Distorted gravity: Heterogeneous Firms, Market Structure and the Geography of International Trade*

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Abstract

By considering only the intensive margin of trade, Krugman (1980) predicts that a higher elasticity of substitution between goods magnifies the impact of trade barriers on trade flows. In this paper, we introduce firm heterogeneity in a simple model of international trade. We prove that the extensive margin, the number of exporters, and intensive margin, the exports per firm, are affected by the elasticity of substitution in exact opposite directions. In sectors with a low elasticity of substitution, the extensive margin is highly sensitive to trade barriers, compared to the intensive margin, and the reverse holds true in sectors with a high elasticity. The extensive margin always dominates, and the predictions of the Krugman model with representative firms are overturned: the impact of trade barriers on trade flows is dampened by the elasticity of substitution, and not magnified.

To test the predictions of the model, we estimate gravity equations at the sectoral level. The estimated elasticities of trade flows with respect to trade barriers are systematically distorted by the degree of firm heterogeneity and by market structure. These distortions are consistent with the predictions of the model with heterogeneous firms, and reject those of the model with representative firms. We also generate predictions for firm level trade matching the stylized facts uncovered in the recent literature.

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1 Introduction

The model most widely used for predicting bilateral trade flows was developed by Paul Krugman in 1980. In this model, identical countries trade differentiated goods despite the presence of trade barriers because consumers have a preference for variety. If goods are more differentiated, consumers are willing to buy foreign varieties even at a higher cost, and trade barriers have little impact on bilateral trade flows. Total exports from country A to country B are given by the following expression:

$$\text{Exports}_{AB} = \text{Constant} \times \frac{\text{GDP}_A \times \text{GDP}_B}{(\text{Trade barriers}_{AB})^{\sigma}}$$

where σ is the elasticity of substitution between varieties. Trade barriers have a strong impact on trade flows when the elasticity of substitution between goods is high, or when goods are highly substitutable. Competition is fierce when the elasticity of substitution is high, and any cost disadvantage translates into large losses of market share. A crucial assumption in this model is that all firms are identical, and that the only form of transportation cost is a variable cost. Under these assumptions, every firm exports to every country in the world, and how much it exports to a given country depends on how competitive it is against other foreign exporters. Differences in competitiveness due to transportation costs have a greater or lesser impact on trade flows depending on whether goods are more or less substitutable.

In this paper, we add firm heterogeneity in productivity, as well as fixed costs associated with exporting. These simple amendments introduce a new margin of adjustment: the extensive margin. When transportation costs vary, not only does each exporter change the size of its exports (the intensive margin), but the set of exporters varies as well (the extensive margin). The main finding of this paper is that the elasticity of substitution has opposite effects on each margin. A higher elasticity makes the intensive margin more sensitive to changes in trade barriers, whereas it makes the extensive margin *less* sensitive. The reason is the following. When trade barriers decrease, new and less productive firms enter the export market, attracted by the potential for higher profits. When the elasticity of substitution is high, a low productivity is a severe disadvantage. These less productive firms can only capture a small market share. The impact of those new entrants on aggregate trade is small. On the other hand, when the elasticity is low, each firm is sheltered from competition. The new entrants capture a large market share. The impact of those new entrants on aggregate trade is large. So the elasticity of substitution magnifies the sensitivity of the intensive margin to changes in trade barriers, whereas it dampens the sensitivity of the extensive margin.

Which effect dominates? Which margin is the most important? We prove that the effect on the extensive margin dominates. Our augmented model predicts that total exports from country A to country B are given by the following expression:

$$\text{Exports}_{AB} = \text{Constant} \times \frac{\text{GDP}_A \times \text{GDP}_B}{(\text{Trade barriers}_{AB})^{\zeta}} \text{ with } \zeta'(\sigma) < 0$$

The elasticity of aggregate trade with respect to trade barriers, ζ, is negatively related to the elasticity of substitution, σ. We find strong support for this prediction in the data. The elasticity of substitution systematically dampens the impact of trade barriers on trade flows.

Our model with heterogeneous firms also predicts that the same trade barriers will have a larger impact on trade flows than in the model with representative firms. On top of the adjustment of the intensive margin of trade described in existing models, there are important adjustments of the extensive margin. When trade barriers decrease, each firm exports more. In addition, new firms start exporting. The entry of new firms is quantitatively important. Given the observed empirical distribution of firm size, we prove that this effect is large. Calibrating the model on the actual distribution of firm size in the US, the elasticity of trade with respect to trade barriers will be twice as large in a model with heterogeneous firms as in a model with representative firms. Anderson and van Wincoop (2004) argue that, using existing models of trade, observed trade flows are consistent with average trade barriers between the US and Canada equivalent to a 46% tariff (table 7 p. 717, Anderson and van Wincoop's results with $\sigma = 8$). This number is unrealistically large. 46% is the punitive tariff imposed by the US on exports from Laos[1]. If our model with heterogeneous firms were the correct model underlying observed trade flows, we would infer from the same data, and assuming the same elasticity, that trade barriers between the US and Canada are equivalent to a 21% tariff. This calibration exercise puts trade barriers back into a more plausible range[2].

The prediction, that the effect of trade barriers on trade flows is magnified by the elasticity of substitution, is not specific to Krugman's model of trade. Obstfeld and Rogoff (2000) explain the six major puzzles in International Macroeconomics by the existence of trade barriers. The simple

[1]Along with Cuba and North Korea, Laos is the only country that has not been offered normal trade relations with the US.

[2]In order to generate an extensive margin, we need to introduce fixed costs on top of those variable costs. Total trade barriers will be larger than the simple estimate of variable costs. However, since we impose that domestic firms also have to pay this fixed cost, we can safely describe these estimated variable costs separately from fixed costs. Anderson and van Wincoop (2004) estimate those fixed costs separately.

model they spell out to illustrate how plausible values for trade barriers can have a large impact on trade flows relies on the magnification by the elasticity of substitution. Anderson (1979) presents a theoretical foundation for the gravity equation based on trade in goods differentiated by country of origin, and consumers with CES preferences. Deardorff (1995) derives predictions equivalent to the gravity equations of trade from a Heckscher-Ohlin model. All these models find that a higher elasticity of substitution magnifies the effect of trade barriers on trade flows, without the need for increasing returns or monopolistic competition. All that is needed is some degree of specialization between countries. CES preferences ensure that the elasticity of substitution is a well defined concept. Since these models implicitly or explicitly assume that firms are identical, they can only describe how each firm, or a representative firm, adjusts its exports decision depending on trade barriers and the structure of demand. In such a framework, it is natural that the effect of trade barriers should be magnified by the degree of substitutability between goods. A notable exception is Eaton and Kortum (2002). Even though they have a CES structure for demand, they predict that the sensitivity of trade flows to trade barriers does not depend on the elasticity of substitution, but on parameters shaping the distribution of comparative advantages. This prediction, although derived from different foundations, is similar to ours.

The main contribution of this paper is to introduce the extensive margin of trade in a simple framework, and to prove that the elasticity of substitution dampens the effect of trade barriers on the extensive margin. The dampening effect on the extensive margin always dominates the magnifying effect on the intensive margin. We find strong support for this prediction in the data. This sheds a new light on many interpretations of the effect of trade barriers. The elasticity of trade flows with respect to trade barriers remains large in our model. Once the extensive margin is considered, it is even larger than what traditional models would predict. However, it is not equal to the elasticity of substitution, and is even inversely related to the elasticity of substitution.

In the remaining of this introduction, we review previous work related to this issue. First, there is a growing body of research linking firm heterogeneity and international trade, both theoretically and empirically. Second, the interaction between market structure and the patterns of trade has long been a central piece in explaining the patterns of international trade. Finally, our empirical procedure is based on the vast literature on estimating gravity equations in international trade.

Melitz (2003) pioneered the study of firm heterogeneity in international trade in a general equilibrium framework. He describes the reallocation of firms within a sector between local and foreign markets triggered by trade opening. He extends the classical model of trade with monopolistic competition developed by Krugman (1980) to allow for firm heterogeneity. He describes precisely the within industry dynamics of reallocation following trade opening, or following further trade integration. We expand this model in the following way. We consider a world with many countries, and study the strategic choice of firms to export or not, and if they export, which countries to target. We embed our model in a global general equilibrium. Such a model generates predictions for the structure of bilateral trade flows. We can pin down exactly which firm from which country is able to enter a given market, and how it is affected by competition from local and other foreign firms. The presence of fixed costs associated with entering foreign markets provides a simple foundation for the extensive margin of trade[3].

An alternative approach has been developed in Eaton and Kortum (2002). They propose a Ricardian model of international trade in the spirit of Dornbush, Fischer and Samuelson (1977), with many countries. Trade flows are determined by comparative advantages arising from productivity differences. Firm level productivity differences directly shape the patterns of international trade. Eaton, Kortum and Kramarz (2004a and 2004b) use this theoretical framework to analyze firm level trade data on French firms. They find that the number of exporters is a crucial variable of adjustment. Aggregate trade flows are mostly determined by the number of French firms, rather than by the amount exported by each individual French producer. Our model is similar in spirit to the model they build. However, it presents the advantage of greater tractability and greater flexibility. We get simple closed form solutions for aggregate trade, and more importantly, for the intensive margin and the extensive margin separately. We get clear predictions for the impact of both variable and fixed costs on each margin, and for the interaction between these margins and measures of market structure and firm heterogeneity.

Bernard and Jensen (1995, 1999, 2001a, 2001b, 2002), Harrigan (1995), Tybout (2003), Bernard, Eaton, Jensen and Kortum (2003), Eaton, Kortum and Kramarz (2004a and 2004b) describe a series of stylized facts on firm level trade. Only a few firms export. Among exporters, only a few firms export to more than a few countries. Most exporters only sell a small fraction of their output abroad. Exporters are different from non exporters in many respects. They are

[3]In a parallel and independent work, Helpman, Melitz and Rubinstein (2004) develop a similar model with heterogeneous firms and fixed costs of accessing each foreign market. Using bounded support for the productivity shocks, they generate predictions for the extensive margin of trade. They can make use of the information contained in the zeros of the trade tables and improve on the traditional gravity regressions. Eaton, Kortum and Kramarz (2004, unpublished) also develop a similar model to calibrate firm level data on French exporters. None of those make any prediction on the impact of market structure on the geography of trade flows.

much larger, they tend to be more productive and more capital intensive. Are exporters more productive because they export, or do they export because they are more productive? This question is still a matter for debate. Bernard and Jensen (2001a) find the strongest support for the latter: the best predictor of whether a firm will export tomorrow is its productivity today. There is also significant evidence for the presence of sunk costs associated with exporting as well. A firm exporting today is 36% more likely to export in the future than a firm not exporting today. Anecdotal evidence collected from entrepreneurs also suggests that a large fraction of the costs associated with exporting take the form of fixed or sunk costs. Our model matchs most of the stylized facts on firm level trade described in this literature.

The importance of market structure in shaping trade flows has long been acknowledged. The path-breaking model of trade by Krugman (1980) explains the existence of intra-industry trade by the mere presence of product differentiation and monopolistic competition. However, relatively little attention has been given to the difference in the patterns of trade across sectors. Davis (1998) points out that the home market hypothesis[4] hangs on differentiated goods with scale economies having greater trade costs than homogeneous goods. Hummels (2001) performs a precise analysis of the impact of trade barriers on trade flows at the sectoral level. Anderson and van Wincoop (2004) extract results from Hummels and show that trade costs are more responsive to distance in sectors with more differentiated goods. The closest to our empirical findings is Rauch (1999). He finds that trade barriers have a lower impact on trade volumes when trade is done on organized markets or when reference prices exist. He argues that those goods are more homogeneous. Differentiated goods on the other hand are harder to compare, and it would be difficult for a trader to quote a single price for them. The explanation put forward by Rauch is that the cost of acquiring information about differentiated goods is high. Therefore differentiated goods are more costly to trade. Yet the fact that a good has a reference price or not is not a direct measure of the degree of differentiation of a good. We focus our empirical analysis on direct measures of product differentiation. We offer an alternative explanation for the interaction between product differentiation and trade barriers. We spell out a clear theoretical channel through which product differentiation affects trade barriers.

The interaction between market structure and the equilibrium distribution of firm size has been studied in a different context in the Industrial Organization literature. Syverson (2004) describes the effect of product substitutability on the selection of firms and the equilibrium dispersion of

[4]The home market hypothesis is the fact that big countries produce more goods with scale economies.

firm productivity. When products become more substitutable, production within an industry is reallocated. Less productive firms disappear. Output shifts towards the most productive firms. Syverson finds strong evidence that a higher degree of substitutability leads to a narrower productivity dispersion (less productive firms disappear), and a higher median productivity (output shifts towards the most productive firms).

We build our empirical analysis upon the large literature regarding estimating gravity equations in trade, founded by Tinbergen (1962). Harrigan (2002), Hutchinson (2002), Evenett and Keller (2002) and Feenstra (2002 and 2003) offer recent surveys of the existing theories behind the gravity equations. Deardorff (1995) gives an elegant derivation of the gravity equations in a neoclassical framework. Anderson and van Wincoop (2003) provide generalizations of the theoretically founded gravity equations, and explain the so-called border effect with a well specified model. We augment traditional estimations of the gravity equations to include measures of the interaction between market structure and trade barriers. We find strong support for the predictions of our model with heterogeneous firms in the data.

The structure of the paper after this introduction is as follows: Section 2 introduces a simple model of trade with heterogeneous firms, and generates a series of testable predictions. Section 3 describes the empirical estimation and tests of the main predictions of the model. Section 4 matches the predictions of the model with existing stylized facts on firm level trade. Section 5 concludes.

2 A simple model of trade with heterogeneous firms

In the next three sections, we develop a theoretical model of trade with heterogeneous firms. In the first section, we present partial equilibrium results. In the second, we compute the general equilibrium of the world economy. In the last section, we identify separately the adjustments of each margin of trade, in response to changes in both variable and fixed trade barriers.

2.1 Set-up

In this section, we introduce the basic ingredients of the model. We define preferences and technologies, and we characterize the optimal strategies of both firms and consumers.

There are N countries that produce goods using only labor. Country n has a population L_n. There are $H+1$ sectors. One sector provides a single homogeneous good that can be freely traded.

It is produced under constant returns to scale with unit labor requirement. The homogeneous good is used as the numeraire. Its price is set equal to 1 so that, provided that every country produces it, wages are equalized to 1 in every country. We shall only consider equilibria where this assumption holds. The other H sectors supply a continuum of differentiated goods. Each firm is a monopolist for the variety it produces.

Preferences: The workers are the only consumers, each endowed with one unit of labor. They all share the same CES preferences over the $H+1$ groups of goods. A consumer that receives q_o units of the homogeneous good, q_h^x units of each variety x of good h, and X_h different varieties of good h gets a utility U:

$$U \equiv q_o^{\mu_0} \prod_{h=1}^{H} \left(\int_0^{X_h} (q_h^x)^{\frac{\sigma_h - 1}{\sigma_h}} \, dx \right)^{\frac{\sigma_h}{\sigma_h - 1}\mu_h} \tag{1}$$

$$\text{with } \mu_0 + \sum_{h=1}^{H} \mu_h = 1 \text{ and } \sigma_h > 1$$

where σ_h is the elasticity of substitution between two varieties in sector h.

Trade barriers: There are two types of trade barriers, a fixed cost and a variable cost. If a firm in country i in sector h exports to country j, it must pay a fixed cost C_{ij}^h. The variable cost takes the form of an "iceberg" transportation cost. If one unit of any differentiated good h is shipped from country i to country j, only a fraction $1/\tau_{ij}^h$ arrives. The rest melts on the way. The higher τ, the higher the variable trade cost[5].

Strategies and equilibrium definition: Each firm in every country chooses a strategy, taking the strategies of other firms and all consumers as given. A strategy for a firm is both a subset of countries where a firm sells its output, and prices it sets for its good in each market. A strategy for a consumer is the quantity consumed of each variety of every good available domestically, given its price[6]. From the optimal strategies of each firm and each consumer in every country, we can compute the world general equilibrium. It is the set of prices and quantities that correspond to a fixed point of the best response graph of each agent worldwide.

Production and pricing: All countries have access to the same technology. Due to the presence of fixed costs, firms in the differentiated sectors operate under increasing returns to scale technology. Each firm in sector h draws a random unit labor productivity x. The cost

[5] $\tau_{ij}^h > 1$ for any $i \neq j$ and $\tau_{ii}^h = 1$. We also impose a triangular inequality to prevent transportation arbitrages: $\forall (i,j,k)$, $\tau_{ik} \leq \tau_{ij} + \tau_{jk}$.

[6] To prevent arbitrage by consumers, we implicitly assume that consumers in j who try and buy varieties in i would have to pay a fixed cost higher than potential exporters in i. Trade is done by firms, and not by consumers.

of producing q units of good and selling them in country j for a firm with productivity x is: $c(q) = q/x + C_{ij}^h$. Firms are price setters. Given that demand functions are isoelastic, the optimal price charged in country j by firm x from country i is a constant mark-up over the unit cost (including transportation costs): $p_{ij}^h(x) = \frac{\sigma_h}{\sigma_h - 1} \times \frac{\tau_{ij}^h}{x}$.[7]

Firm heterogeneity: For simplicity and as in Melitz (2001) and Helpman, Melitz and Yeaple (2004), we assume the following form for the productivity shocks. It is drawn from a Pareto distribution with scaling parameter γ_h.[8] This means that productivity is distributed according to $P(\tilde{x} < x) = F_h(x) = 1 - x^{-\gamma_h}$, and $dF_h(x) = \gamma_h x^{-\gamma_h - 1} dx$, for $x \geq 1$. γ_h is an inverse measure of the heterogeneity in sector h, with $\gamma_h > 2$ and $\gamma_h > \sigma_h - 1$. Sectors with a lower γ are more heterogeneous, in the sense that more output is concentrated among the largest and most productive firms[9].

We also assume that the total mass of firms in country i in each differentiated sector is proportional to the size of country i, L_i.[10]

Demand for differentiated products: Given the optimal pricing of firms and the optimal decision of consumers, exports from country i to country j, by a firm with a labor productivity x, in sector h, and the profits it earns from exporting to j are:

$$t_{ij}(x) = p_{ij}^h(x) q_{ij}^h(x) = \mu_h L_j \left(\frac{p_{ij}^h(x)}{P_j^h} \right)^{1-\sigma_h} \tag{2}$$

$$\pi_{ij}^h(x) = \frac{\mu_h}{\sigma_h} \left(\frac{\sigma_h - 1}{\sigma_h} \right)^{\sigma_h - 1} P_j^{h\,\sigma_h - 1} L_j \left(\frac{x}{\tau_{ij}^h} \right)^{\sigma_h - 1} \tag{3}$$

where P_j^h is the price index for good h in country j.

If only those firms above the productivity threshold $\bar{x}_{kj}^h$ in country k and sector h export to

[7] This price prevents any arbitrage either by domestic firms that might want to resell these goods at home or abroad, or by foreign firms.

[8] See Kortum (1997) and Gabaix (1999) for justifications of this distribution. An alternative justification is provided by Eaton and Kortum (2002): if the observed distribution of productivities among firms is the realization of the maxima a generic distribution for which all moment are not defined, the distribution of the maxima converges in probability towards a Fréchet distribution. A Fréchet distribution with scaling parameter γ approaches a Pareto distribution with scaling parameter γ for x large.

[9] $\ln x$ has a standard deviation equal to $1/\gamma$. The assumption $\gamma > \sigma - 1$ ensures that, in equilibrium, the size distribution of firms has a finite mean. If this assumption were violated, firms with an arbitrarily high productivity would represent an arbitrarily large fraction of all firms, and they would overshadow less productive firms. Results on selection into export markets would be degenerate. This assumption is satisfied in the data for almost all sectors.

[10] Implicitly, we assume that there is a group of entrepreneurs proportional to the size of the country. We could remove this assumption, and allow for the free entry of entrepreneurs, with an infinite set of potential entrepreneurs. Provided that trade barriers are large enough, we would get qualitatively the same results.

country j, the ideal price index for good h in country j, P_j^h, is defined as :

$$P_j^h = \left(\sum_{k=1}^{N} L_k \int_{\bar{x}_{kj}^h}^{\infty} \left(\frac{\sigma_h - 1}{\sigma_h} \times \frac{x}{\tau_{kj}^h} \right)^{\sigma_h - 1} dF(x) \right)^{-1/(\sigma_h - 1)} \tag{4}$$

For now, we will consider only sector h. The other sectors are analogous. For notational clarity, we drop the h subscript and all sectoral variables will refer to sector h when there is no ambiguity.

2.2 Trade with heterogeneous firms

In this section, we compute the global general equilibrium of this world economy. To do so, we define the selection of firms into the export market. We give predictions for aggregate bilateral trade flows.

If firms are heterogeneous and if there are fixed costs for entering foreign markets, there will be selection among exporters. Less productive firms are not able to generate enough profits abroad to cover the fixed cost of entering foreign markets. Exporters are therefore only a subset of domestic firms. The subset of exporters varies with the characteristics of the foreign market.

Productivity threshold: As long as net profits generated by exports in a given country are sufficient to cover the fixed entry cost, a firm will be willing to export there. We know that the profits firm x in i earns from exporting to j are $\pi_{ij}(x) = \frac{\mu}{\sigma} \left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1} \left(P_j^{\sigma-1} L_j\right) \left(\frac{x}{\tau_{ij}}\right)^{\sigma-1}$. Call $\bar{x}_{ij}$ the productivity threshold for the least productive firm in country i able to export to country j. $\bar{x}_{ij}$ corresponds to the productivity of a firm in country i for which gross profits earned in country j are just enough to cover the fixed cost of entering market j:

$$\begin{aligned} \pi_{ij}(\bar{x}_{ij}) &= C_{ij} \\ \Rightarrow \bar{x}_{ij} &= \lambda_1 C_{ij}^{\frac{1}{\sigma-1}} \left(P_j^{\sigma-1} L_j\right)^{\frac{-1}{\sigma-1}} \tau_{ij} \end{aligned} \tag{5}$$

with λ_1 a constant [11]. We assume that trade barriers are always high enough to ensure that $\forall k, l$, $\bar{x}_{kl} > 1$.

Price indices: Up till now, we have considered prices as given. They do indeed adjust depending on country characteristics. We now know exactly the set of firms that export to

[11] $\lambda_1 = \left(\frac{\sigma}{\mu}\right)^{\frac{1}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)$.

country j. Because of the selection that takes place among exporters, this set only depends on country j's characteristics. By definition, the price index in country j is given by $P_j^{1-\sigma} = \sum_{k=1}^{N} L_k \int_{\bar{x}_{kj}}^{\infty} \left(\frac{\sigma-1}{\sigma} \times \frac{\tau_{kj}}{x}\right)^{1-\sigma} dF(x)$. Plugging in the productivity thresholds from Eq. (5), we can solve for the price index:

$$
\begin{aligned}
P_j &= \lambda_2 \times \left(\frac{L_j}{L}\right)^{\frac{1}{\gamma}} \times L_j^{-\frac{1}{\sigma-1}} \times \theta_j \qquad (6)\\
\text{with } \theta_j^{-\gamma} &\equiv \sum_{k=1}^{N} s_k \times \tau_{kj}^{-\gamma} \times C_{kj}^{-\left(\frac{\gamma}{\sigma-1}-1\right)},\ s_k \equiv \frac{L_k}{L} \text{ and } L \equiv \sum_{k=1}^{N} L_k
\end{aligned}
$$

with λ_2 a constant[12].

θ_j is a aggregate index of j's remoteness from the rest of the world[13]. It is similar to the "multilateral resistance variable" introduced by Anderson and van Wincoop (2003). In addition to their measure, it takes into account the impact of fixed costs and of firm heterogeneity on prices.

General equilibrium exports and threshold: Exports by an individual firm depend on its productivity, the trade barriers it must overcome, and the prices set by its competitors. We have solved for the price indices in every country. Plugging the general equilibrium price index from Eq. (6) into the demand function from Eq. (2), and into the productivity threshold from Eq. (5), we can solve for firm level exports and the productivity threshold.

In general equilibrium, exports $t_{ij}(x)$ from country i to country j by an individual firm with productivity x, and the productivity threshold $\bar{x}_{ij}$ above which firms in i export to j, are given by:

$$
\begin{aligned}
t_{ij}(x|x \geq \bar{x}_{ij}) &= \lambda_3 \times \left(\frac{L_j}{L}\right)^{\frac{\sigma-1}{\gamma}} \times \left(\frac{\theta_j}{\tau_{ij}}\right)^{\sigma-1} \times x^{\sigma-1} \qquad (7)\\
\bar{x}_{ij} &= \lambda_4 \times \left(\frac{L}{L_j}\right)^{\frac{1}{\gamma}} \times \left(\frac{\tau_{ij}}{\theta_j}\right) \times C_{ij}^{\frac{1}{\sigma-1}} \qquad (8)
\end{aligned}
$$

with λ_3 and λ_4 constants[14]. They are functions of the size L_j, the trade barriers C_{ij} and τ_{ij}, and the measure of j's remoteness from the rest of the world, θ_j.

[12] $\lambda_2 = (\gamma-(\sigma-1))^{1/\gamma} \left(\frac{\sigma}{\mu}\right)^{1/(\sigma-1)-1/\gamma} \left(\frac{\sigma}{\sigma-1}\right)$.

[13] A simple way to interpret this aggregate index is to look at a symmetrical case: when $\tau_{kj} = \tau_j$ and $C_{ij} = C_j$ for all k's, $\theta_j = C_j^{\frac{1}{\sigma-1}-\frac{1}{\gamma}} \times \tau_j$. In asymmetric cases, θ_j is a weighted average of bilateral trade barriers.

[14] $\lambda_3 = \mu(\gamma-(\sigma-1))^{\frac{\sigma-1}{\gamma}} \left(\frac{\sigma}{\mu}\right)^{1-\frac{\sigma-1}{\gamma}}$ and $\lambda_4 = \left(\frac{\sigma}{\mu(\gamma-(\sigma-1))}\right)^{\frac{1}{\gamma}}$.

As expected from this simple monopolistic competition model, exports by individual firms depend on the transportation cost τ_{ij} with an elasticity $\sigma - 1$. It depends on the size of the destination market L_j with an elasticity less than one, because of the impact of market size on the degree of price competition. This equation is very similar to what a traditional model of trade with representative firms would predict for aggregate trade flows. In our model with firm heterogeneity on the other hand, because of the selection into the export market, aggregate trade will look radically different.

Proposition 1 (aggregate trade) *Total exports T_{ij}^h in sector h from country i to country j are given by:*

$$T_{ij}^h = \mu_h \times \frac{L_i L_j}{L} \times \left(\frac{\tau_{ij}^h}{\theta_j^h}\right)^{-\gamma_h} \times \left(C_{ij}^h\right)^{-\left(\frac{\gamma_h}{\sigma_h - 1} - 1\right)} \tag{9}$$

Exports are a function of the sizes L_i and L_j, the bilateral variable cost τ_{ij}^h, the bilateral fixed cost C_{ij},and the measure of j's remoteness from the rest of the world, θ_j^h.[15]

Proof. By definition, $T_{ij}^h = \int_{\bar{x}_{ij}^h}^{\infty} t_{ij}^h(x) L_i dF(x)$. Using Eq. (8) for the productivity threshold, Eq. (7) for individual firms' exports, and the specific Pareto distribution for the productivity shocks, we solve for aggregate trade. ∎

The gravity structure of trade has been dramatically distorted by the presence of firm heterogeneity.

First note that the elasticity of exports with respect to variable trade barriers, γ_h, is larger than in the absence of firm heterogeneity, and larger than the elasticity for each individual firm (both equal to $\sigma_h - 1$). An increase in variable costs not only causes a reduction in the size of exports of each exporter, but it also forces some exporters to pull out. The extensive margin comes on top of the intensive margin and amplifies the impact of variable costs. This amplification effect is quantitatively important. Anderson and van Wincoop (2004) argue that if one assumes that trade is governed by an underlying model of trade with identical firms, trade barriers between the US and Canada must be equivalent to a 46% tariff in order to explain the observed bilateral trade flows (table 7 p. 717, Anderson, van Wincoop's results with $\sigma = 8$). This number is an

[15] Interestingly, note that the ratio of i's market share in k, and j's market share in k, only depends on the ratio of i's trade barriers and j's trade barriers. If we define the composite measure of trade barriers $\varphi_{ik} = \tau_{ik}^{-\gamma} \times C_{ik}^{-\left(\frac{\gamma}{\sigma-1}-1\right)}$, we get: $\frac{T_{ik}/Li}{T_{jk}/l_j} = \frac{\varphi_{ik}}{\varphi_{jk}}$. Similarly, i's market share only depends on trade barriers from i relative to trade barriers from other countries: $\frac{T_{ij}}{L_j} = \frac{s_i \varphi_{ij}}{\sum_k s_k \varphi_{kj}}$.

indirect measure. It depends crucially on the assumption about the underlying trade model. If our model were correct, and using an average heterogeneity parameter estimated from firm level data ($\frac{\gamma}{\sigma-1} \approx 2$), we would infer from the same trade volume data that trade barriers are equivalent to a 21% tariff $\left(1.21 = \sqrt{1.46}\right)$, far below their 46% estimate.

Second, the elasticity of exports with respect to transportation costs depends on the degree of firm heterogeneity, γ_h. In more homogeneous sectors (γ_h high) large productive firms represent a smaller fraction of firms. The productivity threshold moves in a region where most of the mass of firms lies. In those sectors, aggregate exports are sensitive to changes in transportation costs because many firms exit and enter when variable costs go up and down.

Third and most importantly, the elasticity of exports with respect to variable costs *does not* depend at all on the elasticity of substitution between goods, σ_h[16], and the elasticity of exports with respect to fixed costs is *negatively* related to the elasticity σ_h. This prediction is in stark contrast with models with representative firms. In such models, the elasticity of exports with respect to transportation costs would be equal to $\sigma_h - 1$. We shall see in the next section how σ_h has exact opposite effects on the intensive and the extensive margins of trade.

2.3 Intensive versus extensive margin

In this section, we study separately the intensive and the extensive margins of trade. We describe how the elasticity of substitution magnifies the sensitivity of the intensive margin to trade barriers, and dampens the sensitivity of the extensive margin. We prove that the dampening effect on the extensive margin dominates the magnifying effect of trade barriers on the intensive margin.

We have seen so far that once we take into consideration firm heterogeneity, the selection of firms into the export market becomes a key feature of the adjustment of trade flows. This is the extensive margin of trade. The main prediction of the model is that the extensive margin and the intensive margin are affected in opposite direction by the elasticity of substitution. If the elasticity of substitution is high, the impact of trade barriers on the intensive margin is strong, and mild on the extensive margin. The reverse holds true when the elasticity of substitution is low. The

[16] Eaton and Kortum (2002) derive a similar prediction from a different set-up. In a Ricardian model of trade, they find that bilateral trade flows do not depend on the elasticity of substitution between goods, but only on the scaling parameter of the underlying distribution of productiviy shocks. They use Fréchet distributions, which approach Pareto distributions in their right tails: the distribution for shocks they consider is $1 - F(z) = 1 - e^{-Tz^{-\theta}} \underset{z \to +\infty}{=} Tz^{-\theta} + o\left(z^{-\theta}\right)$. In equilibrium, they predict that the elasticity of trade flows with respect to trade barriers (variable only) is equal to θ.

dampening effect of the elasticity of substitution on the extensive margin always dominates the magnifying effect on the intensive margin.

Proposition 2 (intensive and extensive margins) *The elasticity of substitution (σ) has no effect on the elasticity of trade flows with respect to variable trade costs (ζ), and a negative effect on the elasticity of trade flows with respect to fixed costs (ξ):*

$$\text{if } \zeta \equiv -\frac{d\ln T_{ij}}{d\ln \tau_{ij}} \text{ and } \xi \equiv -\frac{d\ln T_{ij}}{d\ln C_{ij}}, \text{ then } \frac{\partial \zeta}{\partial \sigma} = 0 \text{ and } \frac{\partial \xi}{\partial \sigma} < 0$$

Proof. We go into much details to prove this proposition. In doing so, we introduce formally the intensive and the extensive margins of trade. We describe the adjustment of each margin, and the sensitivity of these adjustments to the elasticity of substitution.

The impact of trade barriers, both variable cost and fixed cost, on aggregate trade flows can be decomposed into two different margins. The intensive margin is defined by how much each existing exporter changes the size of its exports. The extensive margin is defined by how much new entrants export (in the case of a reduction in trade barriers).

Differentiating Eq. (9), we get the following expressions for each margin[17]:

$$\begin{aligned} dT_{ij} &= \left(\int_{\bar{x}_{ij}}^{\infty} \frac{\partial t_{ij}(x)}{\partial \tau_{ij}} f(x)\,dx\right) d\tau_{ij} - \left(t(\bar{x}_{ij}) f(\bar{x}_{ij}) \times \frac{\partial \bar{x}_{ij}}{\partial \tau_{ij}}\right) d\tau_{ij} \\ \text{and } dT_{ij} &= \underbrace{\left(\int_{\bar{x}_{ij}}^{\infty} \frac{\partial t_{ij}(x)}{\partial C_{ij}} f(x)\,dx\right)}_{\text{Intensive margin}} dC_{ij} - \underbrace{\left(t(\bar{x}_{ij}) f(\bar{x}_{ij}) \times \frac{\partial \bar{x}_{ij}}{\partial C_{ij}}\right)}_{\text{Extensive margin}} dC_{ij} \end{aligned}$$

Following a reduction of trade barriers, each existing exporter (all $x > \bar{x}_{ij}$) exports more. This is the intensive margin. At the same time, higher potential profits attract new entrants ($\bar{x}_{ij}$ goes down). This is the extensive margin.

In elasticity notations, we get the following expression for each margin for changes in the variable cost, τ_{ij}:

$$\zeta = \underbrace{(\sigma - 1)}_{\substack{\text{Intensive margin} \\ \text{Elasticity}}} + \underbrace{(\gamma - (\sigma - 1))}_{\substack{\text{Extensive margin} \\ \text{Elasticity}}} = \gamma$$

σ magnifies the intensive margin when variable costs move ($\sigma - 1$ increases with σ), whereas it dampens the extensive margin ($\gamma - (\sigma - 1)$ decreases with σ)[18]. The effect of σ on each margin

[17] We use Leibniz rule to separate the intensive from the extensive margin. We apply Lebesgue's monotone convergence theorem to compute the intensive margin.

[18] We have implicitly assumed that changes in both τ_{ij} and C_{ij} have no significant impact on the general equilibrium. That is, we have assume that $\frac{\partial \theta_j}{\partial \tau_{ij}} = \frac{\partial \theta_j}{\partial C_{ij}} = 0$. This is a fair approximation as long as country i is not too large compared to the rest of the world (s_{ij} small).

cancels out, so that:

$$\frac{\partial \zeta}{\sigma} = 0$$

In elasticity notation, we get the following expression for each margin for changes in the fixed costs, C_{ij}:

$$\xi = \underbrace{0}_{\substack{\text{Intensive margin} \\ \text{Elasticity}}} + \underbrace{\left(\frac{\gamma}{\sigma - 1} - 1\right)}_{\substack{\text{Extensive margin} \\ \text{Elasticity}}} = \frac{\gamma}{\sigma - 1} - 1$$

σ has no impact on the intensive margin when fixed costs move, whereas it dampens the impact on the extensive margin ($\frac{\gamma}{\sigma-1} - 1$ decreases with σ). The impact of σ on the elasticity of trade flows with respect to fixed costs is always negative:

$$\frac{\partial \xi}{\partial \sigma} < 0$$

■

The intuition for these results is the following. When goods are substitutable, the demand for each individual variety is highly sensitive to changes in trade costs. In other words, when σ is high, the intensive margin of trade is strongly affected by trade barriers. This margin is the only one in the Krugman model of trade with representative firms.

The interaction between the elasticity of substitution and the extensive margin is more complex. When σ is low, the market share that each firm is able to capture is relatively insensitive to differences in productivity. Less productive firms are still able to get a relatively large market share, even though they have to charge a higher price than other firms. In the limiting case of a Cobb-Douglas ($\sigma = 1$), differences in productivity have no effect on the market share of each firm. As trade barriers decrease, some firms with a low level of productivity are able to enter. When goods are highly differentiated, these new entrants are relatively large compared to the firms that are already exporting. Therefore the extensive margin is strongly affected by trade barriers when σ is low. The reverse holds when σ is high.

We can describe the impact of a decrease of trade barriers on both the intensive and the extensive margin of trade graphically. This is illustrated on Figure 1, in which we show the density of exports for two sectors, one where goods are differentiated (σ_{low}), and one where goods are easily substitutable (σ_{high}). Aggregate trade is the sum of exports of all firms with a productivity above the productivity threshold $\bar{x}$. It is represented graphically by area A for σ_{low}, and A' for σ_{high}.

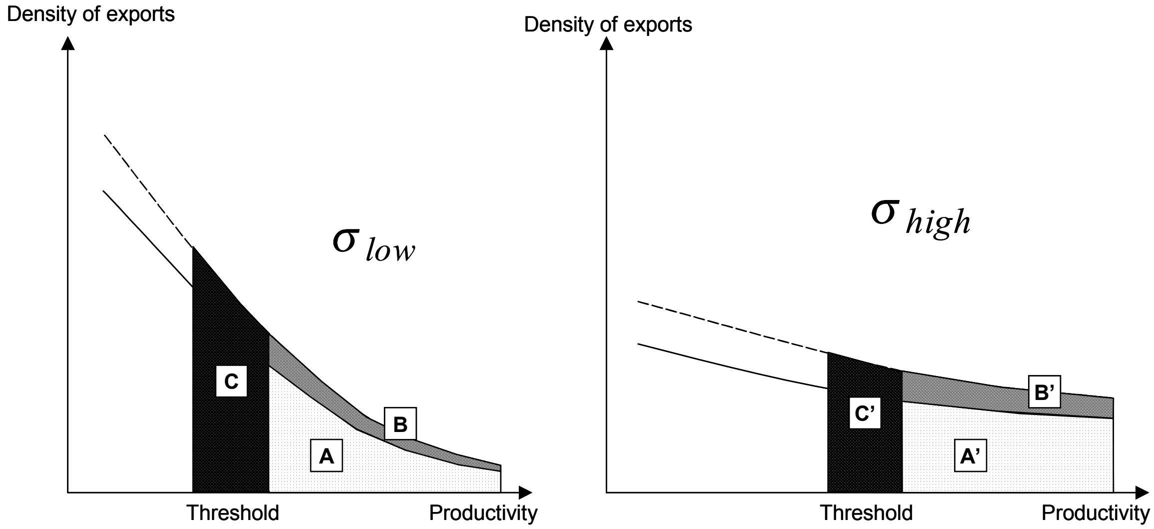

Figure 1: σ magnifies the impact of trade barriers on the intensive margin ($B' > B$), whereas it dampens the impact on the extensive margin ($C' < C$).

When variable trade barriers go down, each firm is able to export a larger volume. The density of exports shifts up. This is the intensive margin of trade. With σ_{low}, each exporter only increases its exports moderately. With σ_{high} on the other hand, the cost advantage from lower trade barriers allows exporters to capture a large market share in the foreign market, and each exporter increases its exports substantially. Aggregate trade is increased by the area B for σ_{low}, and B' for σ_{high}, with $B < B'$. The higher the elasticity of substitution σ, the more sensitive the intensive margin.

In addition, following a decrease in variable trade barriers, new exporters are able to enter the export market. These new entrants are firms with a productivity below the initial productivity threshold. The productivity threshold shifts to the left. This represents the extensive margin of trade. With σ_{low}, the new entrants, despite their lower productivity, capture a large market share in the foreign market. Total exports by new exporters are large. With σ_{high} on the other hand, new entrants, because their lower productivity is a severe handicap in this highly competitive environment, capture only a small market share in the foreign market. Total exports by new entrants are small. Aggregate trade is increased by the area C for σ_{low}, and C' for σ_{high}, with $C > C'$. The lower the elasticity of substitution σ, the more sensitive the extensive margin.

Adjustments to changes in fixed trade barriers are simpler. The intensive margin does not move in response to a reduction of fixed cost, $B = B' = 0$. However, the extensive margin is affected. In contrast with adjustments to changes in variable trade barriers, not only are new entrants larger with σ_{low} than with σ_{high}, but in addition, the productivity threshold moves more when σ_{low} than when σ_{high}. $C > C'$, and even more so than in the case of a reduction of variable trade barriers.

We have proved that σ, the elasticity of substitution between goods, has opposite effects on the extensive margin and on the intensive margin. Which effect dominates? What is the net effect of σ on aggregate trade? Does a larger σ make aggregate trade flows more sensitive to trade barriers (if the intensive margin effect dominates), or less sensitive (if the extensive margin dominates)? In Figure 1, is $B + C$ larger or smaller than $B' + C'$? We have proven in proposition 2 that with Pareto distributed productivity shocks, the effect of σ on the extensive margin always dominates the effect on the intensive margin: $B + C > B' + C'$ if fixed costs are reduced, and $B + C = B' + C'$ if variable costs are reduced.

In this section we have explained why the elasticity of substitution has exactly opposite effects on the intensive and the extensive margins of trade. A higher elasticity of substitution makes the intensive margin more sensitive to changes in trade barriers, whereas it makes the extensive margin less sensitive. What is the net impact of σ on the two margins? We prove in Proposition 2 that the extensive margin always dominates. Contrary to the predictions of the Krugman model with representative firms, the elasticity of substitution σ always dampens the impact of trade barriers on trade flows.

The next section is devoted to testing the predictions from the model. We find strong support for the heterogeneous firms model, thus rejecting the predictions of the Krugman model with representative firms. The interaction between the elasticity of substitution and the sensitivity of trade flows to trade barriers suggest that the extensive margin plays a crucial role in international trade.

3 Estimating distorted gravity equations

In the following sections, we test empirically the predictions of the model with heterogeneous firms against the predictions of the Krugman model with representative firms. If a higher elasticity of substitution dampens the sensitivity of trade flows to trade barriers, the Krugman model with representative firms will be rejected in favor of the model with heterogeneous firms. We find strong support for the model with heterogeneous firms in the data, and reject the Krugman model with representative firms. This finding is consistent with parallel micro evidence on the importance of firm heterogeneity and the extensive margin in international trade.

3.1 Data

In order to test the main prediction of the model, we need data from several sources. We need data on bilateral trade flows, disaggregated at the sector level. We need measures of the degree of heterogeneity between firms within each sector. We need measures of the elasticities of substitution between goods within each sector. Finally, we need measures of trade barriers between trading partners at the sectoral level, either direct measures of trade barriers or proxies for trade barriers.

3.1.1 Bilateral trade flows data

We use bilateral exports data from the World Trade Database and from the World Trade Analyzer. All details from Statistics Canada and NBER preparations are given in Feenstra, Lipsey, Bowen (1997) and Feenstra (2000). Only data for the period 1980-1997 are presented, but the results are similar on other time periods. A total of 169 countries are represented. Results are robust and hold when restricting the analysis to different subsets of countries.

Products are disaggregated according to different classification systems, to ensure that the results are robust to changing the definition of sectors. The most disaggregated classification we use corresponds to the 3-digit SITC revision 3. In this classification, we have data on 265 sectors. We also use a much coarser classification with 34 manufacturing sectors only. This classification is based on the US 1987 Standard Industrial Classification (SIC) and corresponds roughly to 3 digits SIC sectors[19].

3.1.2 Sectoral heterogeneity data

The model predicts that the more heterogeneous a sector, the mildest the impact of trade barriers on trade flows. In order to test this prediction, we need an estimate of firm heterogeneity. Following Melitz, Helpman, Yeaple (2004), we can construct a measure of sectoral heterogeneity by looking directly at the distribution of firm size within sectors. The size distribution of national firms is shaped by the distribution of productivity shocks and the degree of competition. How-

[19] See Table 4 in the appendix for a detailed description of the classification.

ever, the link between the productivity distribution and the size distribution will be more or less distorted by the accessibility of foreign markets.

A firm receiving a random productivity shock $\tilde{x}$ has total sales $S_i(\tilde{x}) = \sum_{j=1}^{N} p_{ij}(\tilde{x}) q_{ij}(\tilde{x})$. More productive firms are able to capture a larger demand. They are also able to reach more countries. They sell more than other firms not only because they can charge lower prices and capture a larger demand in each market, but also because they have access to more markets. In the case of a small and integrated economy, this selection process will magnify the impact of productivity differences between firms.

In large and rather closed economies however, most firms sell only at home, and exporters sell only a fraction of their output abroad. Access to foreign markets has only a mitigated impact on the size distribution of firms within a sector. This is typically the case of the US economy. Bernard et al. (2003) report that 21% of US manufacturing plants export. Even though those plants are large and account for 60% of the US manufacturing sector, the vast majority of exporters sell no more than 10% of their output abroad. Hence when looking at the entire distribution of firm sizes for an economy like the US, we can safely assume that the size of a firm is almost entirely determined by the size of the domestic market: $S(\tilde{x}) \approx p_{US}(\tilde{x}) q_{US}(\tilde{x}) = \lambda_{US} \times \tilde{x}^{\sigma-1}$ with λ_{US} a US specific term common to all US firms[20]. The probability that a firm has a size (measured by sales) larger than S is:

$$\begin{aligned} P_{US}\left(\tilde{S} > S\right) &\approx P\left(\tilde{x} > \left(\frac{S}{\lambda_{US}}\right)^{1/(\sigma-1)}\right) \\ P_{US}\left(\tilde{S} > S\right) &\approx \lambda_{US}^{\gamma/(\sigma-1)} \times S^{-\gamma/(\sigma-1)} \end{aligned} \tag{10}$$

If empirically we have N (large) draws from this distribution, we can estimate the coefficient $\frac{\gamma}{\sigma-1}$ by looking at the rank-size relationship. We order firms according to their size, the largest firm first. Since there are i out of N firms that are larger than the i-th firm, i/N is an estimator of the probability that a firm has a size larger than Size_i. For a firm i:

$$\ln\left(\text{Rank}_i^h / N_h\right) \approx \ln\left(P\left(\tilde{S} > \text{Size}_i^h\right)\right) = a_h - \frac{\gamma_h}{\sigma_h - 1} \ln\left(\text{Size}_i^h\right) \tag{11}$$

Estimating this equation with OLS provides us with an estimator of $\frac{\gamma_h}{\sigma_h-1}$, the scaling coefficient of the size distribution in sector h. This measure of sectoral heterogeneity should amplify the impact of transportation costs on bilateral trade flows. That is in sectors where the distribution

[20] $\lambda_{US} = \mu \left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1} P_{US}^{\sigma-1} L_{US}$.

of the log of firm size has a lower variance ($\frac{\gamma}{\sigma-1}$ is larger), transportation costs should have a larger negative impact on bilateral trade flows.

In order to measure heterogeneity using the distribution of firm size within a sector, we use data from Compustat on the distribution of sales of all publicly traded companies listed in the US stock markets in the year 1996 (we get similar results for other years between 1970 and 1997)[21]. We restrict the sample to US firms only, following the guidance of the model, and exclude affiliates of foreign firms. We compute this measure for the broad 34 manufacturing sectors only. This allows us to get information on a large enough number of firms to compute heterogeneity measures for every sector. A finer definition of sectors such as the 3-digit SITC sectors would give too few datapoints, and would give us unreliable estimates of heterogeneity. Due to selection issues, the rank-size scaling of firms is an appropriate description of the scaling of large firms, but is not accurate for smaller firms. Therefore we restrict the estimation to the largest firms in the sample. We choose to perform the estimation using only the 33% largest firms in the sector[22].

3.1.3 Sectoral elasticity of substitution data

The model also predicts that trade barriers have the largest impact on trade flows in sectors where goods are the most differentiated. It is therefore crucial that we get estimates of sectoral elasticities of substitution. The elasticity of substitution in this model is a demand concept. The simultaneity involved by market clearing makes it difficult to isolate demand from supply considerations. Because of this simultaneity problem, most estimates of those elasticities are either flawed, or irrelevant for our needs. Among other things, we predict that interpreting the elasticity of trade flows with respect to trade barriers in gravity equations as a measure of the elasticity of substitution is incorrect. Empirically, the elasticity of trade with respect to trade barriers *is not* an estimate of the elasticity of substitution in that sector. It is a composite measure of both sectoral elasticity of substitution and sectoral heterogeneity. A proper estimation must be able to estimate demand and supply elasticities simultaneously and distinguish between the two.

We use estimates of elasticities of substitution built by Broda and Weinstein (2004)[23]. They

[21] See Gabaix and Ioannides for a discussion of the various procedures and pitfalls to estimate equations such as Eq. (11).

[22] The choice of the 33% threshold has been dictated by the following consideration. Estimates using thresholds below 33% vary (go up with the threshold), whereas estimates using thresholds above 33% do not vary substantially anymore. The 33% threshold gave us the best information for estimating the shape of the Pareto distribution of firm size, at the lowest cost in terms of departure from the Pareto scaling. See Axtell (2001) for a discussion of Pareto distribution estimates for firm size.

[23] I am immensely indebted to Christian Broda and David Weinstein for providing me with their estimates of

widely extend the seminal work of Feenstra (1994). Using the panel dimension of data, they use the second moments of demand and supply variations to infer demand and supply elasticities separately. Even though they do not account directly for heterogeneity between firms, they use data at a sufficiently fine level of disaggregation to capture most of the heterogeneity. They use price and volume data at a highly disaggregated level. Assuming that the demand and supply elasticities in every sectors are constant across country and over time, and using between country variations, they construct two separate estimates for the demand and the supply elasticities. Their estimation strategy is robust to many different specifications of the underlying structure of the economy. In particular, it is consistent with our model where, due to the selection that takes place among exporters, demand and supply elasticities differ. We use their estimates of the elasticities of substitution over the period 1990-2001 for 3-digit SITC (revision 3) sectors. Our results also hold over the earlier period they consider, 1972-1988.

3.1.4 Trade barriers data

We use both direct and indirect measures of trade barriers. We use several indirect measures of trade costs. The most widely used and those for which we present results here are the bilateral geographical distance between two trading partners, the fact of sharing a common border, and the fact of sharing a common language. We use great distance circles to measure distance between capital cities from L. Eden, Texas A&M University. We use the CIA world factbook for contiguity and language data. The common language variable is a dummy equal to 1 if both countries have the same official language. We do not use more continuous measures of language proximity, such as those used by Jacques Melitz (2003). Implicitly, we assume that those proxies for trade barriers are correlated with both fixed and variable costs.

We use data on freight and tariff from Hummels (2001) as a direct measure of trade costs[24]. Data are disaggregated at the 3-digit SITC level. They correspond to the freight and tariff reported by exporters as a fraction of the value of their exports. Unfortunately, those data are incomplete: they only cover trade towards the US.

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elasticities of substitution.

[24] I am immensely grateful to David Hummels for providing me with those data and helping me organize them at the right level of dissagregation.

Table 1: High and low distance elasticities of trade flows.

Sector (3-digit SITC)	Distance elasticity of trade flows	Distance elasticity of trade costs	Average trade cost	Elasticity of substitution
HIGH ELASTICITY				
Printed Matter	1.5	0.08	9%	2.8
Non alcoholic beverages	1.4	0.15	17%	1.7
Equipment for distributing electricity	1.3	0.1	5%	1.9
LOW ELASTICITY				
Steam and vapor generating boilers	0.6	1.1	8%	12
Road motor vehicles	0.6	0.7	4.5%	19
Pulp and waste paper	0.5	0.08	15%	18
Min< Average <Max	-1.46<.89<1.8	-.7<.27<1.1	1.4%<10%<38%	1.1<3.9<58.5

Source: bilateral trade flows, Feenstra (2000); average freight rate towards the US, Hummels (1999); elasticities of substitution, Broda and Weinstein (2004); data are aggregated at the 3-digit SITC (rev 3) level; year 1997, all countries with GDP/capita above $3000 (PPP) and population above 1 million.

3.1.5 Descriptive statistics

In Table 1, we give summary statistics for a few sectors. We show sectors with distance elasticities of trade among the highest, and sectors with elasticities among the lowest. A model with representative firms would predict that, controling for the transportation technology, sectors with low distance elasticities of trade should have low elasticities of substitution, and the reverse holds true for sectors with high distance elasticities. We observe exactly the opposite. The sectors where distance has a large impact on trade flows are sectors with elasticities of substitution among the lowest, and sectors where distance has a mild impact on trade flows are sectors with elasticities of substitution among the highest. These patterns cannot be explained by differences in transportation technologies. High distance elasticities sectors are neither sectors where freight rates are large in level, nor sectors where freight rates are highly sensitive to distance.

This anecdotal evidence suggests that models with representative firms generate incorrect predictions. Introducing firm heterogeneity and the extensive margin of trade provides with an answer for this apparent puzzle.

3.2 Firm heterogeneity distorts gravity

In this section, we test whether or not the degree of firm heterogeneity affects the sensitivity of trade flows with respect to trade barriers. We find strong support for the predictions of the model model with heterogeneous firms. In sectors where the output is concentrated among a few large firms, trade barriers have a mild impact on trade flows, and a strong impact in sectors where small firms account for a larger share of output.

Our model predicts that the degree of heterogeneity between firms will affect the sensitivity of trade flows to trade barriers. In heterogeneous sectors, defined as sectors where the largest firms account for a large fraction of output, the selection among exporters takes place among small firms. It does not have much of an impact on aggregate trade flows. On the other hand, in homogeneous sectors, defined as sectors where small firms account for a large fraction of output, the entry and exit of less productive firms has a large impact on aggregate trade.

In order to test this prediction, we run the following equation using OLS:

$$\ln\left(\text{Exports}_{ij}^h\right) = B_{ij}^h + X_{ij}B_1 + \left(\frac{\widehat{\gamma_h}}{\sigma_h - 1} \times X_{ij}\right) B_2 + \varepsilon_{ij}^h \tag{12}$$

Exports from country i towards country j in sector h are a function of a constant and a set of dummies (country of origin dummies, country of destination dummies, and sector dummies, B_{ij}^h), a vector of trade barriers (X_{ij} includes the log of bilateral distance, common language and common border dummies), and the interaction between the sectoral heterogeneity and trade barriers ($\frac{\widehat{\gamma_h}}{\sigma_h-1} \times X_{ij}^h$). ε_{ij}^h is assumed to be a normally distributed random shock orthogonal to the right hand side variables. $\frac{\widehat{\gamma_h}}{\sigma_h-1}$ is estimated from the sectoral distribution of firm size in Compustat. A larger coefficient corresponds to a thinner tail for the distribution of firm size, and therefore a more homogeneous sector. The country fixed effects sum up the impact of size and the impact of relative prices on trade flows[25].We cluster observations by country pairs to allow for shocks affecting trade flows in all sectors to differ across country pair.

We expect firm heterogeneity to dampen the effect of trade barriers on bilateral trade flows. More heterogeneous sectors are sectors where the largest firms account for a larger fraction of output; hence the selection among the less productive firms has a minor impact on aggregate trade. We expect B_1 and B_2 to have the same sign.

[25]The impact of prices on trade flows corresponds in our model to the indices of remoteness, the θ_j's. We also test the prediction of the model more directly, using measures of country size.

Table 2: Firm heterogeneity distorts gravity.

Variable	(1)	(2)	(3)	(4)	(5)
$\ln(\text{Distance}_{ij})$	-.9	-.8			-.7
	(.04)***	(.04)***			(.04)***
$\widehat{\frac{\gamma_h}{\sigma_h - 1}} \times \ln(\text{Distance}_{ij})$		-.09			-.09
		(.002)***			(.003)***
Language_{ij}	.3		1.6		-.4
	(.1)***		(.2)***		(.02)**
$\widehat{\frac{\gamma_h}{\sigma_h - 1}} \times \text{Language}_{ij}$			-.4		.4
			(.05)***		(.05)***
Border_{ij}	.8			3.9	1.4
	(.02)***			(.3)***	(.3)***
$\widehat{\frac{\gamma_h}{\sigma_h - 1}} \times \text{Border}_{ij}$				-.7	-.3
				(.008)***	(.08)*
R^2	30%	31%	23%	25%	32%
Number of obs.	65,687	65,687	65,687	65,687	65,687

Note: Dependent variable, log of exports from country i to country j in sector h in 1996. All regressions include sector dummies, origin country and destination country dummies. Observations are clustered within country pairs. Robust standard errors are given in parentheses. Significant at the 1% (***), 5%(**), 10% level (*). Source: 1996 bilateral trade flows, Feenstra (2000); firm heterogeneity, Compustat, rank-size scaling coefficient of sales in 1996; data are aggregated over 35 BEA sectors; countries with a GDP/capita lower than \$3000 (in PPP) or a population smaller than 1 million have been ignored.

The regression results are reported in Table 2. Column (1) is the benchmark gravity regression with no interaction term between sector heterogeneity and trade barriers. The other specifications take into account the interaction between sector heterogeneity and trade barriers. When using distance as a proxy for trade barriers, the predictions from the model are confirmed. Whether we control for other measures of trade barriers or not, in columns (2) and (5) of Table 2, the negative effect of distance on trade is dampened by sectoral heterogeneity (magnified by $\widehat{\frac{\gamma_h}{\sigma_h - 1}}$), as predicted by the theory.

Results on the other proxy measures of trade barriers are more ambiguous. The size, sign and significance of the coefficients vary from one specification to the next.

These qualifications put aside, the predictions of the model with heterogeneous firms are confirmed. In sectors where output is concentrated among the few largest firms, trade barriers have a mild impact on trade flows, whereas the reverse holds in sectors where output is more uniformly spread across firms.

3.3 Market structure distorts gravity

In this section, we evaluate the impact of the elasticity of substitution between goods on how sensitive trade flows are to trade barriers. We find strong support to our model with heterogeneous firms, and reject the model with representative firms. Sectors where the elasticity of substitution is high are sectors where trade barriers have little impact on trade flows, and the opposite in sectors where the elasticity is low.

In order to test the prediction of the model, we estimate the following equation with OLS:

$$\ln\left(\text{Exports}_{ij}^{h}\right) = B_{ij}^{h} + X_{ij}^{h}B_1 + \left(\hat{\sigma}_h \times X_{ij}^{h}\right)B_2 + \varepsilon_{ij}^{h} \tag{13}$$

Exports from country i towards country j in sector h are a function of a constant and a set of dummies (B_{ij}^{h}), a vector of trade barriers (X_{ij}^{h} includes the log of bilateral distance, common language and common border dummies), and the interaction between the sectoral elasticity of substitution and trade barriers ($\hat{\sigma}_h \times X_{ij}^{h}$). ε_{ij}^{h} is assumed to be a normally distributed shock orthogonal to the right hand side variables. $\hat{\sigma}_h$ is the estimated elasticity of substitution in sector h from Broda and Weinstein (2004). The country fixed effects sum up the impact of size and the impact of relative prices on trade flows. We cluster observations by country pairs to allow for shocks affecting trade flows in all sectors to differ across country pair.

This specification enables us to separate the direct impact of trade costs on trade flows from the dampening or magnifying effect of the elasticity of substitution. If the extensive margin effect dominates, we expect the coefficients on trade barriers to be of the opposite sign to the interaction coefficients. B_1 and B_2 should be of opposite signs.

The regression results are given in Table 3. All predictions from the model are confirmed. All coefficients have the expected signs. Simply put, trade barriers reduce trade, but less so in more competitive sectors. This result directly invalidates the prediction of the model with representative firms. The distortion of the elasticity of trade with respect to trade barriers due to the elasticity of substitution between goods is quantitatively important. A one standard deviation increase in the elasticity of substitution (σ increases by 5) corresponds to a reduction of the distance elasticity of trade by a fifth of a standard deviation (from column (5) in Table 3, the distance elasticity of trade decreases by $.015 \times 5 = .075$, which represents 22% of the standard deviation of the distance elasticity of trade, .34).

Table 3: Market structure distorts gravity.

	(1)	(2)	(3)	(4)	(5)
$\ln(\text{Distance}_{ij})$	-.8	-1			-.9
	(.02)***	(.02)***			(.02)***
$\hat{\sigma}_h \times \ln(\text{Distance}_{ij})$		.02			.015
		(.001)***			(.001)***
Language_{ij}	.4		1.2		.5
	(.04)***		(.09)***		(.05)***
$\hat{\sigma}_h \times \text{Language}_{ij}$			-.02		-.02
			(.004)***		(.004)***
Border_{ij}	.5			2.3	.6
	(.08)***			(.1)***	(.09)***
$\hat{\sigma}_h \times \text{Border}_{ij}$				-.04	-.01
				(.006)***	(.006)*
R^2	39%	40%	33%	35%	41%
Number of obs.	270,607	257,583	257,583	257,583	257,583

Note: Dependent variable, log of exports from country i to country j in sector h in 1997. All regressions include sector dummies, origin country and destination country dummies. Observations are clustered within country pairs. Robust standard errors are given in parentheses. Significant at the 1% (***), 5%(**), 10% level (*). Source: 1997 bilateral trade flows, Feenstra (2000); elasticities of substition, Broda and Weinstein (2004), 1980-1997 estimates; data are aggregated at the 3-digit SITC level; countries with a GDP/capita lower than \$3000 (in PPP) or a population smaller than 1 million have been ignored.

We use direct measures of transportation costs (freight rates from Hummels (1999)) to verify that the sectoral distance elasticity of freight is not correlated with the sectoral elasticity of substitution between goods. The correlation is equal to -5.6% (-1.6% if one removes the 10% sectors with the largest elasticities). We conlude that our results are not a consequence of more competitive sectors being sectors with with trade barriers that are less responsive to distance.

This result seems to contradict findings by Hummels (2001, table 4) and presented by Anderson and van Wincoop (2004, figure 1). Based on estimates computed by David Hummels[26], James Anderson and Eric van Wincoop find a strong negative correlation between the distance elasticity of trade costs and the elasticity of substitution between goods. We believe that this correlation is an artefact. Oversimplifying unduly the empirical procedure adopted in Hummels (2001), the regression implicitly imposes that the product of the distance elasticity of trade costs and the

[26] We used the same data on freight as Hummels (2001). Hummels however has access to a larger set of data on direct measures of trade costs than we have. This should not alter the results significantly.

elasticity of substitution between goods is equal to the distance elasticity of trade. The elasticity of substitution between goods is then by construction equal to the ratio of the distance elasticity of trade and the distance elasticity of trade costs. But since the distance elasticity of trade varies very little from one sector to the next (far less than the distance elasticity of trade costs in any case), this amounts to imposing a negative relationship between the distance elasticity of trade costs and the elasticity of substitution between goods.

In addition to this, our theoretical model gives reasons to believe that because of the selection of firms into the export market, the elasticity of aggregate trade with respect to trade barriers is not a relevant measure of the elasticity of substitution between goods. It is even inversely related to the elasticity of substitution between goods. The data provides strong support to this interpretation.

In this section and the previous one, we have found strong support for the model with heterogeneous firms in the data, and we have rejected the model with representative firms. The patterns of international trade suggest that the extensive margin of trade plays a crucial role in the adjustments of trade flows to trade barriers, and that this margin tends to dominate quantitatively the intensive margin of trade. Specifically, trade barriers have relatively little impact on trade flows in sectors with heterogeneous firms, and in sectors where the elasticity of substitution between goods is high.

4 Stylized facts on firm level trade

This model of international trade with heterogeneous firms generates many predictions on firm level trade. In the following sections, we present predictions of our model and match them with existing stylized facts uncovered in the recent empirical literature on firm level trade.

4.1 Stylized facts for the productivity of exporters

In this section, we present a clear prediction for the determinants of the average productivity of exporters.

Firm heterogeneity has a direct impact on the productivity of exporters entering a specific market. Larger and more integrated markets attract more firms, and the new firms that enter are typically less productive. These entries lower the average level of productivity of exporters. Eq. (5) and Eq. (6) give us the following expression for the average productivity of firms exporting from country i towards country j, as a function of the entry cost, C_j, remoteness, θ_j, size, L_j, and trade cost, τ_{ij}:

$$E\left(x|x \geq \bar{x}_{ij}\right) = \frac{\gamma}{\gamma-1}\bar{x}_{ij} = \lambda_5 \times \left(\frac{L}{L_j}\right)^{\frac{1}{\gamma}} \times \left(\frac{\tau_{ij}}{\theta_j}\right) \times C_{ij}^{\frac{1}{\sigma-1}} \tag{14}$$

with λ_5 a constant[27].

As expected, countries that are expensive to enter into (C_{ij} large), far away (τ_{ij} large), or which represent a small market (L_j small), attract only the most productive exporters. If a country is close to the rest of the world (θ_j small) it is harder for firms in i to compete, and only the most productive firms in i are able to enter. These effects are amplified by the degree of heterogeneity in the sector and the degree of product differentiation.

4.2 Matching the stylized facts from Eaton, Kortum and Kramarz (2004)

In this section, we present various stylized facts on the patterns of exports by French firms presented by Eaton, Kortum and Kramarz (2004a and 2004b), and match them with predictions from our model with heterogeneous firms. The facts are as follows: exporters are larger and more productive than non exporters; larger and more productive firms export to more countries; the size of aggregate exports can be primarily explained by the number of exporters, rather than the average size of exports; the number of firms exporting to multiple markets falls off quickly with the number of destinations.

Characteristics of exporters: Eaton, Kortum and Kramarz (2004a) as well as Bernard and Jensen (1995) and Bernard, Eaton, Jensen and Kortum (2003) describe many characteristics of exporters: exporters are larger and more productive than non exporters; larger and more productive firms are able to export to more countries. Our model generates similar predictions. The origin of firm heterogeneity lies in differences in productivity. Because of the fixed costs associated with exporting, only the more productive firms are able to export. Among exporters, only the very productive are able to export to many different destinations. But productivity is also a key determinant of the size of a firm. More productive firms can capture a larger market share, both at home and abroad, and are therefore larger. Hence, because they are more productive, larger firms are more likely to export, and they are able to export to more countries.

[27] $\lambda_5 = \frac{\gamma}{\gamma-1}\left(\frac{\sigma}{\mu(\gamma-(\sigma-1))}\right)^{\frac{1}{\gamma}}$.

Number and size of firms: Eaton, Kortum and Kramarz (2004b) analyze the adjustment in the number and size of French exporters in response to variations in the destination market. They report the following statistics (p. 4): "(...) given market size, a higher French market share in a destination typically reflects 88 percent more firms selling there and 12 percent more sales per firm". Therefore most of the adjustment in aggregate trade flows is made through the number of exporters, rather than through the size of each individual exporter. Our model is very similar in spirit to the theoretical model they propose in order to explain the patterns of the data in Eaton, Kortum and Kramarz (2004a). Yet, it allows for very simple closed form solutions.

When trade barriers decrease, or when the size of the destination country increases, trade flows increase. Part of this increase is due to larger sales by each individual exporter, and part is due to the entry of new exporters. The new entrants are typically smaller and less productive firms. If empirically one looks at the *average* size of exports per firm, one might get the impression that individual firms' exports do not increase much, and infer that most of the increase in aggregate exports is due to the larger number of firms exporting. This would bias downward the estimate of the elasticity of individual firms' exports with respect to distance, or with respect to country size. Indeed, the average exports *among already exporting firms*, or *controlling for selection*, does respond significantly to changes in trade costs or to changes in the size of the foreign market. But at the same time, the distribution of firms' exports shifts to the left, and the entry of small firms prevents the average size of exports from increasing much. This selection process would explain the very large increase in the number of firms found by Eaton, Kortum and Kramarz (2004b).

The average size of exporters is given by:

$$E\left(t_{ij}\left(x\right)|x > x_{ij}^{*}\right) = \frac{\int_{\bar{x}_{ij}}^{\infty} t_{ij}\left(x\right) dF\left(x\right)}{\int_{\bar{x}_{ij}}^{\infty} dF\left(x\right)} = \lambda_6 \times C_{ij} \tag{15}$$

with λ_6 a constant[28].

Variable trade costs or market size have no impact on the average size of exports. The reason is that the entry of smaller and less productive firms in response to lower trade costs or larger foreign demand pulls down the average size of exports and exactly offsets the increase in the size of each existing exporter. Fixed costs on the other hand have a large impact on the average size of exporters. An increase in fixed cost has no impact on the exports of any individual firm, but it forces less productive firms to exit the export market. Only more productive and larger firms

[28] $\lambda_6 = \frac{\gamma\sigma}{\gamma-(\sigma-1)}$.

survive. Therefore the average size of firms is larger.

This does not mean that each individual exporter does not adjust its exports to changes in the accessibility of foreign markets. The size of exports from i to j of an individual exporter (provided it does export to country j) is given in Eq. (7):

$$t_{ij}\left(x|x \geq \bar{x}_{ij}\right) = \lambda_3 \times \left(\frac{L_j}{L}\right)^{\frac{\sigma-1}{\gamma}} \times \left(\frac{\tau_{ij}}{\theta_j}\right)^{-(\sigma-1)} \times x^{\sigma-1}$$

The elasticity of an individual firm's exports with respect to the trade cost τ_{ij} is $\sigma - 1$, and the elasticity with respect to the size L_j is $\frac{\sigma-1}{\gamma}$. These elasticities are undoubtedly positive and large. Note however that they are smaller than the corresponding elasticities of aggregate trade: aggregate trade depends both on the size of each exporter, and on the number of exporters. Most of the adjustment comes from the number N_{ij} of exporters in i exporting to j:

$$N_{ij} = L_i \times P\left(x > x_{ij}^*\right) = \frac{1}{\lambda_6 \times C_{ij}} \times \mu \times \frac{L_i L_j}{L} \times \left(\frac{\tau_{ij}}{\theta_j}\right)^{-\gamma} \times C_{ij}^{-\left(\frac{\gamma}{\sigma-1}-1\right)} \tag{16}$$

The number of firms does react to changes in trade costs τ_{ij} with an elasticity of γ, and to changes in the size of the destination country L_j with an elasticity of 1. This elasticity of 1 is close to the elasticity of .88 reported in Eaton, Kortum and Kramarz (2004b).

How many firms are able to export to multiple markets? Eaton, Kortum and Kramarz (2004b) also report that the number of firms selling to multiple markets falls off with the number of destinations with an elasticity of 2.5. In other words, only few firms are able to export to many different foreign markets. Figure 2 shows how the number of firms falls off with the number of markets. It is reproduced from Eaton, Kortum and Kramarz (2004b, Figure 1A). In a model with a discrete number of countries, it is not easy to match precisely this fact. It is much simpler to consider a continuous version of the model, and focus on the role of trade costs only. Consider a continuum of countries uniformly distributed around a circle. The fixed entry cost is the same for every country, set equal to C. We introduce a specific functional form for the transportation technology: the transportation cost for reaching a country at a distance m is defined by $\tau(m) \equiv m^{\alpha}$, with $\alpha > 0$. A firm with productivity x_m is able to reach a mass $2m$ of countries. x_m is defined by $\pi_m(x_m) = \frac{\mu}{\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1} P_m^{\sigma-1}\left(\frac{x_m}{\tau_m}\right)^{\sigma-1} = C$, where P_m is the price index in the importing country. Since all countries are symmetrical in this model, prices will be identical everywhere, $P_m = P$. The number of firms able to export to $2m$ different countries corresponds in this continuous setting to the density $f(x_m)$. Solving for x_m, we get the following

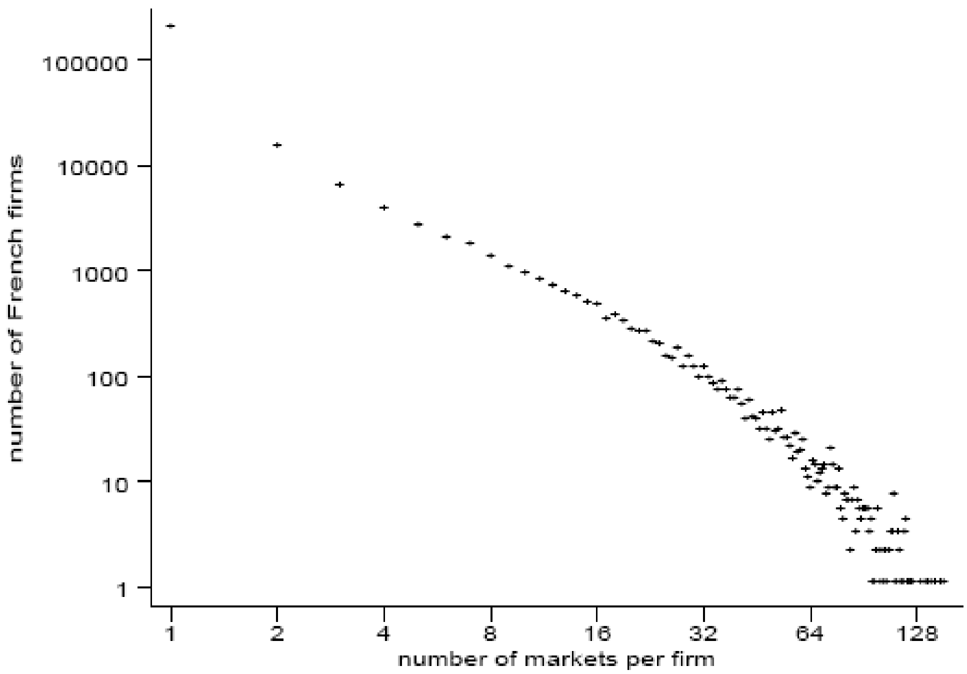

Figure 2: Only few firms export to multiple markets. Source: Eaton, Kortum and Kramarz (2004b).

relation between the number of firms, $f(x_m)$, and the number of countries, $2m$, they are able to reach:

$$f(x_m) = \lambda_7 \times P^{\gamma+1} \times C^{-\frac{\gamma+1}{\sigma-1}} \times (2m)^{-\alpha(\gamma+1)} \tag{17}$$

with λ_7 a constant[29].

There are numerous firms with a relatively low productivity. These firms are only able to export to a few accessible markets. On the other hand, there are only few firms with a high productivity. Those firms are able to export to many markets, even remote ones. The number of firms selling to multiple markets falls off with the number of destinations with an elasticity $\alpha(\gamma+1)$. If distance and transportation costs were the only determinants of trade volume, and if countries were uniformly spread around a one dimensional circle, we would predict that the elasticity should be close to 1, equal to the gravity coefficient on distance[30]. This is obviously

[29] $\lambda_7 = \gamma\left(\frac{\mu}{\sigma}\right)^{\frac{\gamma+1}{\sigma-1}}\left(\frac{\sigma-1}{\sigma}\right)^{\gamma+1}$.

[30] On a two dimensional infinite space the elasticity would be exactly half of the elasticity on a circle: a firm which can reach a mass m of countries must be able to export as far as $r = \sqrt{m/\pi}$. However, on a sphere, like the earth, this property holds only for distances smaller than a quarter of the length of the equator, and is reversed for

a rough approximation of the real world economy. Adding differences in country size would strengthen the selection process among exporters, and increase the estimated elasticity.

We have described in this section how our model with heterogeneous firms generates predictions about firm level trade patterns that match existing stylized facts. We confirm exporters are larger and more productive than non exporters. We also confirm that only a few firms are able to reach many markets, and those firms are larger than the typical exporter. Finally, we predict that the extensive margin is a key variable of adjustment for aggregate trade flows, which is confirmed in the data. Due to the entry and exit of small exporters, the average size of exporters does not respond to changes in variable costs or in market size. Most of the adjustment comes from changes in the number of exporters. These micro evidences for firm heterogeneity come in addition to the macro evidences described in the previous section. In this section we showed that the patterns of aggregate trade flows also suggest that firm heterogeneity plays a crucial role. Therefore the effect of trade barriers on trade flows is dampened by the elasticity of substitution, and not magnified as models with representative firms would predict. We believe that this is the strongest argument in support to our model with heterogeneous firms. It sheds a new light on the interpretation of trade barriers.

5 Conclusion

We have shown that, contrary to the prediction of the Krugman (1980) model with representative firms, the impact of trade barriers is dampened by the elasticity of substitution, and not magnified by it. We introduce adjustments on the extensive margin in a simple model of international trade. We prove that the elasticity of substitution has opposite effects on the sensitivity of each margin to trade barriers. In sectors where the elasticity of substitution is high, the intensive margin of trade is highly sensitive to changes in trade barriers, whereas the extensive margin is not, and the reverse holds true in sectors where the elasticity of substitution is low. The dampening effect of the elasticity on the substitution on the extensive margin always dominates. High competition sectors are global, in the sense that differences in trade barriers have little impact on bilateral trade flows. Low competition sectors are local.

longer distances.

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Table 4: 35 manufacturing sectors.

WTDB	*Industry*	*ISIC, Rev.2*	*US 1987 SIC code*
1	Grain, mill and bakery products	311	204, 205
2	Beverages	313	208
3	Tobacco products	314	21
4	Other food and kindred products	311	201, 202, 203, 206, 207, 209
5	Apparel and other textile products	321+322	22, 23
6	Leather and leather products	323+324	31
7	Pulp, paper and board mills	341	261, 262, 263
8	Other paper and allied products	341	265, 267
9	Printing and publishing	342	27
10	Drugs	352	283
11	Soaps, cleaners and toilet goods	352	284
12	Agricultural chemicals	351	287
13	Industrial chemicals and synthetics	351	281, 282, 286
14	Other chemicals	352	285, 289
15	Rubber products	355	301, 302, 305, 306
16	Miscellaneous plastic products	356	308
17	Primary metal industries: Ferrous	371	331, 332, 339
18	Primary metal industries: Non-ferrous	372	333, 334, 335, 336
19	Fabricated metal products	381	34
20	Farm and garden machinery	382	352
21	Construction, mining, etc machinery	382	353
22	Computer and office equipment	382	357
23	Other non-electric machinery	382	351, 354, 355, 356, 358, 359
24	Household appliances	383	363
25	Household audio and video, etc	383	365, 366
26	Electronic components	383	367
27	Other electrical machinery	383	361, 362, 364, 369
28	Motor vehicles and equipment	384	371
29	Other transportation equipment	384	372, 373, 374, 375, 376, 379
30	Lumber, wood, furniture, etc	331+332	24, 25
31	Glass products	362	321, 322, 323
32	Stone, clay, concrete, gypsum, etc	361+369	324, 325, 326, 327, 328, 329
33	Instruments and apparatus	385	38
34	Other manufacturing	390	39