Conducting Profitability Analysis in Partial Equilibrium Models with Monopolistic Competition

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Abstract

We propose a Partial Equilibrium model that can be used to compute the effects on employment and profits of the domestic industry from changes in trade barriers. Like Krugman (1980), the model assumes that each country has a number of homogeneous firms that produce differentiated goods under monopolistic competition. However, we depart from standard trade models by relaxing the assumption of zero industry profits, so that the initial number of firms in each country is kept fixed in the analysis. With this new assumption, we show that changes in firm revenue as a result of shifts in trade policy can also be used to determine effects on labor needed in production as well as profits of industry participants.

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1 Introduction

Armington-based Partial Equilibrium (PE) models can be used to conduct industry-specific analysis of shifts in trade policy. The Armington model is based on a key assumption that products are differentiated by source country. In the context of modeling potential tariff increases, this implies that products sold in the market can be of three types: subject imports, non-subject imports, or domestic products. Consumers substitute between each source variety at a constant rate that is given by the elasticity of substitution parameter. The model also assumes that producers are perfectly competitive so that each supplier sells at marginal cost and makes zero economic profits. Thus, there is no avenue within this framework for determining the effects on industry profits of changes in trade policy.

This paper discusses a potential extension of the Armington model so that the model, under certain assumptions, can also predict the effects on employment and profits of the domestic industry producing goods that are competing with subject imports. The proposed extension builds on the models introduced in Krugman (1979, 1980) where homogeneous firms in each country produces differentiated goods under monopolistic competition. The Krugman model assumes that there is free entry until firm profits are driven to zero, which allows the model to be solved under general equilibrium. In the short run, though, the assumption of free entry may not hold, allowing us to take the initial number of firms in each source country as fixed. We show that in this instance, the extended Monopolistic Competition (MonComp) PE model is able to determine the effects on labor and profits, along with output and prices, of industry participants of changes in trade barriers.

The rest of the paper is organized as follows. Section 2 presents the theoretical framework of the MonComp PE model. Section 3 describes data inputs and sources while section 4 examines how changes in key inputs affect the model results. Section 5 concludes.

2 Modeling Framework

A Constant Elasticity of Substitution (CES) framework is used to model the preferences of consumers in the home economy for products within a given industry. In this framework, consumers have a love of variety and substitute between the different varieties at a constant rate of σ, the elasticity of substitution.[1] Consumers can buy products from three sources: home country (d), foreign country that is subject to the trade policy change (s), and rest of the world that is not subject to the policy change (r). Each source country $i \in (d, s, r)$ has n_i homogeneous firms that each produce a unique variety of the product. Consumers in the home country face the following utility maximization problem:

$$U = \left(\sum_i n_i b_i q_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad s.t. \quad \sum_i n_i p_i q_i = E \tag{1}$$

Here p_i is the consumer price of varieties produced by firms in country i, q_i is the quantity demanded from a single firm in country i, b_i is a parameter capturing asymmetries in consumer preferences, and lastly E is the level of aggregate expenditure for the industry in the home economy. Maximizing utility subject to a budget constraint gives us the consumer from each source country:

$$q_i = E \beta_i p_i^{-\sigma} P^{\sigma-1} \tag{2}$$

$$P = [\sum_k n_k \beta_k p_k^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{3}$$

Here P represents the industry's aggregate CES price index while $\beta_i = b_i^{\sigma}$.

[1]We can extend this framework to a nested CES demand structure so that consumers in the first stage aggregate over the domestic varieties and a composite import within a given sector, while in the second stage, consumers aggregate over the multiple varieties of foreign goods. See Appendix for details.

To capture aggregate demand effects within our framework, we let $\theta < 0$ be the price elasticity of total demand and k an aggregate demand parameter such that:

$$E = kP^{\theta+1} \tag{4}$$

$$q_i = k\beta_i p_i^{-\sigma} P^{\sigma+\theta} \tag{5}$$

$$V_i = n_i k\beta_i p_i^{1-\sigma} P^{\sigma+\theta} \tag{6}$$

Here V_i are the total home sales of all firms in i. Equation (5) represents the CES demand curve for the variety produced by a firm in source country i and is similar to the demand derived under a Armington framework with perfect competition (Hallren and Riker; 2017).

Let the price received by a firm in country i for its products sold to the home market be given as:[2]

$$pp_i = \frac{p_i}{(1+T_i)} \tag{7}$$

Here T_i represents the ad valorem tariffs faced by all firms in source country i when selling to the home market with $T_d = 0$ for all domestic firms.

Firms use labor as the variable input for production. Let A_i be the inverse productivity of firms in i, or unit labor requirement, such that each firm's demand for variable (i.e., production) labor is given as:

$$L_i(q_i) = A_i q_i \tag{8}$$

Note that with A_i fixed, the model predicts $\hat{L}_i = \hat{q}_i$ where $\hat{L}_i$ and $\hat{q}_i$ are the respective percent changes in labor and quantity of output. Thus, total employment in the industry moves in proportion to output in this framework, as long the firm's fixed costs do not include any

[2] The model assumes a continuum of varieties so each firm prices as if it has no impact on the overall price index.

labor. If the firm has fixed costs of production that also include labor (Krugman, 1980), then L_i will be variable labor such as production workers that will move in proportion to output, rather than total employees.

If w_i is the wage rate in country i, then all firms have a constant marginal cost:

$$c_i = A_i w_i \tag{9}$$

Within this CES demand framework, all firms charge a constant markup over their marginal costs such that:

$$pp_i = \frac{\sigma}{\sigma - 1} c_i \tag{10}$$

and consumer prices are given as

$$p_i = \frac{\sigma}{\sigma - 1}(1 + T_i) c_i \tag{11}$$

Let f_i be the fixed cost a firm in i needs to pay in order to sell to the home market. Then a firm's net profits from selling to the home market is computed as:

$$\pi_i = pp_i q_i - c_i q_i - f_i$$

We can show that a firm's operating profits $\pi_i + f_i$ are proportional to its revenue R_i since

$$\begin{aligned}\pi_i + f_i &= pp_i q_i - c_i q_i \\ &= pp_i q_i - \frac{\sigma - 1}{\sigma} pp_i q_i \\ &= \frac{1}{\sigma} pp_i q_i \\ &= \frac{1}{\sigma} R_i \end{aligned} \tag{12}$$

Thus, changes in the operating profits of firm i are determined jointly by the changes in R_i as well as the value of σ. However, in order to determine changes in the net profits of the domestic industry, we also require information on the initial profit margins at the firm or industry level.[3]

To determine the effects on profitability , we also assume that the number of firms in each country is fixed in the short-run and so, unlike Krugman (1980), there is no need for a zero profit condition for the entire industry. Given this restrictions, it is important to note that the model is only able to provide the short-run effects on market participants from changes in tariffs.

To solve the demand equations in (6), we need to calibrate the product of the fixed number of firms and the preference parameters for each source. The calibration is simplified by normalizing the number of firms and preferences for goods produced in $i \in (s, r)$ by their domestic equivalents so that $n_d \beta_d = 1$.

We can then obtain the following relationship between the model parameters and initial sales:

$$\frac{V_s}{V_d} = \frac{n_s \beta_s p_s^{1-\sigma}}{p_d^{1-\sigma}} \tag{13}$$

$$\frac{V_r}{V_d} = \frac{n_r \beta_r p_r^{1-\sigma}}{p_d^{1-\sigma}} \tag{14}$$

$$k = \frac{V_d}{p_d^{1-\sigma}\left[p_d^{1-\sigma} + n_s \beta_s p_s^{1-\sigma} + n_r \beta_r p_r^{1-\sigma}\right]^{\frac{\theta+\sigma}{1-\sigma}}} \tag{15}$$

[3]Equation (14) implies $\hat{\pi}_i = \frac{1}{\sigma}\left(\frac{R_i}{\pi_i}\right)\hat{R}_i$with $\left(\frac{R_i}{\pi_i}\right)$ the inverse profit margin of firm i

Setting initial consumer prices from all source countries to one allows us to calibrate $n_s, n_r, \beta_s, \beta_r$and k to initial market shares as:

$$\frac{V_s}{V_d} = n_s \beta_s \tag{16}$$

$$\frac{V_r}{V_d} = n_r \beta_r \tag{17}$$

$$k = \frac{V_d}{[1 + n_s\beta_s + n_r\beta_r]^{\frac{\theta+\sigma}{1-\sigma}}} \tag{18}$$

These calibrated parameters allow us to determine the price and quantity effects for each source country i from a change in ad valorem tariffs. We can then use the structural relationships given in (8) and (12) to also determine the effects on labor demand for production and operating profits respectively.

3 Data Requirements

We require the following data inputs to determine the price and quantity effects for the industry:

1. The value of domestic shipments

2. The value of each type of import and initial and new tariff rates

3. Elasticity of substitution and industry demand elasticity

With these inputs, the MonComp model is also able to determine changes in operating profits as well as the impact on production jobs in percent terms. In certain instances, it would be more illustrative to know the actual number of production jobs gained or lost due to tariff shocks. This requires knowledge of the initial number of production workers employed in that industry, which may be hard to obtain for very disaggregate sectors. However, for U.S. industries in the manufacturing sector, the Annual Survey of Manufactures can serve as a useful resource since it includes information on production workers up to the 6-digit NAICS level. If we assume that industries within a broader NAICS sector have the same labor productivity, then the share of domestic shipments by the industry over total shipments at the 6-digit NAICS level can be used to estimate the number of production workers in that industry k since:

$$\frac{Production\ Workers\ in\ Industry\ k}{Production\ Workers\ in\ NAICS\ Sector} = \frac{Domestic\ Shipments\ by\ Industry\ k}{Domestic\ Shipments\ in\ NAICS\ Sector} \tag{19}$$

4 Model Simulations

Table 1 reports the simulated effects on the domestic industry from a reduction in the ad valorem tariff on subject imports from 5 to 0 percent with hypothetical data inputs. We use the MonComp model to compute the following effects on the domestic industry: the change in the industry's overall price index, the change in revenues of domestic firms, the change in operating profit and the change in the number of production workers employed by the industry.[4] The table reports five different versions of the model with alternative assumptions about data inputs such as market shares and elasticity parameters. We also assume that the total firm revenues from all sources in the industry sum to 100 million dollars so that the total firm revenues in each source also represents its respective market share, in percent, in Table 1.

[4]The MonComp model also generates effects on firms operating in subject and non-subject countries, but for the sake of brevity, our discussion focuses on the effects on domestic firms only.

Column v1 in table 1 serves as our benchmark simulation. We see that the elimination of the 5 percent tariff reduces consumer prices of varieties produced in the subject country by 4.80 percent, which is just the change in the power of the tariff, since there is 100 percent pass-through in the MonComp model. Since the MonComp model assumes that firms operate under constant marginal costs, there is no effect on consumer prices of varieties produced by firms in the domestic and non-subject countries. The overall consumer price index for this industry falls by around 1 percent due to the reduction in consumer prices of imports from firms producing in the subject country. The reduction in the tariff on subject imports reduces domestic revenues of firms by around 2 percent, which based on initial revenue translates into a loss of 1.41 Million dollars. The model also computes a loss of 20 production jobs in the domestic industry and a reduction of 0.47 Million dollars in operating profits because of the tariff elimination.

The remaining columns in table 1 report the sensitivity of these effects on the domestic industry to the main data inputs of the model. In column v2, we reduce the initial number of production workers from 1000 to 100 and its leads to smaller loss of 2 production jobs in the domestic industry. All other effects are the same. Therefore, we can use this model to identify industries that will have the biggest effect on production workers and employment from some proposed policy change.

In column v3, we let the domestic industry have the same market share as subject imports, reflecting an industry where firms that produce subject imports are more competitive with domestic firms than in the benchmark scenario. Compared to v1, there is a larger effect in the overall consumer price index with the price index dropping by 2.2 percent. Domestic firms having smaller initial market shares also generates a greater loss in domestic revenues of 4.4 percent and leads to losses of 40 production jobs and 0.66 Million dollars in operating profits. Overall, the simulation in v4 indicates that this model is capable of generating significant adverse effects on domestic firms even in industries that are characterized by a low elasticity of substitution.

Lastly, we use the simulation exercise in columns v4 and v5 to better explore the relationship between the elasticity of substitution and revenue and operating profits in the MonComp model. In column v4, we decrease the elasticity of substitution from the benchmark so that consumers view domestic and foreign goods as less substitutable. The lower elasticity of substitution leads to a smaller loss in domestic revenues of 1 percent and so a smaller decrease in production jobs than v1. In column v5, we increase the elasticity of substitution from the benchmark so that consumers view domestic and foreign goods as more substitutable. The higher elasticity of substitution leads to a greater loss in domestic revenues of 3 percent and thus a bigger decrease in production jobs than v1. In both v4 and v5, the effect on the overall consumer price index from the tariff elimination remains similar to what was observed in v1. So holding everything else constant, a higher elasticity of substitution for the industry leads to tariff reductions having a more adverse effect on domestic revenue and production jobs in this modeling framework.

Unlike revenues, the simulations in columns v4 and v5 show that the relationship between operating profits and the elasticity of substitution is more nuanced. Compared to the benchmark case, in which domestic firms saw a loss in operating profits of -0.47 million, domestic firms see losses in operating profits of -0.35 million in column v4 and -0.53 million in column v5. So while increasing the elasticity of substitution leads to a larger decrease in operating profits, these changes are much less dramatic than what is observed for revenues. As discussed in 2.1, the MonComp model relates operating profits with revenues through the elasticity of substitution term and so the value of the elasticity of substitution chosen in the simulation not only determines the effects on the revenue of domestic firms but also the impact on their operating profits from changes in tariffs. Firms operating in industries with a low elasticity of substitution are able to charge higher initial markups and so can still experience significant losses in operating profits from a tariff elimination, even though the effects on total revenues is muted by the lower substitutability among the varieties in that particular industry.

5 Conclusions

We have shown that a PE model with CES demand and firms operating under short-run monopolistic competition can be used to analyze the effects on industry profits of tariff changes in the short run. Our proposed model is able to relate changes in firm revenue to changes in the number of production workers and the level of operating profits, thus allowing us to determine the effects on both production workers and operating profits from changes in tariffs without the need of extensive additional data. It is important to note that this modeling framework would not be appropriate for concentrated industries with only a few firms and would require a different modeling approach. The next steps would be to consider the impact of relaxing the assumption of firms having identical marginal costs and incorporating firm heterogeneity in production, as in Melitz (2003), into this modeling framework.

Table 1: MonComp Model Simulations

	V1	V2	V3	V4	V5
Data Inputs					
Revenue of Domestic Firms (millions of dollars)	70	70	45	70	70
Revenue of Firms with Subject Imports (millions of dollars)	20	20	45	20	20
Revenue of Firms with Non-Subject Imports (millions of dollars)	10	10	10	10	10
Elasticity of Substitution within the Industry	3	3	3	2	4
Price Elasticity of Total Industry Demand	-1	-1	-1	-1	-1
Production Workers in Domestic Industry	1000	100	1000	1000	1000
Changes in Tariff Policy					
Initial Tariff Rate on Subject Imports (percent)	5	5	5	5	5
New Tariff Rate on Subject Imports (percent)	0	0	0	0	0
Effects on Domestic Industry					
Change in Industry Price Index (percent)	-1.01	-1.01	-2.23	-0.99	-1.03
Change in Revenue of Domestic Firms (percent)	-2.01	-2.01	-4.41	-0.99	-3.06
Change in Revenue of Domestic Firms (millions of dollars)	-1.41	-1.41	-1.98	-0.69	-2.14
Change in Operating Profits of Domestic Firms (millions of dollars)	-0.47	-0.47	-0.66	-0.35	-0.53
Change in Production Workers in Domestic Industry	-20	-2	-40	-10	-31

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Appendix: Extension to the Nested CES Demand

Following Riker and Schrieber (2019), total sales from each source $i \in (d, s, r)$ under a nested CES demand framework are represented as:

$$V_d = kn_d\beta_d p_d^{1-\sigma} P^{\sigma+\theta} \tag{20}$$

$$V_s = kn_s\beta_s p_s^{1-\sigma} PM^{\zeta-\sigma} P^{\sigma+\theta} \tag{21}$$

$$V_r = kn_r\beta_r p_r^{1-\sigma} PM^{\zeta-\sigma} P^{\sigma+\theta} \tag{22}$$

$$PM = [n_s\beta_s p_s^{1-\zeta} + n_r\beta_r p_r^{1-\zeta}]^{\frac{1}{1-\zeta}} \tag{23}$$

$$P = [n_d\beta_d p_d^{1-\sigma} + PM^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{24}$$

We asssume that the elasticity of substitution for the two types of imports ζ is weakly greater than the elasticity of substitution between the domestic good and the composite import σ. Equation (23) is the CES price index for the two types of imports, and equation (24) is the CES price index for the eniter market (domestic and imports).

Again, we normalize the number of firms and preferences for goods produced in $i \in (s, r)$ by their domestic equivalents so that $n_d\beta_d = 1$ and set initial consumer prices as 1 to obtain:

$$\frac{V_s}{V_r} = \frac{n_s\beta_s}{n_r\beta_r} \tag{25}$$

$$\frac{V_s}{V_d} = n_s\beta_s PM^{\zeta-\sigma} \tag{26}$$

$$\frac{V_r}{V_d} = n_r\beta_r PM^{\zeta-\sigma} \tag{27}$$

Using these identities, we are able to calibrate $n_s\beta_s, n_r\beta_r$and k with initial market sales as:

$$n_r\beta_r = \left[\frac{\frac{V_r}{V_d}}{\left(\frac{V_s}{V_r}+1\right)^{\frac{\zeta-\sigma}{1-\sigma}}}\right]^{\frac{1-\zeta}{1-\sigma}} \tag{28}$$

$$n_s\beta_s = \frac{V_s}{V_r}n_r\beta_r \tag{29}$$

and

$$k = \frac{V_d}{\left[1+\left[n_s\beta_s+n_r\beta_r\right]^{\frac{1-\sigma}{1-\zeta}}\right]^{\frac{\theta+\sigma}{1-\sigma}}} \tag{30}$$

Note that in the case of $\sigma = \zeta$, (28)-(30) are equivalent to the calibration in (16)-(18) that was derived for the case of non-nested CES preferences.