

International Trade in a model of Sales with Sails: Theory and Empirics

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Abstract

Why does relative firm performance fluctuate so much across international markets? The existing literature models such fluctuations as firm-product -market level draws from an exogenous distribution. In contrast this paper provides an equilibrium model of the observed variation based on a model of “sales”. In a symmetric model of “sales”, firms will randomize their prices in equilibrium, generating fluctuations in relative performance. It is shown that the incentive to randomize prices persists in an environment of heterogeneity in terms of firm costs (e.g. transport costs - “sails”). This implies that the lowest cost firm won’t necessarily be the lowest priced firm in a market and consequently won’t necessarily have the best relative performance when observed at any point in time. Hence, price dispersion and intra distributional mobility are predictions of this framework. For US import prices, it is found that price dispersion is an important characteristic for a substantial fraction of imported products. For these goods, the aggregate distribution of prices appear to be stable overtime, but there are large fluctuations in the location of countries inside these distributions.

Key Words: International Trade, price dispersion.

JEL Classifications: F13.

1 Introduction

The inclusion of firm level heterogeneity into open economy models is increasingly seen as a necessary component of any analysis of international trade and its subsequent implications. These models imply important and persistent differences not only between exporters and non-exporters, but also among the firms that export within the same industry.¹ Essentially the relative advantages that the best firms possess should be apparent in both the domestic market and also any foreign market. However, recent empirical results suggest that the basic source of heterogeneity is not at the firm level, instead heterogeneity in performance can be found at the firm-product-destination market level. In short firm level characteristics are not sufficient to predict the relative performance of firms from any given country in any given foreign market (i.e. some firms perform relatively well in some markets but not others).² To date these intriguing results have been modeled as firms taking independent draws for each potential market, with entry only occurring for sufficiently favorable realizations. While this seems like a relatively natural extension of the central mechanism in the firm heterogeneity literature, it does imply a critical difference in terms of intra-firm price dispersion. Whereas firm level heterogeneity only implies within firm price dispersion across markets in the transport cost inclusive price, market specific shocks in either demand or supply generally lead to price dispersion that is in excess of transport costs.³

A natural question relates to the mechanism that enables this price dispersion to persist. If the differences in price across markets are in excess of transport costs, then arbitrage opportunities exist that should be exploited over time.⁴ This implies that models based on exogenous draws can only provide a static or partial explanation of relative performance. The goal of this paper is to model differences in relative performance as an equilibrium outcome. The starting point is the model of sales in Varian (1980).⁵ A key aspect of this model is that in equilibrium firms choose to randomize their prices. As a model of price dispersion this has a natural advantage over models that involve pure strategies since the persistence of price dispersion over time in pure strategy models is unlikely as consumers eventually learn the identity of the low priced firms. However, by employing

¹See for example Balistreri, Hillberry, and Rutherford (2008), Bernard, Schott, and Redding (2006), Bombardini (2008), Melitz (2003) and Yeaple (2005)

²For aggregate evidence based on French firms see Eaton, Kortum, and Kramarz (2009). For product level evidence for Danish firms see Munch and Nguyen (2008).

³Using a CES demand structure does not generate this result since the price will be proportional to marginal costs (inclusive of transport costs). Critically the factor of proportionality depends on the constant elasticity of demand, which is independent of demand or supply side shocks. While this assumption is convenient, it seems less plausible in the context of substantial differences in relative performance across markets.

⁴Another possible explanation is price discrimination. See Ganslandt and Maskus (2007) for an example of third degree price discrimination in an international context.

⁵For an overview of the evolution of the subsequent and associated literature see Baye, Morgan, and Scholten (2006).

a mixed strategy a firm does not maintain the same price through time, instead firms randomize their price. This also provides a mechanism for the persistence of price dispersion as no firm is consistently the lowest priced. The randomization of prices also leads to stochastic performance by firms. Hence, no one firm will consistently perform better than another. To date these results have been established for settings with symmetric firms. In this paper it is shown that they carry over to a setting in which firms are asymmetric. This is particularly important in an international context given the prominent role of transport costs (“sails”) and/or comparative advantage in generating cost differences across firms in different locations. Hence, it is not necessarily the case that the lowest cost firm is consistently associated with the best performance in a market. Consequently, when one looks at relative performance across markets, a model of sales with sails predicts that there will not be a strong correlation between cost structure and relative performance at any given point in time.

A second contribution of this paper is to document the degree and persistence of price dispersion in US imports. Starting with highly disaggregated import data (over 15,000 products coming from over 200 countries arriving at 484 US ports per month) a number of interesting phenomena are documented.⁶ While not every product exhibits price dispersion, approximately a fifth of US imports are associated with products that are characterized by pronounced price dispersion. This price dispersion also proves to be remarkably persistent when aggregated across countries, that is the same price distribution describes both monthly dispersion and annual dispersion for a given product. Therefore the distribution of prices tends to be stable through time. For the majority of products in the sample the aggregate distribution is also an appropriate description of the distribution of prices associated with each country exporting to the US. However, these country level distributions tend not to be stable through time. Therefore the picture that emerges is one of aggregate stability in the distribution of prices, though the distribution of prices associated with a country tends to move both up and down from month to month. This is consistent with the model of sales with sails.

To establish these results the paper is organized as follows. In section 2 the symmetric closed economy model of Varian (1980) is reviewed. Section 3 extends the model to an open economy setting, initially with symmetric firms located in different countries and then allowing for asymmetries in the form of transport costs. Section 4 describes the monthly data on US imports and the associated cleaning to ensure that the products included in the analysis of price dispersion are as physically standardized as possible. With the data in hand the construction and analysis of the distribution of prices in the aggregate and for individual countries is conducted in section 5. Conclusions are drawn in section 6.

⁶Other studies using this detailed data set include Bown (2004) and Schaur (2007).

2 Closed Economy Model of Sales

This section presents a simple model of sales based on Varian (1980). The symmetric model consists of 2 firms producing a homogeneous product at the same constant marginal cost (normalized to zero). Firms are assumed to compete on price. The key element of the model is the existence of two types of consumers. The first type of consumer is called a loyal customer and always purchases from the same firm provided the quoted price is below their exogenous reservation value (denoted by r). In total there are L loyal customers in the market. The other type of consumer is a shopper and observes all prices and purchases from the lowest priced firm (provided the price is below its exogenous reservation valuation, r). There are assumed to be S shoppers in the market, and for simplicity each consumer has unit demand, generating an overall market size of $L + S$. Furthermore the loyal consumers are assumed to be evenly distributed across both firms (i.e. each firm has a loyal customer base of $\frac{L}{2}$).⁷

In context of this model, Varian (1980) shows that there is no pure strategy equilibrium. To see this suppose all firms set price equal to r . This can't be an equilibrium since one firm could deviate slightly setting $r - \epsilon$ and attract all the shoppers. This undercutting motive would usually suggest that competition would force firms to set $p = c$. However, this also can't be an equilibrium since now it is profitable to deviate and set $p = r$ and just serve loyal customers. This logic implies that there cannot be a symmetric pure strategy equilibrium.

2.1 Mixed Strategy Equilibrium

To derive the mixed strategy equilibrium let $F(p)$ be the probability that the competing firm charges a price less than p . Given this probability, if a firm is considering setting a price of p , it has the lowest price with probability:

$$1 - F(p)$$

This implies the following profit function:

$$\pi(p) = p \left[\frac{L}{2} + (1 - F(p))S \right]$$

In a mixed strategy equilibrium a firm must be indifferent between all prices it sets. In particular

⁷The Varian (1980) model is an example of a “clearinghouse model”. Baye et al. (2006) establish a duality between the equilibrium of optimal search models and clearinghouse models.

it can always set $p = r$. This implies

$$\pi(r) = r \frac{L}{2}$$

Therefore

$$p \left[\frac{L}{2} + (1 - F(p))S \right] = r \frac{L}{2}$$

Solving for $F(p)$:

$$F(p) = 1 - \left(\frac{(r - p) L}{p 2S} \right)$$

Note that at $p = r$, $F(r) = 1$. To find the lower bound on prices, \underline{p} , solve $F(\underline{p}) = 0$.

$$\begin{aligned} 1 &= \frac{(r - \underline{p}) L}{\underline{p} 2S} \\ \Rightarrow \underline{p} &= \frac{rL}{L + 2S} \end{aligned}$$

Therefore each firm randomizes over $[\underline{p}, r]$ using $F(p)$. This randomization potentially generates price dispersion in two dimensions. First, there will be dispersion of prices within a given time period; that is, despite the fact that the two firms produce a homogeneous product, they will charge different prices in equilibrium. Second, there is also scope for intertemporal price dispersion, where firms take subsequent draws from the equilibrium distribution function. In this second case, no firm builds a reputation for continually being the lowest priced firm. Instead prices are stochastic and the identity of the lowest priced firm varies through time.

3 International Trade in a Model of Sales

3.1 Symmetric Firms and Countries

To extend the model to an international setting start with the simplest possible case of two identical countries ($L + S$ consumers in each country). In addition assume that there is one firm located in each country with the loyal customers in each country evenly divided between the two firms. As a benchmark consider the case of free trade, which implies both markets are integrated. Consequently, shoppers buy from the lowest priced location in the world (and there will be $2S$ shoppers), while loyal customers buy from their favored firm (and there are $2L$ loyals split evenly across the two

countries). In this case the equilibrium distribution function for prices is given by:

$$F(p) = 1 - \left(\frac{(r-p)L}{p} \frac{L}{2S} \right) \quad \text{for } p \in [\underline{p}, r]$$

$$\underline{p} = \frac{L}{L+2S}$$

While dividing the two firms between the two countries does not change the derivation of the equilibrium, it does provide insight into the implications of “sales” for international transactions. First, the volume of international trade will not be constant even though costs and demand are unchanged. Hence, trade flows will be stochastic in an otherwise stable environment. Second, relative firm performance is also stochastic. This implies that observing firm sales at a single point in time provides no information about the relative cost structures of the firms. In this case, both firms have exactly the same costs, but can have very divergent performance. A natural question to ask is whether the equilibrium and the implied behavior is a function of the symmetry assumption. This issue is addressed in the next section and confirms that the general features of the equilibrium are preserved in an asymmetric environment.

3.2 International trade with Sales and Sails (trade costs)

A typical source of asymmetry in a international setting is the transport costs incurred by a foreign supplier. To model these costs assume that to ship a product abroad costs t per unit, and that these costs are symmetric (i.e. not dependent on source or destination countries). We begin the analysis by noting that these costs segment the two markets in the sense that the shoppers only buy based on local prices. Note also that since the costs differ across markets, it may no longer be the case that a firm uses the same distribution function in both markets. Since the distribution functions can differ between home and abroad, denote the local distribution function by a subscript 1 and the distribution function abroad by a subscript of 2. Also since markets are segmented, assume that in each country there are L loyal consumers and S shoppers to be served.

The problem for the local firm can be written as:

$$\max_{F_1(p)} \pi = \int_{\underline{p}}^r p \left(\frac{L}{2} + (1 - F_2(p))S \right) dF_1(p) \quad (1)$$

While the problem for the firm abroad is similar except for the transport cost.

$$\max_{F_2(p)} \pi = \int_{\underline{p}}^r (p - t) \left(\frac{L}{2} + (1 - F_1(p))S \right) dF_2(p) \quad (2)$$

A property of any equilibrium is that both firms must randomize over the same interval of prices. While the upper bound is r , the lower bound is altered by the inclusion of transport costs. In particular, the foreign firm cannot price as low as in the symmetric case. Nevertheless, in a mixed strategy equilibrium the foreign firm must be indifferent between all the prices it sets in the market abroad. Therefore, $\pi_2(\underline{p}) = \pi_2(r)$:

$$\begin{aligned} \Rightarrow (\underline{p} - t)\frac{L}{2} + (\underline{p} - t)S &= (r - t)\frac{L}{2} \\ \Rightarrow \underline{p}\frac{L}{2} + (\underline{p} - t)S &= \frac{L}{2}r \\ \Rightarrow \underline{p} &= \frac{rL + 2St}{L + 2S} \end{aligned}$$

There is no incentive for the local firm to set a price below \underline{p} , and when it does set this price it can guarantee profits of:

$$\begin{aligned} \pi_1(\underline{p}) &= \underline{p}\left(\frac{L}{2} + S\right) \\ \pi_1(\underline{p}) &= \frac{L}{2}r + St \quad \text{using } \underline{p} \end{aligned}$$

Therefore using $\pi_1(\underline{p}) = \pi_1(p)$ implies:

$$\begin{aligned} \Rightarrow \left(\frac{L}{2}r + St\right) &= p\frac{L}{2} + pS(1 - F_2(p)) \\ \Rightarrow F_2(p) &= 1 - \frac{(r - p)L}{p2S} - \frac{t}{p} \end{aligned}$$

Similarly using $\pi_2(p) = \pi_2(r)$ implies:

$$F_1(p) = 1 - \frac{(r - p)L}{(p - t)2S} \quad \text{for } p \in [\underline{p}, r)$$

What happens at $p = r$ since $F_2(r) < 1$? This implies that there must be a mass point. Consequently the equilibrium distribution function for the foreign firm is:

$$F_2(p) = \begin{cases} 1 - \frac{(r - p)L}{p2S} - \frac{t}{p} & \text{for } p \in [\underline{p}, r) \\ 1 & \text{for } p = r \end{cases}$$

Therefore the probability of setting a price of r for firm 2 is $\frac{t}{r}$. This is intuitive since firm 2 is high cost, they will have a tendency to price higher. This distribution function takes it one step further by saying that there is a mass point at r ; i.e. can't shift the whole distribution up because of the

upper bound at r , so the mass accumulates there.

Thus the qualitative predictions from the symmetric model carry over to the asymmetric model; prices are stochastic in equilibrium. This also implies that relative firm performance and trade volumes will also be stochastic. In particular, the low price-high sales firm may not necessarily be the low cost firm.⁸ Furthermore, if this pricing game is repeated through time, the same equilibrium will emerge implying that price dispersion will be persistent.

PROPOSITION 1 *In a model of sales where firms have asymmetric costs, both firms adopt mixed strategies with respect to their prices. Furthermore, the low cost firm will employ a strategy that is unimodal while the high cost firm will use a strategy that is bimodal.*

3.3 Many country model

The model can be extended to an n country world. The focus will be on the symmetric-asymmetric model. That is, each firm can serve their local market without incurring a transport cost, but when shipping to any of the $n - 1$ markets incurs a transport cost of t per unit. Following a similar argument to above, the lower bound on the equilibrium price interval is given by:

$$\underline{p} = \frac{rL + nSt}{L + nS}$$

To find the distribution function for a firm that must pay the transport cost (once again denoted by the subscript 2), we use the equilibrium condition that $\pi_1(\underline{p}) = \pi_1(p)$. This implies:

$$F_2(p) = \begin{cases} 1 - \left(\frac{(r-p)L}{pnS} - \frac{t}{p} \right)^{\frac{1}{n-1}} & \text{for } p \in [\underline{p}, r) \\ 1 & \text{for } p = r \end{cases}$$

The equilibrium distribution function for the firm that doesn't pay the transport cost is implicitly defined by $\pi_2(r) = \pi_2(p)$:

$$(p-t)\frac{L}{n} + (p-t)S(1 - F_2(p))^{n-2}(1 - F_1(p)) = (r-t)\frac{L}{n}$$

This implies:

$$F_1(p) = 1 - \frac{(r-p)L}{(p-t)nS} \left(\frac{nps}{r-p+ntS} \right)^{\frac{n-2}{n-1}} \quad \text{for } p \in [\underline{p}, r)$$

⁸Note also that this model produces the possibility of inefficient trade, that is the high cost foreign firm can ultimately be the low priced firm.

Thus the extension of the model to a many country world preserves the conclusion in Proposition 1. In particular, we see that price dispersion at any point in time will form part of an equilibrium and that this dispersion will persist over time since firms vary their prices optimally from period to period.

4 Empirics

The previous sections developed a model which predicts that not only will prices vary across suppliers but these prices will also vary through time within a supplier. This temporal variation inhibits all consumers from learning the lowest price supplier and implies that price dispersion will be persistent. The goal of this section is to determine whether such temporal variation in prices exists in international trade data. For this purpose we will use monthly product level data on US imports from 1998 to 2001.⁹

4.1 Data

Using detailed US import data to discern patterns consistent with a model of sales raises a number of issues. Some cannot be overcome due to the nature of the data. Foremost among these is the inability to distinguish between the actions of different exporting firms located in the same country. The customs data made available by the US Census Bureau simply list the country of origin and not the identity of the exporting firm. However, the data do offer the advantage of high frequency (monthly data) and universal coverage (all imports are recorded). To exploit this detail two further issues need to be addressed. The first requirement is an ability to approximate the prices associated with imports in order to have the basic input necessary to assess pricing behavior. In this case, it is important to have access to transaction level data or as near as possible in order to isolate prices. The second issue follows from the assumption of homogeneous products that underlies the model. Hence, the definition of a product needs to be as specific as possible. Addressing these issues plays an important role in defining the sample of products that are ultimately analyzed.

4.1.1 How disaggregated is the data?

The data record imports by source country for each of the 10 digit Harmonized System (HS10) products, and this information is additionally broken down by month, mode of transportation (air

⁹Note that this period of time was chosen due to the relative stability in the definition of HS10 products. See Pierce and Schott (2009) for the time profile of adjustments to the definitions of HS10 products.

or sea), customs district of entry and customs district of unloading.¹⁰ An aspect of this data that makes it even more disaggregated than it at first appears is that imports are further broken down by port of unloading (of which there are 484). Unfortunately, no unique identifier is assigned to ports, so they cannot be followed through time. Nevertheless, within a month, a greater disaggregation is possible than implied by the 44 customs districts. In fact, given that observations are broken down by whether or not the customs district of unloading is the same as the customs district of entry, the data in many cases approximates very closely transaction level information.¹¹ With this in mind, an important additional feature of these data are that they contain information on both f.o.b. value and quantity, therefore unit values for a product can be computed at approximately the transaction level. Data of this degree of disaggregation make it possible to explore the behavior of US import prices.

4.1.2 Product definition and standardization

Even if transaction level data can be derived/approximated another issue arises. Despite the large number of product categories defined by the HS10 system, product definition can still be relatively broad and include a diverse set of goods. Consequently price dispersion can arise as an artifact of the differences across products within a HS10 classification rather than due to similar products being priced differently (e.g. 20 inch TV's versus 50 inch TV's). To minimize this issue and focus on a relatively standardized set of products an important feature of the data will be exploited. In particular each observation is associated with a physical unit of measurement (number, barrels, dozen, kilograms etc) defined by the US customs service. In addition, the data also contain information on the weight of a shipment. This enables the calculation of the average weight for a unit of quantity arriving in a port from an exporting country in any month. Therefore, we can standardize the data by only analyzing the subset of observations that are sufficiently homogeneous in terms of their weight per unit. In the analysis that follows we identify the median weight for a product and only include observations that lie within a 20% band around this median.¹² One draw back of using this method of standardization is that any product which is measured by US customs in terms of weight must be dropped from the sample. Nevertheless, the sample from this adjustment, along with the requirements of a sufficient number of observations per exporting country and per month, still accounts for between 20% to 25% of US imports for 1998 to 2001. While the motivation for this

¹⁰There are approximately 15,000 products at the 10 digit level and 44 customs districts. See Bureau of the Census (1990).

¹¹A measure of the number of actual transactions is available since each observations includes a record of the number of customs declarations filed.

¹²That is $\pm 10\%$ of the median.

selection is based on a desire to construct a relatively homogeneous dataset it also helps to address another prominent issue with the data, misclassification. Unit values are notoriously noisy, partly because products are misclassified.¹³

4.2 Decomposing Prices: Systematic and Stochastic Components

Even with the effort to standardize products in terms of physical characteristics, there maybe other characteristics that can contribute to price dispersion. In particular, suppliers have different reputations, there may be demand differences across locations within the US, goods of various qualities are shipped different distances, among other things. Essentially these differences can render a good that appears to be physically similar, effectively a differentiated product. The question is whether price dispersion remains after controlling for the main sources of product heterogeneity/differentiation and how this dispersion or randomness is interpreted. To control for various sources of differentiation, the following specification is used:

$$\ln(UV_{spm}^{ijk}) = \beta_1 \ln(dist_{sd}) + \beta_2 \ln(weight_{spm}^i) + \alpha_j^i + \alpha_k^i + \alpha_d^i + \alpha_s^i + \alpha_m^i + \epsilon_{spm}^{ij} \quad (3)$$

where the subscript p represents a port level observation, by month/year, m , by exporting country, s and the superscript j represents mode of transport, k denotes whether the shipment was direct and i represents product. The specification allows for a correlation between price, $\ln(UV_{spm}^{ijk})$, and weight, $\ln(weight_{spm}^i)$ as well as distance, $\ln(dist_{sd})$. Controls are also included to capture the impact on price of products shipped by sea, α_j^i , shipped directly, α_k^i , destination customs district, α_d^i along with differences induced by exporting country and month/year effects, α_s^i and α_m^i . After controlling for these characteristics the error term, ϵ_{spm}^{ij} is a measure of the residual dispersion in prices for products that have been standardized and purged of observable characteristics along with time, exporter, destination, transport method effects. Ultimately, this residual approximates the percentage deviation of a shipment's price from the geometric mean of the reference group. In the analysis that follows the focus will be on ϵ_{spm}^{ij} .¹⁴ In particular, the model of sales suggests that this residual represents the mixed strategies adopted by firms in their pricing decisions. Of course, other factors are also captured by these residuals, with measurement error being the most obvious component. The challenge is to try to distinguish between the various factors that could be governing the behavior of this residual term.

¹³See GOA, 1995. Other sources of noise in the unit values were found to be incorrect quantities and prototype models.

¹⁴For a similar decomposition but in a closed economy setting see Lach (2002).

4.3 Alternative models

One distinction between these two components of the residual is the distribution implied by measurement error versus that implied by mixed strategies. Here measurement error is assumed to only be associated with the price of the product, with the standard assumption that these errors are normally distributed. In contrast, the mixed strategies adopted imply that the distribution of errors are not symmetric. In particular, in the model of sales with sails, the low cost firm adopts a strategy that has a positive skew, while the high cost firm has a bimodal distribution. If we associate a common cost structure to firms within a country, then evidence of mixed strategy pricing may be found in the distribution of residuals associated with countries. These distinctions will be explored in more detail below.

However, before we reach this point, other models of price dispersion and variation will be examined. Two familiar market structures and their associated pricing paradigms are considered as benchmarks. The first is that of perfect competition subject to random demand and supply shocks. This setting implies that deviations from a reference price are likely to be observed overtime as each period is associated with an idiosyncratic selection of shocks, while the deviations across suppliers within a time period should be negligible. This implies that country fixed effects should be insignificant, while monthly effects may potentially play an important role. Nevertheless, much like the measurement error scenario, the error term would be expected to have a symmetric distribution.

A second benchmark follows from the heterogeneous firm model of Melitz (2003). This model implies that exporting firms from any given country will have a range of productivities and therefore an associated distribution of prices. As noted in the introduction, these firm level effects are assumed to be persistent through time. This implies that the distribution of prices, and the associated deviation from the reference price, should be relatively stable overtime for a given country. A popular assumption in this context is that the distribution of productivities and therefore prices follows a pareto distribution.¹⁵ As a consequence, this implies that the deviations will have a positive skew, much like the low cost firm in the sales with sails model. However, in any given month most countries send a finite number of shipments, implying a relatively small sample of price observations. If a mixed strategy is pursued by the exporting firms, then the location of the distribution of prices will vary from month to month. In contrast, the persistence implied by the heterogeneous firm model predicts that the distribution of prices should be relatively stable, regardless of the number of observations per month. Hence the stability of the price distribution through time within an exporting country will be an important distinguishing characteristic.

¹⁵See for example Helpman, Melitz, and Yeaple (2004) and Chaney (2008) among others.

4.4 Sample and Methodology

After selecting only products that have non-weight quantity measures, and requiring that an exporting country send a minimum of 7 shipments to the US between 1998 and 2001, there are 407 HS10 codes and 107 exporting countries included in the sample. While 407 HS10 codes appears relatively small number compared to the over 15,000 codes that we started out with, they still represent a significant fraction of US imports. In particular, these 407 products accounted for between 20% to 25% of US imports over 1998-2001. For each of these products, equation (3) is separately estimated by OLS and the estimated residuals, $\hat{\epsilon}_{spm}^{ij}$ are derived.

A general overview of the degree of price dispersion across products is given in figure 1. This figure presents the interquartile range of the price deviations plotted against the number of observations per product. By construction the mean of these deviations is zero. The figure conveys the large degree of price dispersion that persists after controlling for both observable characteristics as well as a number of fixed effects. In particular, the interquartile range is greater than 10% for more than 95% of the products in the sample. This dispersion persists even as the the number of observations per product increases (a rough measure of competition). The heavy red line denotes the median number of observations for a product in the sample. As the figure reveals the possibility of pronounced price dispersion is just as likely for the products with the smallest number of observations (bottom 50%) as it is for those with the largest number of observations (top 50%).

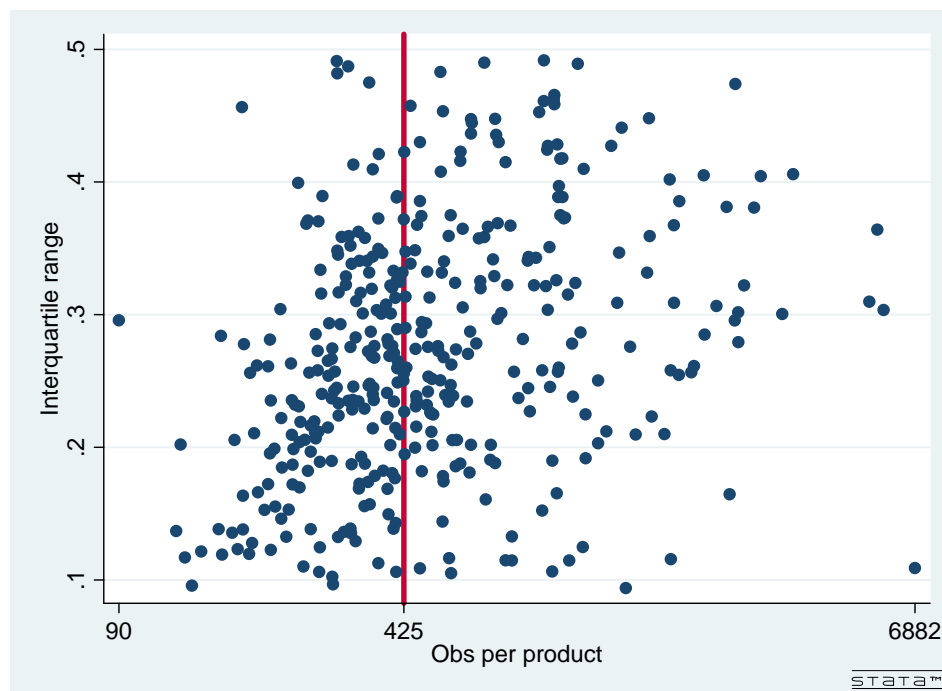


Figure 1: Interquartile range of price deviations

While the emphasis will be placed on understanding why there is price dispersion for products and why it persists, it is also worthwhile considering which products do not exhibit pronounced price dispersion. Among those products whose interquartile range is below 10% are a range of petroleum products (HS10 codes: 2709001000, 2709002000, 2710000530, 2710000550 and 2710002500), all of which have the characteristics of commodities traded on an exchange. Leaving aside these commodities, the notion that the intensity of competition won't necessarily reduce price dispersion is reinforced by figures 2 and 3. Once again the heavy red line indicates the median of either the elasticity or number of exporters shipping a product to the US.¹⁶ As is apparent in all figures, an increase in competitiveness as proxied by number of observations, elasticity or number of exporters is not associated with an evident reduction in price dispersion.

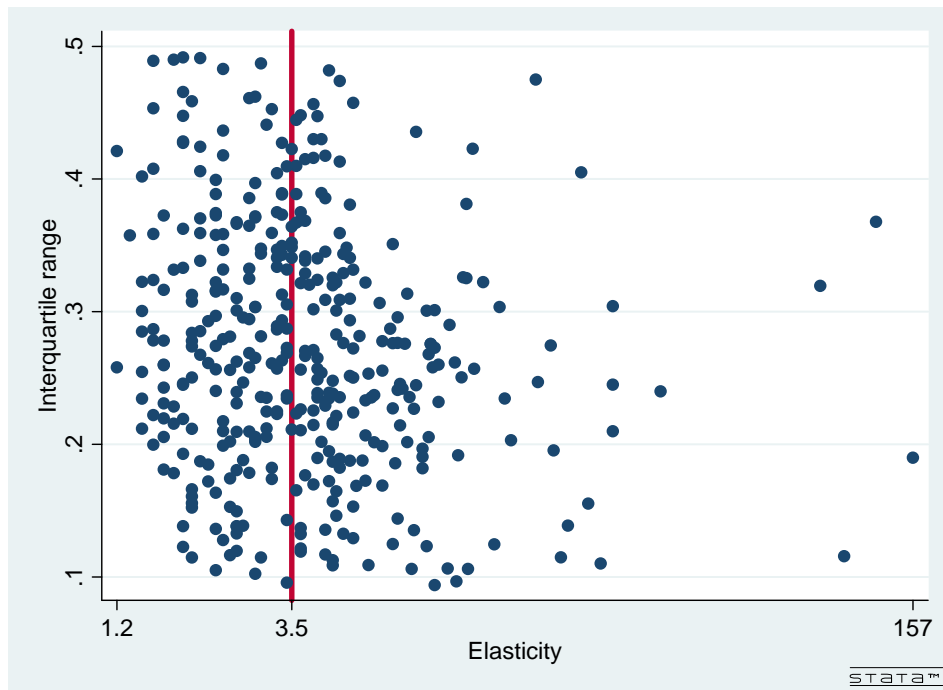


Figure 2: Interquartile range of price deviations and Elasticity

¹⁶The measure of elasticity is taken from Broda and Weinstein (2006).

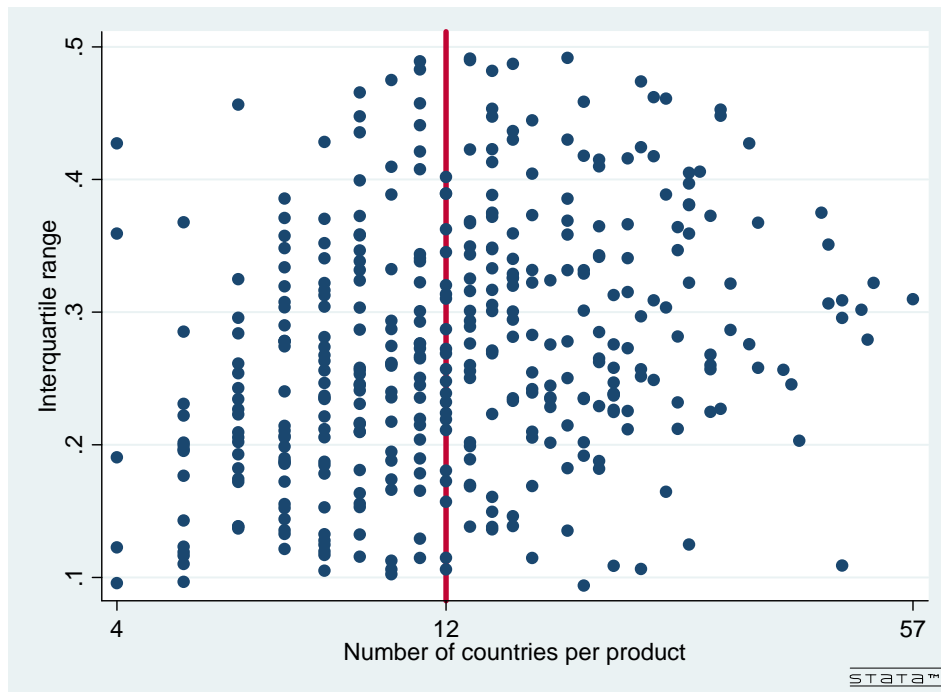


Figure 3: Interquartile range of price deviations and number of exporters

The next step is to adopt a methodology to analyze the factors underlying this price dispersion. Since our interest is in the distribution of the price residuals in various dimensions, a methodology that is relatively robust is employed. In particular, for each product the aggregate distribution is characterized by dividing the estimated residuals into quartiles. That is, each $\hat{\epsilon}_{spm}^{ij}$ is assigned a number from 1 to 4 depending on the quartile they occupy. This gives a relatively broad description of the distribution of price deviations. With this categorization in hand it is then possible to ask whether the aggregate distribution is an appropriate description of the price distributions associated with each month, each country and within each country over time. That is, for each of these perspectives, do we observe an equal frequency of 1's, 2's, 3' and 4's? Or in other words, can we find the same general tendencies to discount or set premiums for each month, for each country, and for each country in every more month?¹⁷ The answers to these questions will provide a characterization of the price dispersion across countries and the persistence of this dispersion. We begin the analysis by investigating the stability of the distribution of prices over time and across countries.

5 Results

5.1 Stability of Price Distribution

Since we are interested in relative frequencies a simple χ^2 test is adopted. The null is one of homogeneity; that is, the same degree of price dispersion is evident for either each month or each country. This provides a relatively strong test, since it only takes one month or one country to have a distribution that differs from the aggregate distribution for the test to be rejected.

Table 1: Distributional Stability

| Variable | Mean | Std. Dev. |
|---------------------------------------|-------------|------------------|
| % of products stable over time | 95.1 | 21.6 |
| % of products stable across countries | 58.2 | 49.4 |
| Observations per product | 551.6 | 735.1 |
| N | | 407 |

Table 1 presents the results for the stability of the distribution of prices overtime and across countries. The first row gives the fraction of products that have stable price distributions over time. That is, based on the annual distribution it gives the fraction of products for which the null hypothesis of homogeneity across months cannot be rejected. In this case, for 95% of the products

¹⁷Employing a Kolmogorov and Smirnov test gives essentially the same results for the analysis at the monthly level and also across countries. However, this methodology is too restrictive when examining the behavior of prices within a country overtime. In contrast, the quartile methodology can be extended in a straight forward way, and for this reason it is the preferred approach.

analyzed the null could not be rejected. This is consistent with the majority of products having a stable distribution of prices overtime. Essentially this says that while prices may be very dispersed, the distribution that they are drawn from is very similar from month to month. In relation to the three models described above, this stability is consistent with two of the three. In relation to both the heterogeneous firm model and the model of sales, one would expected the distribution of price deviations to be relatively stable through time. For the heterogeneous firm model this arises since the data is country level data and the heterogeneity in costs, while persistent, is at the firm level. For the model of sales, while individual prices are random, they are drawn from well defined distributions that are stable through time. Therefore, provided a sufficiently large number of draws are taken from these distributions, the empirical distribution will provide a good approximation to the aggregate distribution. In fact, any model that is associated with a stable distribution of errors is consistent with this finding - heterogeneity, sales and measurement error. Since stability overtime is the norm, it is of interest to ask which products do not exhibit this behavior. Once again it turns out to be the case that petroleum commodities are at odds with the norm. These products are not exceptional in terms of the number of observations, suppliers or elasticity, but since they are traded on an organized exchange price dispersion, if it exists, is unlikely to persist overtime. Therefore any price dispersion that does exist will be due to within month variation, that naturally changes from month to month depending on the nature and size of demand and supply shocks at any point in time.

The second row gives the fraction of products that have stable price distributions across countries. That is, the fraction of products for which the aggregate distribution of price deviations are the same across all countries. In this case, for 60% of the products analyzed the null of homogeneity could not be rejected. This suggests that for the majority of products the distribution of prices associated with each country are very similar. Nevertheless for 40% of products in the sample the evidence is consistent with distribution of prices differing significantly across countries. To explore further, the definition of a product is further refined by considering per unit weights $\pm 5\%$ of the median. While the number of products exhibiting a stable price distribution over time is essentially unchanged, the fraction of products that have similar price distributions across countries increases. Under this tighter definition of a standardized product it is now the case that the null hypothesis of homogeneity cannot be rejected for 75% of the products.

The picture that emerges is one where the distribution of prices are stable overtime, but there may be distinct variation across countries in the propensity to offer discounts or apply premiums. While broadly consistent with the sales framework presented above, this pattern could also be explained by

the standard model of firm heterogeneity. However, such a model predicts that while there may be cross section variation in prices it does not predict that there will be significant temporal variation in prices. This point of departure provides a basis for discriminating between the two models. In addition the model of sales with sails predicts fluctuations in prices won't be uniform across the support. In particular, there is likely to be a mass point at the upper end of the distribution for high cost locations, implying more persistence at this end of the distribution. Moreover, mid-range prices should not be very persistent relative other parts of the distribution.

To examine the temporal variation in prices within a country the probability that the minimum, median and maximum price deviations fall in the same quartile of the aggregate price distribution in the following month is estimated. Using this probability to characterize the stability of a distribution has a number of advantages. In particular, it can be implemented if a country only has a small number of observations in any given month (say for example one observation). If this is the case then the minimum, median and maximum price deviation all coincide and the task is to compare this to the preceding or following months counter-part (where all three concepts need not coincide). Other methods are more data intensive (such as the χ^2 or Kolmogorov and Smirnov tests), which would restrict both the number of countries and products for which persistence or its absence could be characterized.

If the heterogeneous firm model is the underlying explanation for price dispersion, then the probability that these prices move to a different quartile should be close to zero. In contrast, the sales model predicts that the distribution of prices in any one month should be random, implying much higher probabilities of transition. Furthermore, the mass should be at either end of the distribution, implying a lower probability of transition for the minimum and maximum prices, with persistence especially likely for the higher prices. Therefore, while the heterogeneous firm model predicts stability, the sales model predicts a high probability of price transitions. The relative predictions of the two models is depicted in figure 4, where each rectangle is divided into four segments to represent each quartile. The first two rectangles represent the location of the min/max price deviations for adjacent periods. The firm heterogeneity model predicts that the maximum deviations should be in the 4th quartile in all periods, while the minimum deviation should be in the 1st quartile. In contrast, the sales with sails model predicts that the observed price deviations can move around substantially from period to period, even if the when aggregated overtime a country has a price distribution that is very similar to the aggregate price distribution.

To sharpen the focus, only products that have a stable distribution over time have been included. Consequently, the cases examined have the feature that in any period the same distribution of prices

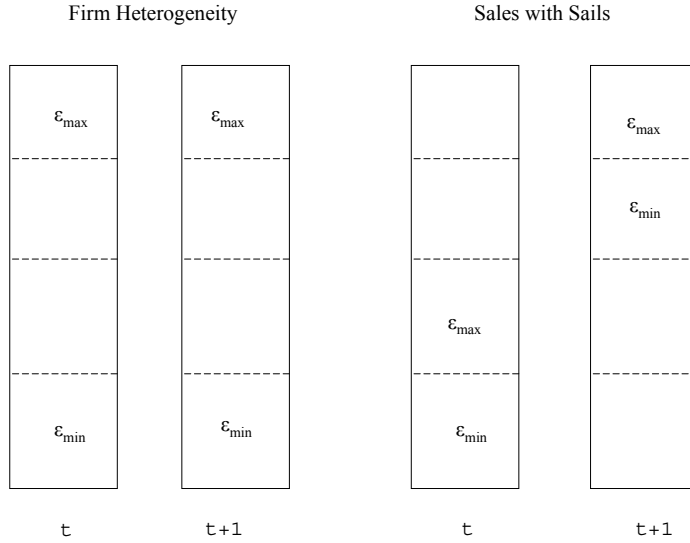


Figure 4: Comparison of intra-distributional dynamics

Table 2: Intra-distributional dynamics

| Variable | Mean | Std. Dev. | Min. | Max. |
|---|------|-----------|------|------|
| Probability of minimum price transition | 66 | 9 | 30 | 82 |
| Probability of median price transition | 72 | 5 | 50 | 88 |
| Probability of maximum price transition | 66 | 9 | 31 | 81 |
| Observations per product | 523 | 663 | 71 | 5636 |
| N | | 387 | | |

are available. The question to be answered is whether these prices persist at the country level. Table 2 presents the transition probabilities associated with the minimum, median and maximum price deviations. Price transitions appear to be a prominent feature of the data, contrary to the predictions of the heterogeneous firm model. Moreover, the transition probabilities have the ordering predicted by the sales with sails model; smaller transitions at the extremes and greater movement at the median. Thus prices do not appear to persist at the country level, despite the fact that they do at the aggregate level each month.

One concern is that since these transition probabilities are calculated at monthly frequencies, the lumpiness of transactions may be driving these results. That is, some months may have a small number of observations which might generate a tight distribution (which would be the case for a single transaction), while the next month may have many observations and more dispersion. In this case, variation in the number of shipments across months could be driving the high transition probabilities. A related concern at the monthly level is that potentially different firms are engaged in transactions. For instance if the heterogeneous firm model or transfer pricing was the reason for the price dispersion, then transitions in the location of the price distribution may be evident solely because the mix of firms varies from month to month. To account for both these concerns the transitions probabilities are calculated at the quarterly and bi-annual frequencies, the results presented in Tables 3 and 4.

Table 3: Intra-distributional dynamics: Quarters

| Variable | Mean | Std. Dev. | Min. | Max. |
|---|-------------|------------------|-------------|-------------|
| Probability of minimum price transition | 55 | 11 | 19 | 77 |
| Probability of median price transition | 71 | 6 | 53 | 86 |
| Probability of maximum price transition | 55 | 11 | 18 | 76 |
| N | 387 | | | |

Table 4: Intra-distributional dynamics: bi-annual

| Variable | Mean | Std. Dev. | Min. | Max. |
|---|-------------|------------------|-------------|-------------|
| Probability of minimum price transition | 44 | 11 | 10 | 71 |
| Probability of median price transition | 68 | 8 | 37 | 90 |
| Probability of maximum price transition | 43 | 11 | 9 | 69 |
| N | 387 | | | |

While it is evident that the transition probabilities are lower, there is still considerable evidence that the set of prices coming from a country don't occupy a fixed segment of the aggregate price distribution. Instead the location of a countries prices within the aggregate distribution tends to move around substantially.

One notable aspect of the above tables is that while the transition probabilities at the upper end of the distribution (i.e. the highest transition probabilities) are relatively unaffected by the time period considered, this is not the case for the smallest transition probabilities that are substantially lower as longer periods are considered. To provide further insight into this behavior the transition probabilities at the HS section level are presented for the minimum and maximum price transitions.

Table 5: **Transition of minimum price by HS section: bi-annual**

| Section | mean | sd | min | max |
|-----------------------|-------------|-----------|------------|------------|
| Prepared foodstuffs | 42 | 8 | 30 | 54 |
| Mineral products | 44 | 12 | 27 | 59 |
| Chemical products | 41 | 16 | 16 | 58 |
| Plastics | 24 | 6 | 17 | 33 |
| Fur and skins | 38 | 9 | 25 | 51 |
| Wood products | 34 | 12 | 18 | 44 |
| Cellulose products | 43 | 8 | 32 | 52 |
| Textiles | 48 | 10 | 15 | 71 |
| Misc/manufactures | 35 | 12 | 11 | 58 |
| Stone & ceramics | 37 | 11 | 18 | 62 |
| Base metals | 38 | 12 | 20 | 54 |
| Machinery/mech. | 46 | 10 | 29 | 60 |
| Vehicles | 39 | 7 | 27 | 48 |
| Precision Instruments | 38 | 17 | 10 | 53 |
| Beds/bedding | 38 | 10 | 24 | 57 |

These tables reveal that the variation in the transition probabilities is very similar across harmonized schedule sections, with more variation within sections than across sections. The lowest transition probability for the minimum price is associated fretted stringed instruments (HS10 code 9207900040). In this case heterogeneity in quality for a given per unit weight is the likely to be driving this result, consistent with the heterogeneous firm model. The lowest transition probability for the maximum price is associated with surgical/medical gloves, of vulcanize rubber, NESOI (HS10 code 4015110000). Once again despite standardization by per unit weight, heterogeneity in quality is likely to be the contributing factor given the catch all nature of NESOI.¹⁸ Both these cases suggest that if heterogeneity is present then it will be detected by the methodology. This suggests that the evidence in this section is consistent with the notion that many heavily traded products have a substantial degree of price dispersion and that by randomizing prices through time this price dispersion can persist.

¹⁸Note also that while the code has 10 digit, it is really a six digit code that has been extended to ten by adding the appropriate number of zeros.

Table 6: **Transition of maximum price HS by section: bi-annual**

| Section | mean | sd | min | max |
|-----------------------|-------------|-----------|------------|------------|
| Prepared foodstuffs | 41 | 12 | 26 | 63 |
| Mineral products | 38 | 10 | 28 | 52 |
| Chemical products | 40 | 17 | 19 | 69 |
| Plastics | 20 | 7 | 9 | 28 |
| Fur and skins | 37 | 11 | 24 | 56 |
| Wood products | 35 | 9 | 23 | 45 |
| Cellulose products | 41 | 3 | 38 | 45 |
| Textiles | 46 | 10 | 15 | 67 |
| Misc/manufactures | 37 | 12 | 13 | 62 |
| Stone & ceramics | 37 | 12 | 13 | 62 |
| Base metals | 38 | 11 | 18 | 49 |
| Machinery/mech. | 44 | 14 | 12 | 60 |
| Vehicles | 41 | 10 | 28 | 52 |
| Precision Instruments | 41 | 10 | 28 | 53 |
| Beds/bedding | 39 | 11 | 16 | 56 |

6 Conclusion

Emerging evidence that firm level characteristics are not sufficient to predict relative performance in export markets presents a challenge and a puzzle to the current literature on international trade flows. Simply extending the existing models to include firm-destination exogenous factors is inadequate to account for this stylized fact since it ignores the possibility that consumers can learn the distribution of prices across markets and take advantage of arbitrage opportunities. Instead of relying on a set of exogenous factors this paper develops an equilibrium model of firm level price dispersion built on a model of sales. The mixed strategies adopted by firms in equilibrium accounts for the lack of cross-sectional correlation in performance across export markets. It also rationalizes why consumers don't learn which firms are consistently low priced in other markets; since the pricing strategy is stochastic no one firm is consistently high or low priced in any market. These results are shown to hold in both a symmetric setting and, more importantly, in an asymmetric setting.

A key prediction of the model is that firms that adopt sales strategies will have broadly similar price distributions but prices won't be persistent overtime. To examine this prediction, the prices associated with US imports are examined. It is found that within a product, the aggregate distribution of prices is relatively stable through time though not necessarily across countries. Furthermore, within countries the distribution of prices tend to move around substantially, despite the stability of the aggregate price distribution for any given product. These results are consistent with a model of sales with sales.

Reference

- Balistreri, E. J., Hillberry, R. H., and Rutherford, T. F. (2008). Structural estimation and solution of international trade models with heterogeneous firms. Department of Economics - Working Papers Series 1056, The University of Melbourne.
- Baye, M. R., Morgan, J., and Scholten, P. (2006). Information, search, and price dispersion. In Hendershott, T. (Ed.), *Handbook in Economics and Information Systems Volume 1*. Elsevier.
- Bernard, A., Schott, P., and Redding, S. (2006). Comparative advantage and heterogeneous firms. *Review of Economic Studies*.
- Bombardini, M. (2008). Firm heterogeneity and lobby participation. *Journal of International Economics*, 75(2), 329–348.
- Bown, C. (2004). How different are safeguards from antidumping? evidence from us trade policies toward steel. Brandeis university working paper.
- Broda, C. and Weinstein, D. E. (2006). Globalization and the gains from variety. *The Quarterly Journal of Economics*, 121(2), 541–585.
- Bureau of the Census (1990). *U.S. Exports and Imports of Merchandise on CD-ROM [machine-readable data file]*.
- Chaney, T. (2008). Distorted gravity: the intensive and extensive margins of international trade. *American Economic Review*, 98(4), 1707–21.
- Eaton, J., Kortum, S. S., and Kramarz, F. (2009). An anatomy of international trade: evidence from french firms. Nber discussion papers, NBER.
- Ganslandt, M. and Maskus, K. E. (2007). Vertical distribution, parallel trade, and price divergence in integrated markets. *European Economic Review*, 51(4), 943–970.
- GOA (1995). *U.S. Imports: Unit Values Vary Widely for Identically Classified Commodities*. Report GAO/GGD-95-90.
- Helpman, E., Melitz, M. J., and Yeaple, S. R. (2004). Export versus fdi with heterogeneous firms. *American Economic Review*, 94(1), 300–316.
- Lach, S. (2002). Existence and persistence of price dispersion: an empirical analysis. *The Review of Economics and Statistics*, 84(3), 433–444.
- Melitz, M. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71, 1695–1725.
- Munch, J. and Nguyen, D. (2008). Decomposing firm level sales variation. working paper.
- Pierce, J. R. and Schott, P. K. (2009). ConCORDING U.S. HARMONIZED SYSTEM CATEGORIES OVER TIME. NBER Working Papers 14837, National Bureau of Economic Research, Inc.
- Schaur, G. (2007). Hedging price volatility using fast transport. University of Tennessee working paper.
- Varian, H. R. (1980). A model of sales. *American Economic Review*, 70(4), 651–59.
- Yeaple, S. (2005). A simple model of firm heterogeneity, international trade, and wages. *Journal of International Economics*, 65, 1–20.