ADDING GENERAL EQUILIBRIUM FEEDBACK INTO INDUSTRY-SPECIFIC MODELS OF TRADE POLICY

David Riker

ECONOMICS WORKING PAPER SERIES
Working Paper 2024–12–B

U.S. INTERNATIONAL TRADE COMMISSION
500 E Street SW
Washington, DC 20436

December 2024

The author thanks Peter Herman, Tyler Loxton-Daun, and Sam Schreiber for helpful comments and suggestions on an earlier draft.

Adding General Equilibrium Feedback into Industry-Specific Models of Trade Policy
David Riker
Economics Working Paper 2024–12–B
December 2024

Abstract

Industry-specific partial equilibrium models of trade policy have several practical advantages. They can capture the distinctive and sometimes complex features of an industry and the fine details of a proposed trade policy. However, partial equilibrium models do not address spillovers to the broader economy or general equilibrium feedback, which can sometimes matter in trade policy analysis. This paper develops a method for adding a general equilibrium extension onto an industry-specific model of trade policy. Using this method, I simulate the economic effects of hypothetical changes in tariffs on U.S. imports of manufactured goods. The simulations demonstrate the usefulness and adequacy of partial equilibrium models. They indicate that a general equilibrium extension can improve estimates of the effects of an industry-specific policy change, but only if the industry comprises a relatively large share of the economy. The simulations also demonstrate that a partial equilibrium model can provide an estimate of the percent change in the value of the aggregate output of the economy that is usually quite close to the estimate from a more extensive general equilibrium model.

David Riker
Research Division, Office of Economics
david.riker@usitc.gov

1 Introduction

Trade policies like tariffs, quotas, and tariff rate quotas are usually applied narrowly to the imports of specific industries, and they usually do not have significant economy-wide effects.[1] Partial equilibrium (PE) simulation models are well-suited for quantifying the economic effects of industry-specific policies. A PE model can be tailored to the distinctive features of the industry, like the degree of market concentration or capacity constraints on production, and in this way the model can provide a more realistic picture of the affected industry. A PE model can also be tailored to the fine details of complex trade policies like rules of origin and tariff rate quotas.[2] Finally, a PE model usually requires less data than comprehensive economy-wide models.

Given these practical advantages, PE models are commonly used in trade policy analysis. Recent examples of tailored PE models of trade policy include a solar safeguard model in U.S. International Trade Commission (2020), an automotive rules of origin model in U.S. International Trade Commission (2023b), a Section 232 tariff model in U.S. International Trade Commission (2023a), and a Section 201 polyester staple fiber tariff rate quota model in U.S. International Trade Commission (2024).

At the same time, PE models have limitations. Models that focus on a single industry do not fully account for the industry's links to the rest of the economy. Resource constraints might lead to significant general equilibrium (GE) feedback in factor prices and aggregate expenditure, even in cases where changes in trade policy are narrowly focused on a single industry, and assuming away this GE feedback might reduce the accuracy of PE estimates.

Quantitative GE trade models like Caliendo and Parro (2022) or Dix-Carneiro, Pessoa, Reyes-Heroles and Traiberman (2023) or computable general equilibrium (CGE) models

[1] Trade policies that are broadly applied, like NAFTA or the more recent Section 301 tariffs on U.S. imports from China, are notable exceptions.

[2] Riker (2018) and Riker (2024) are examples of PE models of rules of origin and TRQs.

like GTAP are alternative tools for analyzing the effects of changes in trade policy.[3] They include inter-industry linkages, economy-wide resource constraints, and GE feedback, and these models can be useful for analyzing the economic impact of broadly applied trade policies; however, they are less useful for analyzing the impact of narrowly applied policies, because they usually rely on stylized representations of highly aggregated sectors.

A practical compromise is to build a PE model that is elaborate and specialized enough to capture the distinctive features of the industry with the change in trade policy and then embed this PE model into a GE framework.[4] In this paper, I demonstrate how to do this, under small country or large country general equilibrium assumptions. These GE extensions can be added to complex PE models as well as the basic PE model that I present in this paper. I use the extended models to quantify the GE feedback and economy-wide effects of an industry-specific change in trade policy and examine whether the GE extensions improve the PE estimates of economic effects.

The simulations demonstrate that PE models provide practical and generally accurate estimates of effects within the industry subject to the tariff change and also of the economy-wide effects of industry-specific tariff changes. Extensions that incorporate GE feedback can improve estimates of the effects of an industry-specific policy change, but only if the industry comprises a relatively large share of the economy.

Section 2 presents a basic PE model of the economic effects of tariffs. Section 3 derives a small country GE extension of this model, and section 4 derives a large country GE extension. Section 5 uses the model to simulate the effects of hypothetical changes in tariffs on U.S. imports in the broader manufacturing sector and in 18 separate industries within this sector. Section 6 explains how to add a GE extension to more elaborate PE models of trade policy. Section 7 provides concluding remarks.

[3]GTAP is the Global Trade Analysis Project at `https://www.gtap.agecon.purdue.edu/`.

[4]Böhringer and Rutherford (2008) presents an alternative method for embedding the detail of a bottom-up industry-specific model in a economy-wide model.

2 A Basic PE Model of Trade Policy

The basic PE model focuses on a single industry with perfect competition and international trade. Factors of production are supplied on broad, economy-wide factor markets. Factor supplies are perfectly price-elastic from the perspective of domestic producers in the single industry, so factor prices are treated as exogenous variables in the PE model. There are domestic and foreign producers. Foreign producer prices, foreign aggregate expenditure, domestic aggregate expenditure, and tariff rates are also treated as exogenous variables.

The industry sells its output to domestic consumers and exports to the rest of the world. Its production function is Cobb-Douglas with constant labor share α. The price of the domestic product is p.

$$p = (w)^{\alpha}\ (r)^{1\ -\ \alpha} \tag{1}$$

w is the wage, and r is the price of an aggregate of non-labor factors of production.

The industry receives a constant share of aggregate expenditure γ.[5] There is a constant elasticity of substitution (CES) between imports and domestic products within the industry with elasticity σ. Aggregate expenditures in the domestic and export markets are E and E^*. Given these assumptions, equations (2) through (4) represent the values of the industry's domestic shipments (V), imports (M), and exports (X).

$$V = \gamma\ E\ (P)^{\sigma-1}\ (p)^{1-\sigma} \tag{2}$$

$$M = \gamma\ E\ (P)^{\sigma-1}\ (p^*\ \tau)^{1-\sigma}\ \psi \tag{3}$$

[5]This reflects a conventional assumption that the elasticity of substitution between industry composites of goods is one.

$$X = \gamma \; E^* \; (P^*)^{\sigma-1} \; (p \; \tau^*)^{1-\sigma} \; \psi^* \tag{4}$$

p^* and τ are the foreign producer price and tariff factor on imports, and ψ is a preference parameter on imports in the domestic market.[6] τ^* is the foreign tariff factor, and ψ^* is the preference parameter on imports in the foreign market. P is the industry's CES price index in the domestic market.

$$P = \left((p)^{1 \; - \; \sigma} \; + \; \psi \; (p^* \; \tau)^{1 \; - \; \sigma}\right)^{\frac{1}{1 \; - \; \sigma}} \tag{5}$$

P^* is the industry's CES price index in the foreign market.

$$P^* = \left((p^*)^{1 \; - \; \sigma} \; + \; \psi^* \; (p \; \tau^*)^{1 \; - \; \sigma}\right)^{\frac{1}{1 \; - \; \sigma}} \tag{6}$$

Domestic employment in the industry (L) is the sum of labor demand from the industry's domestic shipments and exports.

$$L = \frac{\gamma \; E \; (P)^{\sigma-1} \; (p)^{1-\sigma} \; \alpha}{w} \; + \; \frac{\gamma \; E^* \; (P^*)^{\sigma-1} \; (p \; \tau^*)^{1-\sigma} \; \psi^* \; \alpha}{w} \tag{7}$$

Equations (8) to (15) represent the percent changes in industry economic outcomes that would result from a percent change in the tariff factor ($\hat{\tau}$).

No Change in the Price of the Domestic Product

$$\hat{p} = 0 \tag{8}$$

Percent Change in the Delivered Price of Imports

$$\hat{d} = \hat{\tau} \tag{9}$$

[6]The tariff factor is equal to one plus the tariff rate.

Percent Change in the Value of Domestic Shipments

$$\hat{V} = (\sigma \ - \ 1) \ \mu \ \hat{\tau} \tag{10}$$

Percent Change in the Value of Imports

$$\hat{M} = (1 \ - \ \sigma) \ (1 \ - \mu) \ \hat{\tau} \tag{11}$$

No Change in the Value of Exports

$$\hat{X} = 0 \tag{12}$$

Percent Change in Employment in the Domestic Industry

$$\hat{L} = (\sigma \ - \ 1) \ \mu \ \hat{\tau} \ (1 \ - \ \chi) \tag{13}$$

No Change in Wages

$$\hat{w} = 0 \tag{14}$$

Percent Change in the Value of Aggregate Output

$$\hat{Y} = \left(\frac{V}{Y}\right) \ \hat{V} \tag{15}$$

To simplify the notation, I have defined $\mu = \frac{M}{V+M}$ as the industry's initial import share of the domestic market, $\chi = \frac{X}{V+X}$ as the share of the value of the industry's output that is initially exported, $d = p^* \ \tau$ as the initial landed price of industry imports, and Y as the value of the aggregate output of the domestic economy.

These equations embed the PE restrictions of the model: wages, other factor prices,

aggregate expenditure levels, foreign producer prices, and tariff rates are exogenous and not affected by the change in the tariff on imports. Given the constant returns to scale production technology, the prices of domestic producers and their export values are also not affected. These PE restrictions are a good fit when analyzing the effects of tariff changes in an industry that does not account for a large share of the domestic economy.

In this PE model, the percent change in the value of aggregate output is simply the percent change in the value of the industry's domestic shipments ($\hat{V}$) multiplied by the initial share of the value of the industry's shipments in the value of aggregate output in the economy ($\frac{V}{Y}$).

3 Small Country GE Extension

In this section, I extend the model by adding a second industry representing the rest of the economy, and then I solve for the general equilibrium. I label the two industries 1 and 2. With this extension, the model quantifies the general equilibrium feedback in domestic factor prices and aggregate expenditure. In this model, foreign aggregate expenditure levels, foreign producer prices, and tariff rates are exogenous and not affected by the change in the tariff on imports.

This is a small country version of a GE model, because there is inter-industry feedback but not international feedback. (Foreign aggregate expenditure, foreign producer prices, and tariff rates are still treated as exogenous variables.) The small country assumption is a good fit when analyzing the effects of tariff changes in an industry that is large relative to its national economy but small relative to the global economy. The small country GE model has more extensive data requirements than the PE model in section 2, since it also solves for changes in wages, the prices of domestic producers, and the value of their exports.

Equations (16) through (25) fully describe the small country GE extension of the PE

model. The variable $i \in \{1, 2\}$ indexes the industries in the small country. Equation (16) is the price of the domestic product.

$$p_i = (w)^{\alpha_i} \ (r)^{1 \ - \ \alpha_i} \tag{16}$$

Equations (17) and (18) are the industry price indices.

$$P_i = \left((p_i)^{1 \ - \ \sigma_i} \ + \ \psi_i \ (p_i^* \ \tau_i)^{1 \ - \ \sigma_i}\right)^{\frac{1}{1 \ - \ \sigma_i}} \tag{17}$$

$$P_i^* = \left((p_i^*)^{1 \ - \ \sigma_i} \ + \ \psi_i^* \ (p_i \ \tau_i^*))^{1 \ - \ \sigma_i}\right)^{\frac{1}{1 \ - \ \sigma_i}} \tag{18}$$

Equations (19) and (20) equate factor incomes to revenues from domestic shipments and exports.

$$w \ L_i = \gamma_i \ E \ (P_i)^{\sigma_i - 1} \ (p_i)^{1 - \sigma_i} \ \alpha_i \ + \ \gamma_i \ E^* \ (P_i^*)^{\sigma_i - 1} \ (p_i \ \tau_i^*)^{1 - \sigma_i} \ \alpha_i \tag{19}$$

$$r \ K_i = \gamma_i \ E \ (P_i)^{\sigma_i - 1} \ (p_i)^{1 - \sigma_i} \ (1 \ - \ \alpha_i) \ + \ \gamma_i \ E^* \ (P_i^*)^{\sigma_i - 1} \ (p_i \ \tau_i^*)^{1 - \sigma_i} \ (1 \ - \ \alpha_i) \tag{20}$$

Equations (21) and (22) are market clearing conditions.

$$\sum_i L_i = \bar{L} \tag{21}$$

$$\sum_i K_i = \bar{K} \tag{22}$$

Equation (23) equates aggregate expenditure to factor incomes.

$$E = w\ \bar{L}\ +\ r\ \bar{K} \tag{23}$$

$\bar{L}$ and $\bar{K}$ are exogenous factor endowments in the small country. The domestic factor prices, w and r, are not industry-specific. The model assumes that tariff revenues are not redistributed to consumers.

I expect that this small country GE extension will dampen the simulated effect of the tariff change on domestic employment in the industry compared to the employment effects in the PE model, especially if the industry accounts for a large share of the national economy, since the GE extension incorporates crowding out of resources.

4 Large Country GE Extension

Next, I extend the model further to solve for changes in foreign producer prices and aggregate expenditure in a global general equilibrium. In this model, tariff rates are exogenous but prices and expenditure levels are not.This is a large country version of the GE model, because there is international as well as inter-industry feedback. The large country general equilibrium assumption is a good fit when analyzing the effects of tariff changes in an industry that is large relative to both the national and global economies. This GE extension has more extensive data requirements than either of the other two models.

Equations (24) through (29) are the compable equilibrium conditions for the large country GE extension. The variable i indexes industries, and the variables c and c' index countries. Equation (24) is the price of the domestic product.

$$p_{ic} = (w_c)^{\alpha_{ic}}\ (r_c)^{1\ -\ \alpha_{ic}} \tag{24}$$

Equations (25) and (26) equate factor incomes to revenues from domestic shipments and

exports.

$$w_c \; L_{ic} = \sum_{c'} \gamma_i \; E_{c'} \; (P_{ic'})^{\sigma_i - 1} \; (p_{ic} \; \tau_{ic'})^{1-\sigma_i} \; \alpha_{ic} \tag{25}$$

$$r_c \; K_{ic} = \sum_{c'} \gamma_i \; E_{c'} \; (P_{ic'})^{\sigma_i - 1} \; (p_{ic} \; \tau_{ic'})^{1-\sigma_i} \; (1 \; - \; \alpha_{ic}) \tag{26}$$

Equations (27) and (28) are market clearing conditions.

$$\sum_i L_{ic} = \bar{L_c} \tag{27}$$

$$\sum_i K_{ic} = \bar{K_c} \tag{28}$$

Equation (29) equates aggregate expenditure to factor incomes.

$$E_c = w_c \; \bar{L_c} \; + \; r_c \; \bar{K_c} \tag{29}$$

I expect that the large country GE extension will also dampen the PE effects as the crowding out of resources increases wages. In this large country GE extension, there is also an increase in foreign wages that mitigates the decline in the exports of the domestic industry. For this reason, I expect that the estimated employment effects for the large country GE extension will be smaller than the small country estimates and closer to the PE estimates.

5 Applying the Models to Specific Industries

In this section, I use the three versions of the model from sections 2, 3, and 4 to simulate the economic effects of a hypothetical 10% increase in the tariff factor on imports of the broad

manufacturing sector in the United States and the 18 specific industries within this sector.[7]

The simulation models are calibrated to annual 2014 data from the World Input-Output Database (WIOD). This database provides information on trade, output, and intermediate and final consumption for each of 56 sectors in 43 regions that span the global economy.[8] WIOD is widely used in GE models of trade policy, including Caliendo and Parro (2022) and Dix-Carneiro et al. (2023). The simulations set σ equal to 2.53 for all industries. This is the econometric estimate in Caliendo and Parro (2022). The GE extensions of the models calibrate the ratio of aggregate expenditures to aggregate income of the United States to the trade imbalance in WIOD. The simulations fix this ratio and adjust the corresponding ratio in the rest of the world to maintain global trade balance.

The magnitudes of the PE effects of an industry-specific tariff change depend on the magnitude of the tariff change, the elasticity of substitution, and the import and labor cost shares in the industry. Table 1 reports these shares for the entire U.S. manufacturing sector and the 18 industries within the sector, along with each industry's share of the U.S. economy in the 2014 WIOD data.

[7] I use Wolfram Mathematica to run the simulations.

[8] The models incorporate the 2014 World Input-Output Table and the Socio Economic Accounts. These data are publicly available at `https://www.rug.nl/ggdc/valuechain/wiod/?lang=en`.

Table 1: Inputs of the PE Model

Industry	Import Share (%)	Labor Cost Share (%)	Industry's Share of the U.S. economy (%)
Broad Manufacturing Sector	24.59	15.89	19.95
Food, Beverages, and Tobacco	27.26	10.41	3.13
Textiles, Apparel, and Leather	74.77	23.03	0.30
Wood Products	13.05	20.00	0.32
Paper Products	13.03	15.50	0.63
Printing and Recorded Media	3.76	32.08	0.28
Coke and Petroleum Products	12.05	2.23	2.64
Chemical Products	22.60	12.09	1.93
Pharmaceutical Products	23.57	12.09	0.69
Rubber and Plastic Products	19.53	18.27	0.75
Non-Metallic Mineral Products	16.87	22.18	0.38
Basic Metals	26.34	11.40	0.91
Fabricated Metals	15.41	25.51	1.22
Computers and Electronics	50.01	34.34	1.25
Electrical Equipment	48.01	26.72	0.41
Machinery	31.22	22.94	1.31
Motor Vehicles	34.64	10.94	1.92
Other Transportation Equipment	17.89	21.96	1.12
Furniture and Other Manufacturing	30.46	28.52	0.77

The first simulation examines the broad manufacturing sector, and the second and third examine manufacturing industries with high import shares. Motor Vehicles is an example of a relatively large industry with a high import share, and Electrical Equipment is an example of a relatively small industry with a high import share.

5.1 Broad Manufacturing Sector

Table 2 reports the simulated effects of a 10% increase in the tariff factor on all U.S. manufacturing imports. According to WIOD, the output of this broad manufacturing sector accounted for 19.95% of the total output of the U.S. economy in 2014.[9]

[9]The broad manufacturing sector is defined as rows 5 through 21 in the WIOD tables.

Table 2: Simulations for the Broad Manufacturing Sector

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-18.71	-11.83	-14.44
Exports	0.00	-8.88	-5.70
Manufacturing employment	2.87	0.42	1.37
Manufacturing output	2.87	0.24	1.18
Aggregate output	0.50	0.02	0.19

Within the three simulations reported in the columns of table 2, the directions of change in the economic variables are intuitive. The landed value of imports (deflated by the price of imports) and the value of exports (deflated by the price of exports) decrease or stay the same, and domestic employment in the manufacturing sector increases. The value of the manufacturing sector's output (deflated by the price of domestic manufactures) increases along with the value of aggregate U.S. output (deflated by an output-weighted geometric average of the price changes in all sectors of the economy) due to the tariff increase in the manufacturing sector.

Across the three columns of estimates, there is a consistent ranking of the magnitudes of these changes for all economic outcomes except exports: the percent changes are greatest in absolute value for the PE model and are dampened in both GE models. In this sense, the PE estimate is an upper bound on the effects of the industry-specific policy change on these economic outcomes.[10] The effects for the small country GE extension are closer to zero than the PE effects as the crowding out of resources increases wages. The effects for the large country GE extension are not as far from the PE estimate, because the effects of crowding out are mitigated as the increase in foreign wages reduces the decline in exports.

[10]This is not the case for exports, since there are no effects on exports in the PE model.

5.2 Motor Vehicles

Table 3 reports estimates for a second simulation of the effects of a 10% increase in the tariff factor on imports in the U.S. motor vehicle industry. According to WIOD, the output of the motor vehicles industry accounted for 1.92% of the total output of the U.S. economy in 2014, much smaller than the share of the broad manufacturing sector.[11]

Table 3: Simulations for the Motor Vehicles Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-17.55	-16.74	-17.03
Exports	0.00	-1.19	-0.78
Industry employment	4.08	3.72	3.87
Industry output	4.08	3.66	3.80
Aggregate output	0.08	0.06	0.07

The economic variables in table 3 move in the same directions as table 2, with the same ranking of the magnitudes of changes across the columns. Unlike the broader manufacturing sector, there is only slight variation in the effects on aggregate output across the three models, at least at the level of precision reported in the table (one-hundredths of one percent). This reflects the relative size of the industry: it is only 1.92% of the total output of the U.S. economy. Again, the estimates of the effects on aggregate output are higher for the PE model than either of the GE extensions.

5.3 Electrical Equipment

Table 4 reports simulated effects of a 10% increase in the tariff factor on imports in the U.S. electrical equipment industry. The output of the electrical equipment industry accounted for only 0.41% of the total output of the U.S. economy in 2014.[12]

[11]The motor vehicle industry is row 20 in the WIOD tables.
[12]The electrical equipment industry is row 18 in the WIOD tables.

Table 4: Simulations for the Electrical Equipment Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-15.94	-15.75	-15.82
Exports	0.00	-0.31	-0.20
Industry employment	5.21	5.06	5.12
Industry output	5.21	5.06	5.11
Aggregate output	0.02	0.02	0.02

The economic variables in table 4 move in the same direction as the prior two tables and follow the same patterns. For this even smaller industry, there is *no variation* in the effect on aggregate output across the three models at the level of precision reported in the table.

5.4 Comparison of Effects across Industries

In this section, I compare the simulated effects across all 18 U.S. manufacturing industries. Table 5 reports effects on domestic employment for the three versions of the model. All of the simulations assume the same change in the tariff ($\hat{\tau} = 0.10$) and elasticity of substitution ($\sigma = 2.53$). The employment effects from the PE model are significantly larger for industries with higher import shares in table 1.[13] Textiles, Apparel, and Leather, Electrical Equipment, and Computers and Electronics are the three industries with the largest percent change in industry employment, and this reflects their high import shares in table 1.

[13] A regression of the PE employment effects in table 5 on the import share, labor cost share and industry share of the economy from table 5 indicate that only the import share had a statistically significant effect.

Table 5: Effects on Employment by Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Food, Beverages, and Tobacco	3.54	3.24	3.37
Textiles, Apparel, and Leather	9.75	9.50	9.60
Wood Products	1.68	1.68	1.68
Paper Products	1.57	1.55	1.56
Printing and Recorded Media	0.49	0.48	0.48
Coke and Petroleum Products	1.41	1.32	1.36
Chemical Products	2.54	2.35	2.42
Pharmaceutical Products	2.65	2.58	2.60
Rubber and Plastic Products	2.36	2.31	2.33
Non-Metallic Mineral Products	2.13	2.11	2.11
Basic Metals	3.30	3.21	3.25
Fabricated Metals	1.89	1.83	1.85
Computers and Electronics	5.17	4.67	4.85
Electrical Equipment	5.21	5.06	5.12
Machinery	3.24	3.00	3.09
Motor Vehicles	4.08	3.72	3.87
Other Transportation Equipment	1.58	1.48	1.51
Furniture and Other Manufacturing	3.63	3.51	3.56

Table 6 reports simulated effects on the real value of aggregate output, which are very close in magnitude across the three models for all 18 industries. The percent changes for the GE models are the same or lower in absolute value than the percent changes for the PE models, and the small country GE effects are the same or lower in absolute value than the large country GE effects. Food, Beverages, and Tobacco, Motor Vehicles, and Computers and Electronics are the three industries with the largest percent change in the real value of aggregate output, and this reflects their shares of the economy in table 1.

Table 6: Effects on Aggregate Output by Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Food, Beverages, and Tobacco	0.11	0.09	0.10
Textiles, Apparel, and Leather	0.03	0.03	0.03
Wood Products	0.01	0.00	0.01
Paper Products	0.01	0.01	0.01
Printing and Recorded Media	0.00	0.00	0.00
Coke and Petroleum Products	0.04	0.03	0.03
Chemical Products	0.05	0.04	0.05
Pharmaceutical Products	0.02	0.01	0.02
Rubber and Plastic Products	0.02	0.01	0.02
Non-Metallic Mineral Products	0.01	0.01	0.01
Basic Metals	0.03	0.03	0.03
Fabricated Metals	0.02	0.02	0.02
Computers and Electronics	0.06	0.04	0.06
Electrical Equipment	0.02	0.02	0.02
Machinery	0.04	0.03	0.04
Motor Vehicles	0.08	0.06	0.07
Other Transportation Equipment	0.02	0.01	0.02
Furniture and Other Manufacturing	0.03	0.02	0.03

Tables 3 and 4 report the full set of economic outcomes for Motor Vehicles and Electrical Equipment, and the Appendix reports the full set of economic outcomes for the remaining 16 manufacturing industries.

5.5 Further Disaggregation of the Rest of the Economy

The two GE extension models in sections 3 and 4 group the economy into two industries, the industry subject to the tariff increase and an aggregate that combines all of the other industries in the rest of the economy. This is a practical simplification, because it requires collecting fewer additional data inputs. These GE extensions only require data for the total economy and for the subject industry, with the aggregate of rest of the economy calculated as the difference between these two. It turns out that this simplification does not significantly reduce the accuracy of the GE extension estimates.

I reran the large country GE model simulations for the motor vehicle and electrical equipment industries with the rest of the economy separated into 54 industries, rather than a single combined industry, for a total of 55 industries.[14] Tables 7 and 8 report this additional version of the model with 54 industries in the rest of the economy, along with the large country GE extension with a single industry in the rest of the economy and the PE estimate for comparison. For these two industries, going to the additional effort to collect more disaggregated data on the rest of the economy and split it into 54 industries does not significantly alter the large country GE estimates of the economic effects. This further disaggregation moves the large country GE estimates closer to the PE estimate.

Table 7: Additional Simulations for Motor Vehicles

Effects (% Changes)	Basic PE Model	Large Country GE Model with 2 Industries	Large Country GE Model with 55 Industries
Imports	-17.55	-17.03	-17.46
Exports	0.00	-0.78	-0.21
Industry employment	4.08	3.87	4.00
Industry output	4.08	3.80	3.94
Aggregate output	0.08	0.07	0.08

[14] I use 55 sectors from WIOD, the industry subject to the tariff change and 54 others. This version of the model does not include sector 56 (activities of extraterritorial organizations and bodies) in the WIOD tables, because this final section typically has zero values for output.

Table 8: Additional Simulations for Electrical Equipment

Effects (% Changes)	Basic PE Model	Large Country GE Model with 2 Industries	Large Country GE Model with 55 Industries
Imports	-15.94	-15.82	-15.92
Exports	0.00	-0.20	-0.05
Industry employment	5.21	5.12	5.17
Industry output	5.21	5.11	5.17
Aggregate output	0.02	0.02	0.02

These additional simulations indicate that the higher aggregation in the models reported in tables 3 and 4 is not a significant limitation of the GE extension method. The simulations suggest that the magnitude of GE feedback depends on the industry' share of the economy but is less affected by the disaggregation of the industries in the rest of the economy.

6 Using a More Elaborate PE Model

To simplify exposition, sections 2 through 5 used a basic PE model of the industry subject to the tariff increase, but the GE extension method can also be applied to more elaborate PE models that capture the intricacies of a specific industry and the fine details of a change in trade policy, like the solar safeguard model in U.S. International Trade Commission (2020), the automotive rules of origin model in U.S. International Trade Commission (2023b), the Section 232 tariff model in U.S. International Trade Commission (2023a), or the Section 201 polyester staple fiber tariff rate quota model in U.S. International Trade Commission (2024). Although the simulations in section 5 apply the GE extension method to large WIOD sectors, the method could be applied to very narrowly defined industries, and this would only require data for the narrow industry and for the total economy, as explained in section 5.5.

The GE extensions to these models would either add one other aggregated industry (like in sections 5.1, 5.2, and 5.3) or add many disaggregated industries (like in section 5.5),

and w, r, and E would still be determined by additional equations and data representing economy-wide resource constraints and the link between aggregate income and aggregate expenditure at the national level. The GE extensions would treat p^* and E^* as exogenous or endogenous variables, depending on whether it is a small country extension (like in section 3) or a large country extension (like in section 4). With these GE extensions, the more elaborate PE model would incorporate GE feedback in factor prices, aggregate expenditure, and foreign producer prices that the PE model is missing.

7 Conclusions

PE simulation models can be useful tools for estimating the economic impact of industry-specific tariff increases, because they can capture distinctive features of the industry and fine details of the trade policy while maintaining practical data requirements. They can be embedded in a GE framework to improve the estimates of economic effects, though this is often not necessary.

In general, the simulations in section 5 demonstrate the adequacy of PE modeling. In some cases, a relatively simple and practical GE extension provides a slight improvement in the estimates of effects within the industry subject to the tariff increase, especially if the industry accounts for a large share of the national economy. The simulations also demonstrate that the product of the estimated percent increase in the value of industry output from the PE model and the industry's share of the U.S. economy provides a reasonable estimate of the percent increase in the value of aggregate output that is usually not improved by adding GE feedback. The simulations with GE extensions have the same or slightly lower effects than the PE estimate, of effects on aggregate output, and in this sense the PE estimate provides an upper bound estimate.

8 Appendix

The Appendix tables provide simulation results for the individual industries not included in section 5.

Table 9: Simulations for the Food, Beverage, and Tobacco Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-18.41	-17.22	-17.64
Exports	0.00	-1.70	-1.11
Industry employment	3.54	3.24	3.37
Industry output	3.54	3.14	3.27
Aggregate output	0.11	0.09	0.10

Table 10: Simulations for the Textiles, Apparel, and Leather Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-12.55	-12.33	-12.41
Exports	0.00	-0.46	-0.29
Industry employment	9.75	9.50	9.60
Industry output	9.75	9.49	9.59
Aggregate output	0.03	0.03	0.03

Table 11: Simulations for the Wood Products Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-20.01	-19.95	-19.97
Exports	0.00	-0.08	-0.05
Industry employment	1.68	1.68	1.68
Industry output	1.68	1.67	1.68
Aggregate output	0.01	0.00	0.01

Table 12: Simulations for the Paper Products Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-20.01	-19.90	-19.94
Exports	0.00	-0.15	-0.09
Industry employment	1.57	1.55	1.56
Industry output	1.57	1.54	1.55
Aggregate output	0.01	0.01	0.01

Table 13: Simulations for the Printing and Recorded Media Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-21.02	-21.01	-21.01
Exports	0.00	-0.02	-0.01
Industry employment	0.49	0.48	0.48
Industry output	0.49	0.48	0.48
Aggregate output	0.00	0.00	0.00

Table 14: Simulations for the Coke and Petroleum Products Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-20.12	-19.69	-19.84
Exports	0.00	-0.57	-0.38
Industry employment	1.41	1.32	1.36
Industry output	1.41	1.27	1.31
Aggregate output	0.04	0.03	0.03

Table 15: Simulations for the Chemical Products Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-18.94	-18.41	-18.60
Exports	0.00	-0.73	-0.48
Industry employment	2.54	2.35	2.42
Industry output	2.54	2.31	2.38
Aggregate output	0.05	0.04	0.05

Table 16: Simulations for the Pharmaceutical Products Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-18.83	-18.64	-18.70
Exports	0.00	-0.27	-0.18
Industry employment	2.65	2.58	2.60
Industry output	2.65	2.56	2.59
Aggregate output	0.02	0.01	0.02

Table 17: Simulations for the Rubber and Plastic Products Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-19.29	-19.10	-19.16
Exports	0.00	-0.26	-0.17
Industry employment	2.36	2.31	2.33
Industry output	2.36	2.30	2.32
Aggregate output	0.02	0.01	0.02

Table 18: Simulations for the Non-Metallic Mineral Products Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-19.59	-19.50	-19.53
Exports	0.00	-0.12	-0.08
Industry employment	2.13	2.11	2.11
Industry output	2.13	2.10	2.11
Aggregate output	0.01	0.01	0.01

Table 19: Simulations for the Basic Metals Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-18.51	-18.20	-18.31
Exports	0.00	-0.46	-0.30
Industry employment	3.30	3.21	3.25
Industry output	3.30	3.18	3.22
Aggregate output	0.03	0.03	0.03

Table 20: Simulations for the Fabricated Metals Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-19.75	-19.49	-19.59
Exports	0.00	-0.34	-0.22
Industry employment	1.89	1.83	1.85
Industry output	1.89	1.83	1.85
Aggregate output	0.02	0.02	0.02

Table 21: Simulations for the Computers and Electronics Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-15.71	-15.11	-15.32
Exports	0.00	-0.96	-0.62
Industry employment	5.17	4.67	4.85
Industry output	5.17	4.68	4.85
Aggregate output	0.06	0.04	0.06

Table 22: Simulations for the Machinery Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-17.95	-17.52	-17.67
Exports	0.00	-0.62	-0.40
Industry employment	3.24	3.00	3.09
Industry output	3.24	2.99	3.07
Aggregate output	0.04	0.03	0.04

Table 23: Simulations for the Other Transportation Equipment Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-19.47	-19.28	-19.35
Exports	0.00	-0.25	-0.16
Industry employment	1.58	1.48	1.51
Industry output	1.58	1.47	1.51
Aggregate output	0.02	0.01	0.02

Table 24: Simulations for the Furniture and Other Manufacturing Industry

Effects (% Changes)	Basic PE Model	Small Country GE Model	Large Country GE Model
Imports	-18.04	-17.75	-17.86
Exports	0.00	-0.41	-0.26
Industry employment	3.63	3.51	3.56
Industry output	3.63	3.51	3.55
Aggregate output	0.03	0.02	0.03

References

Böhringer, C. and Rutherford, T. F. (2008). Combining Bottom-Up and Top-Down, *Energy Economics* **30**(2): 574–596.

Caliendo, L. and Parro, F. (2022). Trade Policy. Handbook of International Economics, **5**: 219–295.

Dix-Carneiro, R., Pessoa, J., Reyes-Heroles, R. and Traiberman, S. (2023). Globalization, Trade Imbalance, and Labor Market Adjustment, *Quarterly Journal of Economics* **138**(2): 1109–1171.

Riker, D. (2018). Modeling Changes in Preferential Rules of Origin. USITC Economics Working Paper 2018-01-A.

Riker, D. (2024). Tariff Rate Quotas under Uncertainty. USITC Economics Working Paper 2024-05-C.

U.S. International Trade Commission (2020). Crystalline Silicon Photovoltaic Cells, Whether or Not Partially or Fully Assembled Into Other Products: Advice on the Probable Economic Effect of Certain Modifications to the Safeguard Measure. Inv. No. TA-201-76 (Modification). Publication 5032. III-1 to III-33.

U.S. International Trade Commission (2023a). Economic Impact of Section 232 and 301 Tariffs on U.S. Industries. Inv. No. TA-332-591. Publication 5405. 117-134.

U.S. International Trade Commission (2023b). USMCA Automotive Rules of Origin: Economic Impact and Operation, 2023 Report. Inv. No. 332-592. Publication 5443. 163-168.

U.S. International Trade Commission (2024). Fine Denier Polyester Staple Fiber. Inv. No. TA-201-78. Publication 5536. 95-99.