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Effects of a Free Trade Agreement on the Exchange Rate Pass-Through to Import Prices

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This paper investigates the effect of trade liberalization on the exchange rate pass-through (ERPT) to import prices. To do so, it employs an empirical estimation of the effects of NAFTA on the Mexican ERPT, and uses a Ricardian general equilibrium model. The model identifes two channels that explain how the trade liberalization alters the ERPT. The first channel is the direct relationship between the tariffs and the pass-through by good. The second channel is the effect that tariffs have on the composition of imports, altering indirectly the aggregate pass-through.

Keywords: *Ricardian model, exchange rate pass-through, NAFTA*.

JELS F31 and F41.

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1. Introduction

This paper explores the effects of trade liberalization on the "exchange rate pass-through" (ERPT) to import prices. The ERPT is the responsiveness of prices to exchange rate movements. It can be measured in terms of elasticities: the percentage change in the domestic prices of imported goods resulting from a 1% change in the nominal exchange rate between the importing and exporting countries. Trade liberalization is seen in this paper as a two-country tariffs elimination. The contributions of this paper are as follows. First, based on a model, it proposes two channels through which tariffs elimination can alter the ERPT. The first channel is a decrease in the ERPT levels by product. The second channel is a change in the composition of the import bundle, altering the aggregate ERPT. Second, in terms of economic theory, it develops a model that mixes trade theory and new open economy models. Third, it incorporates a case analysis to show that a trade agreement can have an important effect on the ERPT to import prices.

I will begin with a brief review of the literature on ERPT in order to situate the analysis on this literature. The effects of the ERPT on import prices have been analyzed as both a macro phenomenon and a micro phenomenon. In the 1990s, microeconomic studies emphasized industrial organization, price discrimination, and geographical segmentation across product markets as causes for the ERPT. For a survey of this literature see Goldberg and Knetter (1997). More recently, the ERPT has become a central issue in the debates over the election of exchange rate regimes and appropriate monetary policies. One recent hypothesis suggests that the intensity of the ERPT depends on the country's relative monetary stability,[1] that is, once inflation is stabilized, the ERPT to prices becomes weaker since the firm's power to determine the prices is weaker. Choudhri and Hakura (2006) find evidence to support this hypothesis for a sample of 71 countries. Goldfajn and Werlang (2000) and Baqueiro, Díaz de León and Torres (2004) also support this hypothesis using cross-section analysis and time-series analysis, respectively. Furthermore, they show that exchange rate fluctuations are also an important determinant of the ERPT. Finally, another recent study on the determinants of the ERPT is Campa and Goldberg (2005). For a sample of 25 OECD countries, they find that the most important determinants are microeconomic. The countries with a relatively large share of raw materials and energy products in their imports are the ones with higher levels of ERPT. In this paper, I go a step backwards. I suggest that the tariffs structure alters the composition of a country's imports, causing some effects on the aggregate pass-through level. However, I also explore how tariffs elimination affects the ERPT level by product and how this individual effect interacts with the new import bundle to determine the aggregated level of pass-through. Answering these questions is particularly important given the widely extended trade liberalization we see these days.

Moreover, a model to explain the effects of a free trade agreement (FTA) is needed as the relationship between trade liberalization and pass-through is not clear. On one hand, some economists claim that trade liberalization diminishes the pass-through level because it increases competition, thereby reducing the power of firms to move prices. However, on the other hand, empirical evidence (see De Stefano, 2004, and Kardasz and Stollery, 2005) shows that the higher the market power of the firms, the lower the pass-through of exchange rate movements to the final prices. The last result would imply that if the trade liberalization affects the ERPT through an increase in competition, trade liberalization would increase the pass-through. In addition, when analyzing the effects of trade barriers on the pass-through, different studies suggest opposite effects; see, for example, Kardasz and Stollery (2005) and Barhoumi (2006). Therefore, explaining how trade liberalization affects the ERPT is still an open question.

[1] See Taylor (2000) and Devereux and Engel (2001).

A Ricardian two-country model in which there are two types of tradable goods with different pass-through levels is used. The ERPT is modeled on Corsetti and Dedola (2005). That is, an incomplete pass-through arises as a consequence of the need for local distribution services and wage rigidity. The inclusion of the distribution sector is motivated by the importance of this sector in consumer price formation. The empirical evidence for the US (see Burstein, Neves and Rebelo, 2003) shows that the distribution costs represent more than 50% of the retail price in all agricultural products and that the total distribution margin is around 42%. The next section discusses the model, although, some clarifications are needed. For simplicity, I focus on an FTA between two symmetric open economies. Each economy has two tradable sectors: one sector producing high-differentiation goods and another producing low-differentiation goods. Following Campa and Goldberg (2005) and Oliveira, Scarpetta and Pilat (1996), the products that are considered as high-differentiation goods are the manufacturing and high-tech products, and the products that are considered as low-differentiation goods are agricultural products and raw materials. The firms producing tradable goods face monopolistic competition. By assumption, the firms in each country choose a price for each market, domestic and foreign, taking into account the market demand but not the foreign competition. This restriction for the firms with regard to knowing the foreign competition does not seem to be highly unrealistic as the firms are located in different countries. As such, the producers of tradable goods in the other country can enter the market and make positive profits while some domestic producers cannot. This can be considered as a non-Nash behavior of the firms owing to the information restriction on foreign competitors. However, due to the Ricardian production functions, some firms in each country always have a comparative advantage; consequently, there will be imported goods no matter what the rest of the firms do and therefore the results of the paper are not altered due to this assumption.

The model works is as follows. Due to the FTA, both countries import more varieties of low- and high-differentiation goods from the other country. The high-differentiation products have the lowest ERPT to import prices.[2] When the tariffs on the low-differentiation goods sector are higher as compared to those on the high-differentiation goods sector, the number of varieties of high-differentiation goods that are imported increases more than the number of varieties of low-differentiation goods that are imported, thereby decreasing the aggregate ERPT. In addition, the reduction in tariffs decreases the ERPT in each imported good. This occurs because in the model, tariffs have a positive effect on the price elasticity of demand faced by tradable firms and the elasticity is associated with the ERPT. The intuition is that ad-valorem tariffs increase the proportion of the final price influenced by the foreign firm in relation to the share of the price resulting from distribution costs. As the foreign firms have more influence on the final price, they pass-through a higher proportion of the exchange rate movements into import prices since the firm compensates the change in its profits resulting from exchange rate fluctuations with the movements in prices. The simulations performed show that tariffs elimination reduces the pass-through level by good and by sector.

In this model, the demand curve is different across sectors due to the differences in tariffs and market power, and the ERPT varies across sectors because the firms take into account these conditions when they move the price in response to exchange rate movements. In contrast, there are models that rely on the adjustments along the demand curve to model ERPT. For example, in the model of Auer and Chaney (2009), when firms adjust their prices, they move along the demand curve and face different demand elasticities due to the exit of low-quality firms. Exporters adjust their prices in response to the level of competition (number of firms in the market) and cost changes brought about by exchange rate fluctuations.

The rest of the paper is organized as follows: section two presents the case analysis, section three contains the model, section four explains the calibration procedure, and section five gives the numerical results. Finally, section six concludes with a brief summary of the results and the ideas contained in this paper.

[2] See Campa and Goldberg (2005) for the empirical evidence.

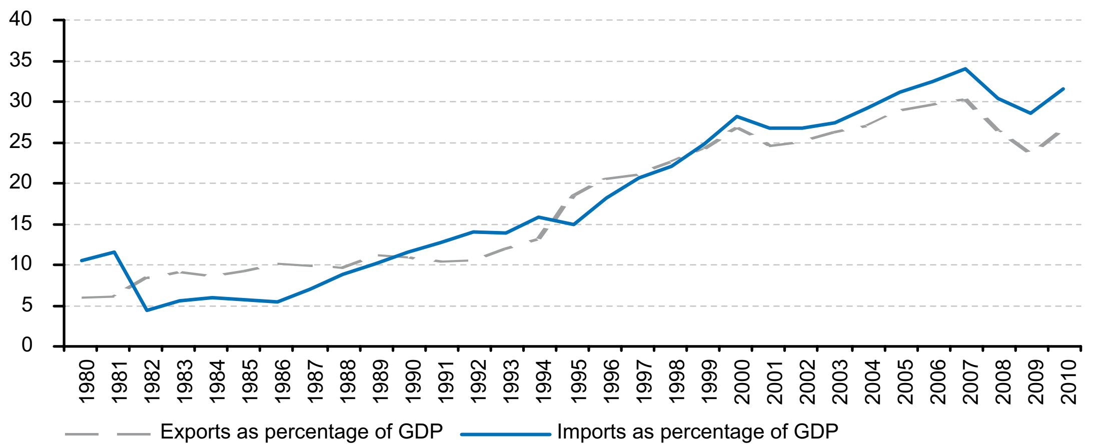
2. Empirical Evidence

The purpose of this section is to use a case analysis to explore empirically the effect of an FTA on the ERPT to import prices. To my knowledge, there is no paper that has attempted to use a case to analyze this issue. The case chosen is the North America Free Trade Agreement (NAFTA) and its effects on the ERPT in Mexico. The case of Mexico is chosen because its high integration with USA provides the following advantages in terms of ERPT measurement. It permits the measurement of the ERPT using an aggregate import price index and yields the possibility of focusing on the transmission of a shock from a single currency (US dollar) movement.

After 1986, Mexico chose the liberalized economy approach. On August 17, 1986, Mexico joined the General Agreement on Trade and Tariffs (GATT) and on January 1, 1994, NAFTA came into effect.

Thanks to these agreements, the trade relationship between Mexico and the USA became more and more important. Graphic 1 shows how the trade of Mexico with the USA started growing after 1987.

Graphic 1
Trade between Mexico and the USA



Source: own calculations

This strong trade relationship ended with the USA becoming the most important trading partner of Mexico, and Mexico becoming the third-most important trading partner of the USA after Canada and China, when trade is measured as the sum of the exports and imports.

With regard to the total Mexican imports, around 70% of the Mexican imports are sourced from the USA. This hard-to-get characteristic implies that the import price index basically represents the pricing decisions of the USA firms for the Mexican market. As such, this index is used to analyze the ERPT behavior when the bilateral trade had been liberalized. Diversified economies' import price indexes would not be capable of capturing the effect of bilateral trade liberalization. Note that an essential characteristic of the import prices variable is its domestic currency denomination, which makes it possible to obtain the final effect on the domestic prices.

The model described in the next section and papers such as Campa and Goldberg (2005) shows that the prices of imported goods depend on their respective production costs, prices in the distribution sector, exchange rate, and market power. The data used in the estimation are as follows. As a dependent variable, I employ an import price index calculated by the

OECD from the prices denominated in the local currency. The exchange rate is denominated in Mexican pesos by US dollars. As a marginal cost, I use the USA payroll index. Due to the lack of a retail sector price index in Mexico, the proxy variable for the price of the distribution services is the Mexican salary index. The producer prices were not chosen as the proxy because this index contains imported goods. The sources of the data appear in appendix 1.

The behavior of the series is analyzed in order to define the estimation model. An analysis of unit root is performed to test whether the series follows a unit root or a stationary trajectory. The unit root analysis consists of three tests, the augmented Dickey-Fuller (ADF) test, Perron test, and Zivot-Andrews test. The ADF is the traditional unit root test. The Perron and the Zivot-Andrews tests take into account the presence of structural breaks. Perron's (1989) procedure is characterized by a single exogenous break, while Zivot and Andrews (1992) selects the break date endogenously. The break date is given by the point where the t-statistic from the ADF test of unit root is at the minimum (most negative). The next table shows that the ADF test rejects the null hypothesis of the unit root process of the following variables: import prices, US payrolls, and Mexican salaries. However, the Perron and Zivot-Andrews tests do not reject the null hypothesis of the unit root process for the import prices, exchange rate, and US payrolls. For the Mexican salaries, the tests give opposite results.

Chart 1

Test for Unit Root of Residuals

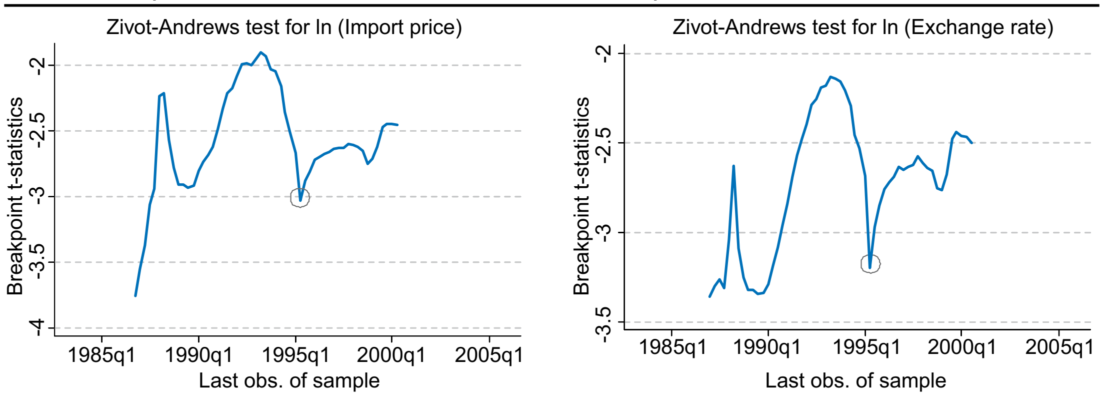
Unit root process. Ho: variable contains a unit root			
Variables	**Augmented Dickey-Fuller test**	**Perron test**	**Zivot-Andrews test**
Import prices	3.657	1.197	3.755
	(1.950)	(3.467)	(5.080)
Exchange rate	0.088	1.696	3.359
	(1.950)	(3.467)	(5.080)
US payrolls	13.768	1.549	2.738
	(1.950)	(3.467)	(5.080)
Mexican salaries	4.753	1.508	7.056
	(1.950)	(3.467)	(5.080)

Numbers in parentheses represent the critical value.
Variables in logs.
Source: own calculations

The Zivot-Andrews test also identifies the break date. The break in the import prices and the break in the exchange rate coincide with the signing of the NAFTA and the Mexican crisis in 1994-1995. We can consider these breaks as shocks that had persistent effects on the long-run level of the variables.

Graphic 2

Break date (t-statistic from the ADF test of unit root)



Source: own calculations

By definition, the difference in a variable that follows a unit root process is stationary. As such, in such a case, an estimation in first differences is chosen.

Thus, the ERPT is calculated as follows:

$$\Delta imp_{j,t} = \beta_0 + \beta_1 \Delta imp_{j,t-1} + \beta_2 \Delta e_t + \beta_3 \Delta c_{j,t} + \beta_4 \Delta pn_{k,t} + \nu_{j,t},\ k \neq j,$$

where Δ represents the first differences, imp_j denotes the import prices in country j denominated in the domestic currency, e denotes the Peso/USD exchange rate, c_j is the marginal cost in country j, pn_k is an indicator of the price of the distribution services in the trade partner k, and v_j is the error term, and all variables are log-transformed. The short-term ERPT is given by the estimated coefficient β_2.

The estimation period is given by the quarterly data from the first quarter of 1987 to the second quarter of 2003. The reasons for choosing the first quarter of 1987 are that the 1980s Mexican crisis came to its end in this period and that the trade liberalization had just begun in this year. The estimation period ends in 2003 because the import prices calculated by the OECD were discontinued after that year. I use this index because it is the only one available that is denominated in the domestic currency and this characteristic permits the capturing of the exchange rate transmission to the final price. The OECD dataset contains three import price indexes for Mexico, total goods, manufacturing goods, and other goods. Here, manufacturing goods comprise machinery, transport equipment, electronics, and intermediate manufacturing goods, and other goods comprise food products, beverages, textiles, and energy products.

The estimation equation in this analysis is very similar to those used by Campa and Goldberg (2005) for OECD countries, Otani, Shiratsuka and Shirota (2003) for Japan and Bugamelli and Tedeschi (2008) for Europe.

A test to analyze multicollinearity is performed. The Variance Inflation Factor (VIF) shows no evidence of multicollinearity among the independent variables (see chart 2). Then, the control variables do not seem to have a strong linear relationship among them.

Chart 2

Multicollinearity test

Variable	VIF	1/VIF
D.Total goods import prices$_{t-1}$	1.32	0.76
D.Exchange rate$_t$	1.23	0.81
D.Mexico salaries$_t$	1.14	0.88
D.US Payrolls$_t$	1.05	0.95

Variables in logs. D denotes in differences. Source: own calculations

The estimation results are as follows:

Chart 3

Estimation results

	Total goods import prices$_t$	Manufacturing goods import prices$_t$	Other goods import prices$_t$
D.Exchange rate$_t$	0.984	0.997	0.913
	(24.50)***	(29.31)***	(1.87)*
D.US payrolls$_t$	0.346	0.672	-4.207
	(1.14)	(2.18)**	(1.38)
D.Mexican salaries$_t$	0.003	-0.021	0.46
	(0.07)	(0.54)	(2.04)**
D.Total goods import prices$_{t-1}$	0.013		
	(0.43)		
D.Manufacturing goods import prices$_{t-1}$		0.017	
		(0.72)	
D.Other goods import prices$_{t-1}$			-0.476
			(1.80)*
Constant	0.001	-0.002	0.051
	(0.14)	(0.62)	(1.43)
Observations	66	66	66
R-squared	0.94	0.95	0.35

Robust t statistics in parentheses. Variables in logs. D denotes in differences.
* significant at 10%; ** significant at 5%; *** significant at 1%.
Manufacturing goods refer to machinery, transport equipment, electronics, and manufacturing intermediate goods.
Other goods refer to food products, beverages, textiles, and energy products. Source: own calculations

The ERPT is significant for each series of import prices. In the case of the prices of manufacturing imports, the US Payroll index has a significant and relevant positive sign. For the other goods, the Mexican costs are the ones with a positive and significant coefficient. This implies that the domestic costs are more important for the determination of the prices of manufacturing imports whereas the foreign distribution costs are more important for the other goods price formation. It seems that the aggregation of manufacturing and other goods in the total imports causes the effect of the costs on the aggregate import prices to cancel out.

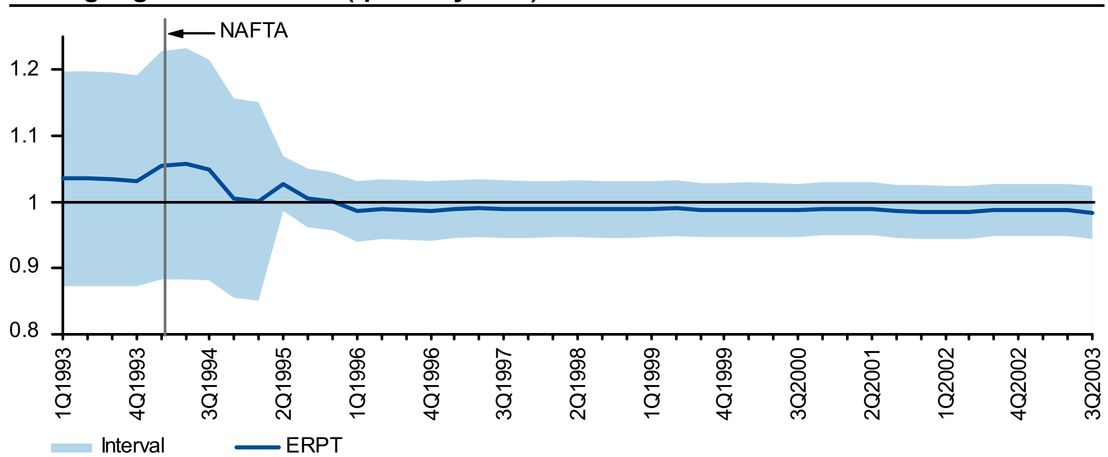
In the case of serial correlation, the estimation results might be subject to potential problems of biased and inconsistent estimators. However, there is no evidence of serial correlation in the estimation of the ERPT for total goods and for manufacturing goods whereas for other goods, there is evidence of only week serial correlation (autocorrelation of the residuals around 0.34). An alternative to eliminate the problems resulting from serial correlation is to use instrumental variables for the suspected endogenous variables.[3] Regardless of the weak evidence of serial autocorrelation, the ERPT was also estimated using a two-stage least squares (2SLS)[4] method yielding asymptotically efficient estimates of the coefficients, including the first and second lags of the suspected endogenous variables as instruments in the regression.[5] The results were the same as in the previous estimation concluding that the serial correlation is not biasing the results.

To analyze the changes in the ERPT over time, I employ the rolling regression method. First, the model estimates the pass-through using a 24 observation subsample. The model then extends the sample to an additional period and later performs the estimation. The process is repeated till the end of the sample. The subsample estimation incorporates the data from the first quarter of 1987 to the fourth quarter of 1992 (24 observations).

Graphic 3 shows that the ERPT seems to be decreasing over time. In particular, we observe two different and persistent levels of pass-through before and after NAFTA. The pass-through level before NAFTA is close to 1.10 and it is 0.98 after NAFTA.

Graphic 3

Rolling regression results (quarterly data)



Source: own calculations

[3] From among the works on the ERPT, Mihailov (2009) applies this technique. The recent studies have also used vectorautoregressions to analyze this issue (see Choudhri, Faruquee and Hakura, 2005, Coricelli, Jazbec and Masten, 2006, McCarthy, 2007, Ito and Sato, 2008). Among the most common critiques to this method is the lack of a theoretical model to define the estimation equations, and in particular, the lags used in the estimation.

[4] This estimator is also known as the Anderson and Hsiao (1981) estimator.

[5] This is particularly true in our case given the small size of our sample. In the case of large samples, the generalized method of moments (GMM), developed by Hansen (1982) provides efficient estimators.

Trade liberalization includes the elimination of both tariff and non-tariff barriers. It is important to note that the trade liberalization of different products came at different points in time due to legal agreements and organizational restrictions, a reason that can explain why the pass-through decreases sharply over time in the first years of NAFTA. Graphic 3 also shows a jump in the ERPT in the first quarter of 1995, when the Mexican crisis begins. However, in spite of the prevailing turbulence during 1995 and 1996 (for example, an inflation rate of 52% in 1995 and 28% in 1996), the pass-through has a stable pattern around 0.98.

The rolling regression method allows us to calculate an ERPT coefficient for each period of time. Consequently, I can try to explain this coefficient. In Mexico and the USA, the variables that can be used to explain the ERPT is inflation, the trade over GDP as a measure of protectionism in a country (tariff and non-tariff trade barriers are not available over time and tariffs are altered only after long periods), and the share of manufacturing imports in total imports.

The Durbin's test for serial autocorrelation shows that the residuals follow an AR(1) process. A feasible generalized least squares (FGLS) estimation is done to take into account this process.

Chart 4

Quarterly Exchange Rate PassThrough$_t$: FGLS Estimation

Trade over GDP$_t$	-0.662
	(7.97)***
Mexico inflation$_t$	0.002
	(3.23)***
US inflation$_t$	-0.007
	(0.02)
Share of manufactures in total imports$_t$	0.174
	(1.12)
Constant	1.086
	(84.40)***
Observations	43
R–squared	0.76

Absolute value of z statistics in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.
Source: own calculations

The estimation shows that the level of trade liberalization, measured as trade over GDP, has a statistically significant negative effect on the ERPT in Mexico. The level of inflation is significant; however, its coefficient is very close to zero. The US inflation and the share of manufactures in total imports are not significant. The VIF test (see chart 5) does not show evidence of multicollinearity among variables used in this regression.

Chart 5

Multicollinearity test: ERPT regression

Variable	VIF	1/VIF
Mexico inflation$_t$	1.48	0.68
Share of manufactures in total imports$_t$	1.48	0.68
Trade over GDP$_t$	1.08	0.92
US inflation$_t$	1.01	0.99

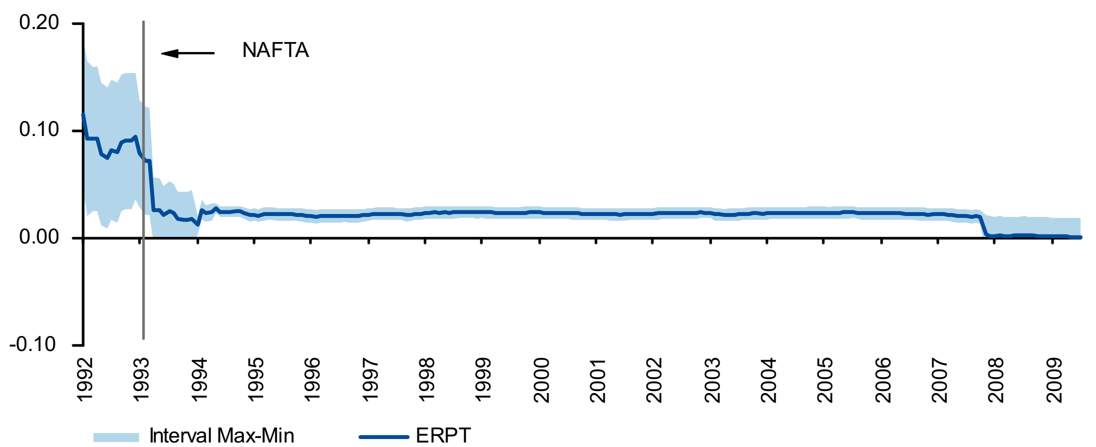
Source: own calculations

A change in the import composition should alter the ERPT since different goods have different pass-through levels. Campa and Goldberg (2005) have shown that this seems to be the case in many OECD countries, wherein the ERPT shows a decreased owing to the higher proportion of manufacturing imports. However, in the case of Mexico, manufactures represent more than 85% of the total imports since 1987 and this measure has been highly persistent, in particular in the last decade. This is possibly the reason for the no significance of the share of manufacturing in the total imports coefficient. Further, it must be noted that the concentration in the manufacturing sector does not necessarily imply a reduction of the ERPT; the ERPT depends on the pass-through level in this sector. The estimation results in chart 3 show that in Mexico, the manufactured goods have a high level of ERPT (0.9) as compared to in other countries (see Campa and Goldberg, 2005).

An alternative index of import prices is calculated by the Central Bank of Mexico. In converse to the index calculated by the OECD, this index is calculated from the prices denominated in US dollars, which makes it more difficult to perceive the transmission of the exchange rate shocks to the final price. In order to derive a contrast to our previous results, the ERPT is calculated using this index in spite of its limitations. The estimation is done following the same procedure described above and uses the same control variables. The estimation results using this monthly index show the same decreasing pattern in the ERPT after NAFTA, as found previously. The estimation also shows an additional reduction in the ERPT in the crisis period of 2009-2010, which may be associated with the demand factors. The ERPT is smaller because it is a monthly pass-through and the index is calculated from the prices in US dollars.

Graphic 4

Rolling regression results (monthly data) with the import prices denominated in US dollars



Source: own calculations

3. Model

A two-country Ricardian model similar to the one described in Corsetti and Dedola (2005) is used. Each country has four sectors: two tradable sectors (one producing high-differentiation products and another producing low-differentiation products), a nontradable sector, and a distribution sector. The firms in each of the tradable sectors produce their goods in a number of varieties or brands; this implies that in each tradable sector the goods (varieties) are slightly different across them. By definition, the high-differentiation goods are more heterogeneous than low-differentiation goods. The firms producing tradable goods sell these goods in both the domestic market and the foreign market. In its own market, the domestic firm sells its good directly to the consumer. In the foreign market, the domestic firm sells the product to a foreign distribution firm. This distribution firm buys the tradable product, pays its import taxes, and distributes it to the consumers using the nontradable good. The nontradable goods are used to make foreign tradable goods available to domestic consumers. One can consider this nontradable good as the service required to distribute and sell a good in the foreign country with the same conditions as in the home country.

Separating the tradable firms from the distribution firms results in two different import prices, the producer price and the consumer price. The producer price is represented by the price that the distribution firm receives from the tradable firm. It does not include the taxes and the distribution costs. The consumer price is given by the final price and includes both the taxes and the distribution costs.

The decision to consider both the producer import price and the consumer import price deserves some discussion. I decided to do so in a way that allows me to calculate an import price consistent with the one calculated by the Bureau of Labor Statistics (BLS) and other international statistical offices. This will allow me to compare the results with the empirical evidence. The BLS reports the import prices on a free on board (f.o.b.) foreign port basis. The f.o.b. foreign port price is the price at the foreign port of export before insurance, freight, or duty are added. Although the f.o.b. foreign port price and the free alongside ship (f.a.s.) price bases are preferred by the BLS, it uses other price bases such as cost, insurance, freight (c.i.f.) for imports as long as the firms can provide consistent price series. However, both the f.o.b. foreign port price series and the c.i.f. USA port price series exclude duty as well as costs associated with domestic intermediaries (for example, wholesalers and retailers). All these factors may affect the final selling price. For purposes of deflating imports, however, the duties are excluded from the prices before the indexes are calculated. Then, the definition on the import prices at the producer level in the model coincides with the BLS definition on the import prices.

The economy is represented by three types of agents in each country: households, firms, and a government. The households in each country own the firms in their respective country. The firms producing tradable goods are monopolistic suppliers of only one variety of goods. For simplicity, I assume that firms producing nontradable goods produce a homogeneous good and face perfect competition. The government transfers its revenues to the households in a lump-sum fashion.

3.1. Households

Both high-differentiation and low-differentiation goods sectors are represented by a continuum of individual differentiated goods, indexed by $h \in [0, 1]$ and $a \in [0, 1]$, where h represents a good in the high-differentiation goods sector and a represents a good in the low-differentiation goods sector. In addition, each country produces a nontradable good, denoted by n. Country 1 is populated by a continuum of households indexed by $i \in [0, 1]$. Similarly, country 2 is populated by differentiated households indexed by $j \in [0, 1]$.

The household i in country 1 consumes differentiated tradable goods. Let $C_{1,A,t}(i)$ and $C_{1,H,t}(i)$, respectively, represent the consumption of low-differentiation and high-differentiation tradable goods in country 1 by the household i in period t. These consumption indexes depend on the consumption of the low-differentiation good a, $c_{1,t}(a, i)$, and the consumption of the high-differentiation good h, $c_{1,t}(h, i)$, in the following manner:

$$C_{1,A,t}(i) = \left(\int_0^1 c_{1,t}(a,i)^{\frac{\psi-1}{\psi}} da\right)^{\frac{\psi}{\psi-1}},$$

$$C_{1,H,t}(i) = \left(\int_0^1 c_{1,t}(h,i)^{\frac{\theta-1}{\theta}} dh\right)^{\frac{\theta}{\theta-1}}.$$

The full-consumption basket of household i is

$$C_{1,t}(i) = C_{1,H,t}^{\alpha}(i) C_{1,A,t}^{1-\alpha}(i).$$

The prices in country 1 of goods a and h are denoted by $p_{1,t}(a)$ and $p_{1,t}(h)$, respectively. The price indexes for the previous consumption indexes are given by

$$P_{1,A,t} = \left(\int_0^1 p_{1,t}(a)^{1-\psi} da\right)^{\frac{1}{1-\psi}},$$

$$P_{1,H,t} = \left(\int_0^1 p_{1,t}(h)^{1-\theta} dh\right)^{\frac{1}{1-\theta}},$$

$$P_{1,t} = \frac{{P_{1,H,t}}^{\alpha} {P_{1,A,t}}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}.$$

Taking into account the previous notation, the representative household i in country 1 maximizes the utility function

$$U_{1,t}(i) = Eo\sum_{t=0}^{\infty}\beta^t \left[\log C_{1,t}(i) + x \log\left(\frac{M_{1,t}(i)}{P_{1,t}}\right) - kl_{1,t}(i)\right], \quad (1)$$

which depends positively on the consumption basket $C_{1,t}(i)$ and the real balances $\frac{M_{1,t}(i)}{P_{1,t}}$, and negatively on the labor $l_{1,t}(i)$. The parameter $\beta \in (0, 1)$ is the discount factor.

Household i in country 1 faces the following budget constraint:

$$M_{1,t}(i) + B_{1,t+1}^1(i) + \mathcal{E}_t B_{1,t+1}^2(i) + P_{1,t}(i) C_{1,t}(i) \leq$$

$$M_{1,t-1}(i) + w_{1,t}(i) l_{1,t}(i) + T_{1,t}(i) + (1 + r_{1,t}) B_{1,t}^1(i) + (1 + r_{2,t}) \mathcal{E}_t B_{1,t}^2(i) + \int_0^1 \pi_{1,t}(h,i) dh + \int_0^1 \pi_{1,t}(a,i) da, \quad (2)$$

where $w_{1,t}(i)$ is the wage associated with the time dedicated to the work by household i, $T_{1,t}(i)$ denotes the transfers made by the government, and $\int \pi_{1,t}(h, i)dh$ and $\int \pi_{1,t}(a, i)da$ are the dividends from the equities of all domestic firms h and a, respectively, in the economy. The domestic currency is represented by $M_{1,t}(i)$. The nominal exchange rate ε_t, defined as the home-currency price of the foreign currency, is used to denominate the prices in the foreign currency. Let $B^1_{1,t}(i)$ and $B^2_{1,t}(i)$ denote the two international bonds denominated in the domestic currency and the foreign currency, respectively, owned by household i. The interest rates paid by these bonds are given by $r_{1,t}$ and $r_{2,t}$. The total bonds owned by household i in country 1 are then given by $B^1_{1,t}(i)+B^2_{1,t}(i) = B_{1,t}(i)$. The same notation applies for the representative agent in country 2.

Define the total income of the household in country 1 at time t as

$$\begin{aligned} I_{1,t}(i) &= M_{1,t-1}(i) - M_{1,t}(i) + w_{1,t}(i)l_{1,t}(i) + T_{1,t}(i) - B^1_{1,t+1}(i) - \mathcal{E}_t B^2_{1,t+1}(i) \\ &\quad + (1+r_{1,t})B^1_{1,t}(i) + (1+r_{2,t})\mathcal{E}_t B^2_{1,t}(i) + \int_0^1 \pi_{1,t}(h,i)dh + \int_0^1 \pi_{1,t}(a,i)da. \end{aligned}$$

A similar condition applies for the households in country 2. Given the utility function (1), the demands for products a and h in household i are given as

$$c_{1,t}(h,i) = \left(\frac{\alpha I_{1,t}(i)}{p_{1,t}(h)}\right)^{\theta} \frac{1}{C^{\theta-1}_{1,H,t}},\ c_{1,t}(a,i) = \left(\frac{(1-\alpha)I_{1,t}(i)}{p_{1,t}(a)}\right)^{\psi} \frac{1}{C^{\psi-1}_{1,A,t}}. \tag{3}$$

As such, ψ and θ represent the elasticities of demand with respect to price. It is assumed that $\psi > \theta > 1$ since low-differentiation goods are by definition more homogeneous than high-differentiation goods, and therefore face higher elasticity levels. In this type of models, ψ and θ also represent the market power of the firms. The closer ψ comes to ∞, the more competitive the sector is.

For household i, the first-order conditions with respect to the bonds demand imply that

$$\frac{1}{C_{1,t}(i)} = \beta E_t \left(\frac{1+r_{1,t+1}}{P_{1,t+1}C_{1,t+1}(i)}\right) P_{1,t}, \tag{4}$$

$$\frac{\mathcal{E}_t}{C_{1,t}(i)} = \beta E_t \left(\frac{\mathcal{E}_t(1+r_{2,t+1})}{P_{1,t+1}C_{1,t+1}(i)}\right) P_{1,t}. \tag{5}$$

The first-order condition with respect to the money demand is given by

$$M_{1,t}(i) = x\frac{(1+r_{1,t+1})}{r_{1,t+1}} P_{1,t}C_{1,t}(i). \tag{6}$$

Similarly, for household j in country 2, the first-order conditions are given by

$$\frac{1}{C_{2,t}(j)} = \beta E_t \left(\frac{1+r_{2,t+1}}{P_{2,t+1}C_{2,t+1}(j)}\right) P_{2,t}, \tag{7}$$

$$\frac{1}{C_{2,t}(j)} = \beta E_t \left(\frac{1+r_{1,t+1}}{P_{2,t+1}C_{2,t+1}(j)\mathcal{E}_{t+1}}\right) P_{2,t}\mathcal{E}_t, \tag{8}$$

$$M_{2,t}(j) = x\frac{(1+r_{2,t+1})}{r_{2,t+1}} P_{2,t}C_{2,t}(j). \tag{9}$$

3.2. Firms

It is worth remembering that this economy has four different sectors: one producing high-differentiation products, one producing low-differentiation products, one nontradable goods sector, and one distribution sector. While the firms in the distribution sector buy tradable goods and use the nontradable goods as an input, the firms in the tradable and nontradable sectors produce using only labor. Let $y^u_t(h)$, $y^u_t(a)$, and $y^u_t(n)$ denote the total outputs of the goods h, a, and n, respectively, produced by country u = 1, 2. The total output can be separated by its country of consumption. For example, $y^u_{1,t}(h)$ and $y^u_{2,t}(h)$ represent the production of good h in country u that is sold in country 1 and in country 2, respectively. Then, $y^u_t(h) = y^u_{1,t}(h)+y^u_{2,t}(h)$. This notation will be useful when solving the firms' problems. A similar notation applies for the low-differentiation sector. The demands for the labor inputs of type i by a firm producing goods

h, a, and n are given by $l_{u,t}(h, i)$, $l_{u,t}(a, i)$, and $l_{u,t}(n, i)$, respectively. The production functions of the firms in each sector are given by

$$y_t^u(h) = y_{1,t}^u(h) + y_{2,t}^u(h) = \frac{1}{b_u(h)} \left(\int_0^1 l_{u,t}^{\frac{\varphi-1}{\varphi}}(h,i)di \right)^{\frac{\varphi}{\varphi-1}}, \; u = 1,2, \tag{10}$$

where

$$b_1(h) = \gamma + \lambda h,$$

$$b_2(h) = \gamma + \lambda(1-h);$$

$$y_t^u(a) = y_{1,t}^u(a) + y_{2,t}^u(a) = \frac{1}{b_u(a)} \left(\int_0^1 l_{u,t}^{\frac{\varphi-1}{\varphi}}(a,i)di \right)^{\frac{\varphi}{\varphi-1}}, \; u = 1,2, \tag{11}$$

where

$$b_1(a) = \gamma + \lambda a,$$

$$b_2(a) = \gamma + \lambda(1-a),$$

$$y_t^u(n) = \left(\int_0^1 l_{u,t}^{\frac{\varphi-1}{\varphi}}(n,i)di \right)^{\frac{\varphi}{\varphi-1}}. \tag{12}$$

Note that φ represents the elasticity of substitution among the labor inputs, and $\frac{1}{b_u(q)}$, $q = h, a$; u =1, 2, denote the productivity parameters that are variety specific. These allow each country to be more efficient in producing some varieties of the goods than the other country. This occurs because the productivity $b_u(q)$, $q = h, a$; $u = 1, 2$, depends on the good q and moves in the opposite directions in each country depending on the variety. Thus, these productivity parameters also imply that the varieties have been lined in the interval [0,1] depending on the differences in their productivities across countries. The varieties with productivities such that their production costs are lower in country 1 than in country 2 are located on the left side of the interval [0,1], whereas the varieties with productivities such that their production costs are lower in country 2 than in country 1 are located on the right side of the interval. The previous production functions for the tradable sectors are referred to as the Ricardian production functions.

This mechanism offers a comparative advantage different from the classical Ricardian model by Dornbusch et al. (1977). While in the mechanism of this model, producing a good requires the same amount of labor across countries but there are differences in the productivity of each country due to variety-specific differences in technology, in the classical mechanism, the amount of labor required to produce one unit of the good is different across countries. Nevertheless, both mechanisms result in lower unit costs for certain varieties in each country.

3.2.1. Wage rigidity

Before explaining the firm's problem by sector, I analyze the wage setting. Nominal rigidities are allowed by assuming that wages in period t are predetermined using the contracts signed at time $t-1$. When setting the wage $w(i)$, each domestic worker acts as a monopolistic supplier of his/her productive input. That is, the worker takes into account the firm's demand in the utility maximization problem.

The demand for labor i by domestic firm h in country 1 is obtained by minimizing the expenditure on labor in firm h as follows

$$l_{1,t}(h,i) = \left(\frac{w_{1,t}(i)}{W_{1,t}}\right)^{-\varphi} l_{1,H,t},$$

where $W_{1,t} = \left(\int_0^1 w_{1,t}^{1-\varphi}(i)di\right)^{\frac{1}{1-\varphi}}$ is the country 1 wage index and $l_{1,H,t} = \left(\int_0^1 l_{1,t}^{\frac{\varphi-1}{\varphi}}(h,i)di\right)^{\frac{\varphi}{\varphi-1}}$ is the total labor demand by firm h. Since φ is the same across sectors, the total demand for labor i is given by

$$l_{1,t}(i) = \left(\frac{w_{1,t}(i)}{W_{1,t}}\right)^{-\varphi} \left(\int_0^1 l_{1,H,t}dh + \int_0^1 l_{1,A,t}da + l_{1,N,t}\right), \qquad (13)$$

where $l_{1,A,t} = \left(\int_0^1 l_{1,t}^{\frac{\varphi-1}{\varphi}}(a,i)di\right)^{\frac{\varphi}{\varphi-1}}$ and $l_{1,N,t} = \left(\int_0^1 l_{1,t}^{\frac{\varphi-1}{\varphi}}(n,i)di\right)^{\frac{\varphi}{\varphi-1}}$ are the total labor demands by firms a and n, respectively.

The workers are assumed to be monopolistic suppliers of a particular type of labor. Thus, they take into account the above labor demand in their utility maximization problem. The first-order condition for the optimal wage contract then becomes

$$w_{1,t}(i) = \frac{\varphi}{\varphi - 1} E_{t-1}\left\{kP_{1,t}C_{1,t}(i)\right\}. \qquad (14)$$

The expected value at period $t-1$ in the right-hand side of the above equation indicates that the wage contracts are set one period in advance.

Once the nominal wages are set, the workers are willing to meet any unanticipated changes in the firm's labor demand, given that the real wages do not fall below the marginal rate of substitution between leisure and consumption:

$$\frac{w_{1,t}(i)}{P_{1,t}C_{1,t}(i)} \geq k. \qquad (15)$$

Therefore, the workers set nominal wages one period in advance, and supply the amount of labor that firms demand at the posted wage ex-post such that (15) is satisfied.[6]

3.2.2 Distribution sector

The distribution firm buys foreign tradable products, pays import taxes, and distributes them to the consumers using the nontradable good. For simplicity, I assume that these firms face perfect competition. As in Erceg and Levin (1995), Burstein, Neves and Rebelo (2003), and Corsetti and Dedola (2005), I assume that making available one unit of a traded good to the consumers requires δ units of a nontradable good.

Due to the distribution costs and the import taxes, there is a wedge between the producer import price and the consumer import price of the traded goods. Define $\widetilde{p}(h)$ and $\widetilde{p}(a)$ as the producer prices of goods h and a, respectively. Further, there is an extra cost for the foreign products sold in the home market, and vice versa, specifically, an ad-valorem tariff.

The origin and the destination of the products are important for the firms for two reasons. (i) In the presence of local distribution services in the foreign market, the tradable firms find it optimal to discriminate their prices across the markets. (ii) The distribution firm only sells the foreign goods by construction. Taking into account the origin of the product and the previous notation, equation (3) can be written as $c_{1,t}^u(h,i) = \left(\frac{\alpha I_{1,t}(i)}{p_{1,t}^u(h)}\right)^{\theta} \frac{1}{C_{1,t,H}^{\theta-1}},\ u = 1,2.$ This equation gives the demand in household i for good h that is produced in country u. Let $p^u{}_1(h)$ be the price in country 1 of a

[6] The parameter k indicates the magnitude of the disutility of labor and it is chosen to obtain labor magnitudes that correspond to the data. The calibration process of labor and the remaining variables allows reasonable relative magnitudes among the variables. Therefore, the assumption in equation (15) should hold by construction as long as the shock remains in a reasonable interval, as is the case in this model.

good h produced in country u. Define $\tau_{u,a}$ and $\tau_{u,h}$ as the ad-valorem tariffs faced by country u when importing low-differentiation products and high-differentiation products, respectively. The script i can be omitted since having a continuum of households $i \in [0, 1]$ populating the country implies that the consumption of the representative household i, denoted by $c_{1,t}(i)$, is also the aggregate consumption in the country, which is denoted by $c_{1,t}$. I derive the optimal prices from the point of view of a firm in country 1. The market-clearing condition $c^{u}_{1,t}(h) = y^{u}_{1,t}(h)$ is satisfied. A firm in country 1 distributing the foreign good h in its own market solves the following profit-maximization problem

$$\underset{y_1^2(h)}{Max}\; p^2_{1,t}(h)y^2_{1,t}(h) - \widetilde{p^2_{1,t}}(h)(1+\tau_{1,h})y^2_{1,t}(h) - \delta p_{1,n,t}\; y^2_{1,t}(h). \qquad (16)$$

Due to the perfect competition that these firms face, it is easy to see that the firms´ optimal prices are equal to their marginal costs. Thus, following the same strategy in the low-differentiation sector, the consumer import prices in country 1 can be written as

$$p^2_{1,t}(h) = \widetilde{p^2_{1,t}}(h)(1+\tau_{1,h}) + \delta p_{1,n,t}, \qquad (17)$$

$$p^2_{1,t}(a) = \widetilde{p^2_{1,t}}(a)(1+\tau_{1,a}) + \delta p_{1,n,t}. \qquad (18)$$

The consumers can buy goods h and a that are produced either in country 1 or in country 2. Then, the distribution sector in country 1 will import the foreign goods that are priced lower than the domestic goods, that is, when

$$p^2_{1,t}(q) < p^1_{1,t}(q),\;\; q = h, a.$$

Note that when the domestic firms in the tradable sectors sell their products in their own markets, they sell the products directly to the consumers. That is, no distribution firm is involved in the selling process. Therefore, the consumer prices correspond to the producer prices:

$$p^1_{1,t}(h) = \widetilde{p^1_{1,t}}(h), \qquad (19)$$

$$p^1_{1,t}(a) = \widetilde{p^1_{1,t}}(a). \qquad (20)$$

Analogous expressions apply to country 2.

3.2.3 Tradable sectors

Given the demands $c^1_{1,t}(h)$ and $c^1_{2,t}(h)$, the representative firm in country 1 in the sector producing high-differentiation goods chooses $\widetilde{p^1_{1,t}}(h)$ and $\widetilde{p^1_{2,t}}(h)$ to maximize its profit. The firm is a monopolistic supplier of the good h and faces the whole demand for the good h; hence, $y^1_{1,t}(h) = c^1_{1,t}(h)$ and $y^1_{2,t}(h) = c^1_{2,t}(h)$. The problem therefore is

$$\underset{\widetilde{p^1_{1,t}}(h),\widetilde{p^2_{1,t}}(h)}{Max}\; \widetilde{p^1_{1,t}}(h)y^1_{1,t}(h) + \mathcal{E}_t\widetilde{p^1_{2,t}}(h)y^1_{2,t}(h) - W_{1,t}l_{1,H,t} \qquad (21)$$

subject to

$$c^1_{1,t}(h) = \left(\frac{\alpha I_{1,t}}{\widetilde{p^1_{1,t}}(h)}\right)^{\theta}\frac{1}{C^{\theta-1}_{1,H,t}} \quad , c^1_{2,t}(h) = \left(\frac{\alpha I_{2,t}}{\widetilde{p^1_{2,t}}(h)(1+\tau_{2,h})+\delta p_{2,n,t}}\right)^{\theta}\frac{1}{C^{\theta-1}_{2,H,t}},$$

$$y^1_t(h) = \frac{l_{1,H,t}}{b_1(h)} = y^1_{1,t}(h) + y^2_{1,t}(h).$$

This problem is based on the assumption that the tradable firm knows the foreign demand but does not know the prices chosen by the foreign competitors. The intuition underlying this assumption is that the tradable firms do not know the decisions made by the competitors since they are in a different country. However, the firm knows the demand through an intermediary, the foreign distribution firm.

Using (17) and (19), I can write the optimal producer prices of the high-differentiation tradable good $\widetilde{p^1_{1,t}}(h)$ and $\widetilde{p^1_{2,t}}(h)$ as

$$\widetilde{p^1_{1,t}}(h) = \frac{\theta}{\theta - 1} W_{1,t} b_1(h), \tag{22}$$

$$\widetilde{p^1_{2,t}}(h) = \frac{\theta}{\theta - 1}\left[\frac{1}{\mathcal{E}_t} + \frac{1}{(1+\tau_{2,h})}\frac{\delta}{\theta}\frac{p_{2,n,t}}{W_{1,t}b_1(h)}\right] W_{1,t} b_1(h). \tag{23}$$

Similarly, the optimal producer prices of the low-differentiation tradable good $\widetilde{p^1_{1,t}}(a)$ and $\widetilde{p^2_{1,t}}(a)$ are given as

$$\widetilde{p^1_{1,t}}(a) = \frac{\psi}{\psi - 1} W_{1,t} b_1(a), \tag{24}$$

$$\widetilde{p^1_{2,t}}(a) = \frac{\psi}{\psi - 1}\left[\frac{1}{\mathcal{E}_t} + \frac{1}{(1+\tau_{2,a})}\frac{\delta}{\psi}\frac{p_{2,n,t}}{W_{1,t}b_1(a)}\right] W_{1,t} b_1(a). \tag{25}$$

The need for local nontraded goods in the foreign market implies that the elasticities of the demands for the traded goods h and a at the wholesale level will be different across countries. The firms then charge different prices in the home market and in the foreign market as shown above. The empirical evidence and the theoretical papers also support this price determination (see Devereux and Engel, 2003 and Choudhri, Faruquee and Hakura, 2005).

3.2.4 Nontradable sector

A competitive domestic firm in country 1 producing nontradable goods solves the problem

Max $p_{1,t}(n)y_{1,t}(n) - W_{1,t}l_{1,N,t}$ subject to $y_{1,t}(n) = l_{1,N,t}$. (26)

Since the firms in this sector face perfect competition, their optimal price is given by

$p_{1,t}(n) = p_{1,n,t} = W_{1,t}$ (27)

A similar price is chosen by the nontradable firms in country 2.

3.3 Government

It is assumed that the government runs a balanced budget in each period, and that it does that by transferring resources directly to the consumers. The revenues from the import tariffs transferred to the households in country 1 and in country 2 are given by

$$RT_{1,t} = \int_{a_{1,t}}^{1} \tau_{1,a}\widetilde{p}_{1,t}(a)c_{1,t}(a)da + \int_{h_{1,t}}^{1} \tau_{1,h}\widetilde{p}_{1,t}(h)c_{1,t}(h)dh,$$

$$RT_{2,t} = \int_{0}^{a_{2,t}} \tau_{2,a}\widetilde{p}_{2,t}(a)c_{2,t}(a)da + \int_{0}^{h_{2,t}} \tau_{2,h}\widetilde{p}_{2,t}(h)c_{2,t}(h)dh.$$

The revenues are calculated over the set of goods where there is trade between the two countries. The limits of the integrals represent the area where this occurs. This is described in the following section.

The government controls the money supply. Both the revenues from the import tariffs and the seigniorage revenues are rebated to the public in the form of lump-sum transfers. No government spending is assumed. The transfers made by the government in country 1 and in country 2 to their representative households i and j, respectively, are given as follows

$$T_{1,t}(i) = M_{1,t} - M_{1,t-1} + RT_{1,t}, \tag{28}$$

$$T_{2,t}(j) = M_{2,t} - M_{2,t-1} + RT_{2,t}. \tag{29}$$

I assume that

$$E(M_{1,t+1}) = M_t.$$

An analogous expression holds for the expected money supply in country 2. This expectational assumption on money supply states that in the present period t, the household expects that monetary policy will not change in the next period. In other words, an increase in the money supply is a non-expected increase. This assumption allows us to have ERPT in the response to a change in money supply as the prices and the exchange rate adjust to the new monetary conditions, but not the wages because they have rigidity and have been determined taking into account the money supply in the previous period. In the case where one enjoys perfect foresight over the monetary policy, the wages in the next period would be determined given the future monetary conditions and therefore wages would adjust along with other variables such as prices. Since the pass-through arises due to the wage rigidity, this adjustment in wages would eliminate the ERPT as wages adjust in the direction opposite to that of the prices. Uncertainty about the future monetary conditions seems a realistic assumption.

3.4 Equilibrium

Dropping the scripts i and j, the variables can be interpreted in per-capita or aggregate terms. Given the initial holdings of bonds ($B_{1,0}$ and $B_{2,0}$) and money ($M_{1,0}$ and $M_{2,0}$), the equilibrium for this economy is a collection of the allocations for country 1 ($c_{1,t}(a)$, $c_{1,t}(h)$, $c_{1,t}(n)$, $l_{1,t}$, $l_{1,H,t}$, $l_{1,A,t}$, $l_{1,N,t}$, $y^1_t(a)$, $y^1_t(h)$, and $y^1_t(n)$), the allocations for country 2 ($c_{2,t}(a)$, $c_{2,t}(h)$, $c_{2,t}(n)$, $l_{2,t}$, $l_{2,H,t}$, $l_{2,A,t}$, $l_{2,N,t}$, $y^2_t(a)$, $y^2_t(h)$, and $y^2_t(n)$), the prices in country 1 ($\widetilde{p^1_{1,t}}(h)$, $\widetilde{p^2_{1,t}}(h)$, $\widetilde{p^1_{1,t}}(a)$, $\widetilde{p^2_{1,t}}(a)$, and $p_{1,n,t}$), the prices in country 2 ($\widetilde{p^1_{2,t}}(h)$, $\widetilde{p^2_{2,t}}(h)$, $\widetilde{p^1_{2,t}}(a)$, $\widetilde{p^2_{2,t}}(a)$, and $p_{2,n,t}$) for $a \in [0, 1]$, $h \in [0, 1]$, $t = 0, 1, ...$, nominal exchange rate ε_t, allocations for wages $W_{1,t}$ and $W_{2,t}$, tariff revenues $T_{1,t}$ and $T_{2,t}$, money $M_{1,t}$ and $M_{2,t}$, and bonds $B^1_{1,t}$, $B^2_{1,t}$, $B^1_{2,t}$, and $B^2_{2,t}$ for all t, the equilibrium is such that (i) taking as given the prices, the consumers' problem (1) subject to (2) is satisfed; (ii) taking as given the demands, the domestic firms engaged in the distribution of high-differentiation tradables, low-differentiation tradables, and nontradables solve problems (16), (21), and (26), respectively, and the foreign firms solve analogous problems; (iii) the prices are given by

$$p_{1,t}(h) = Min[\widetilde{p^1_{1,t}}(h), \quad \widetilde{p^2_{1,t}}(h)(1+\tau_{1,h}) + \delta p_{1,n,t}],$$

$$p_{2,t}(h) = Min[\widetilde{p^1_{2,t}}(h)(1+\tau_{2,h}) + \delta p_{2,n,t}, \quad \widetilde{p^2_{2,t}}(h)],$$

$$p_{1,t}(a) = Min[\widetilde{p^1_{1,t}}(a), \quad \widetilde{p^2_{1,t}}(a)(1+\tau_{1,a}) + \delta p_{1,n,t}],$$

$$p_{2,t}(a) = Min[\widetilde{p^1_{2,t}}(a)(1+\tau_{2,a}) + \delta p_{2,n,t}, \quad \widetilde{p^2_{2,t}}(a)];$$

(iv) the following market-clearing conditions hold

$$\int_0^1 l_{1,H,t}dh + \int_0^1 l_{1,A,t}da + l_{1,N,t} = l_{1,t},$$

$$\int_0^1 l_{2,H,t}dh + \int_0^1 l_{2,A,t}da + l_{2,N,t} = l_{2,t},$$

$$\begin{aligned} y_t^1(h) + y_t^2(h) &= c_{1,t}(h) + c_{2,t}(h), \\ y_t^1(a) + y_t^2(a) &= c_{1,t}(a) + c_{2,t}(a), \\ y_{1,t}(n) &= c_{1,t}(n), \\ y_{2,t}(n) &= c_{2,t}(n); \end{aligned}$$

(v) the transfers (28) and (29) are satisfied; and (vi) the bonds are in zero net supply $B^1_{1,t} + B^1_{2,t} = 0$, $B^2_{1,t} + B^2_{2,t} = 0$

Substituting the bond price from (4) in (8) yields the following equation:

$$E_t\left(\frac{P_{1,t+1}C_{1,t+1}}{P_{2,t+1}C_{2,t+1}\mathcal{E}_{t+1}}\right) = \frac{P_{1,t}C_{1,t}}{P_{2,t}C_{2,t}\mathcal{E}_t}.$$

Iterating, as in Chari, Kehoe and McGrattan (2002), the previous condition can be rewritten as

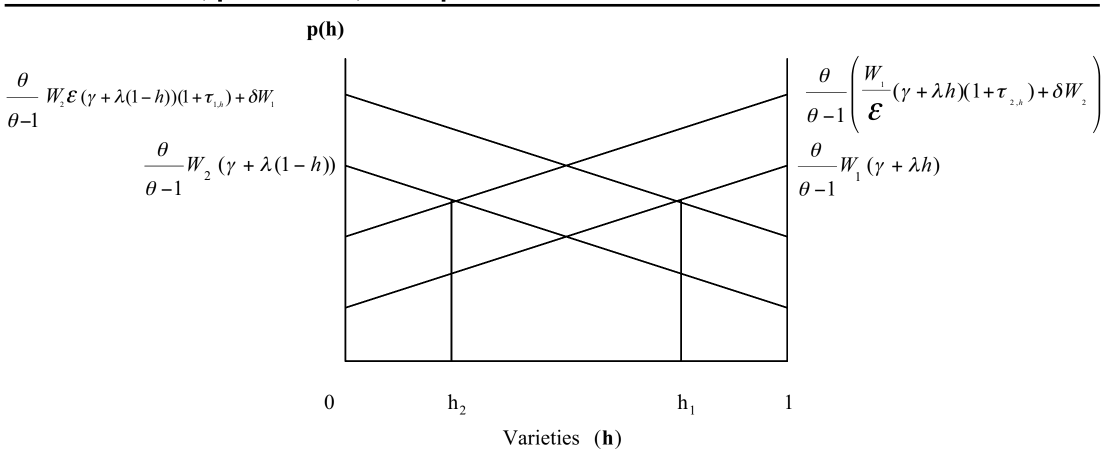
$$E_t\left(\frac{P_{1,t}C_{1,t}}{P_{2,t}C_{2,t}\mathcal{E}_t}\right) = \frac{P_{1,0}C_{1,0}}{P_{2,0}C_{2,0}\mathcal{E}_0}.$$

The right-hand side of the previous equation depends on the initial wealth distribution. Let $v = \frac{P_{1,0}C_{1,0}}{P_{2,0}C_{2,0}\mathcal{E}_0} > 0$. Since symmetrical initial conditions are assumed, $v = 1$. This implies that

$$\mathcal{E}_t = \frac{P_{1,t}C_{1,t}}{P_{2,t}C_{2,t}}.$$

There are two possible non-stochastic steady states, one when there is no trade and the other when there is trade across countries. First, there is no trade in equilibrium when $W_1(\gamma+\lambda) < W_2\mathcal{E}(1+\tau_{1,h})\gamma+\delta W_1$ and $W_2(\gamma+\lambda) < \frac{W_1}{\mathcal{E}}(1+\tau_{2,h})\gamma+W_2$. Second, if $W_1(\gamma+\lambda) > W_2\mathcal{E}(1+\tau_{1,h})\gamma+W_1$ and $W_2(\gamma+\lambda) > \frac{W_1}{\mathcal{E}}(1+\tau_{2,h})\gamma+\delta W_2$, then the pattern of trade, production, and specialization in equilibrium looks as follows.

Graphic 5
Pattern of trade, production, and specialization



Country 1 produces in the interval [1, h_1] and exports the goods in the interval [0, h_2]. Country 2 produces in the interval [h_2, 1] and exports the goods in the interval [h_1, 1]. Therefore, country 1 imports the goods in the interval [h_1, 1] and country 2 imports the goods in the interval [0, h_2]. The goods in the interval [h_2, h_1] are not traded.

$$h_1 = \frac{W_2\mathcal{E}(1+\tau_{1,h})(\gamma+\lambda)+\delta W_1-\gamma W_1}{W_1\lambda+W_2\mathcal{E}(1+\tau_{1,h})\lambda}. \tag{30}$$

$$h_2 = \frac{W_2\mathcal{E}(\gamma+\lambda)-\delta\mathcal{E}W_2-\gamma W_1(1+\tau_{2,h})}{W_1\lambda(1+\tau_{2,h})+W_2\mathcal{E}\lambda}. \tag{31}$$

The prices and production patterns by the variety are included in appendix 2.

In the steady state, the monetary stances are given by $\frac{W_1}{W_2}$ = 1, and since we have symmetry, by $\frac{W_1}{W_2}$ =1. Further, the steady state bonds holdings are assumed to be zero, B_1, B_2 = 0. The equations summarizing the solution of the model in the steady state are included in appendix 3.

3.5 ERPT by good

3.5.1 ERPT at the producer level

Logistics costs, tariffs, and the market structure of each sector have important implications for the ERPT level at the producer level. By definition, the ERPT for the high-differentiation goods is given by

$$\frac{\frac{\partial \widetilde{p^1_{2,t}(h)}}{\widetilde{p^1_{2,t}(h)}}}{\frac{\partial \mathcal{E}_t}{\mathcal{E}_t}} = \frac{1}{1+\frac{\mathcal{E}_t}{(1+\tau_{2,h})}\frac{\delta}{\theta}\frac{W_{2,t}}{W_{1,t}}\frac{1}{b_1(h)}}. \tag{32}$$

The ERPT for the low-differentiation goods is given by

$$\frac{\frac{\partial \widetilde{p^1_{2,t}(a)}}{\widetilde{p^1_{2,t}(a)}}}{\frac{\partial \mathcal{E}_t}{\mathcal{E}_t}} = \frac{1}{1+\frac{\mathcal{E}_t}{(1+\tau_{2,a})}\frac{\delta}{\psi}\frac{W_{2,t}}{W_{1,t}}\frac{1}{b_1(a)}}. \tag{33}$$

Note that the pass-through arises due to the wage rigidities; if there were no wage rigidities, the pass-through would be zero since the wages would make adjustments in the direction to opposite to that of the prices. Eliminating the nontradable sector, δ= 0, would cause complete the pass-through since the firm would be pricing the good for export in the domestic currency, but incorporating the taxes. This is because all the costs would be domestic.

To gain a more intuitive understanding about the previous expressions, consider the producer price elasticity of the export demand of good h

$$\frac{\frac{\partial c^1_{2,t}(h)}{c^1_{2,t}(h)}}{\frac{\partial \widetilde{p^1_{2,t}(h)}}{\widetilde{p^1_{2,t}(h)}}} = \theta\frac{\widetilde{p^1_{2,t}}(h)(1+\tau_{2,h})}{\widetilde{p^1_{2,t}}(h)(1+\tau_{2,h})+\delta p_{2,n,t}} = \frac{\theta(1+\tau_{2,h})W_{1,t}b_1(h)+\mathcal{E}_t\delta W_{2,t}}{(1+\tau_{2,h})W_{1,t}b_1(h)+\mathcal{E}_t\delta W_{2,t}}.$$

The producer price elasticity measures the effect of a decision of a foreign firm in terms of its export prices on the final demand. It is worth stressing that the parameters that are positively related to high price elasticity such as θ, $\tau_{2,h}$ and $b_1(h)$ are also positively related to high ERPT. The intuition behind this is that the firm moves the price in response to an exchange rate movement to maintain its profits to the extent that the demand responds to its price decisions. In other words, the higher the sensitivity of the consumption to the changes in the producer prices, the higher the incentive of the firm to move the prices in response to the exchange rate fluctuations in order to balance its profits.

Equations (32) and (33) indicate that the low-differentiation products face higher levels of pass-through than the high-differentiation products. This occurs because of the following two reasons:

a) Homogeneity of the good: Since $\psi > \theta > 1$, the low-differentiation goods have higher levels of pass-through than the high-differentiation goods. To gain an intuitive understanding of this result, one can compare a firm with perfect competition, that is, $\psi \rightarrow \infty$ (homogeneous good), with a firm with market power. In the case of perfect competition, the ERPT would be complete since the firms have no other choice than to move the price due to the movements in the exchange rate; otherwise, they would face losses and be out of the market. In contrast, a firm with market power sets the price of its product as high as possible given the consumers´ preference for the firm's product. This implies that the producer firm has already set the highest possible price to maximize profits (higher than the marginal cost and taking into account the consumers' preference and income). Therefore it is not profitable to move the price by the same degree as the exchange rate, particularly when the producer firm does not have total control over the final price of the good since there is a local cost associated with its distribution to the final consumer. The fact that the final price is given by both production and distribution costs reduces the capacity of the foreign producer firm to balance its profits after an exchange rate movement by making changes to the prices as it does not fully control the final price, leading to incomplete pass-through. There is empirical evidence regarding industrial organization that supports these results. For example, Campa and Goldberg (2005) say that "Overall, we again find that partial pass-through is a common phenomenon particularly among heterogeneous products. More homogenous products have more extreme pass-through values." Microeconomic studies also show that firms with higher market power move the prices less due to the movements in the exchange rate. Examples are De Stefano (2004) on the Italian car market and Kardasz and Stollery (2005) on the Canadian manufacturing industry.

In addition, the recent study of Bugamelli and Tedeschi (2008) finds that the ERPT is lower in oligopolistic industries than in competitive ones and (as the model in this paper suggests) that the reason for this is the pricing-to-market behavior of firms with pricing power.

b) Tariffs: The varieties in the sector with higher tariffs present higher levels of pass-through at the producer level and at the consumer level (as will be shown later). This result is supported by recent empirical evidence. Mallick and Marques (2008) show that import prices react more to exchange rate changes in sectors with higher effective protection rates. The reasons behind this result are not explored in this study, but the authors suggest that import restrictions or high tariffs might reduce the capacity of foreign firms to maintain market share by adjusting their profit margins in response to a change in the exchange rate. The model developed in this paper provides an alternative explanation for the relation between tariffs and pass-through at the sector level. The sector with higher tariffs has a higher producer price elasticity of the export demand, implying that a foreign firm in a sector with high tariffs has more space to compensate the change in its profits resulting from an exchange rate movement by changing its price as the demand is more producer price sensitive. Empirical evidence shows that agricultural goods and raw materials, the goods with higher levels of pass-through, face higher tariffs than manufacturing goods. For example, according to the CPII, in the European Union (EU)-15, the equivalent average tariff in 2001 in the agricultural sector and in the manufacturing sector is 15.0% and 1.8%, respectively. The calculations from the IMF-World Bank (2001) give an average tariff of 19.5% and 4.1%, respectively. In general, the difference in the pass-through levels between these two sectors comes from the differences in the monopoly power and tariffs.

3.5.2 ERPT at the consumer level

The decision to move the price is only the decision of the firms producing tradables goods, as the competitive distribution firm only buys the foreign tradable product at the given price in its own currency, pays its import taxes, and distributes it to the consumers using the nontradable good. This means that the level of ERPT at the consumer level is a share of the ERPT at the producer level since the price at the consumer level contains the price at the producer level.

The difference between the pass-through at the producer level and at the consumer level is represented by the market structure of each sector. By definition, the ERPT for the high-differentiation goods sector at the consumer level is given by

$$\frac{\frac{\partial p^1_{2,t}(h)}{p^1_{2,t}(h)}}{\frac{\partial \mathcal{E}_t}{\mathcal{E}_t}} = \frac{1}{1 + \frac{\mathcal{E}_t \delta}{(1+\tau_{2,h})} \frac{W_{2,t}}{W_{1,t}} \frac{1}{b_1(h)}}. \tag{34}$$

By the same token, the ERPT for the low-differentiation goods sector is

$$\frac{\frac{\partial p^1_{2_t}(a)}{p^1_{2_t}(a)}}{\frac{\partial \mathcal{E}_t}{\mathcal{E}_t}} = \frac{1}{1 + \frac{\mathcal{E}_t \delta}{(1+\tau_{2,a})} \frac{W_{2,t}}{W_{1,t}} \frac{1}{b_1(a)}}. \tag{35}$$

Note that at the consumer level, the presence of tariffs yields that the low-differentiation products face higher levels of pass-through than high-differentiation products. Further, the goods produced with low technology (high $b_1(q)$, $q = h, a$) face higher pass-through levels.

The aggregate ERPT is obtained by calculating the pass-through from the aggregate price indexes. The aggregate pass-through will depend on the number of varieties imported by sector and the pass-through level of each variety. It is expected that an FTA will result in an increase in the number of varieties imported and a decrease in the pass-through level of each variety. Then, the relative increase in the imports of one sector with respect to the other together with the new pass-through level by sector modifies the aggregate pass-through level.

The analytical expression obtained by calculating the aggregate pass–through does not clearly illustrate the total effect. Thus, some numerical exercises are needed.

4 Calibration and Parametrization

The model has been calibrated to the USA economy for the year 1993, when the USA began signing FTAs with different countries. In order to classify the industries according to the product differentiation, I follow Oliveira, Scarpetta and Pilat (1996). These authors calculate the mark-ups for the period 1970-1992, and classify the industries into high-differentiation industries and low-differentiation industries. Most of the industries classified by Oliveira, et al. (1996) as low-differentiation industries are those producing commodities such as petroleum, leather, wood, steel, etc. The industries classified as high-differentiation industries include machinery and equipment, motor vehicles, medicines, etc. The USA mark-ups for each group are $\frac{\psi}{\psi-1}=1.12$ and $\frac{\theta}{\theta-1}=1.33$.

The low-differentiation goods' share in consumption $1-\alpha$ is chosen such that 40% of the consumption expenditure is devoted to low-differentiation goods. This is consistent with the share of the low-differentiation goods (commodities) in the USA CPI for the base year 1993. According to the World Trade Organization (WTO, 2004), in 2002, the average USA tariffs in the agricultural and nonagricultural sectors were 6.9% and 3.2%, respectively. The exercise involves reducing the average tariffs in both sectors from 20% (the average USA tariffs in 1980) to their current levels in 2002. These values do not seem to be unrealistic since institutions such as the World Bank and the Food and Agriculture Organization (FAO) argue that while average tariffs have generally been reduced following the Uruguay Round of trade negotiations, high duties continue to be placed on certain agricultural products in order to protect domestic producers.

The benchmark for the number of nontraded goods required to distribute a tradable good, δ, is chosen as follows. Burstein, Neves and Rebelo (2003) estimate that the distribution costs represent more than 50% of the retail price in all agricultural products. These margins range from 54% (eggs) to 82% (fresh fruits). The total distribution margin in the USA is estimated as 42%. Then, I set δ such that the share of the nontraded goods on the final price in both sectors ranges from 42% to 82%, depending on the variety, given $\delta = 1.403$. The parameter on the disutility of labor, k, is set equal to 1 to restrict the labor-output ratio to 2/3. The mark-up over the marginal cost of labor is chosen as $\frac{\varphi}{\varphi-1} = 1.15$. This mark-up is consistent with the estimates of the mark-up of union wages over nonunion wages estimated by Lewis (1986).

The productivity parameters γ and λ are obtained after some manipulations over equations (30) and (31). By doing this, I obtain two equations that depend only on wages, tariffs, and marginal costs, which can be calculated or approximated from the data. An explanation of this process is included in appendix 4. The parameters obtained are $\gamma = 0.076$ and $\lambda = 2.110$.[7]

[7] The restriction $\lambda > \gamma\tau_{1,a} + \delta$ must hold to ensure trade across the countries in both sectors.

5 Quantitative Exercise

In this section, I perform two simple exercises. The first one is the determination of how the ERPT by variety is affected by the tariffs elimination. In the second exercise, the effects of an FTA on the aggregate pass-through level are analyzed. Specifically, I compute the impact effects of nominal monetary shock (which is defined as a temporary 1% deviation from the steady-state value) on the pass-through by variety and by sector, on the aggregate pass-through, and on the intervals of the varieties traded in two different scenarios: one where there are high tariffs and another where the tariffs are low.

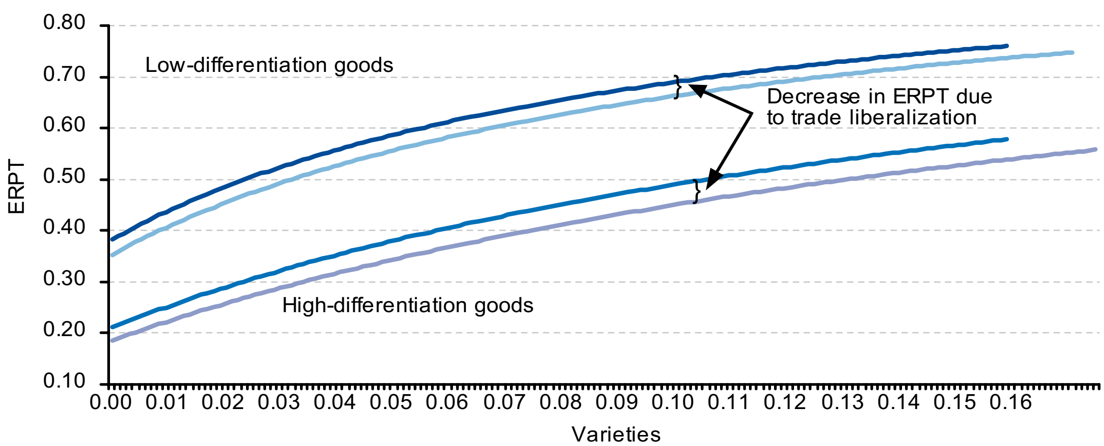
A 1% increase in M_1 from the steady-state causes a movement on the exchange rate from the steady state, and this, in turn, affects the import prices: ERPT.[8] Since wages take one period to adjust, a new steady state is reached after the shock. The one-period-in-advance wage setting is a shortcut that allows the incorporation of wage rigidity and an analytical solution for the model. This wage setting also has a disadvantage. It does not permit the analysis of some interesting dynamics such as the volatility in macroeconomic variables and the ERPT over time. In spite of this disadvantage, this wage setting seems adequate considering that the model focuses on price determination and trade.

To analyze how the different variables change due to a 1% deviation in the money supply from the steady state, I use the method of undetermined coefficients described in Uhlig (1997). Using this method, the deviations of the endogenous variables from the steady state can be rewritten as linear functions of the deviation of the money supply from the steady state.

Graphic 6 shows the results of the first exercise, that is, the ERPT by variety under the two scenarios: high and low tariffs. A decrease in the ERPT in each variety is observed as a consequence of the trade liberalization. High-differentiation goods exhibit a higher decrease in the ERPT by good than the low-differentiation goods because of the higher tariffs elimination in this sector. Further, note that in general, the varieties of the low-differentiation sector reach higher levels of pass-through than the varieties of the high-differentiation sector. This is due to the higher tariffs and the lower market power of the low-differentiation sector. As suggested by the equations (32) and (33), the varieties with the lowest technology in country 1 are those with the highest pass-through.

Graphic 6

Computational results (ERPT by good under different trade liberalization scenarios)



[8] The shocks to the velocity (x) and the disutility of labor (k) are not considered in the model because the exercise focuses on the ERPT in two isolated scenarios, high and low tariffs. For this purpose, it is preferred that a simple mechanism be used to yield the ERPT: an increase in the money supply. This simplification does not alter the general result since the shocks, in the case they were to be incorporated, would be present in both scenarios. However, these shocks could have some influence on the magnitudes of the ERPT since Corsetti and Dedola (2005) finds that these shocks seem to be relevant in modeling the ERTP.

Chart 6 contains the intervals of the varieties imported and the ERPT by sector, and the aggregate pass-through. The first column presents the results in the absence of an FTA while the second column presents the results under an FTA. The third column shows the percentage change in each variable between the two scenarios. The quantitative results support our expected results. First, in the first column, we can see that in the absence of an FTA, for the high-differentiation sector, the model displays an ERPT on the producer import prices of 0.3718, as compared to 0.4519 in the low-differentiation sector. That is, at the producer level, the high-differentiation goods are those with the lowest pass-through level. The opposite occurs at the consumer level because the market power is not the driving force anymore. At the consumer level, the difference in the pass-through between the goods h and a is small, as the difference is given only by the tariffs. As a consequence of the trade liberalization, the varieties of the high-differentiation goods that are imported are more than the varieties of the low-differentiation goods that are imported. The new varieties imported are those with a higher ERPT since they have a lower productivity level, causing a higher aggregate ERPT at the consumer level in the high-differentiation sector. On the aggregate, the model shows an ERPT at the producer level of 0.4038 under high tariffs and 0.3820 under low tariffs. These results are in line with the ERPT in the USA for the period 1994-2003, which is 0.42.[9] The pass-through levels by sector are also close to the results found by Campa and Goldberg (2005) for the OECD countries: 0.50% in the manufacturing sector and 0.64% in the non-manufacturing and raw materials sectors.

Chart 6

Computational results (selected variables under different trade liberalization scenarios)

	No FTA (1)	FTA (2)	Percent change (2) - (1)
High-differentiation goods sector			
Varieties imported:	[0.8509,1.000]	[0.8356,1.000]	10.27%
ERPT:			
Producer import price	0.3718	0.3511	-5.55%
Consumer import price	0.1520	0.1417	-6.84%
Low-differentiation goods sector			
Varieties imported:	[0.8509,1.000]	[0.8392,1.000]	7.86%
ERPT:			
Producer import price	0.4519	0.4283	-5.21%
Consumer import price	0.1342	0.1270	-5.35%
Aggregate			
ERPT:			
Producer import price	0.4038	0.3820	-5.40%
Consumer import price	0.1449	0.1358	-6.28%

The model also predicts that the sign of the FTA would cause a drop in the pass-through at the producer level in the high-differentiation sector of 5.55% and in the low-differentiation sector of 5.21%. At the consumer level, the decrease in the high-differentiation sector is 6.84% and that in the low-differentiation sector 5.35%. In addition, the aggregate pass-through decreases at the producer level by 5.4% and at the consumer level by 6.28%. These measures are located between the values of the two sectors because after the FTA, the varieties of goods imported increase in both the sectors.

[9] The estimation is based on the estimation method proposed by Campa and Goldberg (2005):

$$\Delta imp_t = \alpha + \gamma \Delta imp_{t-1} + \sum_{i=0}^{4} \beta_i \Delta ner_{t-i} + \sum_{i=0}^{4} \delta_i \Delta mc_{t-i} + u_t,$$

where Δ represents the first differences, imp is the import price index (in logarithms), ner denotes the effective nominal exchange rate in the foreign currency per US dollars (in logarithms), mc is the marginal cost (in logarithms), and u is the error term. The marginal cost, mc, is the logarithm transformation of MC=(NER/RER)*ULC, where NER is the effective nominal exchange rate, RER is the effective real exchange rate, and ULC denotes the unit labor costs of the non-agricultural sector (the only sector for which the data are available). The measurement of the marginal cost is based on Otani, Shiratsuka and Shirota (2003). The ERPT is given by β_0. The sources of the data are included in appendix 1.

The varieties of high-differentiation goods increase by 10.27% and those of low-differentiation goods increase by only 7.86%. Then, the aggregate ERPT depends on both the new import bundle and the decrease in the pass-through by good. This result sheds light on the reason why the pass-through level has been decreasing over time. McCarthy (2007) and Otani, Shiratsuka and Shirota (2003) document this fact. In particular, Otani et al. (2003) suggest that the decrease in the pass-through level in Japan is due to its trade liberalization, which is in line with the results obtained here.

In this model, the parameter λ plays an important role since it affects both the ERPT by product and the number of varieties imported. A sensitivity analysis on this parameter is done. Chart 7 contains the varieties imported, and the aggregate ERPT at both the producer level and the consumer level under both tariffs levels for different values of λ:1.60 and 4.00 (that is, one below and one above the benchmark of 2.11). Note that under both values of λ, the condition $\lambda > \gamma\tau_{1,a} + \delta$ holds, which ensures trade across countries in both sectors.

Chart 7

ERPT under different scenarios of the parameter of technology λ

	No FTA (1)				**FTA (2)**				**Percent change (2) - (1)**	
	Varieties of imported low-differentiation goods	Varieties of imported high-differentiation goods	ERPT producer import price	ERPT consumer import price	Varieties of imported low-differentiation goods	Varieties of imported high-differentiation goods	ERPT producer import price	ERPT consumer import price	ERPT producer import price	ERPT consumer import price
Lambda=1.60	0.0516	0.0516	0.3542	0.0972	0.0598	0.0579	0.3332	0.0902	-5.91%	-7.12%
Lambda=2.11	0.1491	0.1491	0.4038	0.1449	0.1643	0.1607	0.3820	0.1358	-5.40%	-6.28%
Lambda=4.00	0.2934	0.2934	0.4314	0.1873	0.3192	0.3132	0.4102	0.1773	-4.91%	-5.32%

When there is no an FTA the varieties imported go from 5 percent to 29 percent of total depending on the level of lambda. The ERPT at producer level goes from 35 to 43 percent while at consumer level it goes from 9 to 18 percent. Similar variations arise under an FTA. The increase in lambda is a decrease in the productivity level which causes that each of the goods the country is importing has a higher pass-through. The percent change of the aggregate ERPT due to the trade liberalization does not change that much across scenarios. The fall of ERPT goes from 4.91 to 5.91 percent at producer level and from 5.32 to 7.12 percent at consumer level.

The model correctly displays the idea of the paper: a decrease in the ERPT by good and on aggregate due to the tariffs elimination and the presence of a new import bundle. However, the decrease in the ERPT does not seem to be very high. There are two reasons for this. First, the symmetry of the model does not allow high movements on the varieties of the imported goods. Second, the tariffs elimination is the only instrument resulting in a decrease in ERPT; however, at the same time, the trade liberalization is also characterized by the elimination of high non-tariff barriers that are not considered in this model. In general, the non-tariff barriers represent the additional regulations that add to the final price of a product as an additional cost. Thus, these non-tariff barriers can be modeled as a tax over the producer price, much like in the model. I conduct an exercise to take into account these non-tariff barriers. According to Looi, Nicita and Olarreaga (2004), in the USA, the non-tariff barriers, measured as an ad-valorem equivalent, are two times the average tariff. Consequently, the new simulation reducing the average tariffs in both sectors from 60% (which is the sum of the average tariffs in 1980, given as 20%, and the non-tariff ad-valorem equivalent, given as 40%) to their current levels in 2002. The 60% figure seems to be moderate, considering that before the trade liberalization in Mexico and the USA, the non-tariff barriers were quite heavy.

Chart 8

Computational results when non-tariff barriers are includes (selected variables)

	No FTA, tariff and non-tariff barriers (1)	FTA (2)	Percent change (2)-(1)
High-differentiation goods sector			
Varieties imported:	[0.8795,1.000]	[0.8356,1.000]	36.43%
ERPT:			
Producer import price	0.413	0.3511	-14.99%
Consumer import price	0.173	0.141	-18.02%
Low-differentiation goods sector			
Varieties imported:	[0.8795,1.000]	[0.8392,1.000]	33.44%
ERPT:			
Producer import price	0.513	0.4283	-16.52%
Consumer import price	0.154	0.1270	-17.35%
Aggregate			
ERPT:			
Producer import price	0.453	0.3820	-15.67%
Consumer import price	0.165	0.1358	-17.77%

Chart 8 is constructed in the same manner as chart 6; however, the results under the label No FTA correspond to the new simulation. The results show that when the non-tariff barriers are included, the ERPT decreases by 16% at the producer level and by 18% at the consumer level. These are substantial decreases in the ERPT, in particular, considering that there are many other economies that have adopted stronger liberalization policies.

6 Conclusion

This paper investigates the effect of the trade liberalization on the ERPT. To do so, it employs an empirical estimation of the effects of the NAFTA on the Mexican ERPT, and uses a Ricardian general equilibrium model that incorporates tradable goods, which may have high or low substitutability, a nontradable sector, and a distribution sector in each of the two symmetric countries.

The main contribution of the model proposed in this paper lies in a disaggregated analysis of the effect of the trade liberalization on the ERPT. An analysis of this type requires limiting some other features of the model, in particular, in terms of the dynamics such as the ERPT over time and the volatility of the macroeconomic variables.

In particular, the model identifies two channels that explain how the bilateral trade liberalization alters the ERPT. The first channel is the direct relationship between the tariffs and the pass-through by good. The second channel is the effect that tariffs have on the composition of imports, altering indirectly the aggregate pass-through.

With respect to the first channel, the model shows that the reduction in trade tariffs decreases the pass-through level by good since the tariffs are positively related to the ERPT. The intuition is that the tariffs increase the proportion of the final price influenced by the foreign firm (gross export price). As the foreign firms have more influence on the final price, in terms of amount, they have more incentives to pass-through a higher proportion of the exchange rate movements to the import prices since the firm balances its profits with price movements.

The second channel is simpler. As the high-differentiation goods face a more stringent tariffs elimination, its share in total imports increases. Since the high-differentiation goods have a lower ERPT than the low differentiated goods, the aggregate ERPT falls. More homogeneity in the goods implies more competition and more pass-through. The higher the competition, the closer the price is to its marginal cost. This implies that after an exchange rate movement, a competitive firm does not have any option but to move the price of its product; otherwise, it would face losses.

In addition, an analysis of the effect of the NAFTA on the ERPT to Mexican import prices is performed, concluding that the trade liberalization has decreased the pass-through level in Mexico.

This paper opens more questions about the effect of the trade liberalization on the ERPT, for example, how and to what extent subsidies affect the ERPT. The case of export subsidies is particularly interesting because they are highly concentrated in some raw materials and agricultural products, which are already seeing intensive discussions by the monetary authorities owing to their high price volatility.

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Appendix 1. Data sources

Chart 1

Quarterly data: USA

Series	Description and sources	Sample period
Import price index	IMF International Financial Statistics	Quarterly: 1Q 1994 - 4Q 2003
Nominal effective exchange rate	IMF International Financial Statistics	Quarterly: 1Q 1994 - 4Q 2003
Real effective exchange rate	IMF International Financial Statistics	Quarterly: 1Q 1994 - 4Q 2003
Unit labor costs	Bureau of Labor Statistics (BLS)	Quarterly: 1Q 1994 - 4Q 2003
Quarterly data: Mexico		
Series	**Description and sources**	**Sample period**
Import price index	OECD (index calculated from prices denominated in local currency)	Quarterly: 1Q 1987 - 2Q 2003
Nominal exchange rate	Central Bank of Mexico (Peso/US dollars)	Quarterly: 1Q 1987 - 2Q 2003
Mexico salary index	Central Bank of Mexico	Quarterly: 1Q 1987 - 2Q 2003
USA payroll index	Bureau of Labor Statistics (BLS)	Quarterly: 1Q 1987 - 2Q 2003
Monthly data: Mexico		
Series	**Description and sources**	**Sample period**
Import price index	Central Bank of Mexico (index calculated from prices denominated in dollars)	Monthly: January 1987 - May 2010
Nominal exchange rate	Central Bank of Mexico	Monthly: January 1987 - May 2010
Mexico manufacturing unit labor costs	Central Bank of Mexico	Monthly: January 1987 - May 2010
USA payroll index	Bureau of Labor Statistics (BLS)	Monthly: January 1987 - May 2010
Data: Explaining the ERPT in Mexico		
Series	**Description and sources**	**Sample period**
Manufacturing imports and total imports	INEGI (millons of dollars)	Quarterly: 1Q 1987 2Q - 2003
Exports and imports	INEGI (millons of dollars)	Quarterly: 1Q 1987 2Q - 2003
Mexico inflation	Central Bank of Mexico	Quarterly: 1Q 1987 2Q - 2003
USA inflation	Bureau of Labor Statistics (BLS)	Quarterly: 1Q 1987 2Q - 2003
Mexico GDP	INEGI (millons of dollars)	Quarterly: 1Q 1987 2Q - 2003

Source: own calculations

Appendix 2. Prices and Output

The consumer prices are

$$p_1(h)=\begin{cases} p_1^1(h)=\frac{\theta}{\theta-1}W_1(\gamma+\lambda h) & ,h\in[0,h_1] \\ p_1^2(h)=\frac{\theta}{\theta-1}(W_2\mathcal{E}(\gamma+\lambda(1-h))(1+\tau_{1,h})+\delta W_1) & ,h\in(h_1,1] \end{cases} \quad (1)$$

$$p_2(h)=\begin{cases} p_2^1(h)=\frac{\theta}{\theta-1}(\frac{W_1}{\mathcal{E}}(\gamma+\lambda h)(1+\tau_{2,h})+\delta W_2) & ,h\in[0,h_2) \\ p_2^2(h)=\frac{\theta}{\theta-1}W_2(\gamma+\lambda(1-h)) & ,h\in[h_2,1] \end{cases} \quad (2)$$

The producer prices are

$$\widetilde{p_1}(h)=\begin{cases} \widetilde{p_1^1}(h)=\frac{\theta}{\theta-1}W_1(\gamma+\lambda h), & h\in[0,h_1] \\ \widetilde{p_1^2}(h)=\frac{\theta}{\theta-1}(W_2\mathcal{E}(\gamma+\lambda(1-h))+\frac{\delta}{\theta}\frac{W_1}{(1+\tau_1)}), & h\in(h_1,1] \end{cases} \quad (3)$$

$$\widetilde{p_2}(h)=\begin{cases} \widetilde{p_2^1}(h)=\frac{\theta}{\theta-1}(\frac{W_1}{\mathcal{E}}(\gamma+\lambda h)+\frac{\delta}{\theta}\frac{W_2}{(1+\tau_{2,h})}), & h\in[0,h_2) \\ \widetilde{p_2^2}(h)=\frac{\theta}{\theta-1}W_2(\gamma+\lambda(1-h)), & h\in[h_2,1] \end{cases} \quad (4)$$

The production is

$$\begin{aligned} y^1(h) &= \left(\frac{\alpha I_1}{p_1(h)}\right)^{\theta}\frac{1}{C_{1,H}^{\theta-1}}+\left(\frac{\alpha I_2}{p_2(h)}\right)^{\theta}\frac{1}{C_{2,H}^{\theta-1}}, \qquad y^2(h)=0, \quad h\in[0,h_2] \\ y^1(h) &= \left(\frac{\alpha I_1}{p_1(h)}\right)^{\theta}\frac{1}{C_{1,H}^{\theta-1}}, \;\; y^2(h)=\left(\frac{\alpha I_2}{p_2(h)}\right)^{\theta}\frac{1}{C_{2,H}^{\theta-1}}, \quad h\in(h_2,h_1) \\ y^1(h) &= 0, \qquad y^2(h)=\left(\frac{\alpha I_1}{p_1(h)}\right)^{\theta}\frac{1}{C_{1,H}^{\theta-1}}+\left(\frac{\alpha I_2}{p_2(h)}\right)^{\theta}\frac{1}{C_{2,H}^{\theta-1}}, \quad h\in[h_1,1] \end{aligned}$$

Analogous expressions can be obtained for the sector producing low-differentiation goods, a.

Appendix 3. Equations summarizing the solution of the model in the steady state

$$h_1=\frac{w_2\mathcal{E}(1+\tau_{2,h})(\gamma+\lambda)+\delta w_1-\gamma w_1}{w_1\lambda+w_2\mathcal{E}(1+\tau_{2,h})\lambda}, \qquad h_2=\frac{w_2\mathcal{E}(\gamma+\lambda)-\delta\mathcal{E}w_2-\gamma w_{1,h}(1+\tau_{1,h})}{w_1\lambda(1+\tau_{1,h})+w_2\mathcal{E}\lambda},$$

$$a_1=\frac{w_2\mathcal{E}(1+\tau_{2,a})(\gamma+\lambda)+\delta w_1-\gamma w_1}{w_1\lambda+w_2\mathcal{E}(1+\tau_{2,a})\lambda}, \qquad a_2=\frac{w_2\mathcal{E}(\gamma+\lambda)-\delta\mathcal{E}w_2-\gamma w_1(1+\tau_{1,a})}{w_1\lambda(1+\tau_{1,a})+w_2\mathcal{E}\lambda},$$

$$\mathcal{E}=\frac{P_1C_1}{P_2C_2}, \qquad \frac{w_1}{w_2}=1,$$

$$M_1=x\frac{1}{\beta}P_1C_1, \qquad M_2=x\frac{1}{\beta}P_2C_2,$$

$$P_1C_1\le\int_0^{h_1}\frac{l_{1,H}}{\gamma+\lambda h}p_1(h)dh+\int_0^{h_2}\frac{l_{1,H}}{\gamma+\lambda h}p_2(h)dh+\int_0^{a_1}\frac{l_{1,A}}{\gamma+\lambda h}p_1(a)da$$
$$+\int_0^{a_2}\frac{l_{1,A}}{\gamma+\lambda a}p_2(a)da+\int_{a_1}^1\tau_{1,a}\widetilde{p}_1(a)\frac{l_{1,A}}{\gamma+\lambda(1-a)}da+\int_{h_1}^1\tau_{1,h}\widetilde{p}_1(h)\frac{l_{1,H}}{\gamma+\lambda(1-h)}dh,$$

$$P_2C_2\le\int_{h_2}^1\frac{l_{2,H}}{\gamma+\lambda(1-h)}p_2(h)dh+\int_{h_1}^1\frac{l_{2,H}}{\gamma+\lambda(1-h)}p_1(h)dh+\int_{a_2}^1\frac{l_{2,A}}{\gamma+\lambda(1-a)}p_2(a)da$$
$$+\int_{a_2}^1\frac{l_{2,A}}{\gamma+\lambda(1-a)}p_1(a)da+\int_0^{a_2}\tau_{2,a}\widetilde{p}_2(a)\frac{l_{1,A}}{\gamma+\lambda h}da+\int_0^{h_2}\tau_{2,h}\widetilde{p}_2(h)\frac{l_{1,H}}{\gamma+\lambda a}dh,$$

$$\int_0^{h_1}\frac{l_{1,H}}{\gamma+\lambda h}dh+\int_{h_2}^1\frac{l_{2,H}}{\gamma+\lambda(1-h)}dh=\alpha C_1, \; \int_0^{a_1}\frac{l_{1,A}}{\gamma+\lambda h}da+\int_{a_1}^1\frac{l_{2,A}}{\gamma+\lambda(1-h)}da=(1-\alpha)C_1,$$

$$\int_{h_2}^1\frac{l_{2,H}}{\gamma+\lambda(1-h)}dh+\int_0^{h_2}\frac{l_{1,H}}{\gamma+\lambda h}dh=\alpha C_2, \; \int_{a_2}^1\frac{l_{2,A}}{\gamma+\lambda(1-a)}da+\int_0^{a_2}\frac{l_{1,A}}{\gamma+\lambda a}da=(1-\alpha)C_2,$$

$$l_{1,N}=\delta\left(\int_{h_1}^1\frac{l_{2,H}}{\gamma+\lambda(1-h)}dh+\int_{a_1}^1\frac{l_{2,A}}{\gamma+\lambda(1-h)}da\right), \; l_{2,N}=\delta\left(\int_0^{h_2}\frac{l_{1,H}}{\gamma+\lambda h}dh+\int_0^{a_2}\frac{l_{1,A}}{\gamma+\lambda h}da\right).$$

Appendix 4. Calibrating the parameters γ and λ

Calibrating the parameters γ and λ is a difficult and challenging task since there is no microeconomic evidence to support these values. Further, these values correspond to the technology parameters, and while γ is only a scaling parameter, λ controls the slope of the productivity across products. This means that λ controls the number of nontraded varieties. It is logically easier to calibrate these parameters for a two-country relationship rather than for a cross-country relationship. However, there is no reason why the domestic technology should be different depending on the trade partner. Since I am calibrating the model using the USA as a benchmark, an important trade partner of this country is needed. Consequently, I chose to calibrate these parameters for the USA-Mexico relationship since both the countries are among each other´s biggest trading partners. The model is calibrated for the year 1993, which is the year before the NAFTA took effect. Consider the USA as country 1 and Mexico as country 2. Sector h represents the manufacturing sector. The values for γ and λ are obtained as follows:

1. Consider

$$h_1 = \frac{w_{2,h}\mathcal{E}(1+\tau_{2,h})(\gamma+\lambda)+\delta p_{1,n}-\gamma w_{1,h}}{w_{1,h}\lambda + w_{2,h}\mathcal{E}(1+\tau_{2,h})\lambda}, \quad (5)$$

$$h_2 = \frac{w_{2,h}\mathcal{E}(\gamma+\lambda)-\delta\mathcal{E}p_{2,n}-\gamma w_{1,h}(1+\tau_{1,h})}{w_{1,h}\lambda(1+\tau_{1,h})+w_{2,h}\mathcal{E}\lambda}. \quad (6)$$

2. Since $p^1_1(h_1) = \frac{\theta}{\theta-1} w_{1,h}(\gamma+\lambda h_1)$, $w_{1,h}(\gamma+\lambda h_1) = MgC_1(h_1)$, where $MgC_1(h_1)$ represents the marginal cost in country 1 of variety h_1 when the distribution sector is not involved. Hence, in country 2, $w_{2,h}(\gamma+\lambda(1 - h_2)) = MgC_2(h_2)$. These two equations can be rewritten as

$$h_1 = \frac{\frac{MgC_1(h_1)}{w_{1,h}} - \gamma}{\lambda}, \quad (7)$$

$$h_2 = 1 - \frac{\frac{MgC_2(h_2)}{w_{2,h}} - \gamma}{\lambda}. \quad (8)$$

3. I substitute (5) and (6) in (7) and (8), respectively. Since γ, λ > 0, the resulting expressions can be written as

$$a(w_{1,h}+w_{2,h}\mathcal{E}(1+\tau_{2,h}))-\delta w_{1,n} = \gamma[2w_{2,h}\mathcal{E}(1+\tau_{2,h})]+\lambda[w_{2,h}\mathcal{E}(1+\tau_{2,h})],$$

$$b(w_{2,h}\mathcal{E}+w_{1,h}(1+\tau_{1,h}))-\delta w_{2,n}\mathcal{E} = \gamma[2w_{1,h}(1+\tau_{1,h})]+\lambda[w_{1,h}(1+\tau_{1,h})],$$

where

$$a = \frac{MgC_1(h_1)}{w_{1,h}} \text{ and } b = \frac{MgC_2(h_2)}{w_{2,h}}.$$

4. These two equations can be written in the matrix form and solved using a Cholesky decomposition

$$\begin{bmatrix} w_{2,h}\mathcal{E}(1+\tau_{2,h}) & 2w_{2,h}\mathcal{E}(1+\tau_{2,h}) \\ w_{1,h}(1+\tau_{1,h}) & 2w_{1,h}(1+\tau_{1,h}) \end{bmatrix} \begin{bmatrix} \lambda \\ \gamma \end{bmatrix} = \begin{bmatrix} a(w_{1,h}+w_{2,h}\mathcal{E}(1+\tau_{2,h}))-\delta w_{1,n} \\ b(w_{2,h}\mathcal{E}+w_{1,h}(1+\tau_{1,h}))-\delta w_{2,n}\mathcal{E} \end{bmatrix}$$

5. The data required to solve the above operations is obtained as follows:

The average wages per hour in the manufacturing sector for each country are obtained in the World Development Indicators 2005, World Bank.

$w_{1,h} = w_{USA,1993,h}$ = 11.74 USD

$w_{2,h} = w_{MEX,1993,h}$ = 2.10 USD

6. The marginal costs are not observable; however, there is a variable that is usually used as a proxy, the unit labor cost (ULC). This measure is an index and gives a relative measure of marginal cost between the USA and Mexico. The ULC for the USA is $ULC_{USA,1994}$ = 100 and that for Mexico is $ULC_{MEX,1994}$ = 15. The marginal cost in the USA for the variety h_1, $MgC_1(h_1)$, is not observable. Consequently, I choose $MgC_1(h_1)$ such that the proportion of non-wage costs to total compensation costs is 21%, as in the 1990s (source: International Labour Organization). As such, $MgC_1(h_1) = w_{\text{USA},1993,h} * 1.21$ = 14.21 USD. Due to the differences in the ULCs across countries, $MgC_2(h_2) = 14.21 * 0.15$ = 2.13 USD.

7. The average tariffs between Mexico and the USA before the NAFTA were $\tau_{1,h} = \tau_{US,h}$ = 2.07%, $\tau_{2,h} = \tau_{MEX,h}$ = 12%, and $\delta = 1.403$, such that the distribution margin is between 40% and 80% of the retail price.

8. By using all these data and solving the two equations, I obtain $\gamma = 0.076$ and $\lambda = 2.110$. The restriction $\lambda > \gamma\, \tau_{1,a} + \delta$ must hold to ensure trade across the countries in both sectors.

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