific Armington PE model confines the effects of the shock to one sector by design, omitting the aforementioned features of the economy from the modeling experiment. We include the calculations of welfare under the PE model for completeness, understanding the limitations.

The marginal welfare cost of abatement is calculated as the change in U.S. welfare that results from a one percentage point increase the coal intensity reduction divided by the resulting change in world emissions. The measure of welfare is calculated using equivalent variation (i.e. the level of income required to reach final utility at original prices), the same welfare measure that GTAP models use (Huff and Hertel (2001))[1]. The utility function can be expressed as:

$$U = \left(\sum b_{i} q_{i}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{15}$$

where b represents market share, q represents quantity demanded, and σ is the Armington elasticity of substitution. We derive industry demand from the utility maximization, and calculate total industry expenditures from the indirect utility function.

Table 2 contains the results of the PE welfare simulations as compared to the results reported by Barbe (2017). The welfare results are substantially different. At the 10 percent restriction, the welfare predictions are 1.283 billion USD apart. The PE prediction is 98.7 percent less than the

[1] *EV = e(p,u') - e(p,u)*, where *e()* is the expenditure function, *p* represents original prices, *u* represents original utility, and *u'* represents final utility.

GE framework. The economic significance of this result increases with the size of the coal intensity reduction as the PE welfare prediction is relatively constant.

We do not evaluate the performance of the PE framework by its ability capture all outcomes as predicted by the GE framework. Instead we evaluate the PE framework by its ability to predict outcomes for which we have GE estimates and that might have otherwise been assessed using partial equilibrium. This is an important nuance for the industry-specific partial equilibrium model of the U.S. electricity generation industry. In partial equilibrium, we hold all other industries and economies constant. As a result, the effect of inter-fuel substitution nationally on the second-order effects on the industries that are intensive in non-coal fossil fuels is not produced in the PE simulation. This is a factor that is important for understanding the large disparity in the PE vs GE model predictions of the change in oil and gas emissions. The differential performance is evidence that the objective will be important for a modeler to consider when deciding between PE and GE frameworks. Barbe (2017) explains that an objective of his CGE study is to assess the extent of the spillovers that result from fuel-specific policies, which is only possible with the structure that exists in the GE framework.

In conclusion, the evidence on the closeness of the PE vs GE model predictions in assessing a restriction on the input ratio of coal in the U.S. electricity generation sector is mixed. The industry-specific partial equilibrium Armington model produces reasonable predictions for the reduction in greenhouse gas emissions attributable to coal, domestically. The PE framework produces a larger prediction of the increase in exports of coal to the rest of the world and greenhouse gases produced in the rest of the world. This prediction is a factor of foreign inter-fuel substitution. The PE model also produces a larger estimate than the GE model of the total decrease in U.S. from all sources that results from the restriction on coal use. The latter mis-match is a factor of domestic inter-fuel substitution and the resulting general equilibrium effects in other industries not captured by the PE model.

4.2 Steel Industry

Lee and van der Mensbrugghe (2003) model a tariff rate quota on imports of steel in the United States that is imposed on a specific group of countries, a policy that went into effect in March 2002. This is a shock imposed on a large industry in the market for inputs to production of intermediates. Lee and van der Mensbrugghe (2003) use the Linkage 5 model, which is a dynamic global CGE model. However, welfare is the only dynamic outcome of this model, all other outcomes are estimated for 2003 relative to the baseline scenario, and welfare is presented in year over year changes. The data comes from the GTAP database, version 5. Per capita GDP growth rates from the World Bank are used to calibrate the baseline from 1997 through 2005. The TRQ is imposed by assigning a tariff rate of 30 percent on the imports of steel beyond the bilateral level imports from certain countries in the year 2000. An important conclusion of Lee and van der Mensbrugghe (2003) is that the welfare effects are quite small, and this could help us understand why there is little pushback against the costs of protectionism in the steel industry.

The partial equilibrium model is modified to simulate the U.S. steel industry with average tariff rates for the subject and non-subject countries in 2003. The tariff-rate quota is imposed on subject countries and is implemented following Lee and van der Mensbrugghe (2003). For a level of imports below the quota level, the tariff remains at the 2003 level. Levels of imports greater than or equal to the quota level carry a 30% tariff.

We present a summary of the outcomes in the Table 2. The PE model predictions are larger across all outcomes except welfare. The increase in the output of steel is accommodated by the increase in average cost. This result is consistent with an increase in industry protection. The industry linkages that feedback from reduced output to fewer steel demanded in the GE framework are turned off in the PE framework. The disparity in exports can be explained by the inability to measure the large response of the steel industries in Canada and Mexico using the partial equilibrium model of the United States. Lee and van der Mensbrugghe (2003) report negative changes in U.S. exports to all other countries and regions ranging between -0.07 percent and -0.17 percent. The deviation between the averages of 0.24 percentage points of U.S. exports of steel is rather small.

The match between the PE vs GE industry-specific model predictions in simulating a TRQ on U.S. imports of steel is not perfect. The partial equilibrium framework predicts that the steel industry increases output by 0.727 percent, while Lee and van der Mensbrugghe (2003) estimated a 0.229 percent increase in output. In 2003, U.S. steel production was 93.7 million metric tons at $110 per ton for a total value of production at $10.3 billion[2]. The .498 percentage point difference

[2]Iron and Steel Statistics, U.S. Geological Survey.

Table 3: TRQ on United States Imports of Steel

Outcome	PE Model Prediction (percent)	GE Model Prediction (percent)
U.S. Output of Steel	0.727	0.229
U.S. Average Cost of Steel	0.117	0.022
Subject Country Imports	-26.90	-2.67
Non-subject Country Imports	2.40	2.20
U.S Exports	-0.23	0.01
U.S. Welfare	-0.18 Million USD	10.6 Million USD

Source: Lee and van der Mensbrugghe (2003) and authors calculations.

in the PE vs GE: model steel output predictions amount to $51.33 million. Given the size of this industry and its many linkages, we think that this prediction difference is economically small.

We calculate the change in U.S. Welfare that results from the TRQ on U.S. imports of steel. The measure of welfare here is also equivalent variation. We find a -0.175 million USD change in welfare that results from the trade policy. This welfare change is in the opposite direction and the total distance is 101.6 percent of the CGE prediction, but just 0.105 percent of output of the steel industry in 2003. Lee and van der Mensbrugghe (2003) attribute much of the increase in U.S. welfare to higher exports. This explains this distance in our welfare outcomes. Because we do not capture the Canadian and Mexican response, we miss this feature of the model. Nonetheless, these welfare values are economically small.

Steel is an industry with important linkages to other industries such as metal products, motor vehicles, other transportation equipment, and construction. Additionally, this is a global market with many large producers and Lee and van der Mensbrugghe (2003) show that the largest producers have changed over time. As a result, shocks to the price of steel by the United States will cause effects across industries and countries, which has the result of dampening the expansion in output enjoyed by United States steel producers. This is one of several linkages that lend feedback in the GE framework and not in the PE framework, which can in part explain the moderately large PE model simulations.

5 Conclusion

The partial equilibrium framework is a tool used by policymakers to simulate probable economic outcomes as the result of industry-specific policy shocks. The partial equilibrium framework is especially useful for studies that are industry-specific and for time-sensitive policy analysis. The caveat is that PE assumes away general equilibrium effects. To understand the trade-offs being made, we draw on two general equilibrium studies and simulate the shocks under identical conditions except that we use a partial equilibrium framework. We compare the simulated outcomes across quantities demanded, imports and exports, prices, and welfare. We find that the partial equilibrium simulations tend to make predictions that are slightly larger than the general equilibrium simulations, except in the case of welfare. We have chosen two studies that use industry-specific shocks but study industries that have many important linkages. Despite the environment that favors general equilibrium, the distance between our PE vs GE model predictions is economically small. This is new evidence that PE is an effective policy tool for evaluating industry-specific shocks. Future research should apply this question in a paired simulation study to focus on the individual model components.

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