MODELING TARIFF POLICY IN CONCENTRATED MARKETS WITH CROSS BORDER OWNERSHIP

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Abstract

This paper introduces a partial equilibrium model for measuring the impact of tariff policy changes in concentrated industries with foreign production and ownership of local affiliates. We apply a Bertrand style imperfect competition model allowing for foreign firm control over its local affiliate's pricing strategy. After introducing the model framework, we conclude by analyzing illustrative simulations of the effects of tariff policy changes on economic measures including producer prices, quantities, and profits.

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1 Introduction

Market concentration and foreign investment often accompany one another. In the United States, industries such as autos, energy, or food processing are characterized by both significant market concentration and high levels of foreign ownership through foreign direct investment. This interaction between market concentration and FDI introduces market dynamics that simple imperfect competition models are unlikely to capture. Imperfect competition models that do not incorporate cross border ownership are unlikely to make reasonable predictions in scenarios where foreign firms simultaneously export and own domestic sources of production. For example, a domestic subsidiary may relinquish pricing decisions to its foreign parent whose pricing strategy must account for its own profitability as well as profits from its subsidiary. Failure to accurately characterize firms' profit-maximizing pricing strategies will ultimately diminish the overall accuracy of models used for trade policy analysis.

This working paper introduces a 3 firm industry-specific partial equilibrium model with 2 domestic firms as well as a foreign source of supply. The model allows for the foreign firm to own a share of one of the domestic sources of production. Model users also specify whether the domestic subsidiary or foreign parent sets prices for the domestic subsidiary. Our model features products differentiated by source, CES demand, constant marginal costs, and Bertrand imperfect competition. The model is particularly useful for predicting the economic impact of tariff policy changes in industries with high levels of market concentration and foreign ownership. The model is calibrated to observable data, namely consumer prices, tariff rates, and firm market shares. After introducing the model in section 2, section 3 provides illustrative model simulations. The paper concludes with a discussion of model limitations and possible extensions.

2 Cross Border Ownership Model

2.1 Model Assumptions

The cross border ownership model presented here considers 2 domestic firms, X and Y, and a foreign firm, F, that is subject to a change in tariff policy. The model combines an assumption of Bertrand imperfect competition with product differentiation by source of supply. As such, firms simultaneously choose prices in order to maximize profits with full knowledge of their competitors' pricing strategies. We assume that demand is characterized by a constant elasticity of substitution between sources of supply. Equation 1 represents the sectoral CES price index.

$$P = ((p_x)^{1-\sigma} + b_y(p_y)^{1-\sigma} + b_f(p_f(1+t_f))^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{1}$$

In the above equation σ represents the Armington elasticity of substitution across products. b_y and b_f are calibrated model parameters, with b_x assigned as the numeraire. t_f captures the tariff rate faced by exporting firm F. This model assumes Cobb-Douglas preferences for products between sectors. As such, we set the price elasticity of total sector demand to -1. Consumer demand is given by equations 2-4 below. The parameter k in these equations represents an additional demand parameter calibrated by the model.

$$q_x = k(P)^{\sigma-1}(p_x)^{-\sigma} \tag{2}$$

$$q_y = k(P)^{\sigma-1}(p_y)^{-\sigma}b_y \tag{3}$$

$$q_f = k(P)^{\sigma-1}(p_f(1+t_f))^{-\sigma}b_f \tag{4}$$

This model allows users to assign various levels of cross border ownership between foreign firm F and domestic firm X. Model users can specify the share of domestic firm X that is owned by the foreign firm F (os_x). Users can also allow firm X to own a share of the foreign firm F (os_f). In doing so, each firm is assigned a portfolio comprised of revenue streams representing the profits generated by each of the differentiated products. For each firm's portfolio, the model user assigns ownership stakes in each revenue stream. Parameters os_x and os_f determine how firms weigh each revenue stream when maximizing their portfolio profits. The below equations represent the variable profits received by each firm, based on designated cross-border ownership shares. In this set of equations m_i represents the marginal cost of production of firm i, while q_i and p_i represent its quantity and price respectively.

$$\pi_x = os_f(p_f - m_f)q_f + (1 - os_x)(p_x - m_x)q_x \quad (5)$$

$$\pi_y = (p_y - m_y)q_y \quad (6)$$

$$\pi_f = (1 - os_f)(p_f - m_f)q_f + os_x(p_x - m_x)q_x \quad (7)$$

Consider an example where a model user assigns 50 percent of firm X ownership to the foreign firm. At the same time, Firm F holds a 100 percent ownership stake in itself. As such, parameters os_x and os_f are assigned values of .5 and 0 respectively. Firm F has a portfolio that receives the entirety of its own revenue stream along with 50 percent of the variable profits generated from the sale of product X. Firm X's portfolio receives the remaining 50 percent of the own revenue stream from its product, $1 - os_x$. In this example, the portfolio of variable profits for firms X and F can be rewritten as equations 8 and 9 below.

$$\pi_x = (.5)(p_x - m_x)q_x \tag{8}$$

$$\pi_f = (p_f - m_f)q_f + (.5)(p_x - m_x)q_x \tag{9}$$

Equations 8 and 9 show how each firm weighs the variable profits generated from each revenue stream. In this scenario firm X receives no revenue from the stream generated by its foreign parent. As such, it places no weight on profits generated by its foreign parent and will not consider the parent firm's profitability when choosing p_x. However, the foreign parent portfolio receives 50 percent of the profits generated by firm X. Therefore, it must weigh profits generated by its subsidiary when choosing its portfolio maximizing price, since a reduction in p_f will reduce the demand for the affiliate's product. Equations 5-7 also imply the below portfolio maximizing first order conditions for each firm, with ε_{ii} and ε_{ij} representing the firms' own and cross price elasticities respectively. Currently, we assume each firm controls price setting for its own products.

$$\frac{\partial \pi_x}{\partial p_x} = (1 - os_x)p_x + (1 - os_x)(p_x - m_x)\varepsilon_{xx} + os_f(p_f - m_f)\varepsilon_{fx}(\frac{q_f}{q_x}) = 0 \tag{10}$$

$$\frac{\partial \pi_y}{\partial p_y} = p_y + (p_y - m_y)\varepsilon_{yy} = 0 \tag{11}$$

$$\frac{\partial \pi_f}{\partial p_f} = os_x(p_x - m_x)\varepsilon_{xf} + (1 - os_f)p_f\frac{q_f}{q_x} + (1 - os_f)(p_f - m_f)\varepsilon_{ff}\frac{q_f}{q_x} = 0 \tag{12}$$

In addition to varying ownership shares, our model allows the user to specify whether the foreign firm controls the prices of its domestic subsidiary, a different scenario than the one represented by equations 10-12. In this case, we assume the foreign parent maximizes its portfolio profits when setting prices for X *and* F. Equation 10 is replaced by equation 13 when firm F is allowed to set prices for its domestic subsidiary. The prices of F and Y are set according to the same profit maximizing equations, regardless of whether firm F controls the pricing of X.

$$\frac{\partial \pi_f}{\partial p_x} = os_x p_x + os_x(p_x - m_x)\varepsilon_{xx} + (1 - os_f)(p_f - m_f)\varepsilon_{fx}(\frac{q_f}{q_x}) \tag{13}$$

Control of price setting is related, but distinct from, ownership structure. Control specifies which firm's *portfolio profits* are maximized when choosing p_x, while ownership shares determine the weights firms F and X give to each revenue stream in their portfolio when setting the prices that they control. Our model allows the user to set ownership structures and price setting control to best fit the industry application. While we imagine most model applications will include a positive relationship between os_x and firm F price control variables, the model allows users to assign a large foreign ownership share of its subsidiary without price control of p_x. Conversely, a foreign firm with a relatively small ownership share can be assigned price control over its subsidiary. Model users are therefore afforded the flexibility to assign ownership shares and price control regimes to fit real world markets.

Equations 10-12 are structurally similar to the first order conditions introduced in Riker (2018) and Riker (2019). If model users assign no cross-border ownership and each firm sets its own price, our model reverts to a standard Bertrand model. However, by allowing cross border ownership to vary, this model captures the reality that the foreign parent and domestic subsidiary consider their cross-border ownership structure when setting prices. Both firm X and firm F choose to set prices in order to maximize their portfolio profits, rather than the profitability of their individual product. As such, either firm can select pricing strategies that do not maximize revenues received from a specific stream. For example, in situations where the foreign ownership of the domestic subsidiary, os_x, is high we may expect to see firm F set its prices higher in order to increase the revenue stream generated by firm X profits, since the two products are substitutes. Conversely, the foreign parent will set prices closer to maximizing revenues generated from its own stream when os_x is small. Our model differs from Riker (2018) and Riker (2019) by allowing for the foreign firm to control prices of its domestic subsidiary. Simulations presented in section 3 demonstrate how various ownership and price setting assumptions affect the response of equilibrium prices, quantities, and profits to tariff changes.

3 Model Application

3.1 Model Calibration and Solving for a New Equilibrium

This model was developed to capture the economic effects of tariff policy changes in highly concentrated markets characterized by foreign ownership. By including cross border ownership, this model captures the presence of foreign direct investment in markets. In particular, ownership shares and price setting control are determined by FDI. Unlike Riker and Schreiber (2019), this model assumes FDI decisions are given exogenously and remained fixed before and after the tariff policy change. Therefore, this model is most appropriate when FDI is an important aspect of the economic landscape but the modeler is not trying to predict how FDI might change in response to tariff changes.

Model users must first provide data on initial firm market shares, initial and final equilibrium tariff rates, cross-border ownership and price control parameters, and an industry specific elasticity of substitution. The model employs user inputs to solve for initial calibration parameters b_i and k as well as firm specific marginal costs m_i. Table 1 provides a summary of model inputs.

Table 1: Summary of Cross Border Ownership Model Parameters

Parameter	**Definition**	**Origin**	***Note**
os_x	Firm F ownership Share of X	User Supplied	Bounded between [0,1]
os_f	Firm X ownership Share of F	User Supplied	Bounded between [0,1]
$ControlF$	Firm F Control of p_x	User Supplied	Binary {0,1}
σ	Armington Substitution Elasticity	User Supplied	
t_{f0}, t_f	Initial and Final Tariff Rates	User Supplied	Ad Valorem
v_x, v_y, v_f	Initial Firm Market Shares	User Supplied	
b_y, b_f, k	Calibration Parameters	Model Calibrated	
m_x, m_y, m_f	Constant Marginal Costs	Model Calibrated	
p_{x0}, p_{y0}, p_{f0}	Initial Firm Prices	Normalized to 1	
p_x, p_y, p_f	New Equilibrium Prices	Solved	
q_x, q_y, q_f	New Equilibrium Quantities Demanded	Solved	

After calibrating the parameters to initial equilibrium conditions, the model solves for the firms' new equilibrium prices following a tariff policy change. To do so, the appropriate first order conditions are re-solved using the updated the tariff rate. The model reports economic changes in percentage terms and include firm and consumer prices, quantities demanded, and firm profits.

One interesting feature of the model is its use of initial market shares to calibrate marginal costs. The model assumes that user-provided initial market conditions are in a state of equilibrium, and each firm has optimally set its price according to the first order conditions given in equations 10-13. As such, the model leverages the user supplied inputs to solve for firms' marginal costs. These marginal costs are assumed constant and are used to solve for new equilibrium prices following the change in tariff policy.

Calibrating marginal costs in the initial equilibrium allows for increased model accessibility as users can run the model without the need to collect sensitive or often publicly unavailable marginal cost data. However, users should note that the assumption that the initial market conditions are in equilibrium may not reflect real world industry-specific market conditions.

As such, violations of this assumption can lead to implausibly calibrated marginal costs. In such cases, the model results are unlikely to be reflective of any real world equilibrium following a change in trade policy. Users should check the calibrated values of the firms' marginal costs to determine whether the model can plausibly simulate the new equilibrium following the policy change.

3.2 Model Demonstration

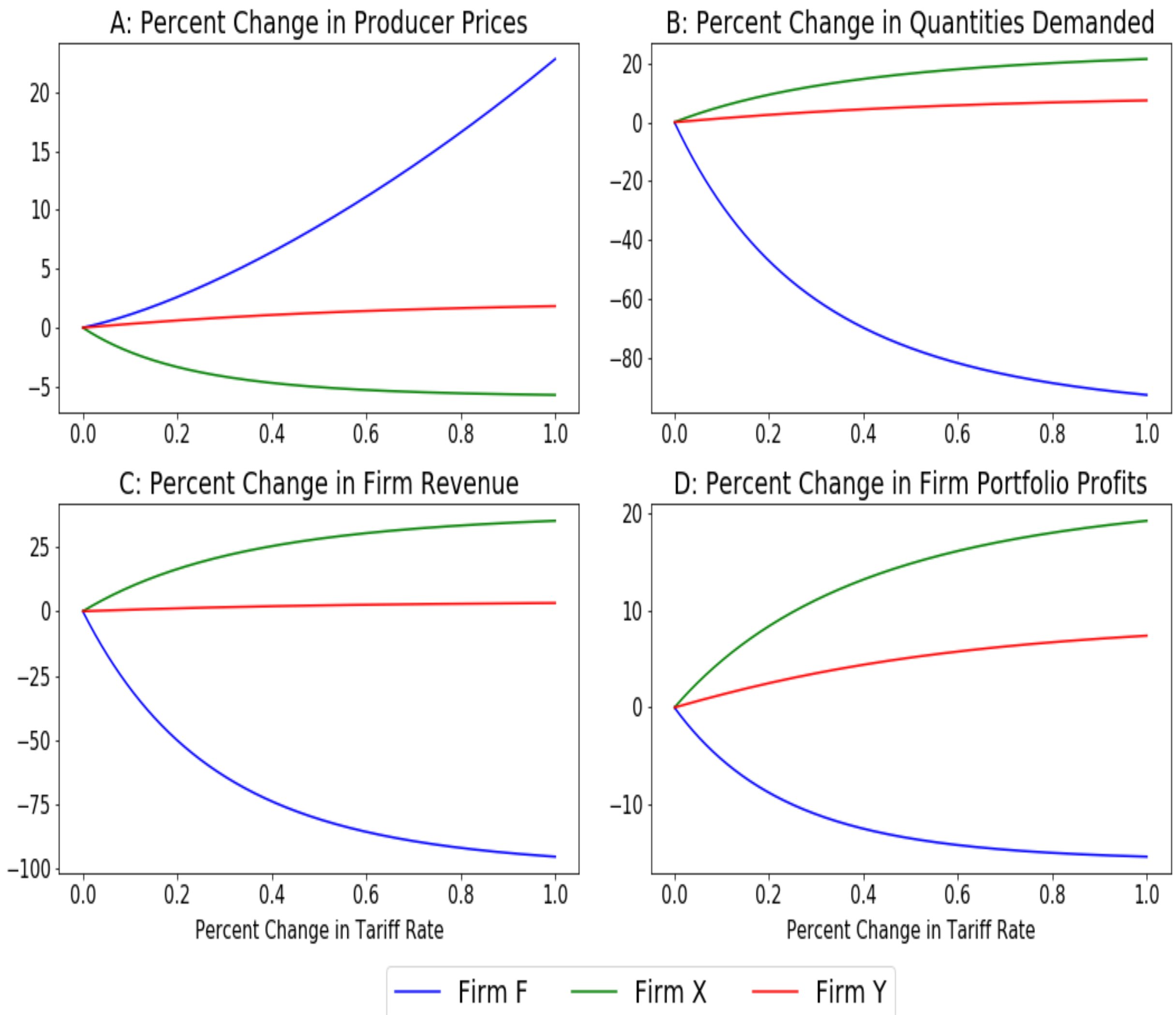
This section provides a demonstration of the model. In this demonstration, multiple simulations are run while allowing the new tariff rate to increase up to 100 percent. All other user-defined values are held constant. Table 2 shows the values of the user-defined parameters used in each simulation. Figure 1 demonstrates how prices, quantities demanded, and revenue streams, and portfolio profits change (Y-axes) for each firm as the tariff increases (X-axes).

Table 2: Selected Parameter Values for Model Simulations

Parameter	**Value**	**Parameter**	**Value**	**Parameter**	**Value**
os_x	.75	os_f	0	$ControlF$	1
σ	3.5	t_{f0}	0	t_f	0 - 100%
v_x	40	v_y	45	v_f	15

The simulated economic changes plotted in Figure 1 highlight several interesting features of the model. As expected, larger tariff rate increases result in greater increases in equilibrium consumer prices for goods produced by the foreign firm. Interestingly, subplot A shows a producer price increase for the foreign product. At the same time, the domestic subsidiary, firm X, lowers its prices following a tariff rate increase. As expected, quantities demanded (subplot B), firm profitability (subplot C), and firm profits received (Subplot D) decrease for firm F and increase for the domestic subsidiary. Following a tariff increase, the unaffiliated

Figure 1: Firm Economic Changes Following the Tariff Increase



*This figure depicts simulated economic changes from a change in tariff policy. Each X-axis represents the simulated percentage change in tariff rates, while Y-axes represent percentage changes in each economic measure. All other parameters are held constant across simulations

domestic firm slightly increases its prices and quantities demanded, resulting in higher profits. As expected, the magnitude of each of these changes increases as the magnitude of the tariff rate change increases.

Figure 1 shows that the foreign firm raises its producer price while the domestic subsidiary lowers its price following a tariff rate increase. This process differs from output generated by the model in Riker (2018) and is driven by our model's inclusion of cross border ownership. Following a tariff increase, firm F raises its producer prices, allowing its domestic subsidiary to capture additional market share. At the same time, firm F sets a lower equilibrium price for X products. In doing so, firm X quantity and revenue increases as shown by subplots B and C. In the new equilibrium, the loss in revenue generated by firm F is partially offset by increased revenue earned by its domestic subsidiary. However, the level of firm F's portfolio profit is unambiguously lower following a tariff rate increase.

3.3 The Importance of Ownership Structure

The simulations described in Figure 1 help demonstrate how the inclusion of cross border ownership in our model shapes firms' pricing strategies following a tariff policy change. Table 3 further illustrates how different ownership parameters drive economic changes following a tariff change. In Scenario 1, the foreign firm does not own a share of firm X, and does not set p_x. This scenario mirrors the Bertrand competition model in Riker (2018) and can serve as a baseline to compare. In Scenario 2, the foreign firm owns 75 percent of X but does not set its prices. Scenario 3 allows the foreign firm to own 75 percent of its subsidiary and set p_x. In each scenario, the initial tariff is increased from 0 to 25 percent.

When compared to Scenario 1, Scenario 2 demonstrates how the introduction of cross border ownership changes the pricing strategy of firm F. Since firm F recoups 75 percent of the revenue generated by its domestic subsidiary, it chooses to increase prices in response to the new tariff. As a result, firm F's producer price change is 3.1 percentage points higher than the baseline with no cross border ownership. Additionally, both domestic firms X and Y choose to set their profit maximizing price slightly higher than the levels produced by the Scenario 1 baseline. Both domestic firms increase quantities by a larger percentage in the

Table 3: Model Simulations with Varying Ownership Structures

Scenario 1	**Scenario 2**	**Scenario 3**
$os_x = 0$ $ControlF = 0$	$os_x = .75$ $ControlF = 0$	$os_x = .75$ $ControlF = 1$
$\Delta\ p_x = 1.75\%$ $\Delta\ p_y = 2.02\%$ $\Delta\ p_f = -1.79\%$	$\Delta\ p_x = 2.09\%$ $\Delta\ p_y = 2.41\%$ $\Delta\ p_f = 2.87\%$	$\Delta\ p_x = -3.79\%$ $\Delta\ p_y = .74\%$ $\Delta\ p_f = 3.47\%$
$\Delta\ q_x = 4.46\%$ $\Delta\ q_y = 3.50\%$ $\Delta\ q_f = -45.86\%$	$\Delta\ q_x = 5.24\%$ $\Delta\ q_y = 4.10\%$ $\Delta\ q_f = -53.10\%$	$\Delta\ q_x = 19.12\%$ $\Delta\ q_y = 1.37\%$ $\Delta\ q_f = -57.7\%$

*Simulations depict economic changes following the introduction of a 25 percent tariff. Other market conditions follow table 2 and are held constant across simulations

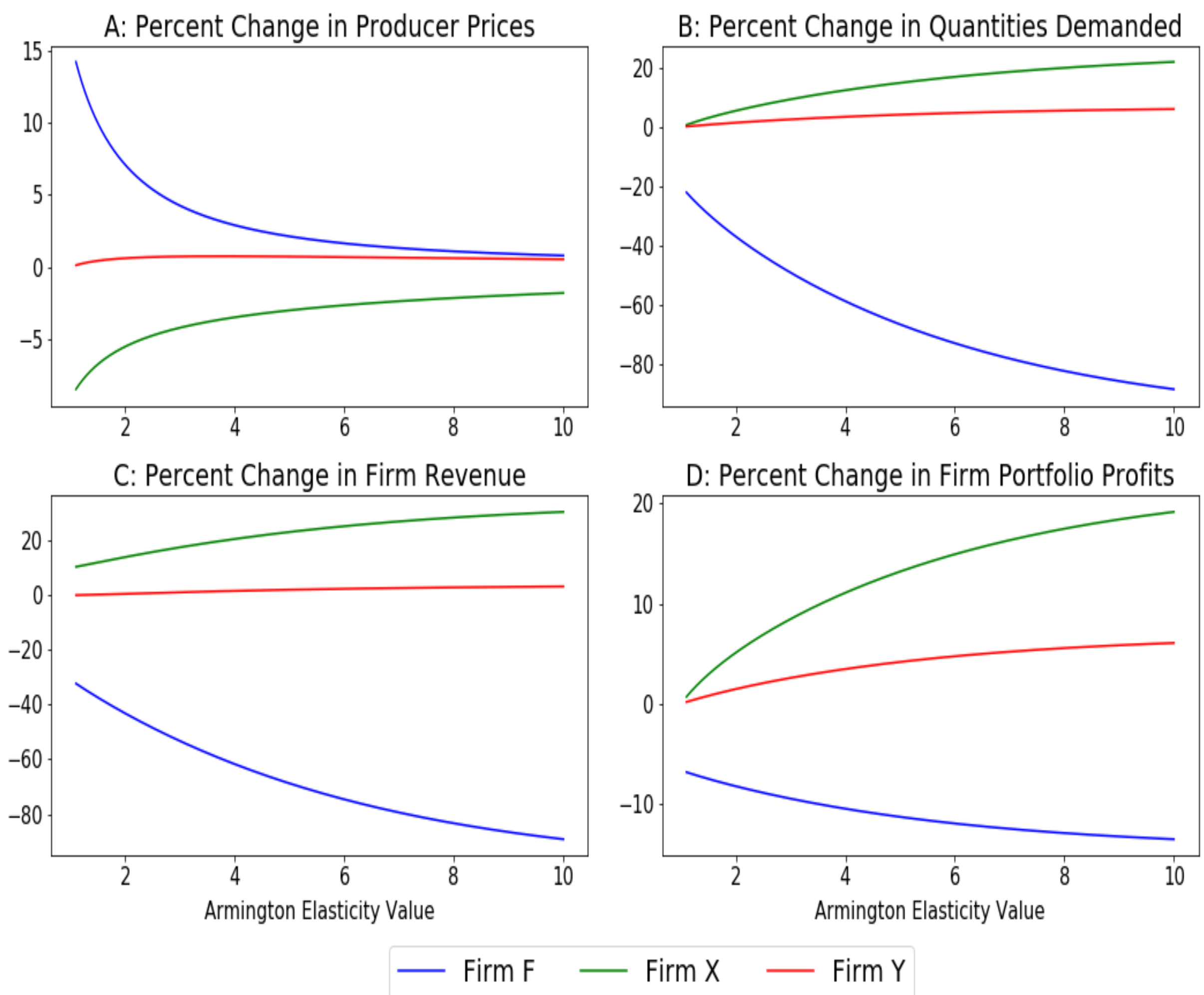
Scenario 2 equilibrium compared to the Scenario 1 baseline. The quantity sold by firm F decreases by an additional 7.25 percentage points compared to the baseline.

Scenario 3 mirrors Scenario 2, however firm F is now allowed to set prices for firm X, a different control scenario. As a result, we witness a price decrease for firm X following the new tariff. Additionally, the new equilibrium change in Firm X quantities more than triples compared to scenario 2. Scenario 3 also shows an even larger increase in Firm F prices, accompanied by larger decline in quantity sold. In effect, Scenario 3 demonstrates that foreign firm relinquishes more market share to its domestic subsidiary when the foreign firm maintains price setting power.

3.4 Armington Elasticity Sensitivity Analysis

One common area of discussion in the international trade literature is the appropriate value of the Armington elasticity of substitution. Estimating an industry or product-specific elasticity of substitution is often difficult. At the same time, the value of this substitution elasticity often contributes significantly to model results. Small changes to the σ parameter can yield noticeably different results. Figure 2 depicts how economic is affected following the addition of a 25 percent tariff across a range of Armington elasticity values.

Figure 2: Sensitivity of economic Changes to Varying σ Values



*Simulations depict economic changes following the introduction of a 25 percent tariff. Armington elasticity values are allowed to vary and are represented by each X-axis. Other market conditions follow Table 2 and are held constant across simulations

Figure 2 demonstrates that substitution elasticity values are inversely related to the magnitude of equilibrium price changes. This finding follows intuition as firms are less willing to change their prices in the presence of strong substitutes. Subplot A suggests that equilibrium price changes are most sensitive to the σ parameter when it is set at relatively low values. In other words, equilibrium price changes across model simulations will vary greatest across simulations when selected substitution elasticities are low.

Subplots B, C, and D show a more linear relationship between substitution elasticities and quantities and profits. Ceteris paribus, changes in quantities demanded and firm profits appear to vary consistently across the range of elasticity values. As such, model users should be aware that the choice of σ parameter remains a significant determinant of model results, especially for changes in quantities demanded and firm profits.

4 Conclusion

This paper has introduced a model that captures the effect of tariff policy changes in highly concentrated markets. It allows for model users to include various cross border ownership and price setting regimes. Illustrative simulations demonstrate how the model captures more nuanced profit maximizing strategies associated with foreign ownership that other imperfect competition models overlook. In particular, it captures a process in which a foreign firm increases prices more and transfers market share to its domestic subsidiary following a tariff increase.

The model described in this working paper was designed to be applied to industry specific tariff policy changes. In its current form, it requires simple and accessible data inputs and can report the simulated effects of a tariff policy change on many important firm and consumer effects. It can also be adapted to better reflect industry specific conditions. Future work on this model can include the addition of new features, such as additional firms or a nested Armington CES structure.

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