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The Impact of Input and Output Tariffs on Firms' Productivity: Theory and Evidence

*Tuan Anh Luong**

Abstract

This paper studies the impact of trade liberalization on productivity. It shows that when intermediate inputs are not highly differentiated, lowering input tariffs leads to a rise in within-firm productivity and wages, and lowering output tariffs has the opposite effect. When intermediate inputs are highly differentiated, the conclusions reverse. These predictions are supported by the data, given by the industrial survey from INEGI (Mexico's Insitituto Nacional de Estadistica Geografia e Informacion) in the period 1984–90. The paper yields estimates for the elasticity of substitution among intermediate inputs, which are useful in determining the direction of the impact of trade liberalization. These estimates can be used to assess the gains from trade liberalization.

1. Introduction

The effects of trade reform on productivity have been thoroughly studied. However the results both theoretical and empirical have been ambiguous. The proponents of protectionism claim that imposing tariffs for a period of time allows domestic firms to grow in size, enabling them to exploit the economies of scale and become more efficient. Moreover, the incentive to invest in superior technology might increase with market size (Rodrik, 1988). In contrast, the supporters of trade liberalization claim that trade liberalization will raise productivity through two channels: the selection effect (Melitz, 2003) and more access to foreign technology (Grossman and Helpman, 1991). Empirically, while trade liberalization might boost productivity in some countries (Amiti and Konings, 2007; Fernandes, 2007; Pavcnik, 2002), in other countries there is little evidence to back this prediction (Muendler, 2004; Tybout et al., 1991).

Consistent with the second channel claimed by Grossman and Helpman (1991), recent work has focused on the role of intermediate inputs. Trade liberalization brings more access to foreign markets. Therefore domestic firms can import higher quality inputs, leading to higher productivity. However, quality is a concept that is not trivial to measure, leaving the assumption difficult to be justified. Moreover the effect of this channel seems to be small (Muendler, 2004). There are other ways to improve productivity through the use of intermediate inputs. The love of variety approach, outlined in Dixit–Stiglitz (1977) model, implies that the firm is more productive when using more varieties of intermediate inputs (Acemoglu and Zilibotti, 2001; Feenstra et al., 1992; Koren and Tenreyro, 2007). Ethier (1982) attributed this effect to "higher specialization in production." In line with Ethier's argument, I address the following question: *How do import tariffs, in particular input tariffs and output tariffs, affect firms' productivity through the import of intermediate inputs*?

*Luong: Princeton University, Princeton, NJ 08540, Email: tluong@princeton.edu. The author would like to thank an anonymous referee, David Atkin, Arnaud Costinot, Richard Chiburis, Penny Goldberg, Joanne Gowa, Gene Grossman, Esteban A. Rossi-Hansberg , Miklos Koren, Marc Melitz, Eric Verhoogen, and participants of seminars at Princeton University, Shanghai University of Finance and Economics, and the University of Navarra for helpful comments. All the remaining errors are those of the author.

On the theory side, the closest papers to mine are Halpern et al. (2006) and Kasahara and Rodrigue (2008). In the former, productivity improvement came from the imported intermediate inputs via their better quality and input complementarity. However their model does not tell us how trade policy, in particular tariff reduction, would change the input quality and how many varieties will be added. Also based on the input complementarity, Kasahara and Rodrigue (2008) showed that a higher share of foreign intermediate inputs leads to a larger number of varieties of intermediate inputs, hence boosting the firm's efficiency, but again, there is no discussion about how tariff changes would affect the share of imported inputs, leaving the question of how tariffs affect productivity unanswered.

Among the papers that look at the effects of tariffs on productivity, only Schor (2004) and Amiti and Konings (2007) discussed the effects of input tariffs on productivity. This distinction between output and input tariffs proves to be important (Ma and Dei, 2009). My paper contributes to the literature by incorporating these two tariffs into a unified model which explains how these tariffs affect productivity. Depending on which market is liberalized, trade liberalization, which means a reduction in tariffs, can increase or decrease total factor productivity (TFP). Tariff reductions in the intermediate and in the final market always have opposite effects on TFP. Moreover, my paper looks at the interaction between the complementarity force and the diminishing return force, which leads to the result that the impact of trade liberalization depends on the degree of differentiation of intermediate inputs.

Since how tariff reduction affects productivity depends on the degree of differentiation, a natural question is how we estimate this parameter. This paper proposes a structural model to estimate the elasticity of substitution. Not many studies in the literature provide these estimates, and they focus on the elasticity of substitution among consumption goods, not intermediate goods. This paper bridges this gap. My estimates are consistent with similar studies (Acemoglu and Ventura, 2002; Broda and Weinstein, 2006; Feenstra, 1994; Hummels and Klenow, 2005). They are both useful in determining the direction of the impact of trade liberalization on productivity, and in quantifying the gains from trade.

Beside total factor productivity, another common measure of productivity is labor productivity, which is captured by labor wages. There is also a large literature that discusses how trade liberalization affects wages: After the country liberalizes, wages might decline (Goldberg and Pavcnik, 2005; Revenga 1997), stay unchanged (Attanasio et al., 2004; Gaston and Trefler, 1997), or even increase (Amiti and Davis, 2008; Trefler 2004). My model proves that each of these contrasting scenarios is possible depending on which markets trade liberalization affects and the degree of differentiation of the intermediate inputs. A similar result is found in Amiti and Davis (2008), however, they needed to use the fair wage assumption to generate this result.

The organization of the paper is as follows. Section 2 presents my model. Section 3 discusses the variety effect. In section 4, I examine how trade policy affects measured productivity and wages. Section 5 tests these predictions and estimates the structural parameters in the model. Section 6 concludes.

2. The Small Open Economy

I consider a modified Ricardo–Viner model applied to a small, open, and developing country. There are two domestic sectors, A and M, employing a common factor which will be denoted as labor. This factor is supplied inelastically. Sector A, considered to be the numeraire, uses only labor whereas sector M will combine labor and imported

intermediate goods to produce a final product. I assume that trade policy, set by the country, only applies to sector M and the intermediate sector which I will denote as X. Sector A is assumed to be duty free. For the notations, as the imported intermediate goods will be used as one of the inputs for the goods in sector M, the tariffs applied to these intermediate goods will be called input tariffs while the one imposed on sector M will be called an output tariff. Also since the country is small, the prices in sector M and sector X will be the world prices plus the tariffs. In particular, if we call p^w and r^w the world prices in sector M and X, p, r the corresponding effective prices and τ^I, τ^O the corresponding tariffs then we have:

$$p = p^w(1+\tau^O),$$

$$r = r^w(1+\tau^I).$$

As p^w and r^w are fixed, p and r can substitute for τ^O and τ^I. To save the notations, I now discuss the effects of p and r as a proxy for trade policy.

Sector A

The production function in this sector is assumed to be as follows:

$$A = L^\gamma - (L - L_A)^\gamma.$$

L is the supply of labor and L_A is the quantity of labor used in sector A. In particular, when γ is equal to 1, we have a linear production function. This form of function, while preserves the conventional characteristics of a production function, helps to solve for an analytical solution in equilibrium, which proves to be useful for my estimations, as we will see in the later parts. The decision in this sector is simply to equate the marginal product of labor with the wage:

$$w = \gamma(L - L_A)^{\gamma-1}. \tag{1}$$

Sector M

Unlike sector A, in sector M a representative firm combines labor and imported intermediate inputs to produce a final homogenous good. The imported intermediate inputs are imperfectly substitutable. In particular, similar to the models used in Romer (1987, 1990), the production function of the representative firm is as follows:

$$M = L_M^\alpha \left(\int_0^n x(j)^\varepsilon dj \right)^{(1-\alpha)/\varepsilon} \tag{2}$$

where L_M is the number of workers hired, $x(j)$ is the amount of intermediate input j used and n is the number of varieties chosen by the firm. I assume that there is no fixed cost of using intermediate input varieties.[1] This assumption implies that the firm chooses optimally labor and the quantity of each intermediate input variety:

$$\alpha p L_M^{\alpha-1} \left(\int_0^n x(j)^\varepsilon dj \right)^{(1-\alpha)/\varepsilon} = w \tag{3}$$

$$(1-\alpha)\, p L_M^\alpha \left(\int_0^n x(j)^\varepsilon dj \right)^{(1-\alpha-\varepsilon)/\varepsilon} x(j)^{\varepsilon-1} = r(j). \tag{4}$$

Sector X

There is evidence that the developing countries experience productivity improvement by importing intermediate inputs from the more developed countries (Coe et al., 1997; Horiuchi and Ishikawa, 2009). I therefore assume here that this small developing country cannot produce the sophisticated intermediate inputs which are required to produce the final goods: they have to buy intermediate inputs from the foreign producers. Each of the foreign producers provide a differentiated intermediate input and has to pay a fixed cost, acting as a set-up cost. With the small country assumption, the world price of the intermediate inputs will not be affected by whatever happens in the Home country. In other words, the price of these inputs that the domestic users have to pay, which is the world price plus the *ad valorem* tariff, will be treated as exogenous variable. Acting as a monopolistic competitor, a foreign supplier has a profit which is proportional to its revenue. Indeed, this profit will be equal to the revenue divided by the elasticity of substitution among intermediate input varieties. Call the fixed set up cost c, the free entry condition implies:

$$\frac{rx(j)}{\sigma} = c. \tag{5}$$

As the fixed cost c is the same across intermediate good producers, the quantity provided by these producers are constant: $x(j) = x$.

3. The Variety Effect in Measured Productivity

To discuss productivity changes, we need a measure of productivity. The most common ones are labor and total factor productivity (TFP). Since there is no reason to prefer one to another, one should consider both of them.

Total factor productivity is defined as follows:

$$\Omega = \frac{M}{L_M^{\alpha} X^{1-\alpha}} = n^{[(1-\alpha)(1-\varepsilon)]/\varepsilon}$$

where $X = \int_0^n x(j)\,dj$ and M is the intermediate input spending. The variety effect appears clearly here. Total factor productivity Ω is an increasing function of n, the number of intermediate input varieties. This effect is supported by recent empirical studies, such as Bas and Strauss-Kahn (2010). The higher $1 - \alpha$ and the lower ε, the higher the effect. The intuition is straightforward. Measured productivity responds highly to the number of intermediate input varieties change when those inputs are more important (high $1 - \alpha$) and when they are more substitutable (low ε).

Another measure is labor productivity. In my set up, the measure of productivity is proportional to the wage in sector M. Therefore instead of discussing another measure of productivity, I can study the effects of tariffs on TFP and wages. Henceforth, I denote productivity as TFP.

4. The Effects of Trade Policy

Here I discuss two scenarios: the short run and the long run. In the short run scenario, labor is assumed to be immobile. This situation is more likely to arise in the developing countries when the labor market is imperfect, highly regulated, or when the moving cost is high or the unions are powerful. In the long run, labor is mobile.

Labor Market Friction: Short Term Equilibrium

In this case, labor is immobile. The system of equations (3), (4) and (5) yields the values of the variables p, $r(j)$ and $x(j)$, which characterize the equilibrium. In particular labor wage and TFP are given as follows:

$$\Omega = A_1 \left(p^w (1+\tau_o)\right)^{[(1-\alpha)(1-\varepsilon)]/(\alpha+\varepsilon-1)} \left(r^w (1+\tau_i)\right)^{\left[-(1-\alpha)^2(1-\varepsilon)\right]/(\alpha+\varepsilon-1)} \tag{6}$$

$$w = A_2 c^{[(1-\alpha)(1-\varepsilon)]/(\alpha+\varepsilon-1)} \left(p^w (1+\tau_o)\right)^{(1-\alpha)/(\alpha+\varepsilon-1)} \left(r^w (1+\tau_i)\right)^{-[(1-\alpha)\varepsilon]/(\alpha+\varepsilon-1)} \tag{7}$$

We can see that the effects of output tariff τ_o and input tariff τ_i on productivity and wages depend on the signs of $\alpha+\varepsilon-1$. In particular when $\alpha+\varepsilon-1>0$, productivity and wages increase when τ_o is higher and τ_i is lower. When $\alpha+\varepsilon-1<0$, productivity and wages increase when τ_o is lower and τ_i is higher. The condition that $\alpha+\varepsilon-1>0$ is equivalent to:

$$\sigma = \frac{1}{1-\varepsilon} > \frac{1}{\alpha}$$

In other words the elasticity of substitution among intermediate inputs has to be greater than the inverse of labor share. These two parameters, σ and α determine the strength of two opposing forces: the complementarity and the diminishing return forces. The former states that intermediate inputs are more efficient, i.e. the real marginal product of those inputs is higher, when there are more varieties as they complement each other. This effect is stronger if intermediate inputs are more differentiated (low σ), i.e. they are more complements than substitutes. The diminishing return force, however, is more pronounced when intermediate inputs are less differentiated (high σ) and when the share of those inputs is smaller (high α). Under this force, intermediate inputs are less efficient when there are more varieties.

Whether the complementarity or the diminishing return force dominates determines how the real marginal product of intermediate inputs responds to the number of varieties. When intermediate inputs are not highly differentiated, to the extent that the elasticity of substitution among those inputs is greater than the inverse of labor share, the diminishing return force dominates the complementarity force. In this case the real marginal product of intermediate inputs increases with the number of varieties. Otherwise, when intermediate inputs are highly differentiated, the real marginal product of intermediate inputs decreases with the number of varieties.

If input tariffs are lower, the marginal cost of intermediate inputs is reduced, implying a smaller marginal product of intermediate inputs in equilibrium. Therefore, if intermediate inputs are not highly differentiated to the extent that the diminishing return force dominates the complementarity force, lowering input tariffs leads to a higher number of varieties, which means a higher productivity by the love of variety. If intermediate inputs are highly differentiated, an input tariff reduction implies a lower number of varieties, or a lower productivity.

If the output tariff is lower, the real marginal product of intermediate inputs has to be higher so that the nominal marginal product is equal to the marginal cost of intermediate inputs in equilibrium. Therefore, with the same argument as in the input tariff case, lowering output tariff leads to lower productivity if intermediate inputs are not highly differentiated, and to a higher productivity otherwise.

To summarize, we have the following result.

Proposition 1. *When labor is immobile between sectors:*

(1) *If intermediate inputs are not highly differentiated, trade liberalization in the final market decreases the extensive margin of imports, i.e. less intermediate input varieties will be imported. As a result, productivity and wages decline. Trade liberalization in the intermediate market, by contrast, increases both the intensive margin and the extensive margin of imports, improves domestic firms' productivity and the wage in the final sector.*
(2) *If intermediate inputs are highly differentiated, we have the opposite conclusions. In particular, trade liberalization in the final market boosts productivity while trade liberalization in the intermediate markets leads to a fall in productivity.*

The Effects in the Long Run

In the long run, labor is no longer immobile. Therefore I need to add equation (1) into the system of equations. Solving this new system yields the equilibrium. With the same intuition as before, we have the following result.

Proposition 2. *When labor is mobile:*

(1) *If intermediate inputs are not highly differentiated, trade liberalization in the final market decreases the extensive margin of imports, i.e. less intermediate input varieties will be imported. As a result, productivity and wages decline. Trade liberalization in the intermediate market, by contrast, increases both the intensive margin and the extensive margin of imports, improves domestic firms' productivity and the wage in the final sector.*
(2) *If intermediate inputs are highly differentiated, we have the opposite conclusions. In particular, trade liberalization in the final market boosts productivity while trade liberalization in the intermediate markets leads to a fall in productivity.*

Proof. By request. □

Long Run versus Short Run

It should not be surprising that the results we receive in both the long run and the short run are similar. Indeed, the short run scenario is a special case of the long run when input and output tariffs (or equivalently the output and input prices) take the values such that labor in manufacturing is as follows:

$$L^M = p^{-\varepsilon/[\alpha\varepsilon-\gamma(\alpha+\varepsilon-1)]}r^{(1-\alpha)\varepsilon/[\alpha\varepsilon-\gamma(\alpha+\varepsilon-1)]}.$$

The difference between the short run and the long run is the magnitude of the effects of tariffs on productivity. Indeed, the following can be shown.

Proposition 3. *The effects of trade policy on the extensive margin of imports, firms' productivity and labor wage are always greater in the long run than in the short run.*

Proof. By request. □

The intuition behind this result is that the effects are magnified in the presence of labor adjustment, which can only happen in the long run. Indeed, labor adjustment

between sectors changes the marginal product of intermediate inputs. In particular, more labor increases the marginal return of intermediate inputs. This attracts even more foreign producers to provide varieties of inputs.

Proposition 3 states that deregulating labor market increases the gains from trade, in particular leads to a larger productivity improvement. Helpman and Itskhoki (2010) showed that lowering labor market frictions is reminiscent of a productivity improvement. Trade liberalization also induces policy makers to deregulate labor market (Boulhol, 2009).

5. Empirics

Data

Data description The data I use in this study is an industrial survey provided by Mexico's Insitituto Nacional de Estadistica Geografia e Informacion (INEGI). This survey covers about 3200 of the largest firms in Mexico for the period 1984–90.[2] This is the period when Mexico experienced significant trade reforms. In the survey, firms were required to answer by law. They reported in this dataset their value of production,[3] their input use, including the use of intermediate inputs, among others. These variables allow me to study the behavior of the firms.

Besides, I also have in the data set the price indices (both output and input prices) and tariffs (both output and input tariffs) at the 4-digit level. These data are provided by Mexico's Secretary of Commerce and Industrial Development (SECOFI).

Imports of intermediate inputs and output Table 1 shows the total real output and the total real imports of raw materials from 1986 to 1990. These variables increase by 35% and 61% respectively over this period, suggesting that Mexico experienced a high productivity gain and a substantial increase in imports of intermediate inputs.

Is there Evidence that Input and Output Tariffs affect TFP through the Import of Intermediate Inputs?

TFP correlation Following Amiti and Konings (2007), I shall regress measured productivity on tariffs. However the way productivity is estimated is controversial. In order to estimate TFP, one needs to estimate the production function; the residual between the actual production and the estimated value is then TFP. The easiest way to estimate the production function is using factor share. This methodology requires perfect competition. One can also use the ordinary least squares (OLS) methodology. The most common way is the approach proposed by Olley and Pakes (1996). This methodology is widely used as in Amiti and Konings (2007), Fernandes(2007), and Pavcnik (2002). Again this method is not perfect yet as Ackerberg et al. (2006), and De Loecker (2010) have pointed out. The discussion of how to estimate productivity

Table 1. Summary Statistics: Real Output and Real Import of Raw Materials

	86	*87*	*88*	*89*	*90*
Output	10,838.56	11,272.77	11,398.59	13,294.49	14,605.19
Import of raw materials	1,020.91	969.12	960.98	1,249.27	1,644.37

is beyond the scope of this paper. For a robustness check I will use the three above-mentioned measures.

Since I explicitly show that changes in tariffs lead to an increase in the import of intermediate inputs, which implies productivity improvement, what I want to test is not simply the correlation between productivity and tariffs, but the correlation between productivity and the tariffs interacted with an indicator that captures the import intensity. A non-zero interaction term implies that firms in sectors that import relatively more intermediate inputs will have more changes in productivity owing to trade liberalization. To compute that indicator, I calculate the weighted ratio between import of raw materials and total output for each sector. Then I establish a ratio ranking—a sector with high rank, say 10, has a higher ratio than a sector with low rank, say 1.

With the measured TFP and the import ranks, I run the following regression:

$$\log(TFP_{jt}) = \rho_j + \rho_t + \rho_1 * OT_{jt} + \rho_2 * IT_{jt} + \rho_o * OT_{jt} * rank_J + \rho_i * IT_{jt} * rank_J + u_{jt}.$$

The dependent variable is the average log of TFP at the four-digit industry level *j*, weighted by output. The independent variables are input tariff (*IT*), output tariff (*OT*) at the f-digit level industry j.

The theory tells us that input and output tariffs should have opposite effects on productivity, which are confirmed by the opposite signs that we see in all three specifications in Table 2. Moreover, in line with Amiti and Davis (2008), and Amiti and Konings (2007), the interaction of input tariffs with the import-intensity rank has a negative impact on productivity.

The theory also tells us about the mechanism of productivity improvement. As a result of the changes in tariffs, the firms adjust the imports of intermediate inputs which lead to productivity changes. This mechanism is confirmed by the following observation in the data. Among the firms whose TFP goes up with output tariffs, 87% of them (in terms of market share) increase (or reduce) their import of intermediate inputs, which increases (or reduces) their TFP. And among the firms whose TFP goes down with input tariffs, 89% of them increase (or reduce) their import of intermediate inputs, which therefore increases (or reduces) their TFP. This result is similar to Fernandes's (2007) where she found that in Colombia, more than 80% of plants with TFP gains under trade liberalization increase their intermediate inputs import–output ratio. This test brings

Table 2. The Effects of Trade Policy on Productivity

Dependent variable: log of TFP			
	(1) *Factor share*	*(2)* *OLS*	*(3)* *OP*
Input tariff	0.95*	0.64	–0.39
Output tariff	–0.05	–0.63	–0.15
Input tariff*Rank	–0.14***	–0.19***	–0.049
Output tariff*Rank	0.015	0.058	0.019
Sector FE	YES	YES	YES
Time FE	YES	YES	YES
Observations	750	903	903

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

the evidence that most of the productivity improvements are effectively from the firms that adjust the import of intermediate inputs in the predicted way.

Explanations for the results in Amiti and Konings (2007) Amiti and Konings (2007) found that in Indonesia, trade liberalization in the intermediate markets has a large negative effect on productivity of the firms, while trade liberalization in the final market has a much smaller, even insignificant impact. However, they had no theory to explain their findings. This paper can provide a possible explanation.

Indeed, what I have done above is to reconfirm the Amiti and Konings (2007) result with the Mexican data. Input tariffs have a negative impact on firms' productivity. Regarding output tariffs, I find a positive impact on productivity. Remember that I ignore the import competition effect which leads to a negative correlation between output tariffs and productivity. Therefore my effect will mitigate, or even cancel out the usual import competition, one that explains why output tariffs have a small, sometimes insignificant effect on productivity.

How are Wages Affected by Trade Policy?

One of the important questions in international economics is how wages are affected after trade liberalization. The answers we have from the literature are mixed: wages could go down (Goldberg and Pavcnik, 2005; Revenga, 1997), stay unchanged (Attanasio et al., 2004) or even increase (Amiti and Davis, 2008). These contrasting answers are possible as a result of the heterogeneity of the firms and the markets that trade liberalization occur as in Amiti and Davis (2008). Their results are similar to the predictions in my model. To test these predictions, I run the following estimation:

$$\ln(w_{jt}) = \phi_j + \phi_t + \phi_1 \times IT_{jt} + \phi_2 \times OT_{jt} + \phi_I \times rank_{jt} \times IT_{jt} + \phi_O \times rank_{it} \times OT_{jt} + \phi_s \times s_{it} + \mu_{jt}.$$

The dependent variable is the average of the log of the wage at the four-digit level, deflated by the price index and weighted by output. Wages are defined as the wage bill divided by the number of workers. The two tariffs variables IT and OT are input and output tariffs at the four-digit industry level, respectively. I also include the wage share of blue-collar workers, which is defined as the ratio between the wages of blue-collar workers and the total wages, for robustness check. The notable variables are the interaction terms between tariffs and the sector rank, defined in the previous section. These terms tell us how the import of intermediate inputs interact with the effects of tariffs on wages.

Results in Table 3 confirm my predictions. The coefficient of the interaction between input tariffs and the sectors' import-intensity rank is significantly negative, implying that the firms in sectors that import relatively more intermediate inputs will see a larger rise in wages after input tariffs are cut. The coefficient of the interaction between output tariffs and the sectors' import-intensity rank is significantly positive, implying that the firms in sectors that import relatively more intermediate inputs will see a bigger fall in wages after output tariffs are cut. These results are robust to the control of the share of blue-collar workers.

Estimating the Structural Parameters

In the theoretical part of the paper, I show that the effects of trade policy depend on the structural parameters, which motivates the need to estimate these parameters, in par-

Table 3. The Effects of Trade Policy on Wages

Dependent variable: log of total wages		
	(1)	*(2)*
Input tariff	1.50***	1.54***
Output tariff	–0.65***	–0.69***
Rank*Input tariff	–0.16***	–0.16***
Rank*Output tariff	0.057***	0.059***
Blue collar share		–1.20**
Sector FE	YES	YES
Time FE	YES	YES
Number of Observations	889	889

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

ticular the elasticity of substitution. There are not many studies, which I will discuss later on, that provide these estimates, especially for the intermediate inputs. These estimates however are useful in assessing the gains from trade liberalization as we know that having more variety owing to opening the markets is more beneficial if the goods are more differentiated.

The domestic inputs share In my setup, α is the share of labor. However, labor is the only domestic factor. Therefore we can imagine labor as a proxy for domestic inputs. In this case, α will be the share of domestic inputs and $1 - \alpha$ is the share of imported intermediate inputs. This leads me to the following way of estimating α:

$$\alpha_J = \sum_{i \in J,t} \frac{sldomesticinput_{it}}{sloutput_{it}} \times sloutput_{it} \Big/ \sum_{i,t} output_{it}.$$

Here i indexes the firm in the two-digit sector J, and t is the time.

The short run scenario From the model I developed above, total spending on intermediate inputs is given by $M = nrx = A_3 c^{\alpha\varepsilon/(\alpha+\varepsilon-1)} p^{\varepsilon/(\alpha+\varepsilon-1)} r^{-(1-\alpha)\varepsilon/(\alpha+\varepsilon-1)}$. I then run the following regression:

$$\ln(m_{jt}) = \beta_J + \beta_{pJ} \ln(p_{jt}) + \beta_{rJ} \ln(r_{jt}) + \eta_{jt}.$$

The dependent variable is the log of spending on imported intermediate inputs at the four-digit industry level j at time t; J is the index of the two-digit industry. The explanatory variables are the log of output price index and of input price index, also at the four-digit industry level. To address the concern that the price indices might not be exogenous as assumed in the model, I instrument them by input and output tariffs at the four-digit level. Equivalently, I could use input and output tariffs in the place of input and output prices:

$$\ln(m_{jt}) = \beta_J + \beta_{OJ} \ln(\tau_{jt}^O) + \beta_{IJ} \ln(\tau_{jt}^I) + \eta_{jt}.$$

Together with the domestic inputs share α, each of the coefficient of tariffs and prices yield the estimates of ε_J,[4] which are reported in Table 4.

Table 4. Estimates of ε in the Short Term

Sector	*(1)*	*(2)*	*(3)*	*(4)*
1. Food Products	0.33***	0.35***	0.32***	0.21***
2. Beverages	0.41***	0.28	0.52***	0.28
3. Tobacco	0.62***	0.61***	0.63***	0.63
4. Textiles	0.37	0.44*	0.20	0.30***
5. Clothing and Apparel	0.37***	0.34***	0.40***	0.73
6. Leather Products and Footwear	0.17***	0.17***	0.17***	0.18***
7. Wood Products and Furniture	0.26	0.22	0.31	0.22***
8. Pulp and Paper	0.35***	0.34***	0.32	0.33***
9. Chemicals	0.46***	0.53***	0.41***	0.47***
10. Plastic and Rubber Products	0.43***	0.46***	0.45***	0.31
11. Glass	0.33***	0.35***	0.31***	0.30***
12. Other Non-metallic Mineral Products	0.46***	0.47***	0.47***	0.56***
13. Iron and Steel	0.47***	0.47***	0.47***	0.43***
14. Non-ferrous Base Products	0.24***	0.29***	0.22***	0.22***
15. Metal Products	0.35***	0.38***	0.34***	0.26***
16. Non-electrical Machinery	0.53***	0.53***	0.58***	0.49***
17. Electrical Machinery	0.40***	0.36***	0.43***	0.48***
18. Transport Equipment	0.32	–0.10	0.55***	0.36
19. Other Manufacturing Industries	0.41***	0.40***	0.41***	0.40***

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

The long run scenario In this scenario, I use the same strategy as in the short run scenario. Here I have another parameter to estimate, γ. This can be done by running another regression:

$$\ln(labor_{jt}) = \theta_J + \theta_{pJ} \times \ln(1 + p_{jt}) + \beta_{rJ} \times \ln(1 + r_{jt}) + \mu_{jt}.$$

The variable *labor* here is the log of the weighted average number of hours working.[5] Similar to the short run scenario, I only need the coefficients of the output price variables δ_{pJ} and θ_{pJ} or those of the input price variables δ_{rJ} and θ_{rJ} to estimate for γ and ε. For instance, I can calculate:

$$\gamma_J = \delta_{pJ} / \theta_{pJ},$$

$$\varepsilon_J = [(1 - \alpha_J)\delta_{pJ}] / (\delta_{pJ} - \alpha_J \theta_{pJ} - 1).$$

Moreover, as in the short run scenario, replacing the price variables by the tariff variables bring two regressions, and therefore two more specifications. The coefficients of output tariffs and input tariffs play the similar role in estimating γ and ε as the coefficients of output prices and input prices. Estimates of ε_J are reported in Table 5.

Discussion of the estimates Little is known about the differentiation of intermediate inputs, which helps us quantify how much the firms gain as a result of trade liberalization in terms of productivity. The estimates of ε in Tables 4 and 5 can be used to compute the elasticity of substitution among intermediate inputs: for each sector I take the average of the statistically significant ε_J and compute $\sigma_J = 1/(1 - \varepsilon_J)$.

Table 5. Estimates of ε in the Long Term

Sector	*(1)*	*(2)*	*(3)*	*(4)*
1. Food Products	0.35***	0.43***	0.36***	0.30***
2. Beverages	–0.10	–0.04	0.75	0.13
3. Tobacco	0.62***	0.61***	0.62***	0.62***
4. Textiles	0.45	0.51	–1.33	0.33***
5. Clothing and Apparel	0.34***	0.30***	0.40***	0.58
6. Leather Products and Footwear	–0.40	–0.30	0.20***	0.59
7. Wood Products and Furniture	0.16	0.14	–0.08	0.14
8. Pulp and Paper	–0.69	–0.67	–4.56	0.57
9. Chemicals	0.61	0.78	0.71	0.71
10. Plastic and Rubber Products	0.28	0.31	–0.47***	0.29
11. Glass	–0.64	–0.72	0.21***	0.27***
12. Other Non-metallic Mineral Products	0.57	0.55	0.41***	0.36***
13. Iron and Steel	0.41***	0.43***	0.87	0.41***
14. Non-ferrous Base Products	0.24***	0.33**	0.20***	0.22***
15. Metal Products	0.31***	0.35***	0.50*	0.27***
16. Non-electrical Machinery	0.52***	0.52	1.83	0.48***
17. Electrical Machinery	0.42***	0.38**	0.51***	0.51***
18. Transport Equipment	0.24	–0.05	5.37	0.24
19. Other Manufacturing Industries	0.37***	0.38***	0.38***	0.40***

Note: * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

The short run estimates are more reliable than the long run ones: they are all in [0, 1] and statistically significant. For the long run estimates that meet these conditions, their values are similar to the short run estimates. Therefore I use the estimates of ε in the short run (Table 4) to compute ω. Results are reported in Table 6.

Broda and Weinstein (2006) find that the elasticities of substitution of US imports at the 3-digit level have the median of 2.5 (from 1972 to 1988) or 2.2 (from 1990 to 2001). These results are consistent with my results in Table 6. Moreover, we all agree that the lowest elasticity of substitution is 1.2 in the Footwear sector.

When compared with other studies (Acemoglu and Ventura, 2002; Feenstra, 1994; Hummels and Klenow, 2005), my elasticities are lower. The reason is because the elasticity of substitution of intermediate goods should be lower than that of final goods as the demand for intermediate inputs of firms tend to be governed by a choice among complementary sets of factors, while the consumer's budget tends to be the choice among mild substitutes (Hicks, 1939; Marshall, 1925).

Higher import volumes are correlated with the industry's productivity growth (Economidou and Murshid, 2008). In Mexico, the weighted average of the parameters are $\alpha = 0.59$ and $\varepsilon = 0.42$. From (6), measured TFP will increase on average 24% if we lower input tariffs by 1% but will decrease by 10% if we lower output tariffs by 1%. From (7), labor wages in the Manufacturing sector increase by 28% with a 1% input tariffs cut, but decreases by 12% with a 1% output tariffs reduction. Trade policy can have huge effects on the industry's productivity and wage.

6. Conclusion

In this paper, I show that the impact of trade liberalization on productivity depends on which markets are liberalized and the degree of differentiation of intermediate inputs.

Table 6. The Elasticity of Substitution Across Sectors

Sector	σ
1. Food Products	1.43
2. Beverages	1.85
3. Tobacco	2.63
4. Textiles	1.59
5. Clothing and Apparel	1.59
6. Leather Products and Footwear	1.20
7. Wood Products and Furniture	1.28
8. Pulp and Paper	1.52
9. Chemicals	1.89
10. Plastic and Rubber Products	1.79
11. Glass	1.47
12. Other Non-metallic Mineral Products	1.96
13. Iron and Steel	1.85
14. Non-ferrous Base Products	1.32
15. Metal Products	1.49
16. Non-electrical Machinery	2.13
17. Electrical Machinery	1.72
18. Transport Equipment	2.22
19. Other Manufacturing Industries	1.67

In particular, trade liberalization in the intermediate markets lead to productivity growth when inputs are not highly differentiated, whereas trade liberalization in the final market leads to productivity growth when inputs are highly differentiated. These results apply for both TFP and labor productivity.

Data in Mexico in the 1980s supports these predictions. The effects of output and input tariffs are higher for the firms that are in sectors importing relatively more intermediate inputs. Moreover, the model provides estimates for the elasticity of substitution among intermediate inputs across sectors. These estimates determine how input and output tariffs affect productivity and wages as is discussed above. Also as the gains in productivity increase when intermediate inputs are more differentiated, these estimates help to compute the gains from trade liberalization.

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Notes

1. This assumption is in contrast to Halpern et al. (2009) where they had a heterogenous fixed cost to explain a feature in their Hungarian data that firms use different numbers of varieties. As we do not have data on the number of varieties, assuming a homogenous fixed cost will create a natural monopoly since the small firms cannot afford to pay this fixed cost: only the largest firm can.
2. I would like to thank James Tybout for giving access to the data.
3. One might have concerns about the subcontracting work in Mexico as in Grether (1996). In the survey that we use, this maquila service can involve two domestic firms as well as a foreign firm. As our model focuses on domestic firms producing for the domestic market, the problem can lie in the fact that one part of the production of the firms will serve the foreign firms (i.e. they will count as export). Fortunately as Grether (1996) noted the output and input uses associated with the maquila service are recorded for the plant that ordered the job, therefore the domestic firms that provide the service for foreign firms will not count that service as their production.
4. For instance, $\varepsilon_J = -\dfrac{\beta_{pJ}(1-\alpha_J)}{1-\beta_{pJ}}$.
5. One may claim that it is not consistent with the way we calculate α where we use domestic input instead of labor. However, when we compute α we need the *nominal* value of domestic inputs and to have α close to two-thirds as we compute seems conventional. Here we need the *real* value of L, and therefore using the number of working hours seems more appropriate.