ALONG CAME A MONEMPORIST:
A MODEL OF BERTRAND-MONOPSONY COMPETITION

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Abstract

In this paper, we derive an industry specific, supply chain model with Bertrand competition in the final demand goods sector and monopsony demand in the value added inputs markets. The literature broadly defines this type of model, a monempory model. This model allows us to explore the within supply-chain feedback effects of trade shocks in industries with oligopolistic, price competition in the final demand goods market. We conduct a series of experiments to test the performance of the model against a similarly designed Armington supply chain model and a simple, non-supply chain, Bertrand model. When tariffs are removed on imports of final demand goods, the simple Bertrand and supply chain Bertrand models generate similar estimates of the effects of tariff removal on prices, quantities demanded, and profits. However, the results diverge as we increase the market share of subject variety imports and the Armington elasticity in the final demand market. When we eliminate a tariff on imports of intermediate goods, the supply chain Bertrand and supply chain Armington models predict similar changes in final demand and intermediate goods prices.

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1 Introduction

We derive a simple supply chain model with Bertrand (price) competition in the final demand market and monospony competition in the value added markets. The literature broadly defines models with seller's power in the downstream market and buyer's power in the upstream market as "monempory" models. (Nichol (1943)) To do this we combine a supply chain model similar to those derived in Hosoe, Gasawa and Hashimoto (2015), Hallren and Riker (2018), and Desai, Hallren J. and Kobza (2019) with a modified version of the Bertrand competition model from Riker (2019). We explicitly model the domestic firm's supply chain and allow for monopsony demand in the labor and capital goods markets. By including these features in a Bertrand competition model, we are able to capture an important feature of Bertrand oligopoly firms, namely that they often exhibit market power in both the final demand and domestic factor markets. Moreover, we are able to simulate how tariff shocks ripple through the supply chain and determine how different the predictions are from those of the simple Bertrand model in Riker (2019).

In the textbook Bertrand case, with one firm in each national market, firms operate as monopsonists in their respective domestic factor markets, conditional on factors being mostly untraded across other domestic industries or across countries. (Robinson (1932)) A market with Bertrand competition that utilizes specialized labor with country specific licensing could easily generate this outcome. (Boal and Ransom (1997)) The implication of the Bertrand firm operating as a monopsonists in the factor market is that if it faces an upward sloping market supply curve, then the firm will pay a lower price and utilize less of the factor than in the perfect competition case. (Robinson (1932))

Additionally, this simple supply chain Bertrand model allows us to capture the vertical and international linkages throughout the production chain. In doing so we are able to estimate not only the direct final demand effects of a policy shock but also the within supply chain feedback effects in the intermediate inputs, labor, and capital markets. Allowing for Bertrand competition creates a model that is more appropriate for industries, such as autos; wide-body jumbo jets; travel services; etc., than a similarly constructed model with Armington CES demand in the final demand sector.

In this paper we run a series of experiments to demonstrate the performance of the model. Additionally, we run the same experiments on the Bertrand model from Riker (2019) and an Armington CES supply chain model that is similar to Desai et al. (2019). We then compare the predictions of the three models to demonstrate the sensitivity of estimates to relaxing the perfect competition assumption in the final demand portion of the model, explicitly including the supply chain of domestic producers, and allowing for the domestic firm to exhibit market power in the domestic labor market.

The paper proceeds as follows. In section 2, we derive a simple supply chain Bertrand partial equilibrium model. In section 3, we conduct a series of experiments to demonstrate the performance of the model. Section 4 summarizes the results and section 5 concludes with a discussion of potential applications.

2 A Bertrand CES Supply Chain Model

Figure 1 illustrates the conceptual structure of our simple Bertrand supply chain model. In this model, the firms engage in Bertrand competition in the final demand sector. The supply chain for the domestic firm is explicitly included. The domestic firm produces output by combining labor (L), capital (K), and an aggregate intermediate input (INT) via Cobb-Douglas production technology.

We assume that the domestic firm operates as a monopsonist in the value added factor markets. Further, we assume that the labor and capital markets exhibit upward sloping market supply equations. We assume that the industry supply of capital is highly inelastic such that demand shocks will primarily translate into changes in price.

In the intermediate goods portion of the model, products are differentiated by country of origin, and there are three sources for intermediate inputs, the domestic market (D), foreign countries subject to a policy shock (S), and foreign countries not subject to a policy shock (N). In the intermediate goods market, we assume that these inputs are sufficiently traded across industries and across countries such that the perfect competition assumption in the aggregate intermediate goods market is reasonable. The domestic firm combines these country specific intermediate input varieties into an aggregate intermediate input via CES technology.

The final demand portion of the model is as in Riker (2019). Therefore, we omit the derivation.[1] Instead, we discuss how we integrate the upstream supply portion of the Armington CES supply chain model from Desai et al. (2019) with the Bertrand model from Riker (2019).

In this model, three firms supply the domestic final demand sector, a domestic firm (D), a foreign firm subject to a policy change (S), and a foreign firm not subject to a policy change (N). Firms are profit maximizers, produce imperfect substitutes, and engage in price (Bertrand) competition. Each firm faces constant marginal cost of production and a fixed cost for entering the market.

Buyers substitute between each firm variety at a constant rate of substitution (CES). Across sectors, we assume that preferences are Cobb-Douglas. Given these assumptions, the system of equations is as in Riker (2019).

The final demand CES price index is

$$P_* = \left(p_D^{1-\sigma} + b_S(p_S t_S)^{1-\sigma} + b_N(p_N t_N)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \quad (1)$$

[1] A detailed derivation is included in the appendix.

Demand for each firm's variety is

$$q_D = k(P_*)^{1-\sigma}(p_D)^{-\sigma} \tag{2}$$

$$q_S = kb_S(P_*)^{1-\sigma}(p_S t_S)^{-\sigma} \tag{3}$$

$$q_N = kb_N(P_*)^{1-\sigma}(p_N)^{-\sigma} \tag{4}$$

The variable t_S is the power of the import tariff on variety S. The power of the tariff is equal to one plus the ad-valorem tariff rate. b_S and b_N are model parameters that are calibrated to initial equilibrium conditions to capture differences in preferences and product quality across varieties. The parameter k is calibrated to the initial size of the market. The firm price is (p_j) for each variety j.

Through some algebraic manipulation, we can calibrate the demand parameter using initial expenditure data, tariff rates, and industry prices as follows.

$$b_h = \left(\frac{V_{h0}}{V_{D0}}\right)\left(\frac{p_{h0}t_{h0}}{p_{D0}}\right)^{\sigma-1} \quad for\ h \in S, N \tag{5}$$

Given the CES preferences, the market share updating equation is equal to equation (6) for the domestic variety and equation (7) for imported varieties. The initial market shares are calibrated via the initial equilibrium expenditure data.[2]

$$m_D = \frac{(p_D)^{1-\sigma}}{p_D + \sum b_h(p_h t_h)^{1-\sigma}} \quad for\ h \in S, N \tag{6}$$

$$m_h = \frac{b_h(p_h t_h)^{1-\sigma}}{p_D + \sum b_h(p_h t_h)^{1-\sigma}} \quad for\ h \in S, N \tag{7}$$

As in Riker (2019), firms produce differentiated products and engage in profit maximizing Bertrand competition. Firms face constant marginal costs and a fixed cost to entering the

[2] See Armington (1969) and Riker (2019)

market. We assume perfect competition in the input markets; and therefore, marginal costs are equal to the price index from the supply chain. Therefore, the firms' equations are as follows:

$$\pi_j = (p_j - c_j)q_j - f_j \ for \ j \in \{D, S, N\} \tag{8}$$

$$c_D = \prod p_l^{\alpha_l} \ for \ l \in \{L, K, INT\} \tag{9}$$

α_l is the cost share of each composite input, labor (L), capital (K), and intermediate input (INT); and each price (p_l) is the market price for the corresponding composite input. In this paper, equation (9) describes the marginal cost for domestic firms. In the calibration phase, the marginal cost for the domestic firm is set equal to the initial equilibrium price index from the supply chain. The initial marginal cost for all other varieties (S,N) are set to 1, and prices are then adjusted until the model matches initial market conditions.[3]

The supply chain portion of a vertical supply chain model is thoroughly presented in Hallren, Nugent and Peters (2019) and Desai et al. (2019).[4] Therefore, we state the key equations and skip the derivation, except where the assumption of monopsony demand in the labor and capital markets requires adjustments to the baseline model.

Domestic firms produce output by combining a labor (L), capital (K), and a composite intermediate input (INT) through Cobb-Douglas technology. Therefore, demand for each factor is:

[3]This deviates from Riker (2019) where initial prices are set to 1 and marginal costs are adjusted until the model matches the initial equilibrium data.

[4]In these papers, the domestic producers combines labor (L) and capital (K) into a composite valued added (VA) input and then combines the composite VA input with a composite intermediate goods input (INT) to produce output. Notably, the substitution elasticities at the VA-INT and L-K nodes are the same. Because of this, we can simplify the model by replacing the VA-INT node with a L-K-INT node. This simplifies the algebra when we introduce monopsonistic demand in the labor and capital markets. See Hallren and Riker (2018)

$$Q_l = \beta_l \frac{p_D}{P_l} q_D \; for \; l \in \{L, K, INT\} \quad (10)$$

We assume constant returns to scale such that $\sum \beta_l = 1$.

We assume monopsonistic demand in the value added factor markets, L and K. To allow for this type of competition, we must explicitly specify supply equations for each value added input. We consider a simple upward sloping supply relationships for labor and capital.[5]

$$Q_f = k_f (P_f)^{1/\epsilon_f} \; for \; f \in \{L, K\} \quad (11)$$

In this equation, we restrict ϵ_f to be greater than zero so that the inverse supply function is increasing in quantity. When an input's (e.g. labor) inverse supply function is increasing in quantity, then the monosponist will utilize less labor than in the competitive equilibrium and use its market power to pay a wage lower than the competitive equilibrium wage. (Robinson (1932) and Boal and Ransom (1997)) In our application, we assume that the supply of capital is highly price inelastic, and the supply of labor is nearly unitary elastic in price.

In equilibrium, the quantity of each value added input utilized is determined by the intersection of the marginal revenue product (MRP) and marginal cost (MC) curves, with respect to each input. However, as the only purchaser, the monopsony firm's buying price is determined by the inverse supply curve for each factor. Additionally, as a monemporist, the firm has to take into account how input procurement decisions affect the price of the final demand good. Therefore, to derive the monopsony equilibrium factor prices and quantities, we write the firm's profit function in terms of labor; capital; the composite intermediate input; the price of labor; the price of capital; the price of intermediate goods; the domestic final demand good production function; and the inverse demand function for domestic

[5]Assuming an upward sloping supply curve is important because when the supply of labor is perfectly elastic, (i.e. Firms can hire as many workers as required at the predominant wage (w).) the monopsony demand outcome, in-terms of quantity of labor demanded and wage paid, is identical to the perfectly competitive market outcome.

output, in lieu of the price of domestic output. (Monago and Tavera (2018))

$$\max \pi = \left(\frac{kP_*^{\theta+\sigma}}{q_D} \right)^{1/\sigma} \left(Q_L^{\beta_L} Q_K^{\beta_K} Q_{INT}^{\beta_{INT}} \right) - Q_L P_L - Q_K P_K - Q_{INT} P_{INT} \tag{12}$$

We then take the partial derivative with respect to each factor and solve the first order conditions. As illustrated in figure 2, the MRP, MC, and inverse supply equations allow us to determine the monempory equilibrium factor prices and quantities (p_f^M, q_f^M). (Boal and Ransom (1997))[6]

$$MRP_f = \beta_f \left(\frac{\sigma - 1}{\sigma} \right) \left(\frac{q_D p_D}{Q_f^M} \right) \ for \ f \in \{L, K\} \tag{13}$$

$$MC_f = P_f^M + \epsilon_f P_f^M \ for \ f \in \{L, K\} \tag{14}$$

$$P_f^M = \left(\frac{Q_f^M}{k_f} \right)^{\epsilon_f} \ for \ f \in \{L, K\} \tag{15}$$

By contrast, in the Armington supply model we assume perfect competition throughout the supply chain and that the domestic industry utilizes a small portion of the labor force. Therefore, domestic producers can hire as many workers as necessary at the exogenous market wage (p_L^{PC}). In the capital goods market, producers face the same highly price inelastic inverse supply equation as specified above, and the competitive capital rent (p_K^{PC}) is determined by supply and demand. Given these conditions, the following will be true: $(p_f^M < p_f^{PC})$ and $(q_f^M < q_f^{PC})$.

With respect to intermediate inputs, domestic firm combines these inputs from the different countries via CES technology into a composite intermediate input (INT) for production of the final demand product. We assume that these are generic intermediate inputs that are highly traded across industries and countries such that the perfect competition assumption holds for this portion of the model. The demand function is

[6] For a concise example of this type of derivation see Shelburne (2004).

$$q_{INT,j} = Q_{INT} b_{INT,j} \left(\frac{P_{INT}}{p_{INT,j}} \right)^{\sigma_{INT}} \quad for\ j \in \{D, S, N\} \tag{16}$$

The shape parameters for the three varieties of products in the industry are $b_{INT,D}$, $b_{INT,S}$, and $b_{INT,N}$. They are calibrated to the initial market shares for the three varieties of products in the industry and sum to one.

The unit cost of the composite intermediate input is the CES price index. Given the perfect competition assumption in the intermediate goods market, equation (16) determines the price of the composite intermediate input (INT) price in lieu of a supply function.

$$P_{INT} = \left[\sum b_{INT,j} p_{INT,j}^{1-\sigma_{INT}} \right]^{\frac{1}{1-\sigma_{INT}}} \quad for\ j \in \{T, S, N\} \tag{17}$$

The consumer prices for the three varieties of intermediate products are $p_{INT,j}$. The producer price of the domestic variety is the same as the consumer price. However, for the two foreign varieties (f), the producer prices are $\frac{p_{INT,f}}{1+\tau_{INT,f}}$. The trade cost factor $\tau_{INT,f}$ is equal to the ad valorem equivalent rate of the import tariff and international transport costs on imports for each variety (f).

Each variety of intermediate inputs (D, S, and N) is supplied via a constant price elasticity supply function:[7]

$$q_{INT,j} = a_{INT,j} \left(\frac{p_{INT,j}}{1 + \tau_{INT,j}} \right)^{\epsilon_{INT,j}} \quad for\ j \in \{D, S, N\} \tag{18}$$

The parameter $\epsilon_{INT,j}$ is the constant price elasticity of supply for each variety j, and $\alpha_{INT,j}$ represents factors that shift each supply curve. The equations for the supply curves assume a specific form (in this case, they are log-linear), and they are tailored to the industry by fitting the supply shift parameters to industry data. The calibrated values of the supply

[7] It is not difficult to extend the model to include imperfect competition, but in this case the producers have cost curves but not supply curves. The models in Khachaturian and Riker (2016) and Barbe, Chambers, Khachaturian and Riker (2017) include monopolistic competition, for example.

shifters reflect a variety of factors, including the level of production capacity and input costs.

We calibrate the labor, capital, and intermediate input portions of the model to the initial equilibrium conditions by setting all prices to 1 and adjusting the shift parameters in the demand equations to the initial FD and INT country variety market shares, setting the productivity terms equal to the cost shares in the factor demand equations, and equating shift parameters in the supply equations to the relevant initial quantities supplied.

3 Experiments

We conduct two experiments. In experiment one, we reduce import tariffs on subject imports from 25% to 0%. We conduct this experiment on three models: a basic Bertrand style model as in Riker (2019), a Bertrand model with monopsonistic demand for labor and capital, and a simple Armington supply chain model. The Armington style supply chain model is similar to Desai et al. (2019) except output (Z) can only be consumed in the domestic market and not exported to the rest of the world. Also, for maximum comparability with the Bertrand models, producers in the final demand sector in the Armington model are assumed to face perfectly elastic supply curves.

In experiment two, we grant duty free status on imports of intermediate inputs and reduce tariffs on subject intermediate imports from 25% to 0%. In this experiment, we compare the predictions of the supply chain Bertrand models to those of the Armington style supply chain model.

By comparing these three model types, we are able to see, in the partial equilibrium context, whether the type of competition assumed in the final demand sector or the explicit inclusion of the domestic supply chain has a greater influence on model predictions. Comparing the supply chain Armington and supply chain Bertrand results will highlight how assuming Bertrand competition versus perfect competition in the final demand sector influences predictions. By contrast, differences between the simple Bertrand model's predictions and the supply chain Bertrand models' predictions will illustrate the effect of allowing for demand and price shocks to flow between the final demand and value added-intermediate goods portions of the model.

4 Results

Table 1 lists the parameterization of the model for the first experiment. We conducted two iterations to test how sensitive results are to changing the market share of subject imports in the final demand sector and the willingness of buyers to substitute between final demand varieties. Table 2 presents the price effects of tariff elimination in experiment 1. In the first iteration, the subject imports of final demand goods have an initial low market share of 25%, and the Armington elasticity is 2. Under this specification, the simple Bertrand model and supply chain Bertrand model predictions are quite close.

Both models predict that the market price (i.e. the price paid by buyers) falls by less than the full amount of the tariff reduction. As expected, prices for domestic firms fall by slightly more in the supply chain model. This occurs because as consumers shift away from the domestic variety to the subject variety, demand declines for inputs in the domestic supply chain. Consequently, prices for these inputs decline and this translates into a reduction in marginal cost for domestic firms. Notably, demand for the domestic variety and domestic profits fall by less in the supply chain Bertrand model than in the basic Bertrand version.

In contrast to the imperfect competition models, the Armington style supply chain model predicts full pass-through of the tariff reduction to the market price for subject imports. This is the result of assuming perfect competition in the final demand market and that producers in this segment face perfectly elastic supply curves. Compared to the Bertrand supply chain model, the Armington supply chain model predicts a decline in the subject price that is more than 50% greater in magnitude. Correspondingly, the shock to quantity demanded is also larger in magnitude. However, the Armington model predicts a smaller decline in the price for the domestic variety and no change in the price for non-subject imports.

In the second iteration, we increase the market share of subject imports from 25% to 50%. Additionally, we increase the Armington elasticity in the final demand market from 2 to 4. In this iteration too the relative predictions of each model are the same as in the first iteration. Between the basic Bertrand and supply chain Bertrand models, the change in subject and non-subject variety prices are quite close.

However, the supply chain Bertrand model predicts a much larger decline in the domestic price. This occurs because the initial substitution effect is much larger than in the previous iteration. Therefore, there is a larger shock to demand for intermediate and value-added inputs. Consequently, marginal costs fall by more in this iteration; and as a result, the predicted effect of duty free treatment of subject imports on the domestic price is larger than in the previous iteration.

As before, the supply chain Bertrand model predicts a smaller decline in domestic profits than the basic Bertrand model does. However, in this iteration the gap is a bit larger than in the previous iteration. Additionally, the supply chain Bertrand model predicts a smaller increase in subject firms' profits than the basic model.

Comparing the supply chain Bertrand and supply chain Armington models, again the Armington model predicts full pass-through of the tariff reduction on subject prices. Additionally, the Armington model predicts a much larger change in quantity demanded for all varieties.

In the second experiment, we reduce the tariff on subject imports of intermediate inputs from 25% to 0%. We run four iterations of this experiment to test the sensitivity of results to variation in the Armington elasticities. We summarize the inputs of the models in table 3 and the results in table 4.

The results in this experiment follow a consistent pattern. In all cases, the Bertrand and Armington supply chain models generate the same signed changes in the prices of intermediate goods. However, the Bertrand supply chain model consistently predicts a larger magnitude change in these prices. The predicted percent changes in prices for final demand goods are quite close across all iterations, though the magnitude change in the domestic variety's price is always larger in the Armington model. One notable difference is that Armington model predicts no change in price of imports of subject and non-subject final goods. This is the result of assuming perfectly elastic supply curves in the final demand market in the Armington model.

5 Conclusions

In this paper, we derive an industry specific, vertically integrated CES Bertrand model. This model allows us to explore the within supply-chain feedback effects of trade shocks in industries with oligopolistic, price competition in the final demand goods market and monopsony demand in the value added factors markets.

We run two experiments to test the performance of the model against a similarly designed Armington supply chain model and a simple, non-supply chain Bertrand model. When the tariff shock is in the final demand market, the simple Bertrand and supply chain Bertrand models generate similar estimates of the effect of the tariff on prices, quantity demanded, and profit. However, the results diverge as we increase the market share of subject variety imports and the Armington elasticity in the final demand market.

When we eliminate a tariff on imports of intermediate goods, the supply chain Bertrand and supply chain Armington models predict similar changes in final demand and intermediate goods prices. One notable difference is that in the Armington model, which is parameterized to simulate constant marginal costs in the final demand market, the model does not allow a spillover effect of the price shock in the domestic variety's supply chain, to the subject and non-subject varieties' prices.

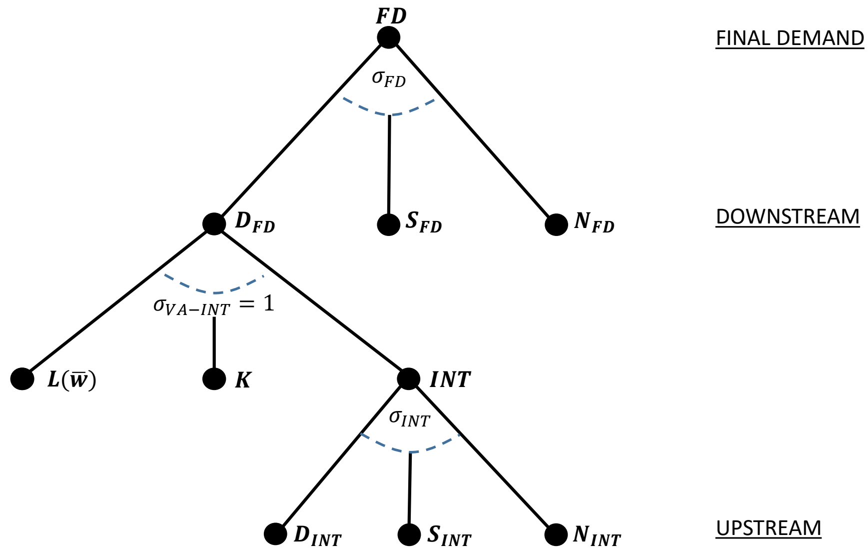

Figure 1: Simple Bertrand Supply Chain Model

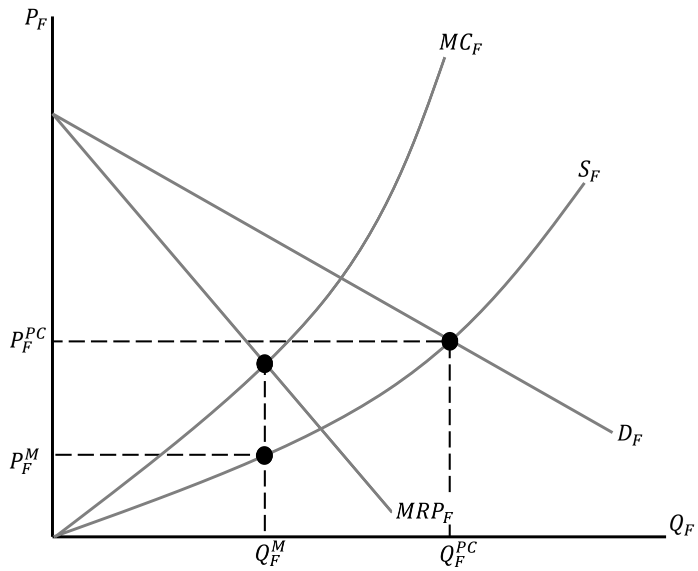

Figure 2: Monempory and Perfect Competition Market Equilibriums

Table 1. Model Inputs for Tariff Reduction on Final Demand Goods Experiment

	Iteration 1	Iteration 2
Armington Elasticity		
Final Demand	2	4
Intermediate Demand	3	3
Industry Price Elasticity	-1	-1
Supply Elasticities (Intermediate Goods)		
Domestic	10	10
Subject	30	30
Non-Subject	100	100
Supply Elasticities (VA Inputs)		
Labor	2	2
Capital	10	10
Initial Market Share - Final Demand		
Domestic	25%	25%
Subject	50%	50%
Non-Subject	25%	25%
Initial Market Shares - Intermediate Goods		
Domestic	33%	33%
Subject	34%	34%
Non-Subject	33%	33%
Cost Shares		
Labor	25%	25%
Capital	25%	25%
Intermediate Goods	50%	50%
Tariffs on Subject Final Demand Goods		
Initial Tariff	25%	25%
Final Tariff	0%	0%

Table 2. Comparative Results from Tariff Reduction on Final Demand Goods

	BERTRAND SUPPLY CHAIN	ARMINGTON SUPPLY CHAIN	BERTRAND BASIC	BERTRAND SUPPLY CHAIN	ARMINGTON SUPPLY CHAIN	BERTRAND BASIC
Percent Change in Market Prices of Final Demand Goods						
Domestic	-3.75	-3.16	-1.43	-5.83	-7.68	-1.74
Subject	-15.83	-25.00	-15.54	-13.86	-25.00	-12.97
Non-Subject	-1.54	0.00	-1.43	-2.02	0.00	-1.74
Percent Change in Price Indices						
Final Demand	-9.72	-14.88	-9.03	-9.46	-17.06	-8.03
Intermediate Inputs	-0.27	-0.54	.	-0.50	-1.36	.
Percent Change in Input Prices						
Labor	-4.18	0.00	.	-7.56	0.00	.
Capital	-5.66	-11.07	.	-10.17	-25.35	.
Percent Change in Quantity Demanded for Final Demand Goods						
Domestic	-2.55	-9.24	-6.37	-5.63	-21.47	-16.55
Subject	27.42	51.32	27.53	34.78	80.30	35.60
Non-Subject	-6.87	-14.88	-6.37	-19.46	-42.95	-16.55
Change in Profits						
Domestic	-1.00	.	-1.25	-1.03	.	-1.64
Subject	9.97	.	10.18	9.71	.	10.46
Non-Subject	-1.34	.	-1.25	-1.90	.	-1.64

Table 3. Model Inputs for Tariff Reduction on Intermediate Goods Experiment

	Iteration 1	Iteration 2	Iteration 3	Iteration 4
Armington Elasticity				
Final Demand	2	2	4	4
Intermediate Demand	2	4	2	4
Industry Price Elasticity	-1	-1	-1	-1
Supply Elasticities (Intermediate Goods)				
Domestic	10	10	10	10
Subject	30	30	30	30
Non-Subject	100	100	100	100
Supply Elasticities (VA Inputs)				
Labor	2	2	2	2
Capital	10	10	10	10
Initial Market Share - Final Demand				
Domestic	33%	33%	33%	33%
Subject	33%	33%	33%	33%
Non-Subject	33%	33%	33%	33%
Initial Market Shares - Intermediate Goods				
Domestic	25%	25%	25%	25%
Subject	50%	50%	50%	50%
Non-Subject	25%	25%	25%	25%
Cost Shares				
Labor	25%	25%	25%	25%
Capital	25%	25%	25%	25%
Intermediate Goods	50%	50%	50%	50%
Tariffs on Subject Intermediate Goods				
Initial Tariff	25%	25%	25%	25%
Final Tariff	0%	0%	0%	0%

Table 4. Comparative Results from Tariff Reduction on Intermediate Goods

	BERTRAND SUPPLY CHAIN				ARMINGTON SUPPLY CHAIN			
	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 1	Iteration 2	Iteration 3	Iteration 4
Percent Change in Market Prices of Final Demand Goods								
Domestic	-3.91	-4.28	-2.83	-3.10	-4.80	-5.25	-3.78	-4.14
Subject	-0.36	-0.40	-0.41	-0.45	0.00	0.00	0.00	0.00
Non-Subject	-0.36	-0.40	-0.41	-0.45	0.00	0.00	0.00	0.00
Percent Change in Market Prices of Intermediate Goods								
Domestic	-0.74	-2.45	-0.53	-2.24	-0.67	-2.38	-0.30	-2.01
Subject	-35.28	-34.96	-35.23	-34.91	-19.08	-18.68	-18.97	-18.56
Non-Subject	-0.09	-0.33	-0.06	-0.30	-0.08	-0.32	-0.04	-0.27
Percent Change in Price Indices								
Final Demand	-1.57	-1.73	-1.24	-1.36	-1.65	-1.81	-1.33	-1.46
Intermediate Inputs	-10.73	-11.70	-10.64	-11.61	-10.70	-11.67	-10.54	-11.51
Percent Change in Input Prices								
Labor	1.62	1.77	3.29	3.61	0.00	0.00	0.00	0.00
Capital	2.21	2.42	4.51	4.95	3.00	3.29	7.11	7.82

References

Armington, P. S. (1969). A Theory of Demand for Products Distinguished by Place of Production, *Staff Papers (International Monetary Fund)* **Vol. 16**(No. 1): 159–178.

Barbe, A., Chambers, A., Khachaturian, T. and Riker, D. (2017). Modeling Trade in Services: Multiple Modes, Barriers to Trade, and Data Limitations, *USITC Working Paper Series* (2017-04-B).

Boal, W. M. and Ransom, M. R. (1997). Monopsony in the Labor Market, *Journal of Economic Literature* **35**(No. 1): 86–112.

Desai, P., Hallren J., R. and Kobza, C. (2019). Do Strong Export Relationships Imply Economic Dependency, *USITC Economics Working Paper Series* (2019-07-B).

Francois, J. F. and Hall, K. (1997). *Partial Equilibrium Modeling*, Cambridge, UK: Cambridge University Press.

Hallren, R., Nugent, R. and Peters, C. (2019). PE vs. GE: Model Predictions of Industry Specific Shocks, *USITC Economics Working Paper Series* (2019-06-B).

Hallren, R. and Riker, D. (2017). An Introduction to Partial Equilibrium Modeling of Trade Policy, *USITC Economics Working Paper Series* (2017-07-B).

Hallren, R. and Riker, D. (2018). Vertically Integrated Armington, *USITC Economics Working Paper Series* (2018-08-E).

Hosoe, N., Gasawa, K. and Hashimoto, H. (2015). *Textbook of Computable General Equilibrium Modeling: Programming and Simulations*, Palgrave Macmillan.

Khachaturian, T. and Riker, D. (2016). A Multi-Mode Partial Equilibrium Model of Trade in Professional Services, *USITC Working Paper Series* (2016-11-A).

Monago, T. O. and Tavera, J. A. (2018). Milking the milkers: a study on buyer power in the dairy market of Peru.

Nichol, A. (1943). Review of *A Theoretical Analysis of Imperfect Competition with Special Application to the Agricultural Industries* by W.H. Nicholls, *Journal of Political Economy* **51**(No. 1): 82–84.

Riker, D. (2019). FDI, Trade, and Pricing in a Bertrand Differentiated Products Model, *USITC Economics Working Paper Series* (2019-04-A).

Robinson, J. (1932). *The Economics of Imperfect Competition*, Macmillan and Co., Ltd.

Shelburne, R. C. (2004). Wage Differentials, Monopsony Labor Markets, and the Trade-Labor Standards Debate, *Journal of Economic Integration* **19**(No. 1): 131–161.

6 Appendix: Detailed Derivation of Bertrand Model

Buyers of the final demand product maximize a utility function with CES preferences, equation (1).[8] Buyers differentiate products by country or region of origin, as in Armington (1969), and substitute between product varieties, indexed j, at a constant rate of substitution (σ). Without loss of generality, the appendix considers a form of the model where there are only three varieties: a domestic variety (D), an import variety subject to the policy change (S), and an import variety that is non-subject to the policy change (N).

$$U = \left(\sum B_j q_j^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \;\; for\ j \in \{D, S, N\} \tag{1}$$

Industry demand (Q) takes a constant elasticity form, equation (2), where P is the industry price index. This assumed industry demand function is standard in the industry specific, partial equilibrium literature (Francois and Hall (1997) and Hallren and Riker (2017)) and some common CGE models (Hosoe et al. (2015)). In (2), θ is the industry price elasticity of industry demand. Typically we assume that consumer preferences across industries are Cobb-Douglas, and therefore $\theta = -1$. However, the derivation proceeds allowing for a wider range of values for this elasticity of demand. The parameter k is an industry demand shift parameter.

$$Q = kP^{\theta} \tag{2}$$

The price index P is determined by the Armington price aggregator in equation (3). In this equation the sum of the weights are equal to one ($\sum B_j = 1$).

$$P = \sum \left[B_j \left(p_j t_j\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \;\; for\ j \in \{D, S, N\} \tag{3}$$

[8]If buyers are profit maximizing firms with CES production technology, the resulting factor demand function will have the same form as the Walrasian CES demand function.

Here p_j is the producer's price for variety j, t_j is the power of the tariff on variety j, and $(p_j t_j)$ is the buyer's price (market price) for variety j.[9] Typically in the model, the tariff rate is non-zero only for the subject variety (S).

Through algebraic manipulation, we can factor out the demand shift parameter β_D and re-define the remaining weights as $b_k = \frac{\beta_k}{\beta_D}\ for\ k \in \{S, N\}$. The new Armington price index can then be re-written as in (4) with the right hand side of the multiplicand relabeled as P_* and defined as in (5)

$$P = B_D^{\frac{1}{1-\sigma}} (p_D^{1-\sigma} + b_S(p_S t_S)^{1-\sigma} + b_N(p_N t_N)^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{4}$$

$$P_* = (p_D^{1-\sigma} + b_S(p_S t_S)^{1-\sigma} + b_N(p_N t_N)^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{5}$$

Equation (6) is the CES demand function from the utility function defined in (1). Hallren and Riker (2017) describes the specific derivation process.

$$q_j = kB_j P^{\theta+\sigma}(p_j t_j)^{-\sigma} \tag{6}$$

If we incorporate the simplifications of the Armington price index from (4) and (5) and fully factored out the term B_D from the price index, then the demand equation for the domestic variety changes to (7).

$$q_D = kB_D P_*^{\frac{1+\theta}{1-\sigma}} p_D^{-\sigma} \tag{7}$$

If buyer's preferences across industries are Cobb-Douglas, and thus the price elasticity of industry demand (θ) is equal to -1, then the parameter B_D collapses to 1. Equations (8) through (11) list the value of the parameter k, given the two qualitative values of θ. If $\theta = -1$, then demand for the domestic variety simplifies to (8) and the shift parameter k is

[9] The power of the tariff, t_j, is equal to one plus the tariff rate $(1 + \tau_j)$.

calibrated as in (9).

$$q_D = kP_*^{\theta+\sigma} p_D^{-\sigma} \tag{8}$$

$$k = q_{D0} P_{*0}^{-(\theta+\sigma)} p_{D0}^{\sigma} \tag{9}$$

If $\theta \neq -1$, then demand for the domestic variety is described by equation (10) and the shift parameter k is calibrated as in (11).

$$q_D = kB_D^{(\frac{1+\theta}{1-\sigma})} P_*^{(\theta+\sigma)} p_D^{\sigma} \tag{10}$$

$$k = q_{D0} B_D^{-(\frac{1+\theta}{1-\sigma})} P_{*0}^{-(\theta+\sigma)} p_{D0}^{\sigma} \tag{11}$$

In this case, we use the fact that the Armington price index weights sum to 1 and write the demand shift parameter B_D in terms of the modified demand shift parameters.

$$B_D = (1 + \sum b_k)^{-1} \; for \; k \neq D \tag{12}$$

Through a similar line of algebra we derive the demand function for imported varieties. We start with equation (13) and eliminate B_k by multiplying by (B_D/B_D) and factoring $B_D^{\frac{\theta+\sigma}{1-\sigma}}$ from $P^{\theta+\sigma}$.

$$q_h = kB_h P^{\theta+\sigma} (p_h t_h)^{-\sigma} \tag{13}$$

$$q_h = kb_h B_h^{\frac{1+\theta}{1-\sigma}} P_*^{\theta+\sigma} (p_h t_h)^{-\sigma} \; for \; h \neq D \tag{14}$$

The term t_h is the power of the tariff and is equal to 0 for non-subject imports. The demand function (14) will be similarly simplify as in (8), if $\theta = -1$.[10]

[10]Because $B_D^{\frac{1+\theta}{1-\sigma}}$ is included in the demand equations and its reciprocal is in the demand shift parameter k, the previous discussion is somewhat trivial.

To recover the remaining demand shift parameters, b_k, we divide q_k by q_D.

$$\frac{q_h}{q_D} = \frac{b_h(p_h t_h)^{-\sigma}}{p_D^{-\sigma}} \; for \; h \neq D \tag{15}$$

Through some algebraic manipulation, we can calibrate the demand parameter using initial expenditure data, tariff rates, and industry prices as follows.

$$b_h = \left(\frac{V_{h0}}{V_{D0}}\right)\left(\frac{p_{h0}t_{h0}}{p_{D0}}\right)^{\sigma-1} \; for \; h \neq D \tag{16}$$

Given the CES preferences, the market share updating equation is equal to equation (17), with initial market share calibrated via the initial equilibrium expenditure data.[11]

$$m_j = \frac{B_j(p_j t_j)^{1-\sigma}}{\sum B_l(p_l t_l)^{1-\sigma}} \; for \; j,l \in \{D,S,N\} \tag{17}$$

Given re-definitions of the demand shift parameters, (17) simplifies to (18) for the domestic variety's market share and (19) for each import variety's market share.

$$m_D = \frac{(p_D)^{1-\sigma}}{p_D + \sum b_h(p_h t_h)^{1-\sigma}} \; for \; h \neq D \tag{18}$$

$$m_h = \frac{b_h(p_h t_h)^{1-\sigma}}{p_D + \sum b_h(p_h t_h)^{1-\sigma}} \; for \; h \neq D \tag{19}$$

As in Riker (2019), firms produce differentiated products and engage in profit maximizing Bertrand competition. Firms face constant marginal costs and a fixed cost to entering the market. We assume perfect competition in the input markets; and therefore, marginal costs are equal to the price index from the supply chain. Therefore, the firms' equations are as follows:

[11] See Armington (1969) and Riker (2019)

$$\pi_j = (p_j - c_j)q_j - f_j \ for \ j \in \{D, S, N\} \tag{20}$$

$$c_D = \prod p_D^{\alpha_l} \ for \ l \in \{L, K, INT\} \tag{21}$$

α_l is the cost share of each composite input, labor (L), capital (K), and intermediate input (INT). In this paper, equation (21) describes the marginal cost for domestic firms. In the calibration phase, the marginal cost for the domestic firm is set equal to the initial equilibrium price index from the supply chain. The supply chain portion of the model is as described in Hallren et al. (2019); Desai et al. (2019); and in the main body of the paper. The initial marginal cost for all other varieties (S,N) are set to 1, and prices are then adjusted until the model matches initial market conditions.