Per Capita Income, Market Access Costs, and Trade Volumes*

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Abstract

There is strong empirical evidence that countries with lower per capita income tend to have smaller trade volumes even after controlling for aggregate income. Furthermore, poorer countries do not just trade less, but have a lower number of trading partners. In this paper, I construct and estimate a general equilibrium model of trade that captures both these features of the trade data. The key element of the model is an association between trade costs (both variable and fixed) and countries' development levels, which can account for the effect of per capita income on trade volumes and explain many zeros in bilateral trade flows. I find that market access costs play an important role in fitting the model to the data. In a counterfactual analysis, I find that removing the asymmetries in trade costs raises welfare in all countries with an average percentage change equal to 29% and larger gains for smaller and poorer countries. Real income inequality falls by 43%.

Keywords: country extensive margin; general equilibrium; structural estimation; trade zeros.

JEL classification: F1

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1 Introduction

There is strong empirical evidence suggesting that poorer countries (with lower per capita income) trade less even after controlling for aggregate income (see for example Hummels and Klenow (2002)). In addition, poorer countries do not just export or import smaller volumes, but have fewer trading partners. In 1995, for instance, 19% of all country pairs among the hundred largest countries in terms of GDP did not trade with each other in at least one direction (9% did not trade at all). However, there were no zero trade flows among the fifty richest countries in the sample. All the country pairs with trade zeros included at least one country belonging to the fifty poorest countries in the sample. This suggests that the country extensive margin (the number of trading partners) is relevant in explaining the relationship between per capita income and trade volumes.

There are several explanations for a positive relationship between trade volumes and per capita income (for instance, nonhomothetic preferences or differences in trade costs). The present paper focuses on an explanation based on cross-country variation in trade costs. To capture the above evidence, I construct and estimate a quantitative general equilibrium model of trade with many asymmetric countries. In the model, I introduce an association between trade costs (both variable and fixed) and exporter and importer development levels. A novel element here is a dependence of the costs of access to foreign markets on an *exporter* development level that I find plays an important role in explaining a number of zero trade flows and the correlation between trade and per capita income in the data.[1]

This association is motivated by indirect evidence suggesting that firms in poorer countries may face higher entry barriers to foreign markets. Indeed, exporting firms may be required to meet certain product standards, quality requirements, and technical regulations imposed by the destination country that are especially restrictive for developing and less developed countries.[2] For instance, studies conducted by the United Nations Conference on Trade and Development find that firms in some developing countries were unable to meet environmental standards and regulations imposed by developed countries, which in turn resulted in considerable export losses (see Chen et al. (2006)).[3] Poor infrastructure and bureaucracy also play a role of entry barriers

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[1] Exporter and importer specific variable trade costs are for instance allowed for in Eaton et al. (2010). Importer specific market access costs are considered in Arkolakis (2010) (see also Eaton et al. (2010)).

[2] See Hallak (2006) for how product quality affects the patterns of bilateral trade.

[3] Quality requirements are another entry barrier for firms from developing and less developed countries. The international management literature emphasizes that one of the key reasons for obtaining quality management

to foreign markets for firms in less developed countries. For example, because of a large number of long administrative procedures and poor logistics services, many firms in less developed countries cannot meet the reliability requirements of foreign partners and, thereby, cannot enter foreign markets (see Nordas et al. (2006)).[4]

I consider an environment based on Melitz (2003) and Chaney (2008) where each country is characterized by its population size and development level. Firms vary according to their productivity, which is defined as the product of a firm-specific productivity and a country development level. Exporting firms incur variable and fixed costs of trade. In the same manner as in Helpman et al. (2008), the model allows for zero exports from i to j: this happens when there are no firms in country i that are productive enough to find it profitable to export to country j. I assume that trade costs depend on development levels of the source and destination countries. Hence, if less developed countries have higher trade costs, then, all else equal, they tend to have smaller trade volumes in equilibrium and, moreover, a lower number of trading partners.

In the model, zero trade flows and the dependence of trade on per capita income can be explained by cross-country variation in variable as well as in fixed costs of trade. To understand the role of each type of trade cost, I estimate the key parameters of the model using 1995 data on bilateral trade flows of the 100 largest countries in terms of total income. The estimation procedure involves minimizing the sum of squared differences between the actual bilateral trade flows and those generated by the model subject to the constraint that the number of zero bilateral trade flows predicted by the model is the same as that in the data.[5] In other words, I estimate bilateral trade flows taking into account the country extensive margin of trade. The novelty of this estimation procedure is that it allows us to estimate both variable and fixed

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certification (ISO 9000) is the requirements of international customers. For instance, Potoski and Prakash (2009) argue that ISO certification is a signal for the quality of a product, which is especially important for developing and less developed countries, as consumers often relate the quality of products to their countries of origin. Meanwhile, the process of certification is costly. It includes both the costs of development and implementation of new production processes satisfying the standards and the costs of certification itself (e.g. the costs of application and documentation review, registrar's visits, etc.). Mersha (1997) documents that achieving the quality management certification is especially complicated in less developed countries (he considers the countries of Sub-Saharan Africa in particular).

[4] According to the Doing Business (2006) report, there is a significant negative correlation between the number of documents required to be filled out before exporting and per capita income of an exporting country: the poorer a country is, the greater the number of documents exporters of that country have to fill out. Since the greater number of documents required to export would typically increase fixed costs of exporting, this evidence suggests that firms in richer countries find it relatively easier to start exporting compared to their counterparts in poorer countries.

[5] Notice that mismatch is possible. The model can predict some zeros that are not actually observed in the data and vice versa.

costs of trade. If we drop the constraint on the zeros, variable and fixed costs of trade are not separately identifiable from the bilateral trade data. Furthermore, in contrast to a reduced form approach (see for example Helpman et al. (2008)), the procedure accounts for the general equilibrium features of the model and enables us to examine how well Melitz-type models perform in explaining the trade data.

The estimated parameters reveal a strong negative correlation between *fixed* costs of trade predicted by the model and exporter and importer development levels. Entry barriers to foreign markets are higher for firms from less developed countries (the exporter effect) and, all else equal, it is more difficult to access markets in less developed countries (the importer effect). As a result, the model predicts that less developed countries tend to have smaller trade volumes and a lower number of trading partners. In contrast, the estimated correlation between *variable* trade costs and countries' development levels appears to be much weaker. These findings emphasize the importance of market entry costs in explaining trade volumes and trade zeros.

I find that the model performs well in matching the data. In the data, doubling a country's per capita income (controlling for the aggregate income) leads to a 19% increase in trade on average, while doubling a country's population increases trade by 85% on average. The model predicts an increase in trade of 13% and 75%, respectively. Given the estimated parameters, the model is able to explain 39% of trade zeros in the data. In other words, 39% of the zeros predicted by the model are zeros that are actually observed in the data (the rest is mismatch).[6] As a comparison, the exact same model but without exporter and importer specific trade costs correctly predicts only 11% of zeros. Hence, the relationship between trade costs and countries' development levels matters and helps to explain 28% of export zeros.

To explore further the role of market access costs, I estimate the model assuming away the dependence of variable trade costs on countries' development levels. In this case, the explanatory power of the model falls by only 0.4% and the quantitative predictions of the model do not considerably change compared to the benchmark model. Moreover, the estimated importer effect of fixed trade costs is quite weak compared to the exporter effect. This suggests that the exporter effect of fixed trade costs plays a dominant role in explaining trade zeros and the dependence of trade on per capita income. I also find that the model with the variation only in variable trade costs (fixed costs are assumed to be identical across the countries) performs

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[6] Remember that the estimation procedure implies that the model predicts the same number of zeros as that in the data.

worse in fitting the data. In particular, the model considerably overestimates the impact of per capita income on trade volumes (the explanatory power of the model falls by 2%). Doubling a country's per capita income (controlling for the aggregate income) results in a 44% increase in trade (compared to a 19% increase in trade in the data). Moreover, the percentage of correctly predicted zeros is 29% compared to 39% predicted by the benchmark model.

Finally, I examine what the welfare gains are if firms in poor countries incur the same trade costs as their counterparts in rich countries. To conduct this counterfactual, I set the fixed costs of trade of all countries equal to the estimated value of those in the U.S. and remove the asymmetries in variable costs of trade (the other parameters of the model are set equal to their estimated values). I find that in this case, welfare in all countries rises with the average percentage change equal to 29% and larger gains for smaller and poorer countries. In particular, the real income inequality (measured as the ratio of the average real income of the ten richest countries to that of the ten poorest countries) falls by 43%.

This paper is closely related to Waugh (2010), who considers a general equilibrium model of trade based on Eaton and Kortum (2002). He assumes that variable trade costs are a function of symmetric relationships (e.g., distance, etc.) and an exporter fixed effect. He finds a negative correlation between exporter per capita income and the fixed effect, implying that poor countries face higher variable trade costs than rich countries. The present paper also focuses on the relationship between trade costs and per capita income and its relevance to trade volumes. However, compared to Waugh (2010), it makes a step further in this direction. The model in the paper allows us to consider cross-country variation in both variable and fixed costs of trade and, thereby, to identify the role of each type of trade costs in explaining the data. In particular, I find that the presence of exporter specific market access costs considerably improves the fit of the model, which can be especially important for welfare implications.

A broad strand of the literature considers nonhomotheticity of consumer preferences as a main driving force of the dependence of trade on per capita income. A significant step in this direction is Fieler (2011), who extends the Ricardian model of trade in Eaton and Kortum (2002) by allowing for nonhomothetic preferences and cross-sector differences in production technologies.[7] The present paper provides another, possibly complementary, explanation of why poorer countries trade less, which is not based on nonhomotheticity of preferences.

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[7] See also Flam and Helpman (1987), Hunter (1991), Markusen (1986), Markusen (2010), Matsuyama (2000), Mitra and Trindade (2005), and Stokey (1991).

The remainder of the paper is organized as follows. Section 2 introduces the basic concepts of the model and describes the equilibrium. Section 3 estimates the model and explores its quantitative implications. Section 4 conducts counterfactual analysis. Section 5 concludes.

2 Theory

I consider a variation of the Melitz model extended to a world with N asymmetric countries. Each country is characterized by its population size and development level. The only factor of production is labor, which is inelastically supplied by agents endowed with one unit of labor each.

2.1 Consumption

I assume that consumers have identical homothetic preferences that take the constant elasticity of substitution (CES) form. In particular, a representative consumer in country j maximizes

$$Q_j = \left(\int_{\omega \in \Omega_j} q_j^{\frac{\sigma-1}{\sigma}}(\omega) d\omega \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

subject to

$$\int_{\omega \in \Omega_j} p_j(\omega) q_j(\omega) d\omega = w_j L_j, \tag{2}$$

where Ω_j is the set of available varieties in country j, $q_j(\omega)$ is quantity consumed, $p_j(\omega)$ is the price of variety ω in country j, L_j is the population size, w_j is the cost of labor, and $\sigma > 1$ is the elasticity of substitution between varieties. This maximization problem yields that

$$q_j(\omega) = \left(\frac{p_j(\omega)}{P_j} \right)^{-\sigma} \frac{w_j L_j}{P_j},$$

where $P_j = \left(\int_{\omega \in \Omega_j} p_j^{1-\sigma}(\omega) d\omega \right)^{\frac{1}{1-\sigma}}$ is the CES price index: i.e., $P_j Q_j = w_j L_j$.

2.2 Production

Production in each country is represented by an average industry with free entry into the industry. To enter the industry in country i, ex-ante identical firms have to make sunk investments $w_i f_e$ associated with the creation of a new variety (where f_e is common for all countries). Once a firm incurs the costs of entry, it obtains a draw θ of its firm-specific productivity from a distribution $G(\theta)$ with the support on $[\theta_L, \theta_H]$. This distribution is common for all firms in all countries. Ex post, firms vary by their productivities, which are the product of a firm-specific productivity

θ and the country development level Z_i. Hence, both population size L_i and development level Z_i can affect equilibrium outcomes for country i.

The price of variety ω sold in country j, $p_j(\omega)$, is determined by the productivity of the firm producing this variety, its country of origin, and the destination market. Therefore, hereafter I omit the notation of ω and use $p_{ij}(\theta)$ instead of $p_j(\omega)$. We define $\pi_{ij}(\theta)$ as the variable profits from exporting to country j of the firm, which produces in country i with firm-specific productivity θ. Then,

$$\pi_{ij}(\theta) = \left(p_{ij}(\theta) - \frac{w_i}{Z_i}\frac{\tau_{ij}}{\theta}\right)\left(\frac{p_{ij}(\theta)}{P_j}\right)^{-\sigma}\frac{w_j L_j}{P_j}, \tag{3}$$

where $p_{ij}(\theta)$ solves the following maximization problem:

$$\max_{p \geq 0}\left(p - \frac{w_i}{Z_i}\frac{\tau_{ij}}{\theta}\right)p^{-\sigma}. \tag{4}$$

Here τ_{ij} stands for variable trade costs between country i and j, which take Samuelson's iceberg form. I set τ_{ii} to unity and assume that the triangle inequality holds for any τ_{ij}: i.e., $\tau_{ij} \leq \tau_{ik}\tau_{kj}$ for any i, j, and k.

The pricing rule maximizing (4) is as follows:

$$p_{ij}(\theta) = \frac{w_i}{Z_i}\frac{\tau_{ij}}{\theta}\frac{\sigma}{(\sigma-1)}. \tag{5}$$

Consequently, the variable profits $\pi_{ij}(\theta)$ are given by

$$\pi_{ij}(\theta) = C\left(\frac{Z_i}{w_i\tau_{ij}}\right)^{\sigma-1}\frac{w_j L_j}{P_j^{1-\sigma}}\theta^{\sigma-1}, \tag{6}$$

where $C = \frac{1}{\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}$.

To export from country i to country j, firms have to pay fixed costs $w_i f_{ij}$ representing the costs of serving market j (here f_{ij} represents the costs in terms of labor units).[8] The presence of fixed costs implies that not all firms find it profitable to export or sell at home. Firms with relatively low productivities exit because of negative potential profits. In particular, firms located in country i with $\theta < \theta_{ij}$ decide not to export to country j, where the cutoff θ_{ij} is determined by

$$\pi_{ij}(\theta_{ij}) = w_i f_{ij}.$$

The last expression implies that the cutoff θ_{ij} is given by

$$\theta_{ij} = \frac{w_i}{Z_i}\tau_{ij}\left(\frac{1}{C}\frac{P_j^{1-\sigma}}{w_j L_j}\right)^{\frac{1}{\sigma-1}}(w_i f_{ij})^{\frac{1}{\sigma-1}}. \tag{7}$$

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[8] The fixed costs of selling at home are $w_i f_{ii}$.

Higher θ_{ij} means that fewer firms based in country i find it profitable to export to country j. In particular, if $\theta_{ij} > \theta_H$, then no firm exports from country i to country j resulting in zero exports from i to j.

We define $r_{ij}(\theta)$ as the revenues received from exporting to country j by a firm with θ located in country i. Then,

$$r_{ij}(\theta) = \sigma C \left(\frac{Z_i}{w_i \tau_{ij}} \right)^{\sigma-1} \frac{w_j L_j}{P_j^{1-\sigma}} \theta^{\sigma-1}. \tag{8}$$

As a result, the total value of exports from country i to country j, X_{ij}, is given by

$$X_{ij} = M_{ei} \int_{\theta_{ij}}^{\theta_H} r_{ij}(\theta) dG(\theta), \tag{9}$$

where M_{ei} is the mass of entrants into the industry.[9] Since there are $M_{ei}dG(\theta)$ firms with productivity θ in country i, the measure of available varieties in country j is equal to:

$$\mu\left(\Omega_j\right) = \textstyle\sum_{i=1}^N M_{ei} \left(1 - G\left(\theta_{ij}\right)\right).$$

2.3 Equilibrium

Given the set of parameters $\{\, f_e,\, f_{ij},\, \tau_{ij},\, \sigma,\, G(\cdot),\, Z_i,\, L_i\}_{i,j=1..N}$, the equilibrium in the model is defined by $\{p_{ij}\left(\theta\right),\, P_i,\, M_{ei},\, \theta_{ij},\, w_i\}_{i,j=1..N}$ such that

1) $\{p_{ij}\left(\theta\right)\}_{i,j=1..N}$ are determined by the firm maximization problem (see (5)).

2) $\{P_i\}_{i=1..N}$ satisfy the following equation:

$$P_i = \left(\int_{\omega\in\Omega_i} p_i^{1-\sigma}(\omega) d\omega \right)^{\frac{1}{1-\sigma}},$$

which is equivalent to

$$P_i^{1-\sigma} = \textstyle\sum_{j=1}^N M_{ej} \displaystyle\int_{\theta_{ji}}^{\theta_H} p_{ji}^{1-\sigma}(\theta) dG(\theta).$$

3) Expected profits of a given firm are equal to zero, meaning that

$$w_i f_e = \textstyle\sum_{j=1}^N \Pr\left(\theta \geq \theta_{ij}\right) E\left(\left(\pi_{ij}(\theta) - w_i f_{ij}\right) | \theta \geq \theta_{ij}\right).$$

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[9] Note that the mass of firms based in country i and serving market j is equal to $M_{ij} = M_{ei}\left(1 - G(\theta_{ij})\right)$. In this manner, the expression (9) can be rewritten as

$$X_{ij} = M_{ij} \int_{\theta_{ij}}^{\theta_H} r_{ij}(\theta) d\frac{G(\theta)}{1 - G(\theta_{ij})},$$

where $G(\theta)/\left(1 - G(\theta_{ij})\right)$ is the distribution of firm-specific productivities conditional on $\theta \geq \theta_{ij}$.

4) $\{\theta_{ij}\}_{i,j=1..N}$ satisfy the zero profit condition (see (7)).

5) Trade is balanced, implying that

$$\sum_{j=1}^{N} M_{ei} \int_{\theta_{ij}}^{\theta_H} r_{ij}(\theta) dG(\theta) = \sum_{j=1}^{N} M_{ej} \int_{\theta_{ji}}^{\theta_H} r_{ji}(\theta) dG(\theta).$$

Note that the set $\{w_i,\, P_i,\, M_{ei}\}_{i=1..N}$ is sufficient to determine all other endogenous variables in the model such as $p_{ij}(\theta)$, $\pi_{ij}(\theta)$, $r_{ij}(\theta)$, and θ_{ij}. This implies that to find the equilibrium in the model, we need to find the set $\{w_i,\, P_i,\, M_{ei}\}_{i=1..N}$, which satisfies the following system of equations:

$$\begin{cases} P_i^{1-\sigma} = \sum_{j=1}^{N} M_{ej} \int_{\theta_{ji}}^{\theta_H} p_{ji}^{1-\sigma}(\theta) dG(\theta), \\ w_i f_e = \sum_{j=1}^{N} \Pr(\theta \geq \theta_{ij}) E\left(\left(\pi_{ij}(\theta) - w_i f_{ij} \right) | \theta \geq \theta_{ij} \right), \\ \sum_{j=1}^{N} M_{ei} \int_{\theta_{ij}}^{\theta_H} r_{ij}(\theta) dG(\theta) = \sum_{j=1}^{N} M_{ej} \int_{\theta_{ji}}^{\theta_H} r_{ji}(\theta) dG(\theta), \end{cases} \tag{10}$$

where $p_{ij}(\theta)$, $\pi_{ij}(\theta)$, $r_{ij}(\theta)$, and θ_{ij} are expressed in terms of $\{w_i,\, P_i,\, M_{ei}\}_{i=1..N}$ and the parameters of the model. Thus, we have the system of $3N$ equations with $3N$ unknowns, $\{w_i,\, P_i,\, M_{ei}\}_{i=1..N}$. Consequently, taking w_N as numeraire, we can solve the system and find the endogenous variables for any given set of the parameters.

3 Estimation

To understand the role of each type of trade costs in explaining the data, I estimate the key parameters of the model. In the estimation procedure, I use 1995 data on total income, population, bilateral trade flows, and cultural and geographical barriers between country pairs. I consider the sample of the hundred largest countries in terms of GDP, for which the data sets are complete.[10] These countries account for 91.6% of world trade in 1995. I assume that the other countries do not exist (these hundred countries constitute the entire world). Exports to non-existent countries are considered as domestic sales.

Data on total income and population are taken from the World Bank (2007). *Table 15* reports the list of the countries in the sample arranged by the size of GDP. Data on bilateral

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[10] Because of entrepot trade, which is not captured by my model, I consider Belgium and Luxemburg as well as China, Hong-Hong, and Macao as one country. There are two outliers in the sample: Malaysia and Singapore. These countries have trade volumes greater than their total incomes (due to entrepot trade). However, their effect on the parameter estimates is negligible. Removing these countries from the sample does not change the estimation results.

trade flows comes from the United Nations (2007).[11] In constructing bilateral trade flows, I follow Feenstra et al. (2005). As a measure of trade volumes between countries, I use trade values reported by the importing country, as they tend to be more precise than those reported by the exporter. However, if an importer report is not available, I use the corresponding exporter report instead.[12] There are 1399 export zeros in the sample, which constitutes 14% of the total number of bilateral trade flows.

As potential trade barriers, I consider distance, the effects of common border and language, and the impact of membership in free trade areas.[13] Hence, for each country pair we need data on whether these countries have a common language or share a common border plus data on distance between them.[14] I take these data sets from CEPII (2005). In addition, I use the data on whether the pair of countries belongs to the North American Trade Agreement (NAFTA) or the European Union (EU).

Figure **??** displays the relationship in the data between the log of trade volumes (the average between exports and imports) and the log of GDP. As is evident from the figure, there is a strong positive correlation between countries' trade volumes and total incomes. This is in line with the previous empirical studies on the gravity equation. *Figure* **??** depicts the relationship between the residuals and countries' logs of income per capita and population size. As it is inferred from the figure, there is a significant positive correlation between the residuals and income per capita. This suggests that conditional on GDP, richer countries trade more.

3.1 Parametrization

To estimate the model, we need to parametrize the distribution of firm-specific productivity draws $G(\theta)$ and trade costs (τ_{ij} and f_{ij}). In parametrizing $G(\theta)$, I follow a number of studies using a truncated Pareto distribution to describe the distribution of firm productivities.[15] In

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[11] An alternative source for data on trade flows is the NBER-UN data set constructed by Feenstra et al. (2005). However, this data set includes only trade flows in a certain category with values greater than $100.000 per year. When aggregating, this may potentially lead to underestimation of aggregate exports and imports and overestimation of the number of zero trade flows.

[12] The proportion of trade flows replaced by the mirror data (trade flows reported by exporters) is 13%.

[13] Many other variables (for instance, religion or colonial origin) can be used as additional measures of trade barriers between countries. However, to reduce the number of parameters I need to estimate, I consider only language, border, distance, and membership in free trade areas.

[14] By distance between two countries, I mean the distance between the main cities in the countries. Usually, the main city is the capital. However, in some cases, the capital is not populated enough to serve a role of the economic center of the country. In these cases, the most populated city represents the country.

[15] See e.g. Helpman et al. (2008) or Johnson (2010).

particular, I assume that

$$G(\theta) = \frac{\frac{1}{\theta_L^k} - \frac{1}{\theta^k}}{\frac{1}{\theta_L^k} - \frac{1}{\theta_H^k}} \text{ on } [\theta_L, \theta_H], \tag{11}$$

where $\infty \geq \theta_H > \theta_L > 0$ and $k > \sigma - 1$. The last condition guarantees that in the case when $\theta_H = \infty$, the integral $\int_{\theta_{ij}}^{\theta_H} \theta^{\sigma-1} dG(\theta)$ exists.

For fixed costs of trade, I consider the following functional form:

$$f_{ij} = \begin{cases} f_x / Z_i^{\delta_{EX}^f} Z_j^{\delta_{IM}^f}, & \text{if } j \neq i, \\ 0, & \text{otherwise,} \end{cases} \tag{12}$$

where f_x is common for all countries. Here parameters δ_{EX}^f and δ_{IM}^f describe how exporter and importer development levels affect fixed costs of trade. For instance, if $\delta_{EX}^f > 0$, then firms in more developed countries face relatively easier access to foreign markets. In the same manner, if $\delta_{IM}^f > 0$, then all else equal, it is easier to get access to markets in more developed countries. Note that as in Helpman et al. (2008), I set fixed costs of selling domestically to zero.

I assume that variable trade costs are given by

$$\tau_{ij} = 1 + \frac{\gamma_0}{Z_i^{\delta_{EX}^\tau} Z_j^{\delta_{IM}^\tau}} D_{ij}^{\gamma_1} \gamma_2^{B_{ij}} \gamma_3^{LNG_{ij}} \gamma_4^{NAF_{ij}} \gamma_5^{EU_{ij}} \quad \text{for } j \neq i. \tag{13}$$

Here D_{ij} is the distance between countries i and j, B_{ij} and LNG_{ij} are dummy variables for common border and language, and NAF_{ij} and EU_{ij} are dummy variables for whether countries i and j are members of NAFTA or EU, respectively. For instance, if γ_2 is less (greater) than one, then sharing a common border reduces (increases) the costs of trade between countries. Finally, parameters δ_{EX}^τ and δ_{IM}^τ describe how exporter and importer development levels affect variable costs of trade.

Thus, the set of parameters of the model is given by

$$\left\{\gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \delta_{EX}^\tau, \delta_{IM}^\tau, f_x, \delta_{EX}^f, \delta_{IM}^f, \sigma, k, \theta_L, \theta_H, f_e\right\}. \tag{14}$$

However, parameters $\{\sigma, k, \theta_L, \theta_H, f_e\}$ are not identifiable from the trade data (i.e., the fit of the model does not vary as the parameters change). Therefore, to estimate the model, I fix those parameters at certain values.

In fixing σ, I follow results in the previous studies estimating the elasticity of substitution. In particular, Bernard et al. (2003) argue that σ equal to 3.8 captures the export behavior of the U.S. plants best. Broda and Weinstein (2006) estimate the elasticity of substitution for different aggregation levels. In period 1990-2001 for SITC-3 aggregation level, the estimates vary from

Table 1: Values assigned to the unidentifiable parameters.

Parameter	Value
Elasticity of substitution, σ	3.8
Shape parameter, k	3.4
Lower bound, θ_L	1
Upper bound, θ_H	20
Costs of entry, f_e	1

1.2 (thermionic, cold cathode, photocathode valves, etc.) to 22.1 (crude oil from petroleum or bituminous minerals) with the mean equal to 4. Basing on these findings, I set σ equal to 3.8.

The distribution of productivity draws in (11) is characterized by θ_L, θ_H, and k. I normalize θ_L to unity. In many studies, to simplify analytical derivations, θ_H is set to infinity.[16] However, setting θ_H to infinity implies that there always exist some relatively productive firms that find it profitable to export to any country. In this case, the model does not generate trade zeros, which is at odds with the data. In the paper, I set θ_H equal to 20.[17] Following Ghironi and Melitz (2005) and Bernard et al. (2007), I set k equal to 3.4. Finally, as changes in f_e only rescale the mass of entrants into the industry and have no impact on trade volumes, I normalize f_e to unity.

Hereafter, I assume that the set of parameters $\{\sigma, k, \theta_L, \theta_H, f_e\}$ is fixed at the values reported in *Table 1*. In Appendix *A*, I perform several robustness checks by trying some other parameter values. I find that changes in the values do not substantially alter the quantitative implications of the model.

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[16] See for example Chaney (2008).

[17] The choice of the value for θ_H is partly based on the studies measuring firm productivity differences within an industry. For instance, Syverson (2004) finds that within 4-digit SIC industries in the U.S. manufacturing sector, plants at the $90th$ percentile of the productivity distribution on average have productivities twice higher than those of plants at the $10th$ percentile. Hsieh and Klenow (2009) find that the most productive firms in China and India on average have productivities five times higher than those of the least productive firms. Hence, productivity differences within an industry can be quite high but not infinitely high. This makes setting θ_H at 20 reasonable. In Appendix *A*, I perform several robustness checks. In particular, I set θ_H at 5, 50, and even 100. Although, the estimates of the parameters change, the quantitative predictions of the model (regarding trade elasticities, trade zeros, and counterfactuals) do not considerably change.

3.2 Estimation Procedure

To estimate the rest of the parameters given by

$$\Theta = \left\{ \gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \delta_{EX}^{\tau}, \delta_{IM}^{\tau}, f_x, \delta_{EX}^{f}, \delta_{IM}^{f} \right\},$$

I use a restricted non-linear least squares procedure.[18] The procedure is as follows. For given Θ and $\{Z_i, L_i\}_{i=1..N}$, we can solve the system of equations (10) and find the equilibrium values of $\{w_i,\ P_i,\ M_{ei}\}_{i=1..N}$ (notice that if we know Θ, we can construct $\{\tau_{ij}, f_{ij}\}_{i,j=1..N}$ using (13) and (12)). Then, using (9), we can find bilateral trade flows generated by the model conditional on Θ, Z, and L (here $Z = \{Z_i\}_{i=1..N}$ and $L = \{L_i\}_{i=1..N}$). To estimate Θ, I solve the following minimization problem:

$$\min_{\Theta} \textstyle\sum_{i,j:i\neq j} \left(X_{ij}^{o} - X_{ij}(Z, L, \Theta) \right)^2 \tag{15}$$

subject to

$$\Psi\left(Z, L, \Theta\right) = 0, \tag{16}$$

where $\{X_{ij}(Z, L, \Theta)\}_{i,j=1..N}$ and $\{X_{ij}^{o}\}_{i,j=1..N}$ are trade flows generated by the model and observed in the data, respectively. In (16), $\Psi\left(Z, L, \Theta\right)$ stands for the difference between the number of zeros predicted by the model and the actual number of zero bilateral trade flows in the data (the "actual" zeros).[19]

This estimation technique allows us to account for the general equilibrium features of the model (including the effects of free entry into the industry) and to use the information containing

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[18] In Appendix *C*, I consider non-linear least deviations as an alternative estimation procedure. I find that this estimation procedure yields similar predictions as the procedure used in the paper.

[19] The estimation procedure implies that the model fits just the number of zeros. However, it is possible that the model generates zeros that are not actually observed in the data and vice versa. Therefore, we can decompose $\Psi\left(Z, L, \Theta\right)$ into the sum of two terms:

$$\Psi\left(Z, L, \Theta\right) = \Psi_T\left(Z, L, \Theta\right) + \Psi_F\left(Z, L, \Theta\right). \tag{17}$$

In (17), $\Psi_T\left(Z, L, \Theta\right)$ is the difference between the number of *correctly* predicted zeros (zeros predicted by the model and observed in the data) and the number of "actual" zeros, while $\Psi_F\left(Z, L, \Theta\right)$ is the mismatch (zeros that are predicted by the model but not observed in the data). Hence, the restriction (16) implies that equal weights are attached to $\Psi_T\left(Z, L, \Theta\right)$ and $\Psi_F\left(Z, L, \Theta\right)$. In Appendix *B*, I examine alternative restrictions in the minimization problem. In particular, I consider the following restriction:

$$(1-\varepsilon)\Psi_T\left(Z, L, \Theta\right) + \varepsilon\Psi_F\left(Z, L, \Theta\right) = 0,$$

where $\varepsilon \in [0, 1]$ represents a certain weight attached to the mismatch. For instance, if ε is equal to zero, then the mismatch is of no importance and, as a result, the model predicts all the zeros in the data plus some others. If ε is equal to unity, then we only care about the mismatch. All zeros generated by the model match the zeros in the data. Notice that if ε is equal to 0.5, then we obtain the restriction in (17). In the Appendix, I consider ε equal to 0.25 and 0.75. I find that changes in ε mainly affect the implications of the model regarding zeros only (see Appendix *B* for details).

in trade zeros. The restriction in (16) is imposed for identification purposes. Specifically, variable and fixed costs of trade are not separately identifiable from just bilateral trade data. Changes in fixed costs of trade can be offset by proper changes in variable costs without affecting the value of the objective function in (15). Given the restriction, I estimate bilateral trade flows taking into account the country extensive margin of trade. This in turn allows me to estimate both variable and fixed costs of trade.

The above estimation procedure is based on the fact that we know the values of Z and L. While for $\{L_i\}_{i=1..N}$ we can use the data on population size in the countries, $\{Z_i\}_{i=1..N}$ are not observable.[20] To resolve this problem, I use the data on per capita income levels to infer $\{Z_i\}_{i=1..N}$. Since in the model w_i is equal to per capita income in country i, I back out Z so that the equilibrium values of $\{w_i\}_{i=1..N}$ correspond to countries' per capita incomes (see also Fieler (2011)). Specifically, in the general equilibrium, wages depend on Θ, Z, and L: i.e., $w = w(Z, L, \Theta)$, where $w = \{w_i\}_{i=1..N}$. We can invert the function $w(Z, L, \Theta)$ and derive a formal dependence of Z on w, L, and Θ: $Z = Z(w, L, \Theta)$.[21] Then, the minimization problem can be rewritten as follows:

$$\min_{\Theta} \textstyle\sum_{i,j:i\neq j} \left(X^o_{ij} - X_{ij}(Z(w, L, \Theta), L, \Theta)\right)^2 \tag{18}$$

subject to

$$\Psi\left(Z(w, L, \Theta), L, \Theta\right) = 0, \tag{19}$$

where $\{L_i\}_{i=1..N}$ and $\{w_i\}_{i=1..N}$ are countries' population sizes and per capita incomes, respectively.

3.3 Results

As a measure of the explanatory power of the model, I use

$$R^2 = 1 - \frac{\sum_{i,j:i\neq j} \left(X^o_{ij} - X_{ij}(Z(w, L, \hat{\Theta}), L, \hat{\Theta})\right)^2}{\sum_{i,j:i\neq j} \left(X^o_{ij}\right)^2},$$

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[20] Note that in the model L_i can be interpreted not only as population size in country i, but also as the size of labor force in that country. While in the paper I use the data on population sizes to construct $\{L_i\}_{i=1..N}$, I also estimate the model using the data on the size of labor force in the countries. I find that the results do not substantially differ from those obtained in the paper.

[21] Note that the structure of the equations in (10) is nonlinear. This implies that the function $w(Z, L, \Theta)$ is not necessarily one-to-one. For instance, several different values of Z may lead to the same value of w. However, no such examples occur in the numerical analysis I conduct in the paper.

where $\hat{\Theta}$ is the estimate of Θ. The explanatory power is 100%, if we are able to fit perfectly all bilateral trade flows: i.e., $\sum_{i,j:i\neq j}\left(X_{ij}^{o}-X_{ij}(Z(w,L,\hat{\Theta}),L,\hat{\Theta})\right)^{2}=0$.

Table 2 reports the results obtained from solving (18) subject to (19).[22] The explanatory power of the model is 82%. As in traditional estimates of the gravity equation, the results show that countries i and j trade more if they are closer to each other, have a common border, share a common language, or belong to the same regional trade agreement (NAFTA or EU). The estimated values of δ_{EX}^{f} and δ_{IM}^{f} (0.77 and 0.30) imply a strong negative correlation between exporter and importer development levels and fixed costs of trade. All else equal, firms from less developed countries tend to face higher entry barriers to foreign markets and it is more difficult to access markets in less developed countries.[23] The estimates of δ_{EX}^{τ} and δ_{IM}^{τ} (-0.05 and -0.08) in turn show a much weaker correlation between variable trade costs and countries' development levels.

To compare the quantitative implications of the model with the data, I run the following regression (robust standard errors in parentheses):

$$\ln\frac{T_i}{T_i(\hat{\Theta})}=\underset{(0.55)}{-3.75}+\underset{(0.03)}{0.10}\ln GDP_i+\underset{(0.04)}{0.06}\ln\frac{GDP_i}{L_i}, \tag{20}$$

where T_i is the actual trade volumes of country i and $T_i(\hat{\Theta})$ is the volumes of trade generated by the model given the estimated values of the parameters (see *Table 2*).[24] As can be seen from (20), the model captures the effect of per capita income on trade volumes (conditional on total income) quite well. The corresponding coefficient is not significantly different from zero at 10% level of confidence. Meanwhile, the estimates in (20) suggest that the model somewhat underestimates trade volumes of large population countries. *Table 3* reports the elasticities of trade with respect to total and per capita incomes observed in the data and generated by the model (the first and second columns, respectively). In the data, doubling a country income per capita (keeping the total income unaltered) leads on average to an increase in trade volumes of 19% and doubling a country population size raises trade volumes by 85%. The model predicts a rise in trade volumes of 13% and 75%, respectively.

Recall that the restriction in (19) implies that the number of zero trade flows generated by

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[22] I do not report the asymptotic errors, as it is extremely hard to explore the asymptotic properties of the obtained estimate.

[23] Eaton et al. (2010) find mixed evidence of the effect of importer per capita income on market entry costs. In particular, data on the exports of French firms in 1986 show a negative effect of importer per capita income on entry costs. However, data from other countries (Denmark and Uruguay) do not reveal such a correlation.

[24] By trade volumes of a country, I mean the average between total exports and imports of that country.

Table 2: Parameter estimates.

γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	δ^{τ}_{EX}	δ^{τ}_{IM}	f_x	δ^{f}_{EX}	δ^{f}_{IM}	R^2
0.47	0.16	0.76	0.96	0.80	0.94	$-\mathbf{0.05}$	$-\mathbf{0.08}$	0.60	**0.77**	**0.30**	82%

the model is the same as that in the data. However, as discussed above, mismatch is possible. I find that the model explains 39% of the zeros in the data. In other words, 39% of zeros generated by the model match the zeros observed in the data, while the rest are mismatched. The key point is that the model underestimates trade volumes of large population countries. As a result, it generates a number of "false" zeros among countries with large population and does not predict many zeros in the data among small population countries. It should be noted that the estimated association between trade costs and countries' development levels helps to explain many zeros in the data. In the next section, I estimate a similar model but without exporter and importer specific trade costs. In that case, the mismatch constitutes 89%.

3.3.1 No $Z's$ in Trade Costs: Comparison

In this section, I consider a variation of the model where trade costs do not depend on countries' development levels. In particular, I assume that

$$f_{ij} = w_i f_x \text{ for } i \neq j,$$

implying identical fixed costs of trade (in terms of labor) across the countries. Moreover, I remove the asymmetries in variable trade costs. Namely, variable trade costs are given by

$$\tau_{ij} = 1 + \gamma_0 D_{ij}^{\gamma_1} \gamma_2^{B_{ij}} \gamma_3^{LNG_{ij}} \gamma_4^{NAF_{ij}} \gamma_5^{EU_{ij}} \quad \text{for } j \neq i.$$

Hence, the set of parameters needed to be estimated is $\{\gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, f_x\}$.

Table 4 reports the estimated values of the parameters. The explanatory power of the model falls from 82% to 74%. Hence, country specific trade costs introduced in the model explain 8% of the variation in the bilateral trade flows. The third column of *Table 3* shows the trade elasticities generated by the model. As can be seen from the table, the model does slightly better in predicting trade volumes of large population countries. Doubling a country population size raises trade volumes by 79% compared to an increase of 85% in the data. However, the effect of per capita income on trade volumes is substantially lower than that in the data. Conditional on

Table 3: Trade elasticities and zeros.

	Data	Benchmark model	No $Z's$ in trade costs
Dependent variable:	$\ln T_i$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$
Log of GDP	0.85^{**}	0.75^{**}	0.79^{**}
	(0.03)	(0.02)	(0.03)
Log of GDP per capita	0.19^{**}	0.13^{**}	0.03^{*}
	(0.04)	(0.02)	(0.016)
Correctly predicted zeros:	100%	39%	11%
Observations:	100	100	100

Note. Robust standard errors in parentheses.

Table 4: Parameter estimates (no Z's in trade costs).

γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	δ^{τ}_{EX}	δ^{τ}_{IM}	f_x	δ^{f}_{EX}	δ^{f}_{IM}	R^2
0.01	0.41	0.66	0.86	0.70	1.19	–	–	104.1	–	–	74%

the total income, doubling a country income per capita leads on average to an increase in trade volumes of 3% (which is not significant at 5% level of confidence), while the effect observed in the data is 19%. Finally, the percentage of correctly predicted zeros is 11%. This constitutes the mismatch of 89%, which is much greater than the mismatch obtained in the case when trade costs depend on countries' development levels.

3.3.2 The Role of Market Access Costs

The estimates of $\delta' s$ (δ^{τ}_{EX}, δ^{τ}_{IM}, δ^{f}_{EX}, and δ^{f}_{IM}) show a weak correlation between variable trade costs and countries' development levels. This suggests that fixed costs of trade play a major role in explaining the dependence of trade volumes on per capita income and trade zeros in the data. In this section, I explore further the importance of market access costs in explaining the trade data. In particular, I estimate the model and compare its quantitative implications when only one type of trade costs (variable or fixed) depends on exporter and importer development levels.

Table 5: Parameter estimates when only one type of trade costs depends on countries' development levels.

	Benchmark model	$Z's$ in fixed costs only	$Z's$ in variable costs only
γ_0	0.47	0.37	0.17
γ_1	0.16	0.16	0.20
γ_2	0.76	0.74	0.70
γ_3	0.96	0.97	0.98
γ_4	0.80	0.78	0.73
γ_5	0.94	0.94	0.97
δ^{τ}_{EX}	**−0.05**	–	**0.13**
δ^{τ}_{IM}	**−0.08**	–	**0.11**
f_x	0.60	1.81	15.07
δ^{f}_{EX}	**0.77**	**0.63**	–
δ^{f}_{IM}	**0.30**	**0.10**	–
R^2	82%	81.6%	80%

The second column in *Table 5* shows the estimates of the parameters when only fixed costs of trade depend on countries' development levels (variable trade costs are symmetric). As can be seen, the explanatory power of the model falls by only 0.4%. Moreover, the trade elasticities generated by the model and the percentage of correctly predicted zeros do not substantially change compared to the benchmark model (see the third column in *Table 6*). These findings suggest that the dependence of variable trade costs on countries' development levels does not contribute a lot in fitting the model to the data. It should also be noted that the exporter effect of fixed trade costs plays a major role in explaining the data. The estimate of δ^{f}_{EX} is 0.63, while the estimate of δ^{f}_{IM} is only 0.10.

When only variable trade costs depend on development levels, the explanatory power of the model falls from 82% to 80% (see the third column in *Table 5*). However, in this case the model considerably overestimates the impact of per capita income on trade volumes (see the fourth column in *Table 6*). The model predicts that controlling for the total income, doubling a country income per increases trade volumes of that country by 44% (compared to 19% in the data). Moreover, the percentage of correctly predicted zeros falls from 39% to 29%. Hence, while the relationship between variable costs of trade and development levels can also account

Table 6: Trade elasticities and zeros when only one type of trade costs depends on countries' development levels

	Data	Benchmark model	$Z's$ in fix.	$Z's$ in var.
Dependent variable:	$\ln T_i$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$
Log of GDP	0.85^{**}	0.75^{**}	0.72^{**}	0.70^{**}
	(0.03)	(0.02)	(0.02)	(0.03)
Log of GDP per capita	0.19^{**}	0.13^{**}	0.21^{**}	0.44^{**}
	(0.04)	(0.02)	(0.02)	(0.03)
Predicted zeros:	100%	39%	37%	29%
Observations:	100	100	100	100

Note. Robust standard errors in parentheses.

for greater trade volumes of richer countries and zero trade flows in the data, the model in this case performs much worse in matching the trade elasticities and zeros in the data.

4 Counterfactuals

In this section, I explore how the elimination of asymmetries in trade costs affects consumer welfare across the countries. Specifically, I consider an experiment where the values of δ^{τ}_{EX}, δ^{τ}_{IM}, δ^{f}_{EX}, and δ^{f}_{IM} are set to zero, which removes the relationship between trade costs and exporter and importer development levels, and examine the corresponding changes in consumer welfare. The other parameters including Z are fixed at the values obtained from the benchmark estimation procedure (see *Table 2*).

Consumer welfare in country i (denoted as W_i) is equal to the real wage in that country. Namely, for $i = 1..N$

$$W_i \equiv \frac{Q_i}{L_i} = \frac{w_i}{P_i}. \tag{21}$$

Hence, given the parameters of the model, we can solve (10) for $\{w_i, P_i, M_{ei}\}_{i=1..N}$ and then using (21), find the equilibrium value of consumer welfare in country i. Let us denote $\triangle W_i/W_i$ as the percentage change in welfare in country i given the changes in the parameters of the model. That is,

$$\frac{\triangle W_i}{W_i} = \frac{W_i^{after}}{W_i^{before}} - 1,$$

where W_i^{before} is the equilibrium value of welfare when the parameters are equal to their estimated values and W_i^{after} is welfare when $\delta' s$ (δ^{τ}_{EX}, δ^{τ}_{IM}, δ^{f}_{EX}, and δ^{f}_{IM}) are set to zero (the other parameters remain unchanged).

I find that all countries gain from the elimination of asymmetries in trade costs with the average percentage change in welfare being equal to 29%. The next regression illustrates how the gains depend on country characteristics. In particular, I regress $\triangle W_i/W_i$ on the logs of GDP_i and GDP_i/L_i:

$$\frac{\triangle W_i}{W_i} = \underset{(0.21)}{2.44} - \underset{(0.01)}{0.05} \ln GDP_i - \underset{(0.01)}{0.12} \ln \frac{GDP_i}{L_i}. \tag{22}$$

As can be seen, doubling a country population size on average reduces the welfare gains by 5%, while doubling a country per capita income (controlling for the total income of that country) reduces the gains by 12%. The former effect is explained by the fact that removing trade asymmetries enhances trade in all countries. Since countries with larger population tend to have a lower trade to GDP ratio, those countries gain less compared to small population countries. The latter effect is based on the feature of the model that trade costs depend on countries' development levels. Since fixing $\delta' s$ at zero eliminates this relationship, the changes in welfare are more substantial for less developed countries.

The findings above suggest that eliminating asymmetries in trade costs not only raises consumer welfare, but also reduces welfare inequality across countries (as poor countries gain relatively more). In particular, as a measure of the welfare inequality in the model, I consider the ratio of the average income of the ten richest (in real terms) countries to that of the ten poorest countries. I find that setting $\delta' s$ to zero reduces the measured welfare inequality by 43%.

5 Concluding Remarks

This paper contributes to a rapidly growing literature analyzing the role of fixed costs of trade in explaining trade volumes. In particular, I show that an association between market access costs and countries' development levels can quantitatively account for the relationship between per capita income and trade volumes observed in the data and explain a number of zeros in bilateral trade flows.

There are several directions in which further research can be pursued. First, in the paper, the association between trade costs and development levels is estimated to match the data on aggregate trade volumes. It might seem desirable, however, to estimate this association using micro-level ("independent") data and then to examine how much of the relationship between per capita income and trade volumes is explained by the variation in trade costs. Secondly, it might be interesting to incorporate nonhomothetic preferences in the model. This would enable us to capture the effects of both consumer preferences and trade costs on trade volumes in a general equilibrium framework. Finally, in the paper, I consider an environment where countries trade only in a differentiated good. This framework is more applicable to the case of trade among rich countries. In particular, the setup of the model assumes away the possibility that trade flows can be generated by differences in factor endowments. To explain better trade between countries with different factor endowments, we can extend the model by incorporating the Heckscher-Ohlin trade theory (see for example Bernard et al. (2007)). This would allow us to analyze both intra-industry and inter-industry trade and, thereby, to improve the fit of the model. I leave all the issues discussed above for future work.

Appendix A: Robustness Checks

In this part of the Appendix, I check the robustness of the quantitative implications of the model to changes in the values of $\{\sigma, k, \theta_H\}$. In particular, I consider the following changes in the parameters: σ falls from 3.8 to 3; k rises from 3.4 to 4; σ *and* k rise to 6 and 5.5, respectively. Finally, I estimate the model when θ_H falls to 5 and rises to 50 (the benchmark value is 20).

Table 7 reports the parameter estimates when σ and k change. As can be seen, changes in $\{\sigma, k\}$ result in the different estimates. However, the explanatory power does not substantially change. *Table 8* shows the trade elasticities and the percentage of correctly predicted zeros. Given the new values of $\{\sigma, k\}$, the model predicts similar effects of population size and per capita income on trade volumes as the benchmark model does. Moreover, in all cases, exporter and importer effects of fixed trade costs play a dominant role in fitting the model to the data.

Table 9 reports the parameter estimates when the upper bound of the productivity distribution, θ_H, changes. Although, changes in θ_H result in the different estimates, the explanatory power of the model does not substantially change. Moreover, given the new values of θ_H, the model predicts similar effects of population size and per capita income on trade volumes as the benchmark model does (see *Table 10*). Again, in all cases, exporter and importer effects of fixed trade costs play a dominant role.

Appendix B: Alternative Restrictions

In this section, I consider alternative restrictions in the estimation procedure. Specifically, I solve

$$\min_{\Theta} \sum_{i,j:i\neq j} \left(X_{ij}^{o} - X_{ij}(Z(w,L,\Theta),L,\Theta)\right)^2$$

subject to

$$(1-\varepsilon)\Psi_T\left(Z(w,L,\Theta),L,\Theta\right) + \varepsilon\Psi_F\left(Z(w,L,\Theta),L,\Theta\right) = 0,$$

where $\Psi_T\left(Z,L,\Theta\right)$ is the difference between the number of correctly predicted zeros and the number of zeros in the data and $\Psi_F\left(Z,L,\Theta\right)$ is the mismatch (zeros that are predicted by the model but not observed in the data). I consider two cases: $\varepsilon = 0.25$ and $\varepsilon = 0.75$. Recall that in the main model, $\varepsilon = 0.5$. Hence, the former case implies a lower weight attached to the mismatch compared to the main model, while the latter implies a higher weight.

Table 11 reports the results. As can be seen, the estimates of many parameters do not change compared to the benchmark model (the only substantial changes are in the estimates of γ_0 and f_x). The explanatory power of the model does not substantially change as well. *Table 12* shows the trade elasticities and the number of zero trade flows simulated by the model for the different restrictions. As can be inferred from the table, a lower weight attached to the mismatch leads to much more zeros predicted by the model. If $\varepsilon = 0.25$, then the model predicts 2549 zeros (compared to 1399 when $\varepsilon = 0.5$). However, many of those zeros are "false" zeros. The number of correctly predicted zeros is 825. Therefore, lower ε increases both the number of correctly predicted zeros and the mismatch. Similarly, higher ε reduces both the mismatch and the number of correctly predicted zeros (see the fourth column of *Table 12*). Finally, the simulated trade elasticities are not much different from those obtained before.

Appendix C: An Alternative Estimation Procedure

Another robustness check is to apply an alternative estimation procedure. The idea behind this is that non-linear least squares (NLLS) attach greater weights to observations with higher values. Therefore, if high value observations have larger variance, then non-linear least squares may lead to inefficient estimates. As a robustness check, I examine restricted non-linear least deviations (NLLD). This procedure attaches lower weights to high value observations compared to the procedure used in the paper.

In the case of non-linear least deviations we solve the following minimization problem:

$$\min_{\Theta} \sum_{i,j:i\neq j} \left| X_{ij}^o - X_{ij}(Z(w,L,\Theta),L,\Theta) \right|$$

subject to

$$\Psi\left(Z(w,L,\Theta),L,\Theta\right) = 0.$$

Table 13 reports the parameter estimates obtained by applying *NLLD* (the first column of the table shows the non-linear least squares estimates). The results of applying *NLLD* show a strong negative correlation between exporter and importer development levels and market access costs. Moreover, the estimates of $\delta's$ are quite close to those obtained by applying *NLLS.* The estimates of the other parameters do not vary considerably as well.

Table 14 shows trade elasticities generated by the model when different estimation procedures are applied. As can be inferred, the model estimated by *NLLD* slightly reduces the effect of population size on trade volumes and amplifies the impact of per capita income compared to the model estimated by *NLLS.* Finally, both procedures result in the similar percentage of correctly predicted zeros.

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Table 7: Robustness checks: parameter estimates.

	Benchmark model: $\sigma = 3.8,\ k = 3.4$	Model: $\sigma = 3,\ k = 3.4$	Model: $\sigma = 3.8,\ k = 4$	Model: $\sigma = 6,\ k = 5.5$
γ_0	0.47	0.38	0.30	0.16
γ_1	0.16	0.17	0.17	0.17
γ_2	0.76	0.70	0.72	0.73
γ_3	0.96	0.96	0.97	0.96
γ_4	0.80	0.75	0.77	0.77
γ_5	0.94	0.90	0.93	0.95
δ^{τ}_{EX}	**−0.05**	**−0.13**	**−0.11**	**−0.00**
δ^{τ}_{IM}	**−0.08**	**−0.14**	**−0.11**	**−0.06**
f_x	0.60	1.00	1.29	94.25
δ^{f}_{EX}	**0.77**	**0.74**	**0.99**	**0.98**
δ^{f}_{IM}	**0.30**	**0.09**	**0.24**	**0.41**
R^2	82%	82%	82%	81.7%

Table 8: Robustness checks: trade elasticities and zeros.

	Bench.	M.: $\sigma = 3$	M.: $k = 4$	M.: $\sigma = 6$, $k = 5.5$
Dependent variable:	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$
Log of *GDP*	0.75^{**}	0.75^{**}	0.74^{**}	0.73^{**}
	(0.02)	(0.02)	(0.02)	(0.02)
Log of *GDP* per cap.	0.13^{**}	0.13^{**}	0.14^{**}	0.16^{**}
	(0.02)	(0.02)	(0.02)	(0.02)
Predicted zeros:	39%	37%	38%	39%
Observations:	100	100	100	100

Note. Robust standard errors in parentheses.

Table 9: Parameter estimates for different θ_H.

	Benchmark model:	Model:	Model:	Model:
	$\theta_H = 20$	$\theta_H = 5$	$\theta_H = 50$	$\theta_H = 100$
γ_0	0.47	0.70	0.38	0.29
γ_1	0.16	0.18	0.16	0.19
γ_2	0.76	0.78	0.72	0.69
γ_3	0.96	0.96	0.94	0.95
γ_4	0.80	0.83	0.74	0.73
γ_5	0.94	1.02	0.89	0.92
δ^{τ}_{EX}	**−0.05**	**−0.03**	**−0.07**	**−0.10**
δ^{τ}_{IM}	**−0.08**	**−0.03**	**−0.08**	**−0.09**
f_x	0.60	0.003	4.67	11.62
δ^{f}_{EX}	**0.77**	**0.66**	**0.86**	**0.82**
δ^{f}_{IM}	**0.30**	**0.47**	**0.42**	**0.76**
R^2	82%	81%	81.9%	81.7%

Table 10: Trade elasticities and zeros for different θ_H.

Dependent variable:	Bench. $\ln T_i(\hat{\Theta})$	M.: $\theta_H = 5$ $\ln T_i(\hat{\Theta})$	M.: $\theta_H = 50$ $\ln T_i(\hat{\Theta})$	M.: $\theta_H = 100$ $\ln T_i(\hat{\Theta})$
Log of GDP	0.75^{**}	0.74^{**}	0.74^{**}	0.74^{**}
	(0.02)	(0.02)	(0.02)	(0.02)
Log of GDP per cap.	0.13^{**}	0.17^{**}	0.14^{**}	0.15^{**}
	(0.02)	(0.02)	(0.02)	(0.02)
Predicted zeros:	39%	39%	39%	38%
Observations:	100	100	100	100

Note. Robust standard errors in parentheses.

Table 11: Alternative restrictions: parameter estimates.

The restriction:	Benchmark model: $\varepsilon = 0.5$	Model: $\varepsilon = 0.75$	Model: $\varepsilon = 0.25$
γ_0	0.47	0.61	0.44
γ_1	0.16	0.15	0.15
γ_2	0.76	0.77	0.74
γ_3	0.96	0.95	0.94
γ_4	0.80	0.80	0.77
γ_5	0.94	0.93	0.90
δ^{τ}_{EX}	**−0.05**	**−0.06**	**−0.08**
δ^{τ}_{IM}	**−0.08**	**−0.05**	**−0.09**
f_x	0.60	0.17	1.66
δ^{f}_{EX}	**0.77**	**0.75**	**0.73**
δ^{f}_{IM}	**0.30**	**0.36**	**0.37**
R^2	82%	82.2%	81.5%

Table 12: Alternative restrictions: trade elasticities and zeros.

	Data	$\varepsilon = 0.5$	$\varepsilon = 0.75$	$\varepsilon = 0.25$
Dependent variable:	$\ln T_i$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$
Log of GDP	0.85^{**}	0.75^{**}	0.75^{**}	0.75^{**}
	(0.03)	(0.02)	(0.02)	(0.02)
Log of GDP per capita	0.19^{**}	0.13^{**}	0.10^{**}	0.18^{**}
	(0.04)	(0.02)	(0.02)	(0.02)
Total number of zeros:	1399	1399	637	2549
Correctly predicted zeros:	1399	539	258	825

Note. Robust standard errors in parentheses.

Table 13: An alternative estimation procedure: parameter estimates.

Estimation procedure:	*NLLS* (benchmark model)	*NLLD*
γ_0	0.47	0.53
γ_1	0.16	0.19
γ_2	0.76	0.72
γ_3	0.96	0.85
γ_4	0.80	0.70
γ_5	0.94	0.87
δ^{τ}_{EX}	**−0.05**	**0.04**
δ^{τ}_{IM}	**−0.08**	**0.004**
f_x	0.60	0.45
δ^{f}_{EX}	**0.77**	**0.54**
δ^{f}_{IM}	**0.30**	**0.27**
R^2	82%	45.5%

Table 14: An alternative estimation procedure: trade elasticities and zeros.

	Data	NLLS	NLLD
Dependent variable:	$\ln T_i$	$\ln T_i(\hat{\Theta})$	$\ln T_i(\hat{\Theta})$
Log of GDP	0.85^{**}	0.75^{**}	0.63^{**}
	(0.03)	(0.02)	(0.02)
Log of GDP per capita	0.19^{**}	0.13^{**}	0.41^{**}
	(0.04)	(0.02)	(0.03)
Correctly predicted zeros:	100%	39%	36%
Observations:	100	100	100

Note. Robust standard errors in parentheses.

Figure 1: Trade vs GDP in 1995 (100 largest countries in terms of GDP)

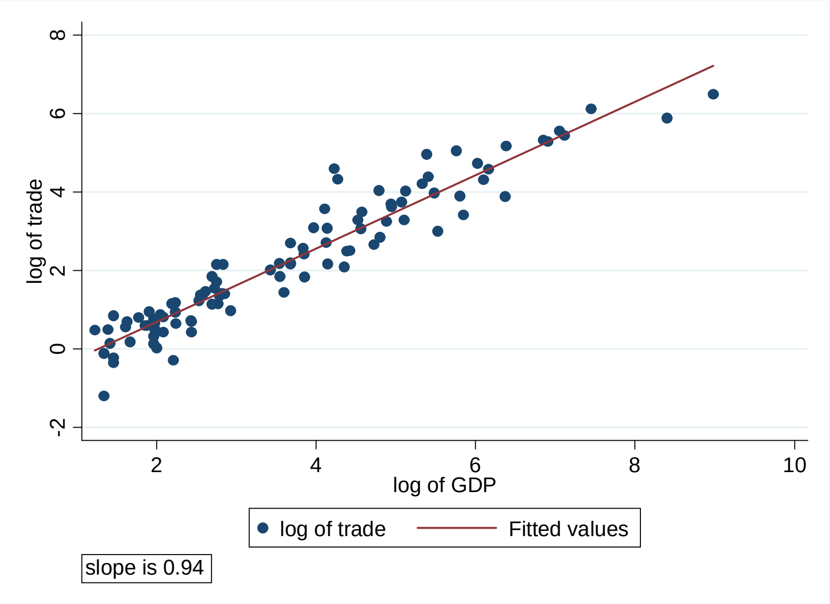

Figure 2: Residuals vs GDP per capita and population size

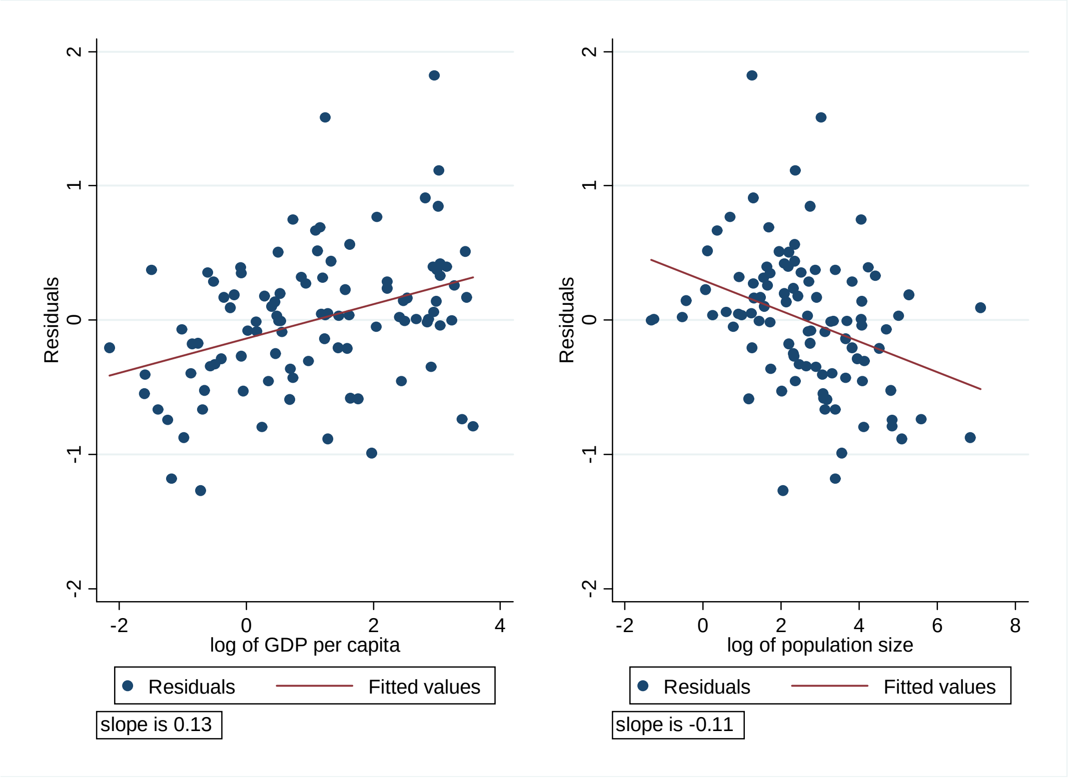

Table 15: List of Countries

Country name	**GDP per capita (2000US$)**	**GDP (2000US$ billion)**
United States	29942	7972.80
Japan	35439	4445.37
Germany	21073	1720.46
United Kingdom	21160	1232.58
France	19990	1156.29
Italy	17565	998.50
China, Hong Kong	777	941.32
Canada	20170	592.06
Brazil	3613	583.91
Spain	12056	474.85
Mexico	4892	445.85
Korea Republic	9159	413.01
India	372	346.57
Australia	18267	330.12
Netherlands	20427	315.81
Argentina	7184	250.26
Russian Federation	1618	239.71
Switzerland	31614	222.60
Belgium, Luxemburg	20672	218.01
Sweden	23374	206.42
Austria	21088	167.72
Turkey	2666	164.60
Indonesia	827	159.38
Norway	32214	140.45
Denmark	26599	139.06
Poland	3411	131.63
Greece	11445	121.71
Thailand	2086	120.01
Venezuela	5120	112.85
Finland	18899	96.54
Israel	17246	95.63
Portugal	9196	92.21
Iran	1409	83.07
Colombia	2092	80.04

Table 15: List of Countries (continued)

Country name	**GDP per capita (2000US$)**	**GDP (2000US$ billion)**
Egypt	1278	77.51
Malaysia	3471	71.47
Singapore	19359	68.23
Pakistan	515	63.00
Philippines	913	62.59
Chile	4295	61.82
Ireland	16799	60.62
Czech Republic	5100	52.69
Peru	1976	47.13
Algeria	1662	46.96
NewZealand	12635	46.41
Nigeria	363	39.54
Romania	1742	39.50
Hungary	3812	39.37
Bangladesh	289	36.54
Ukraine	672	34.60
Kuwait	19048	34.33
Morocco	1160	30.66
Uruguay	5786	18.62
Syrian Arab Republic	1181	17.26
Slovak Republic	3174	17.03
Oman	7749	16.83
Kazakhstan	1023	16.18
Guatemala	1589	15.89
Croatia	3337	15.58
Slovenia	7828	15.58
Ecuador	1335	15.21
Lebanon	4245	14.82
Tunisia	1651	14.79
Dominican Republic	1694	13.58
Bulgaria	1564	13.14
SriLanka	704	12.77
Costa Rica	3608	12.54

Table 15: List of Countries (continued)

Country name	GDP per capita (2000US$)	GDP (2000US$ billion)
Kenya	417	11.42
Uzbekistan	500	11.39
ElSalvador	2006	11.30
Belarus	920	9.38
Lithuania	2561	9.30
Panama	3470	9.27
Sudan	307	9.06
Coted'Ivoire	596	8.93
Jamaica	3241	8.04
Cameroon	568	7.99
Cyprus	11870	7.73
Tanzania	249	7.43
Jordan	1723	7.23
Yemen Rep.	465	7.22
Zimbabwe	606	7.15
Paraguay	1488	7.14
Bolivia	948	7.09
Iceland	25489	6.83
Angola	544	6.70
Bahrain	11170	6.45
Trinidad and Tobago	5037	6.40
Latvia	2364	5.95
Dem.Rep. Congo	116	5.26
Honduras	921	5.13
Gabon	4737	5.00
Nepal	200	4.34
Uganda	203	4.32
Estonia	2986	4.29
Bahamas	14477	4.06
Ghana	225	4.03
Senegal	424	3.84
Azerbaijan	488	3.75
Mauritius	3064	3.44