

# Understanding International Price Dispersion

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# Dissertation Abstract

Data on international relative prices show that changes in producer prices are not fully passed on to export prices. Standard trade models have so far failed to explain this observation. In the first chapter, I introduce a model of international trade with heterogeneous firms and incomplete information. I show that when firms have incomplete information on their rivals costs and face international trade frictions, they optimally choose to price to market. The model successfully reproduces main features of international relative price fluctuations once calibrated to fit the US trade data. Moreover, it provides two testable predictions on pricing to market behavior at the firm level: 1. There is less pricing to market and higher pass-through in differentiated good prices, 2. Pass-through is higher for high productivity firms than low productivity firms.

The 1990s were a time of substantially declining international trade costs for the U.S. and its trading partners. In the second chapter, we use this time period to test the basic prediction of the trade cost model that price dispersion should decline alongside trade costs. We conduct this test by harmonizing two existing panel datasets on microeconomic trade costs and prices. We construct trade-weighted averages for price dispersion and trade costs. We show that the trade cost models prediction is broadly consistent with the data over the period 1990-1997. Our measure of average trade costs and average price dispersion both fell substantially during this period. During 1997-2005, however, average price dispersion increased while trade costs were

unchanged.

The third chapter tries to account for the increase in average price dispersion over the second half of the 1990s that is documented in the previous chapter. Here, I build on the observation that in the second half of the 1990s, total factor productivity growth accelerated in the U.S. as a result of investments in information and communication technologies, while it decelerated in Europe. This productivity difference was especially high in the retail sector. I show that a trade model that includes a retail sector calibrated to fit the productivity data can reproduce the divergence observed in international prices of tradable goods.

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All errors are of my own.

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# Chapter 1

## International Price Dispersion and Pricing-to-Market when Rivals' Costs are Unknown

Data on international relative prices show that changes in producer prices are not fully passed on to export prices. Standard trade models, however, have so far failed to explain this observation. In this paper, I introduce a model of international trade with heterogeneous firms and incomplete information. I show that when firms have incomplete information on their rivals' costs and face international trade frictions, they optimally choose to price to market. The model successfully reproduces main features of international relative price fluctuations once calibrated to fit the US trade data. Moreover, it provides two testable predictions on pricing to market behavior at the firm level: The model implies that there is less pricing-to-market and higher pass-through in differentiated good prices, and that high productivity firms pass through their costs into their prices more so than lower productivity firms.

## 1.1 Introduction

A growing body of empirical work on international price dispersion suggests that *pricing-to-market* is an important aspect of what determines the relative prices of traded goods. Alessandria and Kaboski (2007) and Simanovska (2008), for example, show that exporters price-to-market across high and low income destinations. Campa and Goldberg (2005), Hellerstein et al.(2006), Gopinath and Rigobon (2008) find that when exchange rates change, only a fraction of the change is passed through to export prices. This is true even at the individual good level. Such deviations from the law of one price are further documented by case studies of export markets, as in Goldberg (1995) and Knetter (1993). Pricing-to-market behavior seems to be pervasive among many countries and across many industries. But, the standard trade cost model cannot account for this type of price setting.

This paper develops a new model of pricing-to-market. The model relaxes one simple assumption of an otherwise standard heterogeneous-firm trade model. This assumption is that firms know their competitors costs. By relaxing this assumption, price competition takes the form of a first-price sealed-bid auction. Price dispersion arises because firms lower their markups strategically in markets where they are weak bidders.

What motivates the model are two simple observations about how traded goods are actually *sold* in the U.S. and other countries. First, most goods are sold by large chain-store retailers such as Wal-Mart. In the U.S. in 2005, for example, chain stores accounted for about 61% of total retail sales. This phenomenon is probably even more important for internationally traded goods. Wal-Mart alone sells 10% of U.S. imports from China although its U.S. retail market share is only 7%. Understanding international price dispersion, therefore, has become synonymous with understanding how large chain stores set prices. And understanding international producer price dispersion, has become synonymous with understanding how producers set their prices

in competition to become suppliers for these large chain stores. I'm going to focus on the latter of these aspects.

The second observation involves how the chain stores acquire their goods-for-sale. An auction-like mechanism seems to be an important part of it. Wal-Mart sources its products from a pool of international suppliers. It collects price quotes and supplier information electronically over the internet. For a supplier in this pool it's hard to know who its rivals are, what they are bidding and what production costs they face. Moreover, this system makes it easy for Wal-Mart to find and connect with new suppliers. As Krugman pointed out "*Wal-Mart is so big and so centralized that it can all at once hook Chinese and other suppliers into its digital system. So—wham!—you have a large switch to overseas sourcing in a period quicker than under the old rules of retailing.*"<sup>1</sup> The whole system resembles an ongoing international procurement auction with new firms and quotes added every day from all around the world. The lowest priced firm wins!

I build my model using the above ideas. Details of the model are as follows. There are a continuum of goods. Heterogeneous firms compete in prices to be the unique supplier of each good. The key assumption is that each firm can observe its production cost but not that of its rivals. Competition, then, takes the form of a first-price sealed-bid auction. Each firm observes its own cost, knows the distribution of its rivals' costs and enters a bid price to be the sole supplier of the good. The optimal bidding strategy trades off high profits against a lower probability of winning.

Pricing-to-market is driven by how trade costs introduce a natural asymmetry into these bidding strategies. A foreign firm faces trade costs in addition to its production cost whereas a domestic firm does not. Firms are *weak* competitors whenever they compete in the foreign market. They bid more aggressively by charging lower markups on their export prices. This asymmetry in pricing strategies is also reflected in firms'

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<sup>1</sup>Fast Company Issue 77, December 2003.

responses to changes in relative production costs across countries. In response to an increase in the relative costs, firms decrease their markups on their export price more so than on their domestic price. Here, pricing-to-market arises as an optimal pricing strategy for internationally competing firms.

In this paper, first I show that the proposed model can generate movements in aggregate price indices as observed in the data. When calibrated to match US trade data, I show that the model reproduces movements in terms of trade that are less volatile than the real exchange rates as documented by Atkeson and Burstein (2008). Then, I discuss the implications of the model on pricing-to-market behavior at the firm level.

This model is part of a growing literature that extends the Ricardian model in Dornbusch, Fischer and Samuelson (1977) and Helpman and Krugman's (1985) model based on imperfect competition. It builds on recent work by Eaton and Kortum (2002), Melitz (2003) and Bernard, Eaton, Jensen and Kortum (2003) and Atkeson and Burstein (2007). My model is close to the one analyzed in Atkeson and Burstein (2007) where firms engage in Bertrand competition. The main difference is that in my model information is incomplete; firms cannot observe their rivals' costs. This simple extension not only resolves the discontinuity in Bertrand competition but also induces different implications for pricing-to-market behavior.

As Atkeson and Burstein (2007) demonstrate, under perfect information, Bertrand competition can generate pricing to market to the extent that latent competitors are not the same in different countries. The intuition for pricing-to-market is different in my model and so are its implications. For example, a higher elasticity of substitution in models with Bertrand competition reduces the number of firms that face different latent competitors. This implies a higher pass-through of costs to export prices and a lower degree of pricing-to-market as goods become more homogeneous. My model implies the opposite. The higher is the elasticity of substitution, the more responsive

is the demand to changes in price. This eases the trade-off between probability of winning and profits. Firms find it easier to price-to-market and not pass the increase in their costs to their prices. Thus, my model implies a lower pass-through and a higher degree of pricing-to-market as goods become more homogeneous. This intuition is similar to Krugman (1987) which states that pass-through should be higher for differentiated goods than for homogeneous goods. Gopinath and Rigobon (2008) find evidence in the same direction using firm level import price data.

Other models of pricing-to-market in the recent literature include Alessandria and Kaboski (2007) and Drozd and Nosal (2008) where pricing-to-market arises as a consequence of search frictions. Atkeson and Burstein (2008) consider quantity competition a la Cournot within a nested CES demand system. Burnstein and Jaimovic (2009) use a model with Bertrand competition similar to Atkeson and Burstein (2007). This paper proposes a new model that can quantitatively generate similar moments to the ones observed in the aggregate prices, and that has different implications for pricing-to-market behavior at the firm level.

The paper is organized as follows. The next section, Section 2, presents the model in full detail. Section 3 describes how the model is quantified and how the key parameters are pinned down. Section 4 reports the results and compares them to main stylized facts on international relative prices. Section 5 describes the implications of the model at the firm level and discusses the differences in these implications with other studies. Section 6 concludes.

## 1.2 The Model

I develop a model of international trade where firm heterogeneity and incomplete information leads to strategic pricing by firms. The model is built on the Ricardian model presented by Dornbusch, Fischer and Samuelson (1977) and extends the model

in Atkeson and Burstein (2007). I consider a world with two symmetric countries, home and foreign, depicted as country  $i = 1, 2$ , respectively. These countries engage in trade of goods because of the differences in their productivities.

There is a continuum tradable goods indexed by  $\omega \in [0, 1]$  that is consumed in both countries. Consumers get utility by consuming an aggregate basket of these goods. I assume that each good is an imperfect substitute to all other goods. Consumers' utility in country  $i$  are defined as

$$U_i = \left[ \int_{\omega} q_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \quad (1.1)$$

where  $q_i(\omega)$  is the amount of good  $\omega$  consumed and  $\sigma$  is the constant elasticity of substitution between goods. As is well known, this type of preferences implies the following demand function

$$x_i(\omega) = Q_i \left( \frac{p_i(\omega)}{P_i} \right)^{-\sigma}, \quad (1.2)$$

where  $p_i(\omega)$  is the price of good  $\omega$ ,  $Q_i$  denotes the aggregate quantity consumed and  $P_i$  is the aggregate price given by

$$P_i = \left[ \int_{\omega \subset \Omega} p_i(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}. \quad (1.3)$$

There are  $n$  firms competing to produce each good in each country. Firms are indexed as  $k = 1, \dots, 2n$ , where the first  $n$  firms are in the home country and the last  $n$  are in the foreign country. The production technology is linear and common to all firms. Each firm in country  $i$  has a cost function of the form  $c_{ik}(\omega) = c_i \theta_k q_i(\omega)$ , where  $c_i$  is the cost of the bundle of inputs in country  $i$ , and  $\theta_k$  is the technology parameter of firm  $k$ . Technology parameters are drawn from the distribution  $F(\theta)$  with density  $f(\theta)$  which is common to both countries.

The technology parameter of a firm is its private information. Firm  $k$  only knows the value of its own parameter  $\theta_k$  but not the value of other firms' parameters  $\theta_l$ ,  $l \neq k$ . However, the distribution function  $F(\theta)$  is public knowledge.

Goods are mobile across countries. For one unit of a good to arrive at its destination,  $\tau \geq 1$  units have to be shipped. I assume that this cost is the same for both countries. Since goods can be transported across countries, there are  $2n$  firms that can potentially deliver a good to any location. Firms engage in price competition at each location to be the actual supplier. If the price of a local firm is the lowest, then the good is produced locally by that firm, if the price of a foreign firm is the lowest then the good is imported.

The timing of the events is as follows; i) firms observe their own technology parameter  $\theta_k$  ii) given  $\theta_k$  and the distribution function  $F(\theta)$ , each firm announces their selling price in the market simultaneously iii) consumers observe the menu of prices and buy their goods from the firm with the lowest price.

I assume that there are no capacity constraints; each firm is capable of supplying all the demand for a good in the economy. Hence, only the firm with the lowest price engages in production and makes profits.

### **1.2.1 Pricing Strategies Under Incomplete Information**

In models with complete information, i.e., where firms' technology parameters are common knowledge, pricing strategies would be simple: The lowest cost firm would observe the marginal costs of other firms and charge a price equal to the marginal cost of the second lowest cost firm. This way it would have the lowest price in the market and become the only supplier.

When rivals' costs are unknown, the competition becomes a first-price sealed bid auction. Firms do not know each other's marginal cost, hence, they do not know whether they are the lowest cost firm or not. They only have information on the



distribution of marginal costs. They have to choose a price greater than their own marginal cost to make profits. However, the higher the price they choose, the lower is the probability that their price will be the lowest price in the market. If their price is not the lowest then, their sales are equal to zero and they don't make any profits. Hence, the mechanism here is very much like a procurement auction where bidders compete to bid the lowest price simultaneously.

In the model described here, the firms (bidders) from different countries are asymmetric. Although the technology parameter in both countries is drawn from a common distribution function, the existence of trade costs causes asymmetry among firms when they compete at different locations. In the home country, local firms have an advantage over the foreign firms; they don't pay any trade costs. Hence, their marginal costs are "stochastically lower" than the foreign firms. In terms of auction theory terminology they are "strong" bidders while the foreign firms are "weak" bidders. This means that the distribution function of local firms at home,  $F_{ii}$ , is stochastically dominated by the distribution function of foreign firms that compete in home country,  $F_{ij}$ , i.e.,  $F_{ii}(\theta) \geq F_{ij}(\theta)$ . This causes firms to have different pricing strategies at different locations. In other words, firms price to market. Below, I describe how I derive these optimal pricing strategies.

Suppose that there is an equilibrium where the firms within a country follow symmetric pricing strategies; in country  $i$ , let  $\beta_{ii}$  be the symmetric strategy for the local firms, and  $\beta_{ij}$  be the symmetric strategy for the foreign firms. Assume that these strategies are increasing and differentiable and have inverses  $\phi_{ii}(p) = \beta_{ii}^{-1}$  and  $\phi_{ij}(p) = \beta_{ij}^{-1}$ , respectively.

Given that firms in country  $j = 1, 2$  that compete in country  $i = 1, 2$  follow the strategy  $\beta_{ii}(\theta)$  and  $\beta_{ij}(\theta)$ , the expected profit of a firm from country  $j$  competing in

country  $i$  when its technology parameter is  $\theta_j$  and he charges price  $p$  is

$$\Pi_{ii}(p, \theta) = [1 - F_{ij}(\phi_{ij}(p))]^n [1 - F_{ii}(\phi_{ii}(p))]^{n-1} \pi(p, \theta_i) \quad (1.4)$$

$$\Pi_{ij}(p, \theta) = [1 - F_{ii}(\phi_{ii}(p))]^n [1 - F_{ij}(\phi_{ij}(p))]^{n-1} \pi(p, \theta_j), \quad (1.5)$$

where  $\pi$  is the profit function. In the first equation, the first term is the probability that the price of a local firm is the lowest compared to all foreign firms. The second term is the probability that it is the lowest price among the local firms. The last term is the monopoly profit that the firm is going to make if it is the lowest priced firm among all firms.

Here, it is important to note that if a local firm has the lowest marginal cost among all local firms, it will also have the lowest price among them. But the same is not true when it is compared to the foreign firms. Even if the marginal cost of a local firm is lower than that of a foreign firm, its price can be higher. That's why it is not sufficient to compare the marginal costs of local and foreign firms to determine who will have the lowest price. We need to make use of the pricing strategy of the foreign firms. For that we need to determine the marginal cost of a foreign firm who would charge the same price as a local firm. That is given by  $\phi_{ij}(p)$ . Now, if this is the lowest marginal cost among all foreign firms, then we can say that the local firm's price is indeed the lowest price. Hence, the probability that a local firm, which charges price  $p$ , is the lowest priced firm among all foreign firms is given by  $[1 - F_{ij}(\phi_{ij}(p))]^n$ . This argument holds true for the problem of the foreign firm defined by equation (1.18) in a symmetric way.

In order to find the pricing strategies, I solve the firms' maximization problem. Note that I'm solving the maximization problem to determine two pricing functions, not two price points that maximize the expected profits. The first order condition for

a local firm in country  $i$  is

$$\frac{\pi'(p, \phi_{ii}(p))}{\pi(p, \phi_{ii}(p))} = (n-1)v(\phi_{ii}(p))\phi'_{ii}(p) + nv(\phi_{ij}(p))\phi'_{ij}(p), \quad (1.6)$$

$$\frac{\pi'(p, \phi_{ij}(p))}{\pi(p, \phi_{ij}(p))} = (n-1)v(\phi_{ij}(p))\phi'_{ij}(p) + nv(\phi_{ii}(p))\phi'_{ii}(p), \quad (1.7)$$

where  $v(\cdot)$  is the hazard rate given by  $v(\phi(p)) = \frac{f(\phi(p))}{1 - F(\phi(p))}$ .

The optimal pricing strategy of local and foreign firms is the solution to the system of differential equations given by (3.2) and (3.3) and the relevant boundary conditions at each location  $i$ . Since the countries are symmetric, here, I only demonstrate the problem of firms that compete in the home country, denoted as country 1.

The first order conditions (3.2) and (3.3) yields the following system of differential equations for pricing strategies of local and foreign firms in the home country, respectively:

$$\phi'_{11}(p) = \frac{1}{(2n-1)v(\phi_{11}(p))} \left( \frac{n}{p - \phi_{12}(p)} - \frac{n-1}{p - \phi_{11}(p)} - \frac{\sigma}{p} \right) \quad (1.8)$$

$$\phi'_{12}(p) = \frac{1}{(2n-1)v(\phi_{12}(p))} \left( \frac{n}{p - \phi_{11}(p)} - \frac{n-1}{p - \phi_{12}(p)} - \frac{\sigma}{p} \right) \quad (1.9)$$

and the boundary conditions

$$\phi_{11}(\underline{p}) = \underline{\theta}_1 \quad \phi_{12}(\underline{p}) = \underline{\theta}_2 \quad (1.10)$$

$$\phi_{11}(\bar{p}) = \bar{\theta}_1 \quad \phi_{12}(\bar{p}) = \bar{\theta}_2 \quad (1.11)$$

for given bounds of the technology parameter  $[\underline{\theta}_1, \bar{\theta}_1]$  and  $[\underline{\theta}_2, \bar{\theta}_2]$ . Note that the pricing strategies of the local and the foreign firms have a common bound. That is, neither of them will charge a price lower than  $\underline{p}$  or higher than  $\bar{p}$ . I discuss how these bounds are found in the section below.

In equation (1.8), the first order condition for a local firm who competes in home

country, the first term represents the competition from the foreign firms. Out of  $2n - 1$  firms  $n$  of them are foreign and are competing in the home country. The remaining  $n - 1$  firms are local and are also competing in the same market. The effect of the competition from local firms is reflected by the second term in the equation. Lastly, the third term in the equation represents the effect of the monopolistic competition. Besides engaging in price competition with the firms who supply the same good, the firm is in monopolistic competition with the firms who supply differentiated goods. The extent of this competition depends on the elasticity of substitution parameter  $\sigma$ .

### 1.2.2 Boundary Conditions

In order to solve this system of ordinary differential equations (ODEs), we need to know at least one of the boundary conditions. The upper bound is the maximum equilibrium price which is characterized as

$$\bar{p} = \min\{\arg \max_p \pi(p, \bar{\theta}_1)(1 - F_2(p))\} \in (\bar{\theta}_1, \bar{\theta}_2),$$

when  $\bar{\theta}_1 < \bar{\theta}_2$ .<sup>2</sup> Although it is easy to solve for the upper bound, the ODEs above are ill behaved at this boundary.<sup>3</sup> The lower bound, on the other hand, cannot be solved for analytically. In order to tackle this problem, I write a shooting algorithm that makes an initial guess for the lower bound, solves the differential equations given this bound and then checks whether the upper bound is satisfied or not. If not, it updates the initial guess for the lower bound and continues until the upper bound is satisfied.

### 1.2.3 Pricing Strategies

In order to solve the pricing strategies, I parameterize the productivity distribution  $F(\theta)$ . I assume that the productivity parameter  $\theta$  is distributed Pareto and bounded

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<sup>2</sup>This characterization is an adaptation from Maskin and Riley (2003).

<sup>3</sup>See Appendix for details.

by  $\theta_{min}$  and  $\theta_{max}$ . I choose the bounds such that the marginal cost distribution has the normalized support  $[1,2]$ .<sup>4</sup> The resulting pricing strategies are depicted in Figure 1.6. Local firms charge higher prices than foreign firms even if they have the same marginal cost after accounting for the trade cost because they are the strong bidders. Foreign firms charge lower markups to compensate for their disadvantage in the local market caused by the trade costs because they are the weak bidders.

This result is well known in auction theory where weak bidders undercut their prices. McAfee and McMillan (1989) discusses this property in international procurement auctions in detail and provide a mechanism for the auctioneer to eliminate this effect for the sake of efficiency. Because the competition here is not a designed auction and there is no auctioneer, such a mechanism is not possible to implement. The inefficiency arises here because information on rivals' marginal costs is incomplete.

Figure 1.2 shows how the heterogeneity in firm productivity affects markups. Lower cost firms charge higher markups than high cost firms. This is true for both the local and foreign firms, but markups of local firms are higher. An increase in number of firms brings down the markups and brings the pricing strategies closer to each other. In the limit when  $n = \infty$ , all firms charge a price equal to their marginal costs.

Figure 1.3 shows local firms' export and domestic pricing strategies. Because of the symmetry between the countries, the export pricing strategy depicted in red is actually the same line as the pricing strategy for foreign firms. In this figure, the marginal costs are used for labeling firms so that the red line is the export price and the domestic price strategy for firms can be seen together. In the figure, the export prices firms choose to charge are higher than the domestic prices after accounting for the trade cost. However, the export price is much less than trade costs added to the domestic price, denoted by the dash line in the figure. Firms compensate for the trade

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<sup>4</sup>Arkolakis and Muendler (2009) show that the distribution of exporter sales and scope resemble a Pareto distribution using firm level data.

cost by decreasing their markups in the export market in order to be competitive. Therefore, firms price to market by charging lower markups in the foreign market.

The figure also shows that the extent of the decrease in the markup varies with firm productivity. The degree of pricing-to-market seems to have a hump shape. High productivity firms are able to squeeze their markups almost enough to discount for the full amount of the trade costs. As productivity decreases firms charge higher markups. This is because the low productivity firms are the ones that charge lower markups. They cannot decrease their markups as much as the trade costs. Finally, very unproductive firms with high marginal costs have to squeeze their markups a lot to be competitive and remain in the auction.

Figure 1.4 and Figure 1.5 show the asymmetric case where the cost of inputs is high in the home country relative to the foreign country. First, notice that all prices, denoted by the dash lines, are higher than the symmetric case. In the home country, the local firms, strong bidders, became weaker and the weak bidders, the foreign firms, became stronger. Therefore, the pricing strategies got closer to each other. In other words, foreign firms do not price as aggressively as before and local firms do not charge as higher markups as before. In the foreign country, local firms have a greater advantage. The strong bidders became stronger, and the weak bidders became weaker. Therefore, pricing strategies are further apart from each other. Home country firms price more aggressively than before by decreasing their markups further and the local firms charge higher markups than before.

It is important to note here that what makes the model promising in terms of generating pricing-to-market observed in the data is that local firms decrease their markups more in the foreign market than in the local market. This can be seen in Figure 1.6 which depicts the export price relative to the domestic price. For most of the exporters export price decreases relative to the domestic price when domestic prices increase.

These figures show intuitively how the model is able to generate pricing-to-market. Now, I go on to explain how I solve for the general equilibrium and show quantitatively what the degree of pricing to market is and how well the model fits the data.

### 1.2.4 General Equilibrium

In order to close the model, I need to explicitly define the input bundle used in production.<sup>5</sup> For simplicity, I assume that the input bundle required to produce a unit of output is labor only. Under this assumption the production function becomes  $q_i(\omega) = l_i(\omega)/\theta$ , where  $l(\omega)$  is the labor hours used to produce good  $\omega$ . Labor is inelastic and the aggregate amount of labor in each country is given by  $L_i$  and it is paid the wage rate  $W_i$ .

After solving for the pricing strategies as described above, I find the equilibrium prices using a simulation that generates the cost parameters from the underlying distribution function. This allows me to calculate the price indices given by (1.3) and expenditure shares given by

$$s_i(\omega) = \left( \frac{p_i(\omega)}{P_i} \right)^{1-\sigma} \quad (1.12)$$

for each good in the economy. In order to pin down the quantities produced, I impose the condition that total expenditure has to be equal to the sum of total wages and profits,  $W_i L_i + \Pi_i = Q_i P_i$ .

## 1.3 Quantification

The model provides an explanation for differences in firm's pricing at different locations. However, it does not yield analytical solutions that can be used to assess the affects of changes in the economy on international relative prices. In order to see how

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<sup>5</sup>BEJK(2003) discusses several ways of doing this.

much of the relative price fluctuations the model can account for quantitatively, I use a simulation to reproduce the relative statistics in the data.

I examine a change in the relative cost of the input bundle,  $c_1/c_2$ . Particularly, I consider the case where production costs in home country increase by 10% but stays the same in the foreign country. I show that in response to this change, the model implies an increase in the producer prices that is greater than the increase in export prices. I report the changes in the real exchange rate, terms of trade and real prices of exports and imports and show that the model can quantitatively generate moments quite close to the ones in the data.

### 1.3.1 Parameterization and Simulation

There are three key parameters to be set in the model, the elasticity of substitution,  $\sigma$ , the trade cost,  $\tau$ , and the shape parameter,  $\alpha$ , in the productivity distribution. I set these values, in the symmetric equilibrium, by trying to match two properties of US trade data. The first one is the export and import share of manufactures. These ratios varied over time in the US from 11% in 1987 to 21% in 2003. Following Atkeson and Burstein (2008), I target the average of these values, 16.5%.

The second statistic I target is the share of exporting firms in the US. BEJK (2003) reports this as 21% depending on Census data. Atkeson and Burstein (2008) consider the average of firms that report to export anything between years 1987 and 1992 as 25%. I target a value somewhere between these numbers.

In order to pin down the right shape parameter in the Pareto distribution, I try to match the variance of firm sales in the US data. BEJK (2003) reports that the standard deviation of the log plant level sales is equal to 1.67.

The model does not provide analytical expressions I can use to set the parameters. Therefore, I try to match the vector of the three statistics described above by minimizing the distance between the vector and the statistics implied by the model



after solving for them numerically. Table 1 summarizes the chosen values, implied statistics and the data.

Parameters		
sigma	3.6	
tau	1.4	
alpha	3.4	

	Statistics	Data
import share	15.6	16.5
% of firms that export	18	21
st. dev of firm sales	1.38	1.67

Given the set of parameters, I simulate the model for 20,000 goods, making 40,000 draws from the underlying distributions of technology parameters. Given the firms' marginal costs in each country, I find the prices they charge using the pricing strategies I derived above. I determine the "winning" firm for the supply of each good by comparing their prices. Then, I recalculate the pricing strategies and marginal costs for the case of an increase in the relative cost of inputs by 10% and find the new "winning" firms and equilibrium prices.

I compare some micro and macro level statistics of interest before and after the increase in the cost of inputs in the home country. In each case, I calculate the good-by-good price differences, firm markups and the pricing to market margin. Then, I calculate the changes in aggregate values; real exchange rate, terms of trade, consumer price index, producer price index and related components.

In order to calculate the change in aggregate indexes I follow the same procedure as the BEA. For the changes in CPI, I take the expenditure shares implied by the symmetric equilibrium as constant. I use them as weights while calculating the average change in goods' prices. The change in CPI calculated this way is given by

$$\widehat{CPI}_i = \sum_{\omega \in \Omega} s_i(\omega) \hat{p}_i(\omega), \quad (1.13)$$

where  $\hat{p}_i(\omega)$  is the change in the price of a good after the increase in the relative cost of inputs and  $\Omega$  is the set of all goods consumed in the economy.

BEA reports the producer price index as a combination of price of goods produced and distributed domestically and the price of exports. The change in PPI is calculated as the expenditure share weighted average of the change in price of exported goods and locally produced and consumed goods.

$$\widehat{PPI}_i = (1 - s_x) \sum_{\omega \in \Omega_D} s_i(\omega) \hat{p}_i(\omega) + s_x \sum_{\omega \in \Omega_X} s_i(\omega) \hat{p}_i(\omega). \quad (1.14)$$

Here,  $s_x$  denotes the share of exports,  $\Omega_D$  is the subset of goods that are produced and consumed locally and  $\Omega_X$  is the subset of goods that are produced locally and exported.

## 1.4 Results

Here, I document the model's predictions of price dispersion at the aggregate and disaggregate level. At the aggregate level the model is able to match the two important features of the data that (i) the terms of trade is more volatile than the producer price based real exchange rate, (ii) the consumer price based real exchange rate is almost as volatile as the producer price based real exchange rate. At the disaggregate level, I report the price differences across locations for actually traded goods. I show that the law of one price does not hold not only at the aggregate level but also at the individual good level.

### 1.4.1 Aggregate Price Dispersion

Table 2 shows the change in the producer price (PPI) based real exchange rate (RER), terms of trade (TOT), pricing-to-market in exports, pricing-to-market in imports and

the change in consumer price (CPI) based real exchange rate as a percentage of the producer price based real exchange rate implied by the model and in the data. The table also shows the results under the alternative setting of perfect competition.

Table 1.2: Response of Aggregate Prices

PPI based RER decomposition			
	Benchmark	Perfect competition	Data
TOT	59%	100%	33-66%
PPI/EXP	14%	0%	27-47%
IPI/PPI*	27%	0%	40-60%
(CPI/PPI)	85%	67%	97-104%

In the data, terms of trade is less volatile than the PPI based real exchange rate.<sup>6</sup> This can only be true when export and import prices do not change one-to-one with the underlying producer prices. In fact, the benchmark model implies an increase in the PPI/EPI ratio that is greater than zero because firms price to market: In response to an increase in their marginal cost, firms increase their markups in the local market more than their markups in the foreign market. This feature of the model is key to the results presented. Under perfect competition markups are constant and the same in both markets. That’s why the standard model fails to match this observation.

The model performs well in matching the data quantitatively as well. In the data, terms of trade between US and its trading partners is 1/3 to 2/3 less volatile than the trade weighted PPI based real exchange rate. Under the calibrated parameter setting, the model reproduces a number in the same range.

The data also shows that the CPI based real exchange rate is almost as volatile as the PPI based real exchange rate. The model performs better than the standard model in matching this observation. A 10% change in the PPI based real exchange rate implies an 8.5% change in the CPI based real exchange rate while the standard model predicts an increase of 6.7%.

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<sup>6</sup>Atkeson and Burstein (2008) summarizes data statistics using quarterly data on US export, import and producer price indices, 1978-2005.

### 1.4.2 Price Dispersion at Good Level

Price dispersion, measured as the average of good-by-good absolute price differences between countries, and how it responds to a 10% increase in input costs at home country are shown in Table 3. Remember that in the model with perfect competition, the price difference of an actually traded good is exactly the trade cost. The average price dispersion for traded goods in this model is much less, between 14-15%.

After a 10% increase in the home country's input costs, the price difference for imported goods decrease by 2.47% while the price difference for exported goods increase by 1.82%. This happens because after the change, the pricing functions of the firms move further apart from each other in the foreign country, and become closer in the home country. Firms increase their prices less at the location where their pricing functions are more similar. This causes exporters in home country to charge higher prices abroad relative to domestic prices, and the exporters in foreign country to charge lower prices in home country relative to their domestic prices.

Firms squeeze their markups in the market where they are in a tighter competition. Average markup in the country with higher relative cost decreases, while the average markup in the country with lower relative cost increases. In other words, firms price to market because the competition in the two countries are different. That's why we see variation in actually traded good prices.

For the average price dispersion, I find that it is significantly lower than the trade cost over all goods. In response to a change in the relative wages, this average does not change much because the increase in exported good price dispersion and the decrease in imported good price dispersion cancel each other out.

Table 1.3: Response of Average Product Level Prices

Absolute log price differences		
	level	change
Overall price dispersion	0.1104	0.76%
Price dispersion exports	0.1368	-1.82%
Price dispersion imports	0.1448	2.47%
Not traded	0.0643	0.85%
<hr/>		
Average domestic markup	0.28	-0.81%
Average foreign markup	0.28	1.25%

## 1.5 Pricing-to-Market Behavior at the Firm Level

An important feature of the model is that it generates a high level of heterogeneity in the degree of pricing-to-market at firm level. Unlike the Bertrand competition models in international trade such as Burstein and Jaimovic (2009) and Atkeson and Burstein (2007), in which some firms price to market fully and others do not price to market at all, in this model all firms price to market and the extent and direction of pricing-to-market behavior varies with firm productivity. The model also differs from Bertrand competition models in its implications at sectoral level. It implies that in sectors that produces highly differentiated goods, i.e. sectors with a low elasticity of substitution, firms price-to-market less when compared to firms in sectors that produce more homogeneous goods, i.e. sectors with a high elasticity of substitution. Below, I describe the intuition behind these results in detail.

### 1.5.1 Effects of Heterogeneity in Productivity

The model implies that firms differ widely in the extent and direction they price to market. Figure 1.6 shows how the firms' export price relative to their domestic price varies with productivity. The hump shape in the figure is caused by the shifted support in the marginal cost distribution. Remember that the exporters face trade costs, therefore the support of their marginal cost distribution is shifted.

The shift in the support of marginal costs separates the low cost firms at home from the higher cost firms. A low cost firm at the tail of the distribution in home country has a high cost advantage compared to a foreign firm because its marginal cost is lower than the lower bound for the foreign firm. Lowering its price just a little bit gives the low cost local firm a very high possibility of win. But the opposite is true when it competes in the foreign market. Its marginal cost is at least as high as some foreign firms, therefore, a decrease in its price yields less increase in its probability of win. That's why low cost firms' relative export price is low to the left of the hump.

On the other side, both home and foreign firms compete under similar level of uncertainty so the general intuition applies. High cost firms are less competitive, hence they charge lower markups in both the domestic and foreign markets but even lower in the export market. Therefore, their export price relative to their domestic price is lower than low cost firms.

The shift in the picture shows the response to a change in relative costs. The new line is to the left of the original line. Relative export price decreased for high cost firms. These firms have increased their domestic price more than their export price. The low cost firms on the other hand did the opposite. Their relative price increased after the change in relative costs. On average high cost firms dominate the low cost firms behavior, and the relative export price decreases when costs in home country increases relative to the costs in the foreign country.

The selected bounds for the distribution function are important for these results. When the bounds are selected to reflect a stretch in the support of the marginal cost distribution rather than a shift, e.g.  $\theta \in [0, 1]$  for local firms and  $\theta \in [0, \tau]$  for foreign firms, the hump shape disappears and the relative export price decreases for all firms. In this case, all firms price-to-market in the same direction and the average level of pricing-to-market increases. This makes the aggregate results reported in Table 2 stronger. Heterogeneity among firms in the degree of pricing-to-market remains.

High productivity firms price-to-market less than the low productivity firms.

### 1.5.2 Sectoral Differences in Pricing-to-Market

Figure 1.7 and Figure 1.8 show the changes in export pricing strategy and the domestic pricing strategy for the home country firms at different levels of elasticity of substitution. For sectors where demand is affected less by a change in price, the sectors that produce differentiated goods, i.e. the change in the export pricing strategy is more similar to the change in the domestic pricing strategy, i.e. the increase in export prices are closer to the increase in domestic prices. The intuition is as follows: When demand is not very responsive to price changes, a price increase does not decrease the demand much, and hence increases the profits more. Then for a given increase in price, the decrease in probability of win is the same while profits are higher when elasticity of substitution is lower. This allows the firms in sectors with low price elasticity, to pass-through the increases in their costs into their prices more.

In models with Bertrand competition a low elasticity of substitution increases the number of firms that price to market. This is due to the decrease in the number of firms that hit the monopolistic markup bound while pricing their goods. This markup is higher and the probability of hitting the bound is lower when the elasticity of substitution is low. If firms hit this bound, they do not price to market even if they face different latent competitors in different markets. Therefore as elasticity decreases, the number of firms that price-to-market increases. Since in these models firms that price to market do so fully — the pass-through is zero— on average pass-through of costs into export prices decreases and pricing-to-market increases.

The model presented in this paper implies the opposite. The higher is the elasticity of substitution, the more responsive is the demand to changes in price. This eases the trade-off between probability of winning and profits. Firms find it easier to price-to-market and not pass the increase in their costs into their prices. Thus,

the model implies a lower pass-through and a higher degree of pricing-to-market as goods become more homogeneous. This intuition is similar to Dornbusch (1987) and Krugman (1987) which states that pass-through should be higher for differentiated goods than for homogeneous goods. Gopinath and Rigobon (2008) finds evidence in the same direction using firm level import price data for the United States.

## 1.6 Conclusion

I propose a new model of international trade with heterogeneous firms and price setting under incomplete information. Firms price to market by strategically adjusting their markups when faced with a change in their relative production costs. Incomplete information and trade costs are the key features of the model that generates this kind of pricing behavior. I show that under these assumptions the model is able to regenerate the main features of the data on the international relative prices. This paper contributes to the literature on understanding international price dispersion by proposing a new market structure, explaining the pricing-to-market behavior of firms.

This model also breaks away from the classical model where law of one price holds up to a trade cost. Here, trade costs are necessary for segmenting the markets; however, they are not the determinants of the good by good price differences. Rather, these price differences depend on the level of competition between firms in different markets.

The model presented here provides testable predictions for pricing-to-market behavior at the firm level. Specifically, it offers a relationship between firm level productivity and the extent of pricing-to-market. It also reinforces the intuition behind the Dornbusch and Krugman effect of pricing-to-market that we should expect to see higher pass-through and lower pricing-to-market in sectors that produce differentiated



goods.

In future research, it would be useful to test the model's implications at the firm level, using micro level data on international prices and firm characteristics. Such data are hard to find, however, recent interest in firm level studies in international trade has opened the door to obtaining them easier than before.

## 1.A Appendix

In this appendix, I show the derivations of the first order conditions for firms' maximization problem and the boundary conditions of pricing strategies.

The expected profit of local and foreign firms that compete in country 1 with marginal cost  $\theta_1$  and  $\theta_2$ , respectively are

$$\Pi_{11}(p, \theta) = [1 - F_{12}(\phi_{12}(p))]^n [1 - F_{11}(\phi_{11}(p))]^{n-1} \pi(p, \theta_1) \quad (1.15)$$

$$\Pi_{12}(p, \theta) = [1 - F_{11}(\phi_{11}(p))]^n [1 - F_{12}(\phi_{12}(p))]^{n-1} \pi(p, \theta_2) \quad (1.16)$$

where the monopolistic profit functions are given by

$$\pi(p, \theta_1) = Q_1 \left( \frac{p_1(\omega)}{P_1} \right)^{-\sigma} (p - \theta_1) \quad (1.17)$$

$$\pi(p, \theta_2) = Q_2 \left( \frac{p_2(\omega)}{P_2} \right)^{-\sigma} (p - \theta_2) \quad (1.18)$$

Firms choose a pricing strategy that maximizes their expected profit. The first order conditions for the firms' maximization problem are

$$\frac{n\phi'_{12}(p)f(\phi_{12})}{1 - F(\phi_{12})} + \frac{(n-1)\phi'_{11}(p)f(\phi_{11})}{1 - F(\phi_{11})} = \frac{\pi'_{11}}{\pi_{11}} \quad (1.19)$$

$$\frac{n\phi'_{11}(p)f(\phi_{11})}{1 - F(\phi_{11})} + \frac{(n-1)\phi'_{12}(p)f(\phi_{12})}{1 - F(\phi_{12})} = \frac{\pi'_{12}}{\pi_{12}}. \quad (1.20)$$

I define the hazard rate of the marginal cost distributions as

$$v_{11}(\phi_{11}) = \frac{f_{11}(\theta)}{1 - F_{11}(\theta)} \quad (1.21)$$

$$v_{12}(\phi_{12}) = \frac{f_{12}(\theta)}{1 - F_{12}(\theta)}. \quad (1.22)$$

Using this definition and combining equations (1.17) and (1.18) we can arrange the

first order conditions to yield the following ordinary differential equation system

$$\phi'_{11}(p) = \frac{1}{(2n-1)v(\phi_{11}(p))} \left( \frac{n}{p-\phi_{12}(p)} - \frac{n-1}{p-\phi_{11}(p)} - \frac{\sigma}{p} \right) \quad (1.23)$$

$$\phi'_{12}(p) = \frac{1}{(2n-1)v(\phi_{12}(p))} \left( \frac{n}{p-\phi_{11}(p)} - \frac{n-1}{p-\phi_{12}(p)} - \frac{\sigma}{p} \right). \quad (1.24)$$

I assume that firms draw their technology parameter from a bounded Pareto distribution

$$G(z) = \frac{1 - (z_{min}/z)^\alpha}{1 - (z_{min}/z_{max})^\alpha}, \quad (1.25)$$

where  $z_{min}$  is normalized to 1. Marginal costs of local firms in the home country and the foreign country are given respectively by

$$\theta_{11} = \frac{w}{zZ} \quad (1.26)$$

$$\theta_{12} = \frac{\tau w}{zZ}. \quad (1.27)$$

The country specific productivity  $Z$  and the nominal wage  $w$  are both normalized to 1 in the symmetric case and they are the same in the foreign country. Using the expression for the distribution function and the marginal costs, I find the the hazard rates for marginal cost distributions of local and foreign firms as

$$v_{11}(\theta) = \frac{\alpha\theta^{\alpha-1}}{(z_{max})^\alpha - \theta^\alpha} \quad (1.28)$$

$$v_{12}(\theta) = \frac{\alpha\theta^{\alpha-1}}{(\tau z_{max})^\alpha - \theta^\alpha}. \quad (1.29)$$

Equations (1.23) and (1.24) together with the hazard rates given by equations (1.28) and (1.29) describe the ordinary differential equations derived from the first order conditions. In order to solve this system of differential equations we need to find the boundary conditions. As noted in the text, the lower bound cannot be solved for

analytically but the upper bound can be computed. Using Lemma (3) from Maskin and Riley (2003) we can write the upper bound as a solution to the following problem

$$\bar{p} = \min\{\arg \max_p \pi(p, \bar{\theta}_1)(1 - F_2(p))\} \in (\bar{\theta}_1, \bar{\theta}_2), \quad (1.30)$$

when  $\bar{\theta}_1 < \bar{\theta}_2$ . Using the monopolistic profit function given in equation (1.17) and the marginal cost distribution we can write this problem as

$$\bar{p} = \min\{\arg \max_p Q_1 \left(\frac{p}{F_1}\right)^{-\sigma} (p - \bar{\theta}_1)(1 - F_2(p))\} \quad (1.31)$$

Given the parameters of the model, I solve the maximization problem above and compute the upper bound. However, the ordinary differential system described by equations(1.23) and (1.24) is ill behaved at this bound.  $\phi'_{12}(p)$  approaches infinity as  $p$  approaches the upper bound because at the upper bound price of a foreign firm is equal to its marginal cost,  $\theta = \bar{p}$ .

$$\lim_{p \rightarrow \bar{p}} \phi'_{12}(p) = \infty \quad (1.32)$$

Even after computing the upper bound, there is still no analytic solution to the differential equation system described above. Therefore, I solve it numerically using a shooting algorithm described in Section 3.

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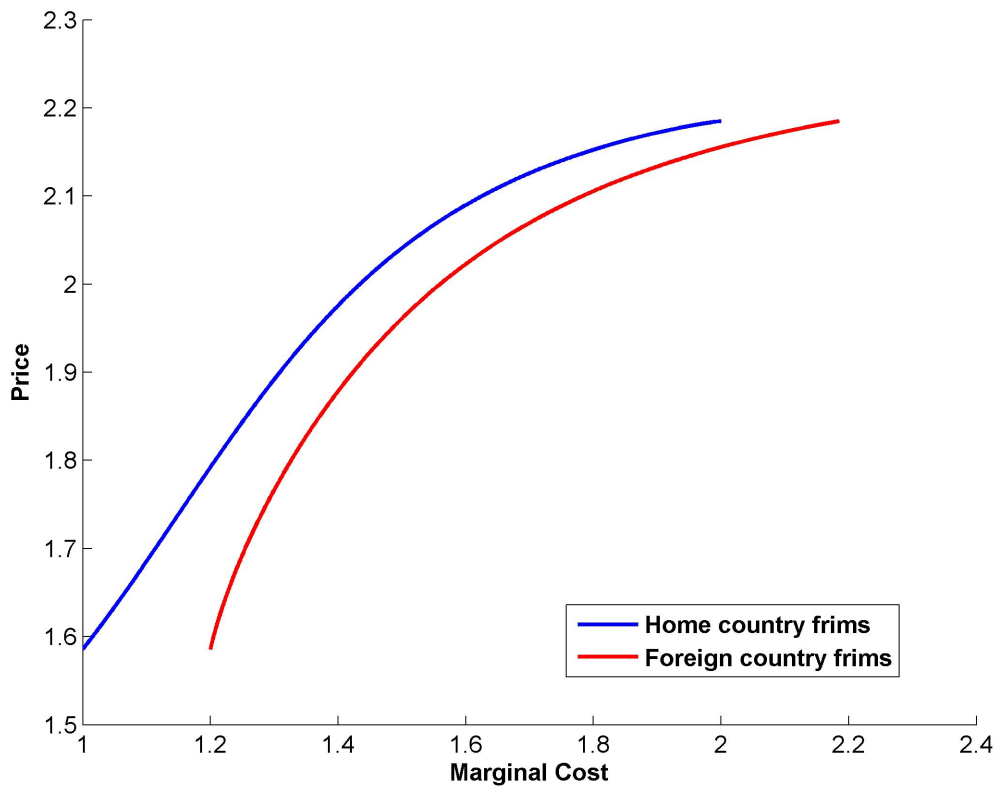


Figure 1.1: Pricing strategy of local and foreign firms in home country



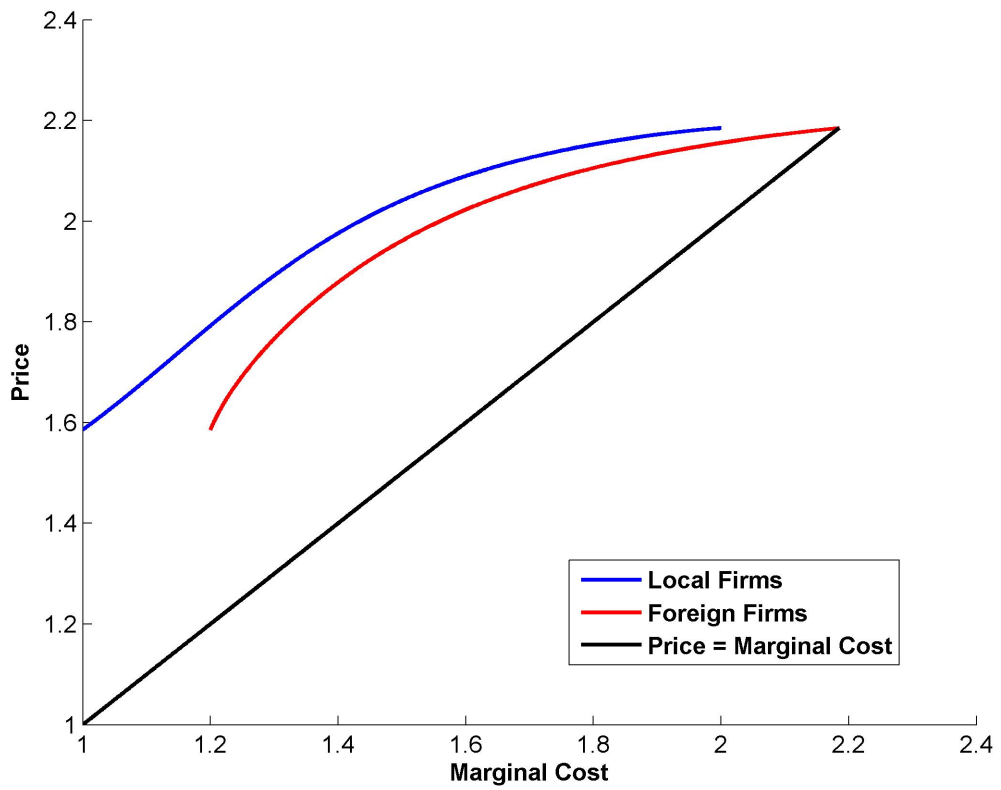


Figure 1.2: Distribution of markups across firms

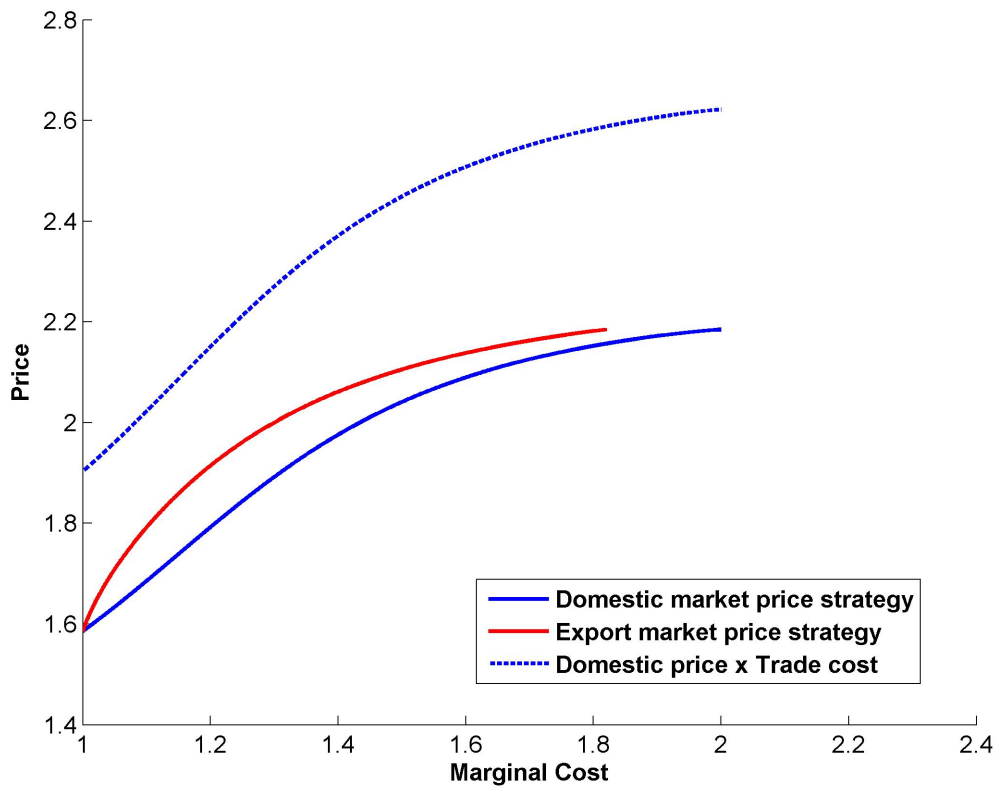


Figure 1.3: Home country firms' domestic and export pricing strategies

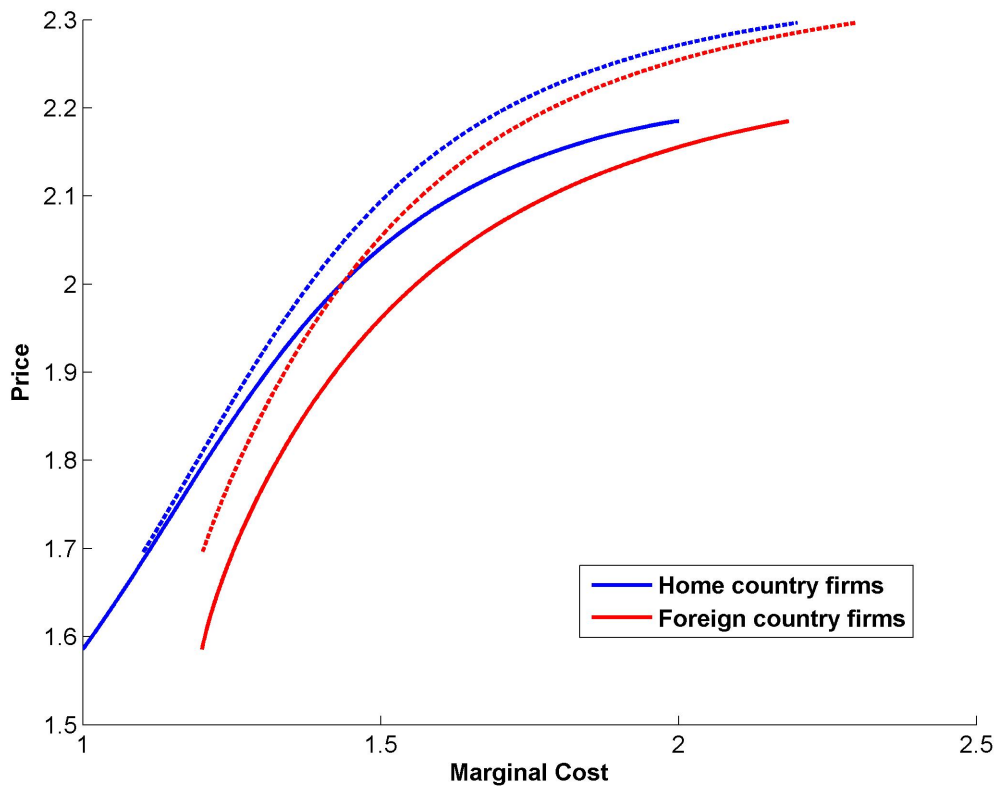


Figure 1.4: Pricing strategies in the domestic market after shock

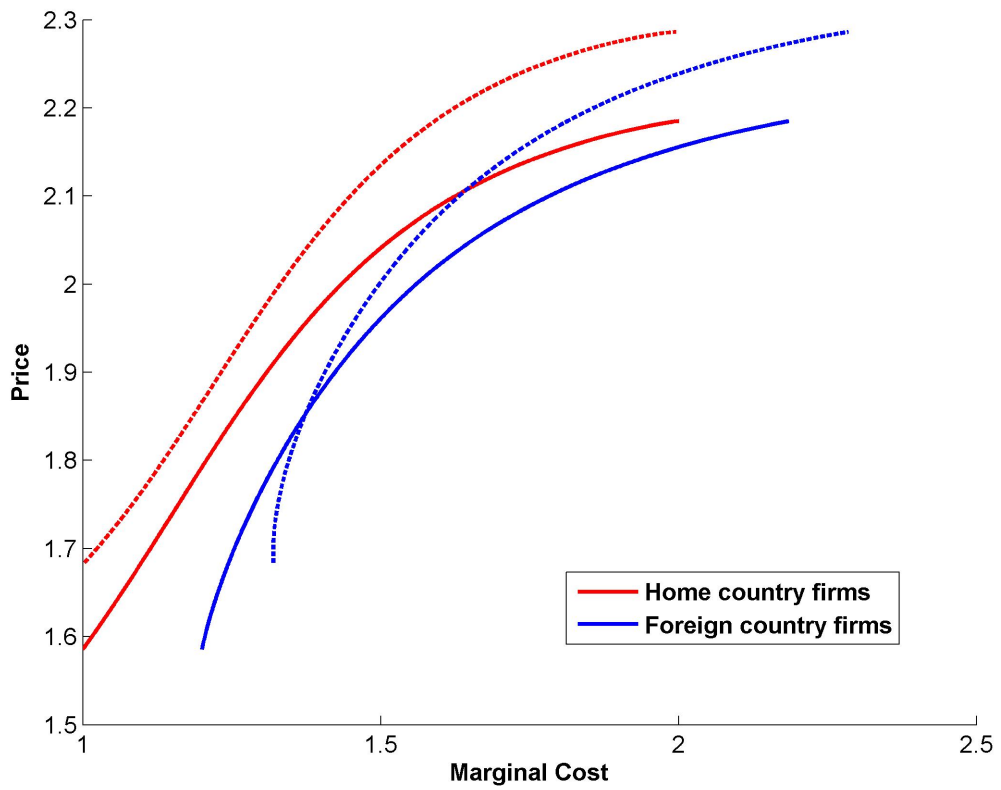


Figure 1.5: Pricing strategies in the foreign market after shock

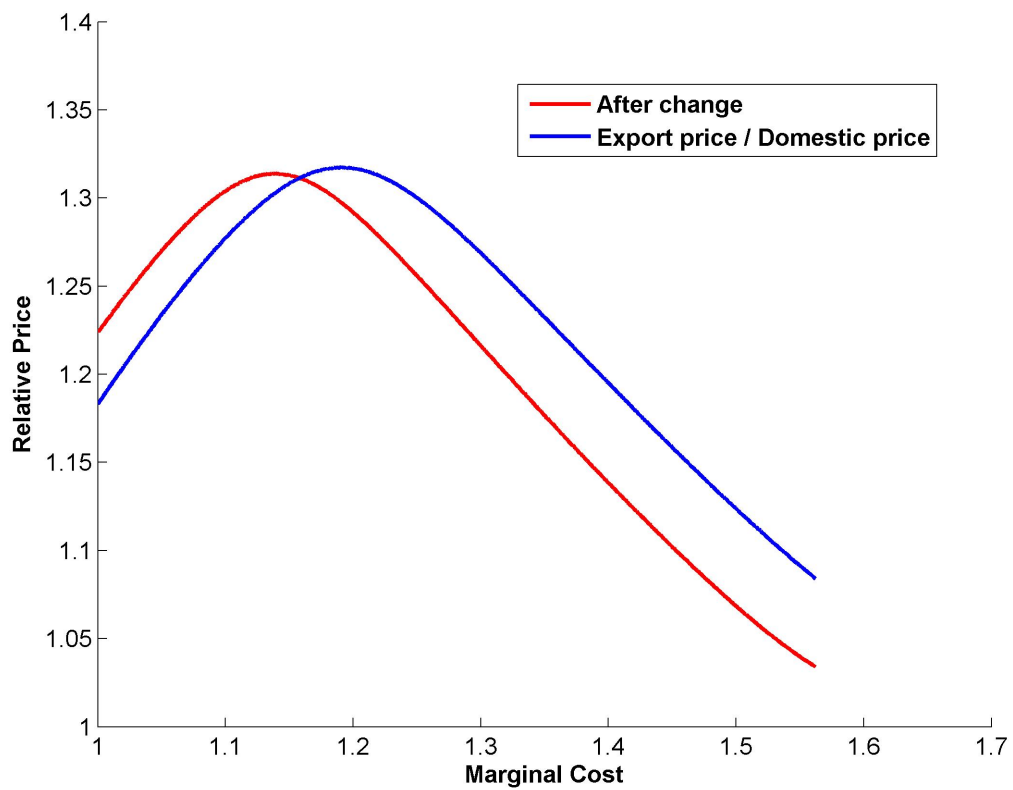


Figure 1.6: Distribution of export price change across firms

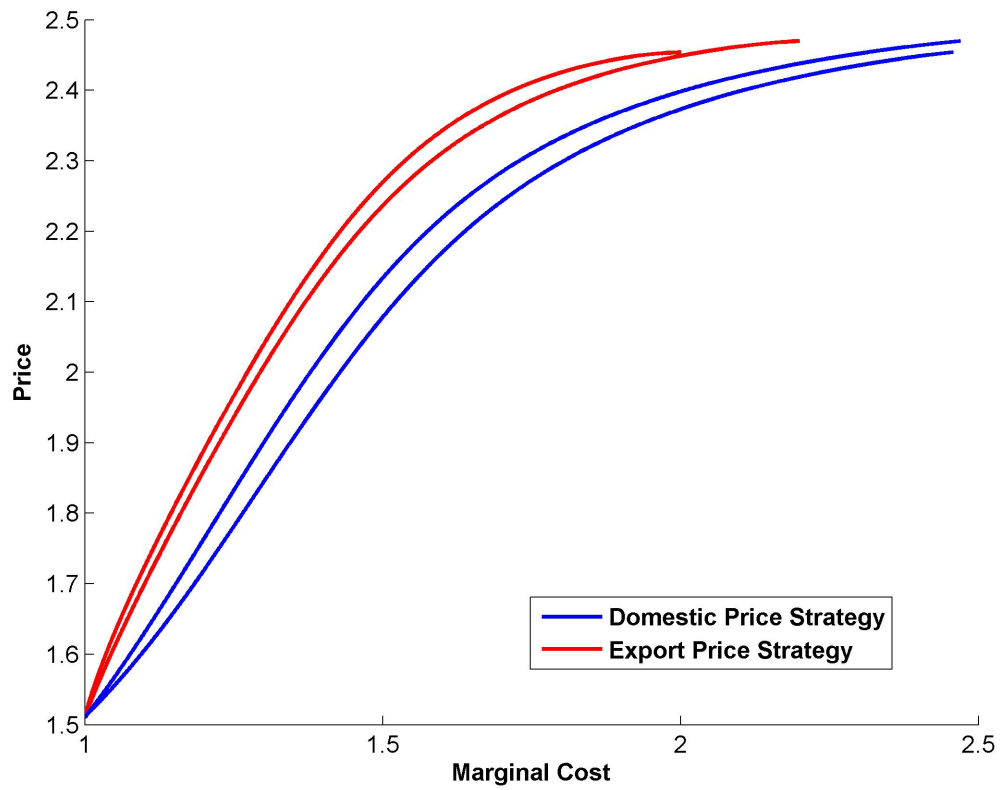


Figure 1.7: Changes in pricing strategies for a low level of elasticity of substitution

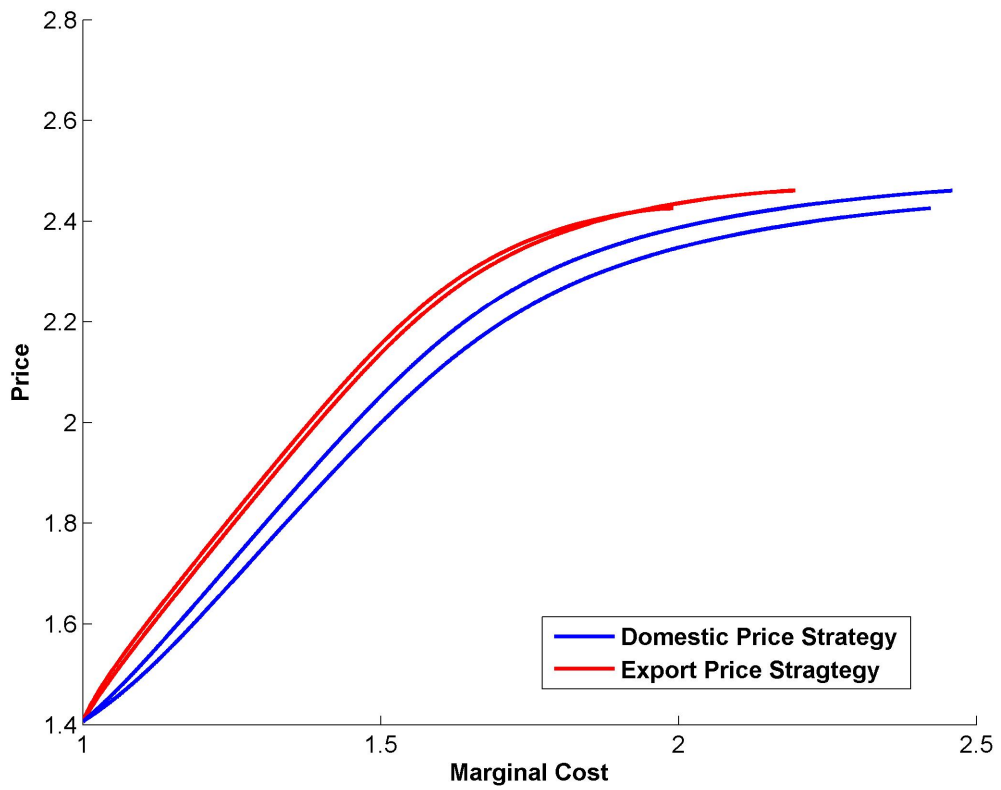


Figure 1.8: Changes in pricing strategies for a high level of elasticity of substitution

## Chapter 2

# Trade Costs and Microeconomic Price Dispersion

*joint work with Mario Crucini and Chris Telmer*

International trade costs fell between the U.S. and its trading partners over the period 1990-2005. We use this period to investigate how important trade costs are for understanding microeconomic international price dispersion. We develop a new dataset that links good-specific measures of trade costs — defined as explicit shipping costs plus customs duties — to good-specific measures of law-of-one-price deviations. We find that both trade costs and price dispersion fell by similar magnitudes over the 1990s. This is supportive of the basic trade-cost model. However, in contrast, price dispersion subsequently increased between 2000 and 2005 while trade costs did not. We rule out changes in city-specific ‘fixed-effects’ as being an explanation for the latter. Our basic message is that trade costs are empirically relevant but, not surprisingly, they are not the only game in town.

### 2.1 Introduction

Why are prices of similar goods different in different countries? A common answer is ‘trade costs:’ the multitude of costs incurred in bringing a good from its production location to the consumer. There are, of course, other answers. Non-traded input costs,



market segmentation, sticky prices and informational asymmetries are but a few. But trade costs have typically played a primary role in both models and measurement. Indeed, even models that don't emphasize trade costs often rely on them in one way or another. This paper develops a new dataset linking good-specific trade costs to good-specific international price dispersion. It examines the trade-cost model's most basic prediction: that if trade costs fall so should price dispersion.

To measure *absolute* trade costs is very challenging (see, for instance, Wincoop (2004)). The range of potential costs is large, ranging from tariffs to the costs of enforcing contracts. Our exercise is made more manageable by focusing on *changes* in a very narrow measure of trade costs. We examine the U.S. and its trading partners over the period 1990-2005, a period that saw the implementation of the North American Free Trade Agreement of 1994, which followed in the wake of the Canada-U.S. Free Trade Agreement of 1988. We define trade costs as explicit transport costs plus customs duties, what we'll label *shipping costs*. Following Bernard, Jensen and Schott (2006) — who argue that this data and time-period represent are useful for understanding the empirical relevance of the recent class of heterogeneous-firm trade models — we quantify the extent to which shipping costs fell. We then ask whether or not there was an associated decline in price dispersion. The extent to which there was is supportive of a shipping cost model. The extent to which there wasn't raises doubts. Of course, lots of other things may have changed. Our hope is that by documenting the joint behavior of shipping costs and price dispersion we can shed light on what else may or may not have been important.

Consistent with this, our findings are a mix of support for shipping costs and a hint of what else might be going on. We begin by showing that, not surprisingly, the decline in shipping costs was substantial. Between 1990 and 2000 the average good saw its shipping cost drop by about 1/3, from 15 to 10.5 percentage points. Between 2000 and 2005 the pattern is fairly flat. Price dispersion, in contrast, displays a U-

shape. Between 1990 and 2000 it fell (for the average good) by 9 percentage points — from about 0.50 to 0.41 — but then gave 3 of these points back by 2005. Bergin and Glick (2007) have documented a similar U-shaped pattern in price dispersion for a broader set of countries. Our results indicate that, for the U.S., the declining part of the U is qualitatively and quantitatively consistent with declining trade costs, but that the increasing part is not. Moreover, we develop a measure of the difference in non-traded input costs — time-variation in city-specific price dispersion effects — and show that it can account for almost none of the U-shape. Something happened in the period 2000-2005 that made price dispersion increase. It wasn't shipping costs and it wasn't city effects.

Our main point, then, is that the shipping cost model has some bite in terms of accounting for price dispersion, but that there's a lot more going on. A relatively large change in shipping costs — the NAFTA event — is correlated with a relatively large change in average price dispersion. This seems comforting for theory, much of which relies on shipping costs, either directly or indirectly. On the other hand, most of the *level* of the price dispersion that we see in the world cannot be associated with shipping costs and neither can the 2000-2005 *increase* associated with the U.S. and its trading partners.

The remainder of our paper is organized as follows. Section 2.2 describes our shipping cost and price dispersion data. Section 2.3 examines the trade cost data and documents the decline in average trade costs and dispersion around the average. Section 2.4 brings the trade cost data together at the good level with measures of price dispersion and presents our main results. Section 2.5 offers conclusions and directions for future work.

## 2.2 Data

### 2.2.1 Trade Costs

Our trade-cost data are annual, 1990-2005, on tariffs and transport costs for U.S. *imports*. We will use these data to evaluate LOP deviations between the U.S. and its trading partners, so we'd obviously like to have data on both import *and* export trade costs. The latter, however, are not available. We're therefore forced to assume that import and export trade costs are symmetric.

More specifically, we obtain annual data on U.S. imports, exports and tariffs from the U.S. International Trade Commission (USITC). The USITC provides data at varying levels of aggregation, according to industry classification systems. In order to match trade-cost data to our good-by-good price data, we use the level of least aggregation, the HTS10 classification. In many cases this allows for a good-specific match. For example, we have price data on the cost of 1 kilogram of tomatoes in both Houston and Mexico City. The HTS10 data allow us to compute trade costs on U.S. imports of tomatoes from Mexico.

For each country that exports into the U.S., the data are available for each good and year. We use the triplet  $(i, j, t)$  to denote good  $i$ , country  $j$  and year  $t$ . For each triplet we obtain the following three data items.

1. *FOB Customs Value:  $fob_{ijt}$* . The *free-on-board* customs value is the value of imports as appraised by the U.S. Customs Service. It is defined as the price actually paid or payable for merchandise, excluding U.S. import duties, freight, insurance, and other charges.
2. *CIF Import Value:  $cif_{ijt}$* . This is the *cost, insurance and freight* value, in U.S. dollars (USD), of goods at their first port of arrival. It is equal to 'import charges' plus 'customs value.' It excludes U.S. import duties.

3. *Calculated Duties:  $duties_{ijt}$ .* Duties are the (estimated) import duties collected. They are calculated based on the applicable rate(s) of duty as shown in the Harmonized Tariff Schedule.

The variables that we use in our analysis are computed as follows. The duty rate is denote  $d_{ijt}$ :

$$d_{it} = \frac{duties_{ijt}}{fob_{ijt}} .$$

The freight-and-insurance rate — the transport cost — is denoted  $f_{ijt}$ :

$$f_{ijt} = \frac{cif_{it}}{fob_{it}} - 1 .$$

The *ad valorem* trade cost, denoted  $\tau_{ijt}$ , is defined as the sum of the freight-and-insurance and duty rates:

$$\tau_{ijt} = d_{it} + f_{it} .$$

In some cases it will be useful to aggregate and compute industry-level trade costs. To do so we follow exactly the methodology of Bernard, Jensen and Schott (2006). They construct trade costs for goods defined at the 4-digit SIC level of aggregation based on U.S. import data, following Feenstra (1996). The rate for industry  $i$  is the weighted average rate across all products in  $i$ , using the import values from all source countries as weights. The concordance provided by Feenstra, Romalis, Schott (2002) is used to match products to four-digit SIC industries.

Finally, the USITC also provides good-by-good import shares. We use  $\gamma_{ijt}$ ,  $\sum_j \gamma_{ijt} = 1$ , for each  $i$  and  $t$ , to denote the import share for good  $i$ , country  $j$ , at date  $t$ . Note that our set of countries is smaller than the overall set provided by the USITC. However, we have verified that in all but a small number of cases U.S. imports originating from countries outside of our set of 78 source-countries are negligible.

## 2.2.2 Prices

The source of our micro-data on retail prices is the *Worldwide Cost of Living Survey* coordinated and compiled by the *Economist Intelligence Unit* (EIU). The target market for this data source are corporations seeking to determine compensation levels for employees residing in different cities around the world. While the goods and services reflect this objective to some extent, the sample is broadly representative of what would appear in the consumption basket of an urban consumer.<sup>1</sup> What makes the data attractive for research purposes is the fact that the prices are in absolute currency units and the survey is conducted by a single agency in a consistent manner over time. It also has a limited *intra*-national dimension, thus providing a useful contrast between domestic and international price dispersion.

More specifically, the EIU dataset consists of local-currency retail prices, inclusive of sales tax, on as many as 301 goods and services, sampled in 123 cities from 78 different countries. The data are annual, 1990-2005. The country with the most intranational observations is the U.S., with 16, followed by Australia, China and Germany with 5, Canada with 4, Saudi Arabia with 3, and Brazil, France, Italy, Russia, Spain, Switzerland, UK, India, Japan, Vietnam, New Zealand with 2. A number of recent papers have used this data, including Crucini and Shintani (2004), Engel and Rogers (2004), Parsley and Wei (2000) and Rogers (2002).<sup>2</sup>

We denote  $P_{ijt}$  as the local-currency price of good  $i$  in city  $j$  in year  $t$  and  $S_{jk,t}$  as the date  $t$  nominal exchange rate between cities  $j$  and  $k$ , in units of city  $k$  ( $S_{jk,t} = 1$  if cities  $j$  and  $k$  are in the same country). We transform prices into bilateral log

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<sup>1</sup>Rogers (2002) conducts an extensive comparison between the EIU data and data from national statistical agencies. He finds that the EIU data are broadly representative of what the consumer price index data tell us.

<sup>2</sup>See <http://bertha.tepper.cmu.edu/telmerc/eurostat> for a list of all goods-and-services and all cities

deviations from the law-of-one-price (LOP):<sup>3</sup>

$$q_{i,jk,t} = \log\left(\frac{P_{ij,t}S_{jk,t}}{P_{ik,t}}\right), \quad (2.1)$$

In words, these LOP deviations are the date  $t$  (log) prices of good  $i$  in city  $j$  in units of good  $i$  in city  $k$ .

Figure 2.5 shows estimates of the density function for  $q_{i,jk,t}$  for 1990, 1995, 2000 and 2005, for both international city-pairs and U.S. city-pairs (the graph is quite similar for intranational pairs more broadly). The graph shows that dispersion in good-by-good LOP deviations is large, and substantially larger once we include a wide array of international location-pairs.

Finally, we eliminate non-traded goods from our sample and construct a concordance to match goods with their respective measures of trade costs and U.S. import shares.

## 2.3 The Behavior of Trade Costs

Our trade cost data are  $\tau_{ijt}$ : the trade cost at date  $t$  for good  $i$  which the U.S. imports from country  $j$ . We use these data to compute a single trade cost per-good by taking a trade-weighted average across exporters:

$$\tau_{it} = \sum_{j=1}^M \gamma_{ijt} \tau_{ijt} ,$$

where  $\gamma_{ijt}$  is the share of total U.S. imports of good  $i$  which are received from country  $j$ . We compute the trade shares  $\gamma_{ijt}$  using the customs values data described in

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<sup>3</sup>A previous version of the paper employed an alternative LOP measure, the log deviation from the cross-city geometric average:  $\log(S_{jn,t}P_{ijt}) / \sum_{j=1}^M \log(S_{jn,t}P_{ijt})$  where  $M$  denotes the total number of cities and  $n$  denotes the numeraire currency in units of which all prices are expressed (our measures of price dispersion are independent of the choice of the numeraire currency). While this definition results in lower overall LOP variability (by construction), the main message of our paper remains unchanged.

Section 2.2. The number of countries we average across,  $M$ , is 78. However U.S. imports are almost always highly concentrated among sources, with the top source typically accounting for more than half of all imports. This is demonstrated by Figure 2.5, which plots the cumulative import share for the average good,  $i$ . The graph shows that the top 5 importers typically account for more than 90% of all imports. Figure ?? supplements this information by asking “how much of all this trade comes from Canada and Mexico? The answer is a lot, but not that much. While there are many goods where the vast majority of the imports come from Canada or Mexico, this is not the case for the median good, where 80% of imports come from other countries.

Turning to the trade costs, Figure 2.5 plots the trade-weighted, cross-good average for the years 1990-2005:

$$\tau_t = \sum_{i=1}^N \sum_{j=1}^M \gamma_{ijt} \tau_{ijt} / N$$

We see what will be an important trend for our entire paper; average trade costs on U.S. imports declined from roughly 15% in 1990 to roughly 10% in 2005. This seems substantial. However there’s a lot going on in the cross-section as well. Figure 2.5 shows the distribution of declines in trade costs across all 243 goods. While the average good saw a decline of 5 percentage points, there are a number of goods with declines in the neighborhood of 20 percentage points. There are also goods with increases in trade costs, but none over 10 percentage points. A important goal of our paper is to exploit this variation in the cross-section.

## 2.4 Trade Costs and Price Dispersion

For many goods, trade costs have declined. What has been the associated change in price dispersion for consumer goods?

Recall that our price data are  $q_{i,jk,t}$ , the (log) LOP deviation for good  $i$  between

cities  $j$  and  $k$  at date  $t$ . Before examining how these things are related to trade costs we'd like to strip-away other determinants of price dispersion. Since our data are on retail goods, a leading candidate is the differential cost of non-traded inputs such as labor, rent and so on. As a proxy for these things we use city-specific averages. That is, we transform the data as

$$\hat{q}_{i,jk,t} = q_{i,jk,t} - \mu_{jk,t} \text{ ,}$$

where  $\mu_{jk,t}$  is the date- $t$  average LOP deviation (across all goods  $i$ ) between cities  $j$  and  $k$ . Implicit in this calculation is the assumption that non-traded input costs vary across cities but not across goods within a city. For notational simplicity, we omit the 'hat' hereafter, so that  $q_{i,jk,t}$  is understood to be the LOP deviation exclusive of city-effects.

Next, our trade-cost data exist at the country level, not the city level. We therefore average across U.S. city pairs to arrive at one LOP deviation per country, vis-a-vis the U.S..<sup>4</sup> This further re-defines  $q_{i,jk,t}$  so that  $jk$  refers to *countries*, not cities, with  $j$  always being the U.S.. Finally, as we did with the trade cost data, we compute a single measure of price dispersion *per-good* by taking a trade-share-weighted average across locations:

$$q_{it} = \sum_{jk} \gamma_{i,jk,t} |q_{i,jk,t}| \text{ ,} \tag{2.2}$$

where summing over  $jk$ , in this instance, is to be understood as summing across

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<sup>4</sup>More specifically, we proceed as follows. We have data on 16 U.S. cities. For cases in which the data are limited to only one city for the non-U.S. country, we simply average across the U.S. city pairs. For example, for Mexico the only city we have is Mexico City. So  $q_{i,j,t}$  is the average LOP deviation (for good  $i$  at date  $t$ ) taken across 16 bilateral pairs of U.S. cities and Mexico City. For cases in which there is more than one non U.S. city, we match each U.S. city with it's foreign counterpart which is geographically nearest. We then average across the 16 U.S.-non-U.S. city pairs. For example, for Canada-U.S. we match Seattle with Vancouver, Cleveland with Toronto, and so on. This results in 16 bilateral pairs which we then take the average of.



U.S.-foreign country pairs, not city pairs. Note that, since we sum over the absolute values,  $q_{it}$  is a measure of average price *dispersion* between the U.S. and its trading partners for good  $i$ .

Figure 2.5 plots the cross-good average of  $q_{it}$  for each time period. The solid line is inclusive of our measure on non-traded input costs and the dashed line removes them. We see that the net effect is not large, with between 4 and 6 percentage points being attributable to the city effects.

Figure 2.5 brings together our measures of trade costs and price dispersion and makes our paper's main point. The blue line (left scale) is the average level of trade costs, reproduced from Figure 2.5. The red line (right scale) is the average level of price dispersion, net of our measure of non-traded input costs, reproduced from Figure 2.5. It is important to take note of the difference in the left and right scale. If they were the same, then tradecosts would 'explain' all of price dispersion! But they are not. The price dispersion scale is roughly 4 times larger than the tradecosts scale. Three quarters of the average level of price dispersion in our data cannot be accounted for by the combination of tradecosts and (our measure of) non-traded input costs.

The main point of Figure 2.5 is simple. The first half of the 1990s saw substantial declines in explicit trade costs between the U.S. and its trading partners. Price dispersion followed suit, and the magnitude of the *change* was comparable. However, in the latter half of the 90s and the first five years of the ensuing decade price dispersion seems to have rebounded, giving back about half of what it lost, and this increase seems disassociated with trade costs. As mentioned above, this U-shape in price dispersion has also been documented for a broader set of countries by Bergin and Glick (2007). What we show is that, for the U.S., the declining part of the U is qualitatively and quantitatively consistent with declining trade costs, but that the increasing part is not. Moreover, changes in non-traded cost differentials can explain only a very small amount of the increase (see Figure 2.5).

## 2.5 Conclusion

The most rudimentary model of why the prices of similar goods are different in different locations is the *iceberg shipping cost model*. It predicts that the price in the consumption location will be greater than that in the production location by a proportion that represents the resources required to physically move the good. Many more realistic and sophisticated theories exist, yet the shipping-cost model still plays an important role either directly or indirectly.

We ask whether there is empirical support for the shipping cost model by exploiting new data on absolute measures of good-by-good price dispersion as they relate to associated measures in *changes* in shipping costs. We (heroically) assume that, between the U.S. and its trading partners, *differences* in the myriad of non-shipping-cost reasons for price dispersion did not change over the period 1990-2005. This assumption leads to our null hypothesis: if shipping costs declined then price dispersion should have declined. We do not reject the hypothesis for the years 1990-2000 but, because of an *increase* in price dispersion between 2000 and 2005, we do reject it for these latter years. We view this evidence as being mildly encouraging for the trade-cost model, yet at the same time pointing in useful directions for understanding price dispersion in the broader context in which it obviously must be viewed.

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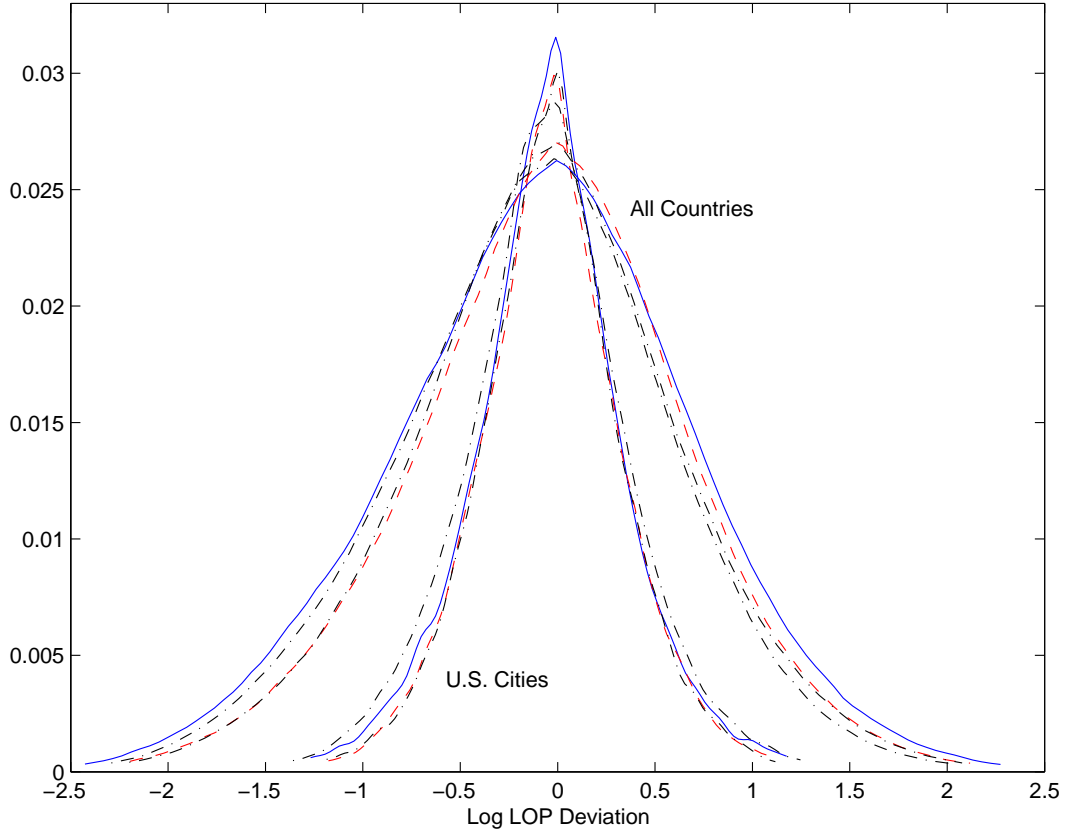
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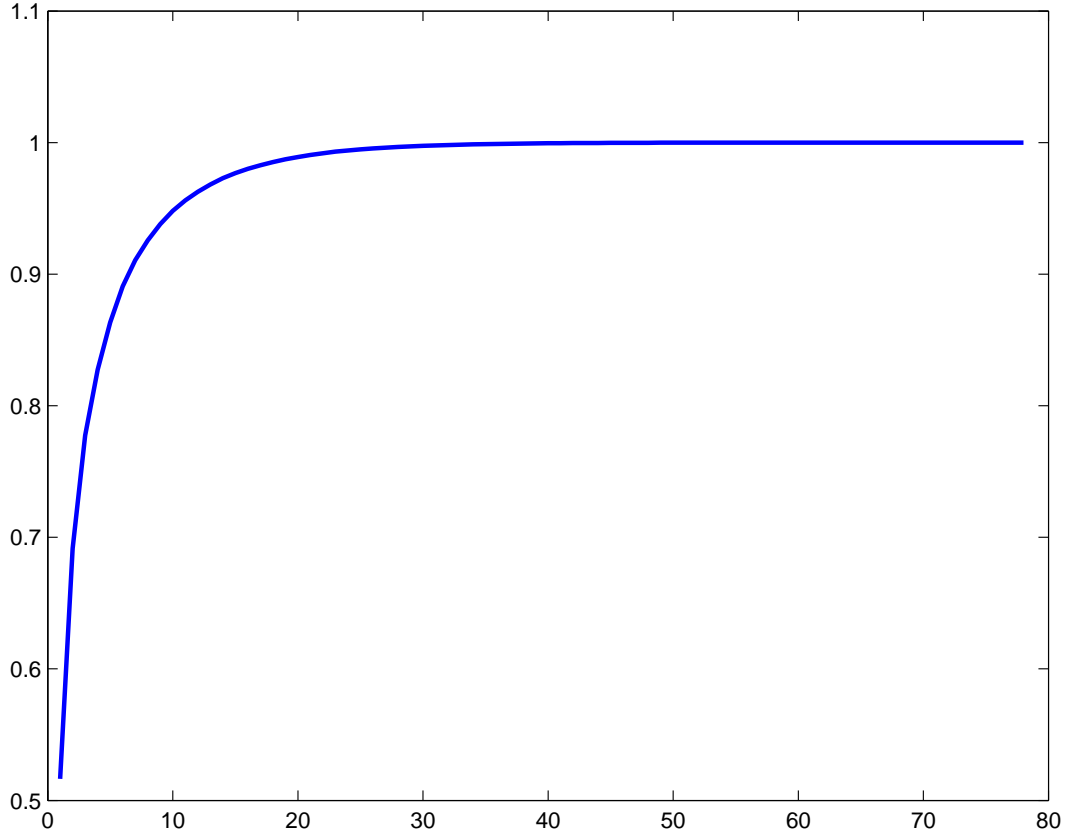


**Figure 2.1: Distribution of LOP Deviations**

Density of log LOP deviations across (i) U.S. and Canadian location-pairs, and (ii) all location-pairs. The densities describe variation in  $q_{i,jk,t}$  across goods  $i$  and location-pairs  $jk$ , where  $q_{i,jk,t}$  is computed as

$$q_{i,jk,t} = \log\left(\frac{P_{ij,t}S_{jk,t}}{P_{ik,t}}\right),$$

and  $P$  and  $S$  are local-currency prices and the nominal exchange rate. For each set of cities there are four lines:  $t = 1990, 1995, 2000$  and  $2005$ .

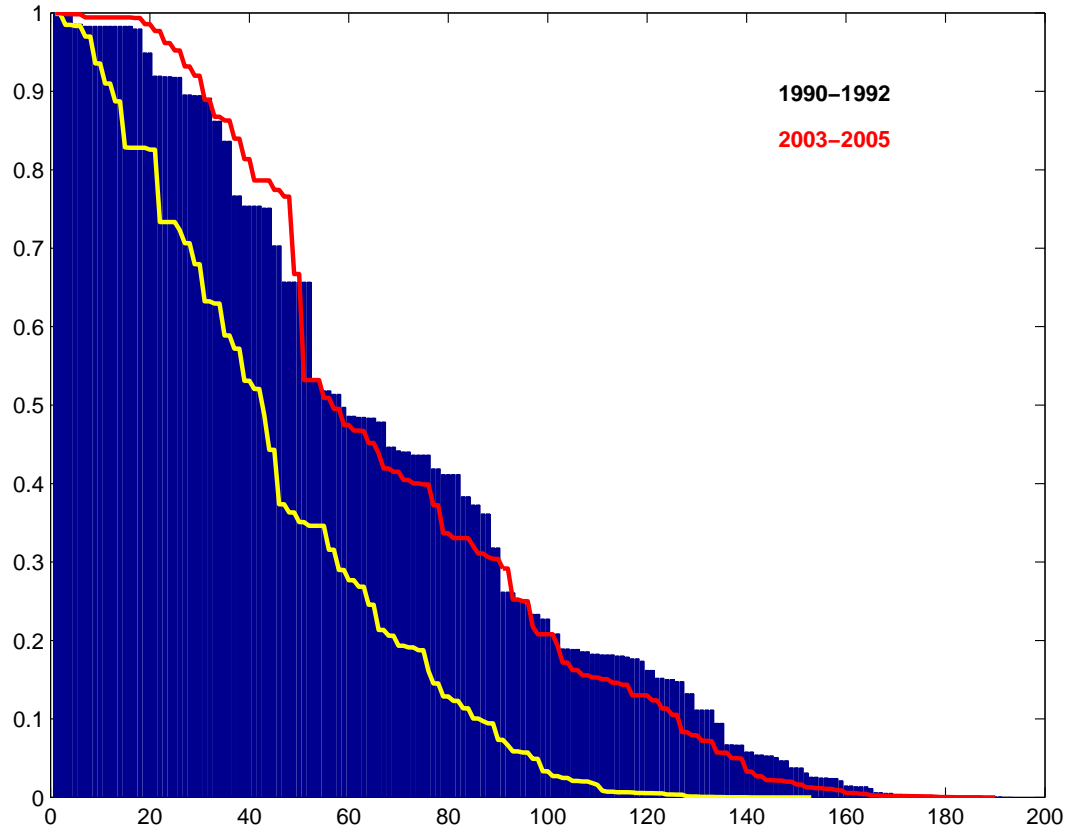


**Figure 2.2: Concentration of U.S. Importers**

The graph plots the average (across goods) cumulative trade share, where the cumulation is across importers ranked from largest to smallest. More specifically, for the  $i^{th}$  good, the trade share (defined in the text) is  $\gamma_{ijt}$ . This is the fraction of total U.S. imports received from country  $j$  at date  $t$ . The  $m^{th}$  cumulative trade share for good  $i$  is  $\sum_{j=1}^m \gamma_{ijt}$ , where the countries in the summation are ranked from largest import source (for good  $i$ ) to smallest import source. The  $m^{th}$  observation in the graph is this summation averaged across goods:

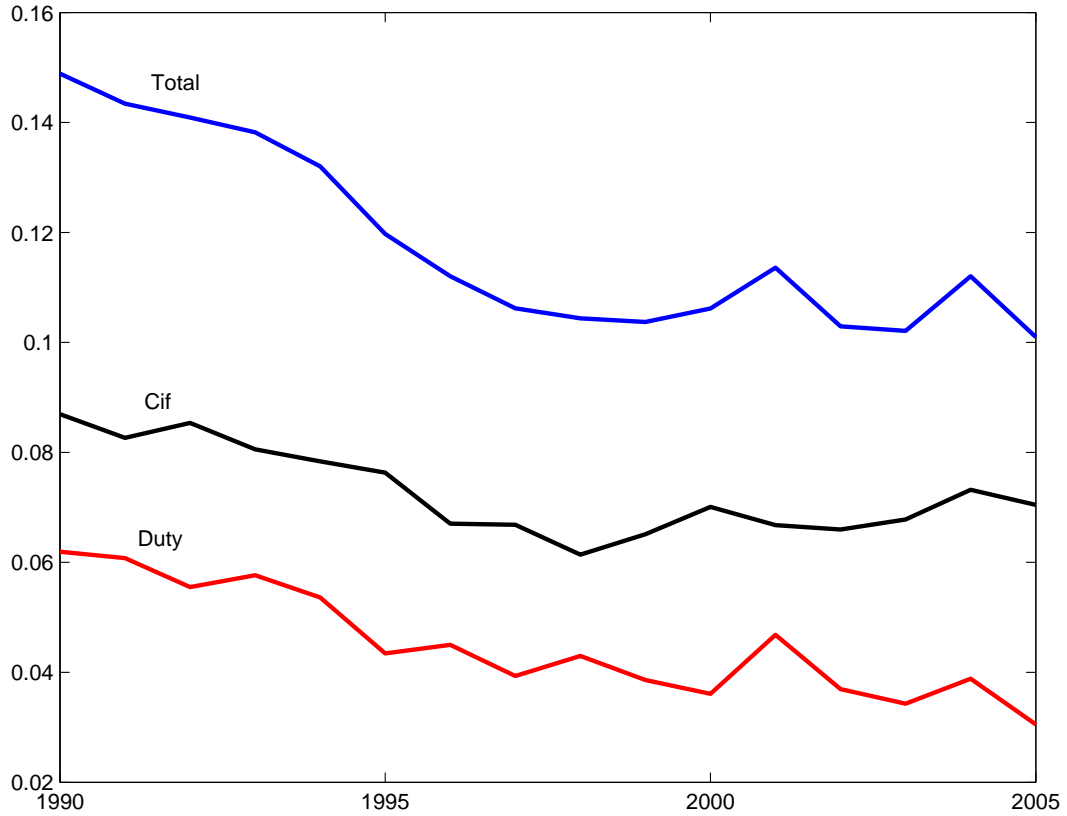
$$\sum_{i=1}^N \sum_{j=1}^m \gamma_{ijt} / N .$$

So, on average, the top exporter supplies just over 50% of all U.S. imports. The top 5 supply more than 90%.



**Figure 2.3: Fraction of Imports from Canada or Mexico**

The horizontal axis represents goods. The vertical axis represents the fraction of U.S. imports, for each good, that comes from the combination of Canada and Mexico. The goods are ordered, starting from the left, from largest Canada-Mexico import share to smallest. The blue area is averaged over all years, 1990-2005. The yellow and red lines, respectively, correspond to 1990-1992 and 2003-2005. The point of the graph is that, while there are some goods that are almost exclusively imported from either Canada or Mexico, this is not true on average. For the median good 80% of U.S. imports arise from outside of North America. Over time, the Canada-Mexico share has grown.

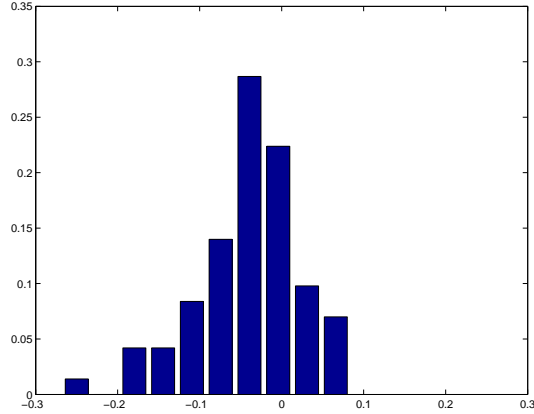


**Figure 2.4: Average Trade Costs**

The trade cost for good  $i$  between the U.S. and country  $j$  at date  $t$  is described in Section 2.2 and defined as  $\tau_{ijt}$ . The import share is similarly described and defined as  $\gamma_{ijt}$ , where  $\sum_j \gamma_{ijt} = 1$ . This graph reports the average (across goods) trade-weighted trade cost for each date  $t$ :

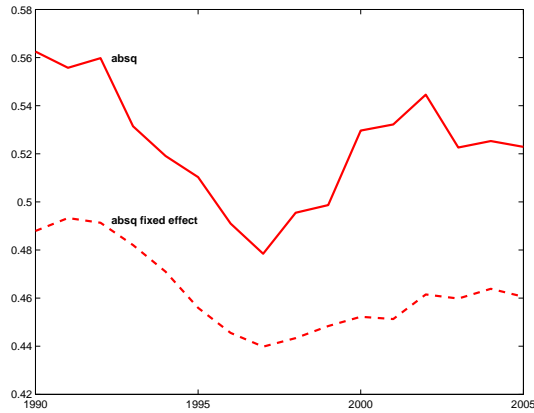
$$\tau_t = \sum_{i=1}^N \sum_{j=1}^M \gamma_{ijt} \tau_{ijt} / N$$

The total number of goods is  $N = 243$ . The total number of countries is  $M = 78$ . For most goods the U.S. imports from only a small set of the total number of countries, so that the vast majority of the weights  $\gamma_{ijt}$  are zero. The concentration of U.S. import sources is discussed in more detail in Section 2.3.



**Figure 2.5: Dispersion of Declines in Trade Costs**

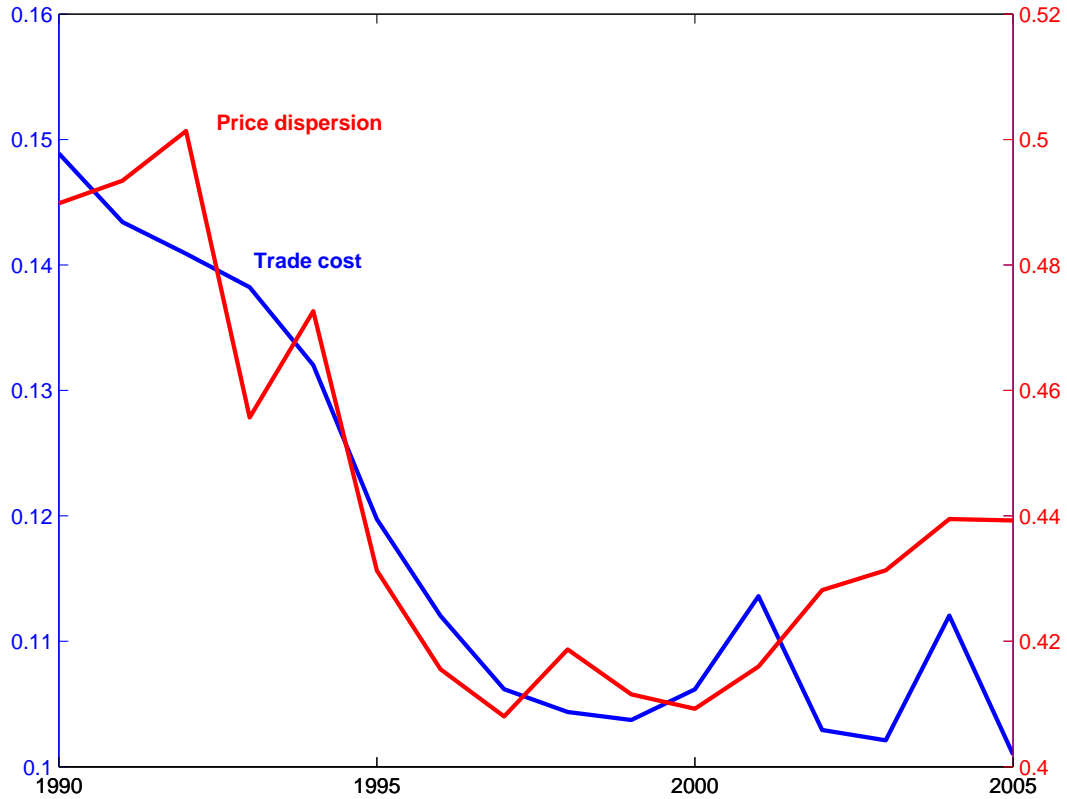
Histogram of the percentage decline in trade costs over the period 1990-2005 for each of the 243 goods in our sample. The mean, median and standard deviation are  $-0.0435$ ,  $-0.0386$  and  $0.0623$  respectively.



**Figure 2.6: Average Price Dispersion**

Plot of the cross-good average measure of price dispersion defined in equation (2.2). Specifically, each data point is  $q_t = \sum_i q_{it}/M$ , for  $M = 243$  goods,  $q_{it} = \sum_{jk} \gamma_{i,jk,t} |q_{i,jk,t}|$  is the trade-weighted measure of price dispersion for good  $i$  defined in equation ((2.2) of Section 2.3, and  $q_{i,jk,t}$  is the LOP deviation for good  $i$  at date  $t$  between cities  $j$  and  $k$ . The dashed line controls for differences in non-traded input cost whereas the solid line does not.





**Figure 2.7: Price Dispersion and Trade Costs**

The blue line (left scale) is the average level of trade costs, reproduced from Figure 2.5. The red line (right scale) is the average level of price dispersion, net of our measure of non-traded input costs, reproduced from Figure 2.5. It is important to take note of the difference in the left and right scale. If they were the same, then tradecosts would ‘explain’ all of price dispersion! But they are not. The price dispersion scale is roughly 4 times larger than the tradecosts scale. Three quarters of the average level of price dispersion in our data cannot be accounted for by the combination of tradecosts and (our measure of) non-traded input costs.

# Chapter 3

## Why are International Prices Diverging?

The early 1990s was a period of substantial fall in trade costs. During the following period 1997-2005, trade costs remained low, basically unchanged, however, average price dispersion between US and its trading partners increased. Why did the relative price of traded goods increase? In this paper, I build on the observation that in the second half of the 1990s, both labor and total factor productivity growth accelerated in the U.S. as a result of investments in information and communication technologies, while it decelerated or stagnated in Europe and Japan. This productivity difference was especially important in the retail sector. van Ark et al. (2002) report that the labor productivity growth was three times faster in the US retail sector, while in the EU it only increased by thirty percent. I show to what extent an international macro model that includes a retail sector calibrated to fit this productivity data can reproduce the divergence we observe in international prices of tradable consumption goods in the second half of the 1990s.

### 3.1 Introduction

During the second half of the 1990s, labor and total factor productivity (TFP) accelerated in the United States but not in most other major economies. In the same time period, international price dispersion between U.S. and its trading partners increased substantially. This paper raises the question whether the two facts could be related.

International price differentials raise a lot of interest among economist since their existence contradicts the most basic prediction of the standard trade model, known as the Law-of-One-Price. In this paper, I try to understand the price differences of individual consumption goods. According to the standard theory these price differences has to move one-to-one with the associated trade costs. However, recent research shows that these price differences can fluctuate independently of the changes in trade costs.

This paper studies a specific time period where trade costs did not change much while the price differences among individual goods in different countries have in-

creased. In order to explain the divergence in international prices, I formulate a general equilibrium model which features differences in distribution sectors in different countries. I show that, to the extent that the productivity levels in distribution sectors are different, prices of same goods can be different in the two countries.

This type of models are not new in the literature, however, the novelty here comes from the nature of the quantitative exercise conducted. I bring together two stylized facts during a specific time period. The change in microeconomic price dispersion and the substantial widening of the differences in the retail sector productivity between the US and Europe over 1990s. I calibrate the proposed model using the data described in detail in the following sections and show that the increase in price dispersion can indeed be attributed to the increase in productivity differentials.

The increase in price dispersion between US and Europe is documented by Bergin and Glick (2007) and Crucini, Imamoglu and Telmer (2006). Both studies show that there was a decrease in price dispersion in the early 1990s but it was mostly offset after 1995 when prices started diverging. Although the initial decrease in the price dispersion can be attributed to the corresponding decrease in trade costs during this time period, there is no explanation yet offered for what caused the prices to diverge after 1995.

There is a large class of studies that document the acceleration in TFP in the United States after mid-1990s. van Ark et al. (2002) shows that both labor productivity and total productivity growth accelerated in the U.S. while it decelerated in Europe and Japan. Jorgenson and Stiroh (2000) examine the acceleration in the US in further detail while Foster, Haltiwanger and Krizan (2002) study TFP growth in the retail industry specifically.

The role of distribution services in determining international relative prices have been studied widely in the literature. Burstein, Neves, Rebelo (2002) documents the extent of distributive margin in retail prices for the US and Argentina and its importance for real exchange rate fluctuations. Corsetti and Dedola (2005) develop a model, similar to the one studied here, in which differences in distribution sectors across countries imply incomplete exchange rate pass-through. Corsetti, Dedola and Leduc (2008) studies the real exchange rate fluctuations extending this model. Anderson and Wincoop (2004) estimates the distribution costs and documents their importance for trade flows accross countries.

In this paper, I try to demonstrate whether the acceleration in labor productivity in the U.S. might have caused the observed divergence in international prices. First, I document the changes in labor productivity and TFP in the U.S. and other major economies such as U.K., France, Germany and Japan. Second, I document the evidence for the increase in relative prices. Thirdly, I build and calibrate an international macro model which features a retail sector to analyze how much of the change in relative micro prices can be attributed to fluctuations in retail sector productivity.

## 3.2 Stylized Facts

In this section, I document two stylized facts. First one is that during the second half of the 1990s, there was a substantial gap in the labor productivity growth between US and some of the major economies in Europe. Second, the consumer prices in US and Europe have diverged during the same time period.

### 3.2.1 Labor and Total Factor Productivity in the U.S. and Europe

A large class of studies has documented the acceleration in the total factor productivity of the U.S. over the second half of the 1990s. Basu et al. (2003) report the TFP growth at the industry level. Table 3.1 summarizes their findings for the time period 1990–2000.

Table 3.1: U.S.: Total Factor Productivity Growth by Industry in Private Non-Farm Business

	Productivity (Value Added)	
	pre-1995	post-1995
Private Non-Farm Economy	0.91	2.08
Manufacturing	2.40	2.76
Wholesale Trade	1.66	5.37
Retail Trade	0.83	5.33
Finance and Insurance	0.44	3.39
Business Services and Real Estate	1.12	0.40

As the table shows, the acceleration in retail and wholesale sectors are very large. Retail sector value added average annual TFP growth was 0.83 before 1995 but has increased to 5.33 after 1995. This high acceleration is attributed to the increase in using information and communication technologies (ICT). In the retail sector, this period of time in the US witnessed introduction of scanners and electronic cashiers as well as computerized supply management. These technologies allowed emergence and development of big chain retailers what's now known as "The Wal-Mart Revolution".

What was going on in Europe? Table 3.2 shows the TFP growth in the United Kingdom over the same time period. There is a deceleration in the retail TFP growth as well as in the overall economy. The gap is partially explained by a lag in using the ICT in Europe but why such a lag had occurred is still not very clear. However, in this paper, I will focus on the gap between the TFP growths specifically in the retail sector.

Labor productivity shows a similar pattern, especially for the retail and wholesale industries. Table 3.3 shows the average annual growth rate of labor productivity for periods 1990–1995 and 1995–2000 using OECD data.<sup>1</sup> the labor productivity in the retail sector in US grew three times faster over the second half of the 1990s than over

<sup>1</sup>Source: van Ark et al. (2002)

Table 3.2: U.K.: Total Factor Productivity Growth by Industry in Private Non-Farm Business

	Productivity (Value Added)	
	pre-1995	post-1995
Private Non-Farm Economy	2.56	1.25
Manufacturing	3.03	1.42
Wholesale Trade	3.44	3.71
Retail Trade	0.73	-1.17
Finance and Insurance	1.89	3.87
Business Services and Real Estate	1.13	0.99

the first half. The deceleration in Europe as a whole can be seen in the first column. Canada on the other hand shows a pattern similar to the US while Japan also has experienced a productivity slow down in the second half of this time period.

Table 3.3: Labor Productivity Growth

Period	Sector	EU	US	UK	Canada	Japan	France	Germany
1990-1995	Wholesale	2.9	3.4	4.9	3.7	2	2.9	3.1
	Retail	1.1	2.3	2.6	1.1	0	1.3	0.2
1995-2000	Wholesale	1.2	6.1	0.4	2.9	0.2	1.6	-0.3
	Retail	1.4	6.9	3.5	2.9	-2.7	0.9	-0.2

### 3.2.2 Price Dispersion

I use price data obtained from the *Worldwide Cost of Living Survey* coordinated and compiled by the Economist Intelligence Unit (EIU). Figure 3.1 shows the price dispersion among U.S. and the major European economies.<sup>2</sup> Price dispersion is computed as the trade weighted average of absolute relative prices across 243 tradable goods over the period 1990–2005. In the figure, there was a notable decrease in the price dispersion over the first half of the 1990s. However, this decrease is more than offset by the increase after 1995.

Bergin and Glick (2007) documents a similar U shape in the price dispersion among US and the rest of the world and relate the increase in the price dispersion in the second half of the 1990s to the increase in the oil prices. While the increase in oil prices might have caused an increase in the trade costs, there is no evidence for it in the data. In fact, Crucini, Imamoglu and Telmer (2006) document trade costs directly measured at the port of entry as the sum of tariffs and shipping costs as a fraction of the value of goods shipped, and they find no evidence of an increase.

Figure 3.2 shows the trade weighted average of trade costs associated with importing goods from the three European countries together with the changes in price

<sup>2</sup>See list in Appendix.

dispersion. It is clear from the figure that the divergence of prices in the second half of the 1990s was not caused by an increase in trade costs. In fact, trade costs continued decreasing during this time period.

Figure 3.3 shows the case of Canada. The decrease in price dispersion continued in Canada over the second half of the 1990s unlike in Europe. As Table 3.3 shows, the productivity pattern is very similar between Canada and US as well.

### 3.3 The Model

I develop a model where two countries produce and trade a continuum of goods in the international markets. My aim is to study the effects of a temporary productivity gain in the distribution sector on international relative prices. There are two countries in the economy, home and foreign. Each country specializes in production of different sets of goods. There are no fixed costs in the economy, therefore, all goods are traded except for the distribution services which are not tradable. These services can only be consumed whenever a tradable good is consumed and not otherwise. Below, I describe the environment in the home country. The environment in the foreign country is symmetric.

Households: Preferences of the representative consumer over an aggregate final consumption good  $C$  and labor,  $l$ , are defined by the following function

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \log[C_t^\mu (1 - l_t)^{1-\mu}] \quad (3.1)$$

where  $\beta$  is the discount factor. I assume that the consumers in both countries trade a complete set of assets, i.e. there is complete risk sharing between the two countries. The solution to consumers' utility maximization problem yields the following first order conditions

$$\frac{1 - \mu}{\mu} \frac{C_t}{1 - l_t} = \frac{W_t}{P_t} \quad (3.2)$$

$$\frac{C_t^*}{C_t} = \frac{P_t}{P_t^*} \quad (3.3)$$

where  $W_t$  denotes the wage rate and  $P_t$  is the price of the aggregate consumption good. Foreign variables are denoted by an asterisk. These first order conditions hold at every point in time in both countries. For simplicity of notation, I will drop the time subscript while describing the economy from now on.

The aggregate consumption good is defined by the following function

$$C = \left[ \int_{\omega \in \Omega} c(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \quad (3.4)$$

where  $c(\omega)$  is the amount of good  $\omega$  consumed, and  $\Omega$  is the set of goods available in home country. Parameter  $\sigma$  determines the elasticity of substitution across goods.

Let  $p(\omega)$  denote the price of good  $\omega$ . Then the consumption based price index in home country is

$$P = \left[ \int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}, \quad (3.5)$$

and the demand for good  $\omega$  is

$$c(\omega) = C \left( \frac{p(\omega)}{P} \right)^{-\sigma}. \quad (3.6)$$

Production: There are two sectors in the economy, a tradables sector and a distribution sector. The tradables sector produces the goods that are traded in domestic and foreign markets. The distribution sector transforms these tradables into final consumption goods available to be purchased by local consumers. Both sectors use labor as input which is supplied by the households. The firm specific labor demand is denoted by  $l_T$  and  $l_D$  in the tradables sector and the distribution sector, respectively. Labor in both sectors is paid the common wage rate  $W$ . Below, I describe the production technologies available in each sector.

There is a continuum of firms in the tradables sector. Each firm produces a different variety,  $\omega$  and these varieties are imperfect substitutes. In order to produce one unit of output,  $1/Z_T$  units of labor is needed. Here,  $Z_T$  denotes the productivity in the tradables sector and is country specific. Output is given by

$$y_T(\omega) = Z_T l_T(\omega). \quad (3.7)$$

There is a continuum of firms in the distribution sector that provides the necessary services for varieties to be transformed into a final consumption good. The production technology is linear in labor and it is described by the following production function:

$$y_D(\omega) = Z_D l_D(\omega), \quad (3.8)$$

where  $Z_D$  is the productivity level in the distribution sector. I model the only input needed in this sector as labor.<sup>3</sup> Here,  $y_D$  represents the services needed to transform tradables into final consumption goods. In order to transform one unit of tradables into a unit consumption good  $\eta$  units of distribution services is needed. Therefore demand for the distribution services is  $\eta c(\omega)$ .

Therefore the retail price of a good,  $p(\omega)$  is composed of the producer price and the cost of distribution services.

$$p(\omega) = p_T(\omega) + \eta p_D(\omega) \quad (3.9)$$

The demand for a tradable good depends on its retail price observed by the con-

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<sup>3</sup>as in Atkeson and Burstein (2008).

sumers. Hence, the demand for tradable good  $\omega$  is

$$c(\omega) = C \left( \frac{p_T + \eta p_D}{P} \right)^{-\sigma}. \quad (3.10)$$

Given the demand function (3.10), profit maximization implies that the producer price for tradables,  $p_T(\omega)$ , is a constant markup over the unit cost and is given by the following expressions in home market and in foreign market respectively:

$$p_T(\omega) = \frac{\sigma}{\sigma - 1} \left( 1 + \frac{\eta}{1 - \sigma} \frac{Z_T}{Z_D} \right) \frac{W}{Z_T} \quad (3.11)$$

$$p_T^*(\omega) = \frac{\sigma}{\sigma - 1} \left( 1 + \frac{\eta}{1 - \sigma} \frac{W^* Z_T}{W Z_D^*} \right) \frac{\tau W}{Z_T}. \quad (3.12)$$

Notice that the markup in this model is not the same as the standard monopolistic competition models without distribution costs. The distribution sector not only places a wedge between the producer price and the consumer price but also affects the producer price directly. International relative producer prices, then, will be different than unity. Denoting all foreign variables by asterisk, it follows from (3.9) and (3.11) that the ratio of producer price of good  $\omega$  in foreign country to home country is

$$\rho_T(\omega) = \frac{p_T^*(\omega)}{p_T(\omega)} = \tau \left( 1 + \frac{\eta}{\sigma} \frac{W^* Z_T}{W Z_D^*} \right). \quad (3.13)$$

where  $\tau$  is the iceberg type trade cost. The relative price will be affected by shocks to productivity in the tradables sector in the home country as well as shocks to the distribution sector in the foreign country.

The retail price of good  $\omega$  in home and foreign country are given respectively by

$$p(\omega) = \frac{\sigma}{\sigma - 1} \left( 1 + \eta \frac{\sigma}{1 - \sigma} \frac{Z_T}{Z_D} \right) \frac{W}{Z_T} \quad (3.14)$$

$$p^*(\omega) = \frac{\sigma}{\sigma - 1} \left( 1 + \eta \frac{\sigma}{1 - \sigma} \frac{W^* Z_T}{W Z_D^*} \right) \frac{\tau W}{Z_T}. \quad (3.15)$$

The retail prices of traded goods depend on both the producer prices and the price of the distribution services. Therefore, a shock to the distribution services affects the retail prices from two channels, a direct one and an indirect one.

### 3.4 General Equilibrium

In this paper, I solve for a static general equilibrium at every time point given the realizations of the productivity parameters and changes in trade costs. In doing so, I solve a fixed point problem at every time point as described below.

Taking the aggregate variables  $W$ ,  $P$  and  $C$  as given and normalizing  $W^*$  to 1, I find the wholesale and retail prices of tradable goods using (3.11), (3.12), (3.14) and



(3.15). The aggregate price index is then given by (3.5). The quantities produced for each consumption good  $\omega$  is given by (3.10). Using (3.7) and (3.8), I find the total labor demand by adding up the implied labor demand for tradables and distribution services in the economy. I find a fixed point for the variables  $(C, C^*P, P^*, W)$  where the first order conditions given by (3.2) and (3.3) in both countries are satisfied.

### 3.4.1 Characterization of Equilibrium

Given the shocks to productivity and trade costs  $(Z_{Tt}, Z_{Dt}, \tau_t)$ , the equilibrium is the set of allocations and prices  $(C_t, C_t^*, l_{Dt}, l_{Tt}, l_{Dt}^*, l_{Tt}^*, P_t, P_t^*, W_t, W_t^*)$  that satisfy the home and foreign consumers' optimality conditions, maximize firm profits and satisfy the labor and good market clearing conditions.

## 3.5 Quantification

Here, I present a plausibly parameterized version of the model and show that it can reproduce the observed fluctuations in the price dispersion between US and its main trading partners as cited above. Specifically, I show that, in response to exogenous shocks to aggregate productivity in the distribution sector across countries, this model implies an increase in the overall price dispersion across countries.

### 3.5.1 Parameters

The two parameters that characterizes the utility function, the discount factor  $\beta$  and the share of leisure  $\mu$  are set to their standard values in the real business cycles literature,  $\beta = 0.96$  and  $\mu = 2/3$ . The elasticity of substitution  $\sigma$  is set to 3.6. This is a value used in many studies in international trade literature that yields plausible markups in the range of 20 – 40%.

The share of distribution services is the most important parameter in this paper. It directly affects the impact of changes in distribution productivity on the wholesale and retail price. The higher the share of distribution services, the more important are the productivity differences across countries. Burstein, Neves and Rebelo (2000) report this value for US to be at least as high as 42%. Anderson and van Wincoop (2004) estimate it to be as high as 50% and finally Basu et. al. (2002) measure it at 60%. Here, I set the benchmark value to be 60% and test the sensitivity of the results later on.

The labor productivity in the distribution sector is calibrated to fit the empirical facts cited in Section 3.2. In order to match the observed price dispersion levels I set the initial relative productivity between the US and Europe to be  $Z_D/Z_D^* = 2.7$ . That is I assume that the labor in the retail sector in the US was, on average, nearly 3 times more productive than the labor in European retail sector. Then during the period 1990-1995 and 1995-2000 labor productivity differences grew over time as summarized in Table 3.4. The percentages indicate the average annual growth over the specified time periods.

Table 3.4: Labor Productivity Growth

	Europe	United States
1990-1995	1.1%	2.3%
1995-2000	1.4%	6.9%

The trade cost parameter  $\tau$  is calibrated using the data from the second chapter of this thesis which is micro data on tariffs and shipping costs obtained from the US International Trade Commission.<sup>4</sup> Between Europe and the US, over the time period 1990-2000, the average trade cost was 13.5%. Figure 3.2 shows the level of trade costs for each period in time.

Taking the parameter values described above as given, and using the productivity differences and trade cost levels at each time period I solve for the static general equilibrium at every point in time. The results of my calculations are summarized below.

### 3.6 Results

The implied price dispersion generated by the model for the time period 1990–2000 is depicted in Figure 3.4 along with the change in trade costs. During the first half of the 1990s, labor productivity differences between the US and Europe are small and this implies small increases in the price dispersion. However, as the figure shows, trade costs during this period are declining. Overall, the model implies almost no change in price dispersion during this period. This result is mostly due to the fact that the trade costs did not decrease significantly throughout this period.

The second half of 1990s is different. Although the trade costs are still declining through this period, the implied price dispersion increases. The reason for this increase is the fast productivity growth in the retail sector in the US relative to Europe. From 1995 to 2000, the model implies an increase in price dispersion of about 4 percentage points.

Figure 3.5 shows the actual price dispersion during the 1990s and the model’s predictions. The model underpredicts the decline in price dispersion in the first half of the 1990s. The decline in trade costs is not enough to account for this decline. However, the model’s predictions in the second half of the time period is broadly consistent with that of the data.

### 3.7 Conclusion

In this paper, I formulated a model of international trade where distribution services plays an important role in consumption of tradable goods. I showed that the differences between the retail sectors that provide these services are important for determining international price dispersion across countries.

<sup>4</sup>For details see Section 2.2.

I documented the labor productivity differences in the retail sector for a broad set of countries. I showed that the labor productivity in the US has accelerated over the second half of the 1990s much faster than its major trading countries. I also showed evidence that over the same time period, price dispersion between US and its trading partners has significantly increased.

I used the data presented to plausibly calibrate the model and solve for the general equilibrium and implied price dispersion. The model's predictions are consistent with an increase in the price dispersion in the second half of the 1990s. The observed productivity differentials do indeed imply an increase in price differences of individual goods across countries.

In this paper, I abstracted from all other possible differences across countries such as productivity differences in manufacturing sector, or cost of inputs. The model can easily be extended to include these features. The model also has desirable implications for examining aggregate price differences across countries.<sup>5</sup> These are not presented here as they are beyond the purpose of this paper but can be exploited in future studies.

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<sup>5</sup>See Corsetti and Dedola (2005).

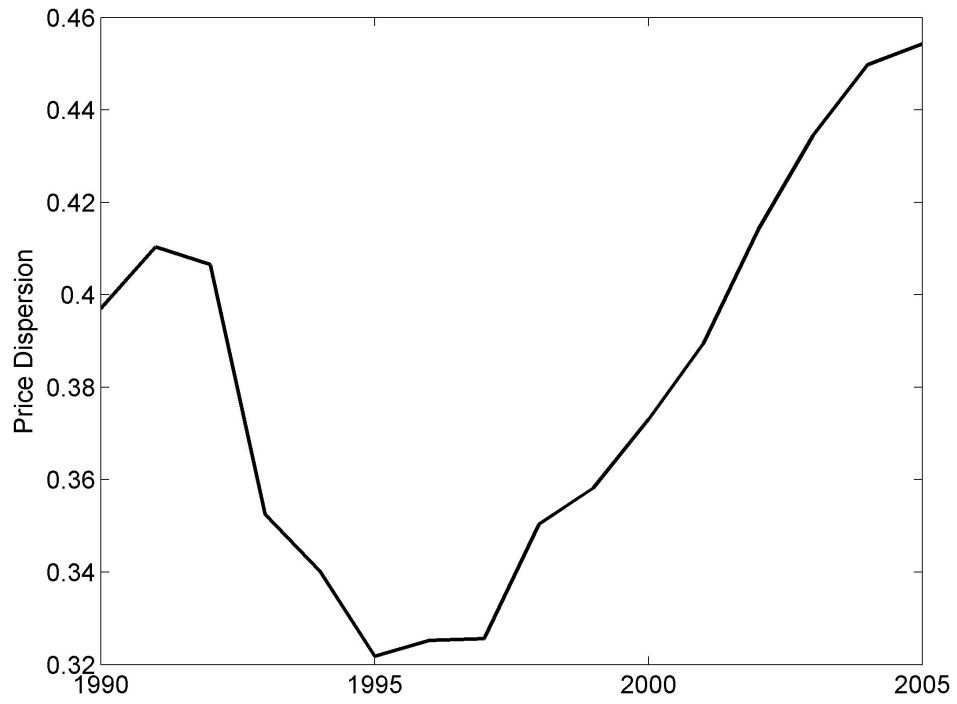
## 3.A Appendix

List of countries included in the EU is as follows:

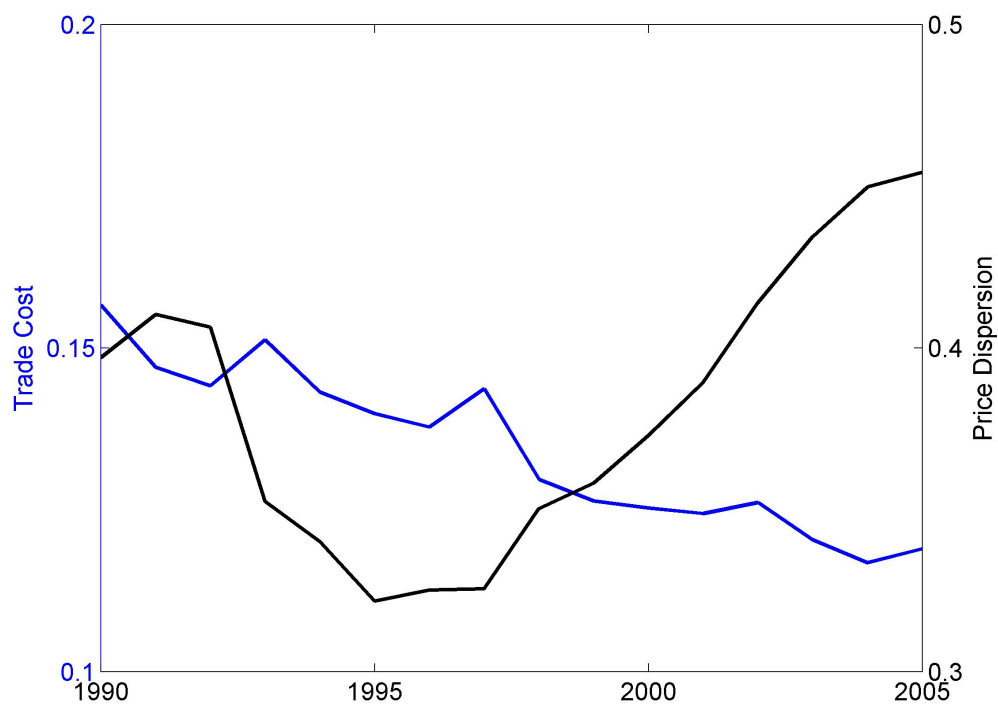
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Italy  
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United Kingdom

## References

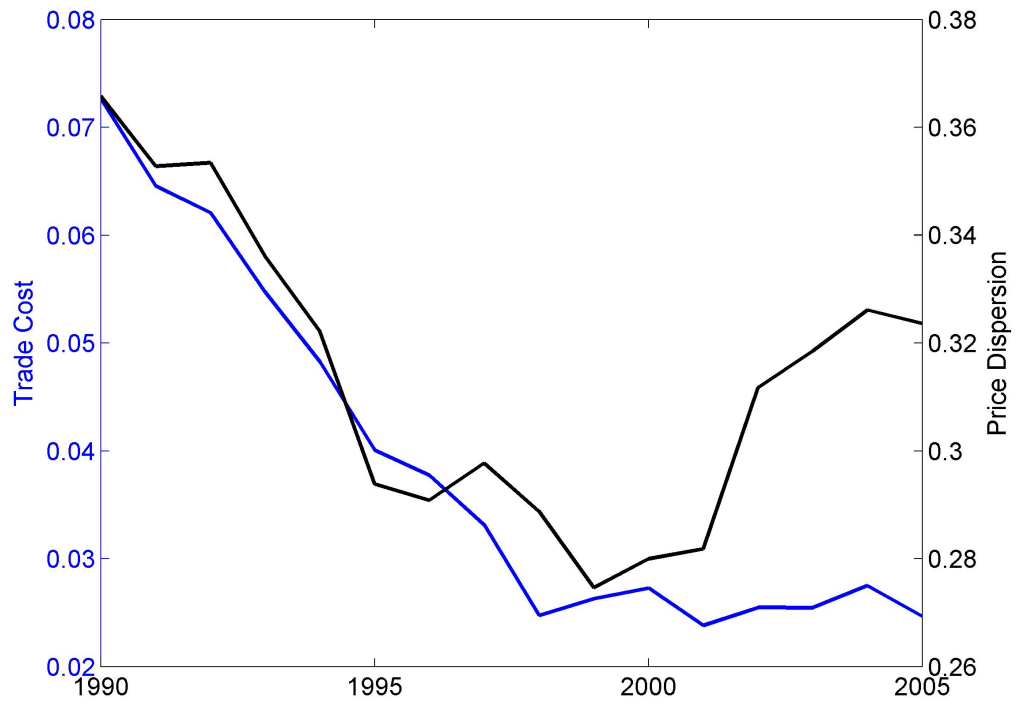
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**Figure 3.1: Average (across goods) price dispersion between US and Europe**



**Figure 3.2: Average cost of imports and price dispersion between U.S. and Europe**



**Figure 3.3: Average cost of imports and price dispersion between US and Canada**



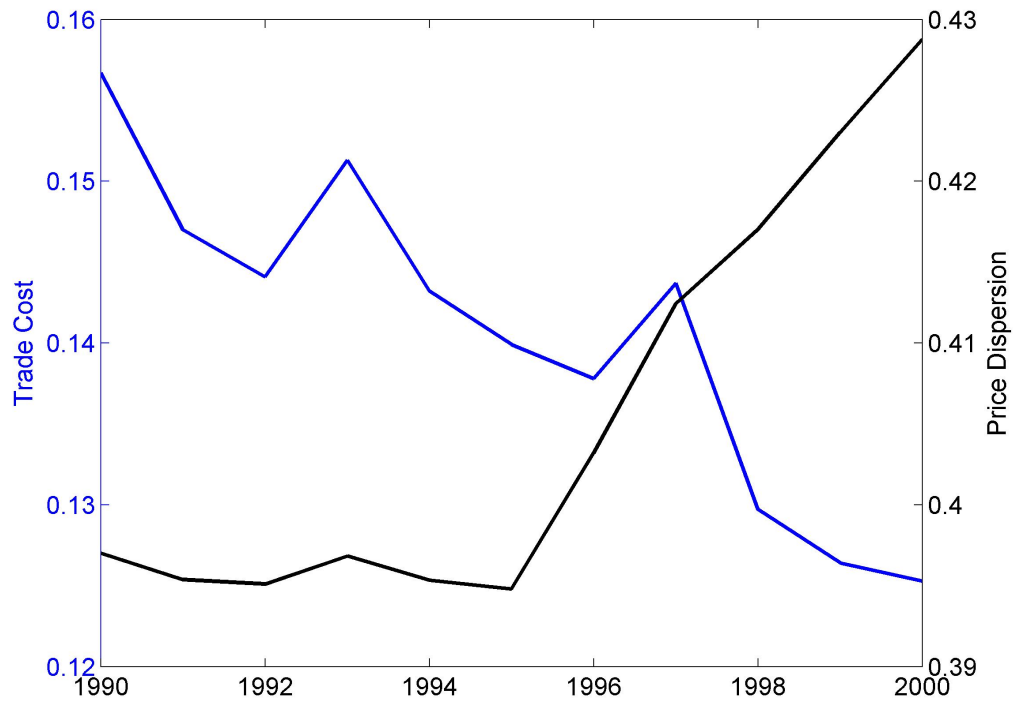
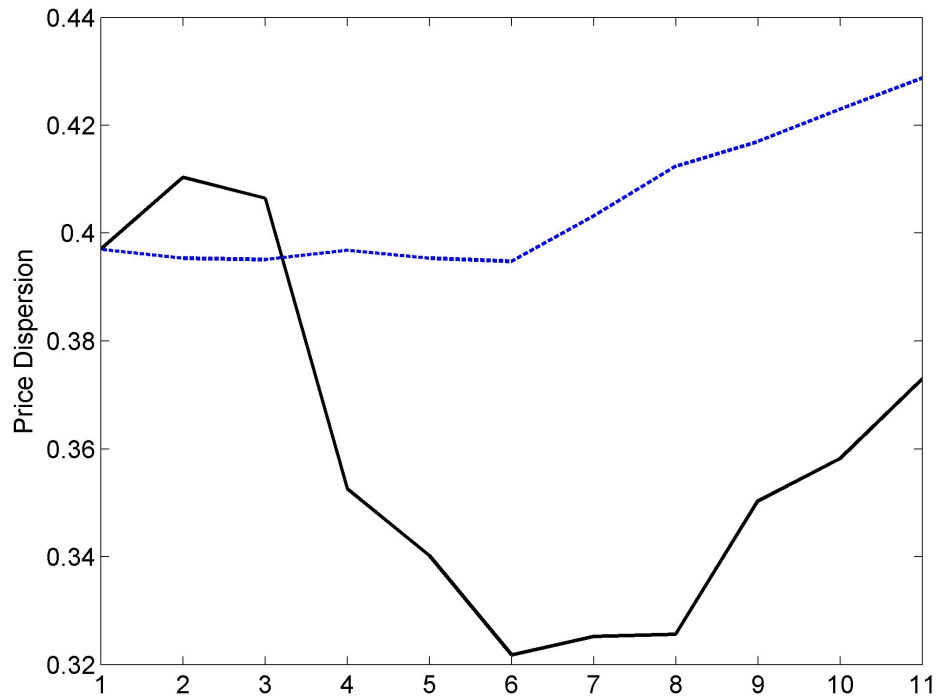


Figure 3.4: Simulated price dispersion and trade costs



**Figure 3.5: Average (across goods) price dispersion between US and Europe**

The dash line represents the simulated price dispersion and the solid black line represents the actual average price dispersion. The x-axis shows the number of years of simulation.