Deconstructing Gravity: Trade Costs and Extensive and Intensive Margins

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Central Bank of Ireland

August 2008

Central Bank & Financial Services Authority of Ireland
EUROSYSTEM

5/RT/08 August 2008

Research Technical Paper

Deconstructing Gravity: Trade Costs and Extensive and Intensive Margins

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*Thanks to Kristen Corwin at the US Census Bureau for making unpublished data from the Profile of Exporting Firms available to me. The views expressed in this paper are the author's own, and do not necessarily reflect the views of the Central Bank and Financial Services Authority of Ireland or the ESCB.
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Abstract

One of the most robust empirical results in international economics is the existence of a negative relationship between trade flows and distance. More recent research on exporting activity at the firm level has established an apparently equally robust result—few firms export, and exporting firms do not sell in all possible markets. This paper uses data on US exports across 156 countries to decompose exports to each market into the number of firms exporting (the extensive margin) and average export sales per firm (the intensive margin). We show how the effects of distance and a range of other proxies for trade costs have different impacts on the two margins. We find that distance has a negative effect on both margins, but the magnitude of the coefficient is considerably larger and more significant for the extensive margin. Most of the variables capturing language, internal geography, infrastructure and import cost barriers work solely through the extensive margin. We show that these results are consistent with the predictions of a Melitz-style model of trade with heterogeneous firm productivity and fixed costs.

Non-Technical Summary

This paper decomposes total trade from the United States to its destination countries into two components - an extensive margin capturing the number of exporting firms and an intensive margin related to the average exports per firm. It then examines how a range of variables related to trade costs affects total trade, the number of firms and average exports. One of the longest-standing and most robust empirical results in international economics is the existence of a negative relationship between aggregate exports and distance.

More recent research on exporting activity at the firm level has established an apparently equally robust result—few firms export, and exporting firms usually sell in a limited number of markets. This has led to the development of new models of trade that focus on firm-level exporting decisions. The most influential of these has been Melitz's (2003) model, which is based on assumptions of firm heterogeneity in productivity and fixed costs. This combination implies the existence of a productivity threshold for each country that firms must exceed if they are to export to that country.

This paper uses data from the US Census Bureau, detailing exports and numbers of exporting firms from the US to 156 destination markets. We examine the impact of a wide range of variables such as common language, influences of internal geography, and infrastructure.

In addition, we use new data from the World Bank on the costs associated with importing procedures (Djankov, Freund and Pham, 2008). These include financial costs coming from customs and port fees as well as less tangible costs such as the length of time it takes for imports to be processed and the complexity of the importing procedure, measured by the number of documents that have to be completed for each container-load.

We show how the Melitz (2003) model can be used to derive predictions for how various factors will affect the two margins. The predictions of the model can be summarized as follows.

- The number of firms exporting to a market should depend positively on the market's GDP and negatively on factors that affect the fixed and variable trade costs associated with the market.

- The model has more ambiguous predictions for sales per firm. Factors that reduce variable trade costs tend to increase sales of existing firms but reductions in fixed and variable trade costs also allow more marginal producers into the market, thus implying an ambiguous effect on sales per firms for a range of variables expected to impact upon trade costs.

- Export market GDP has an ambiguous direct effect on sales per firm but it likely has a positive effect if it raises fixed trade costs.

Most of the variables relating to trade costs which affect US exports do so only through their influence on the extensive margin. In addition, regressions for the extensive margin have a much better fit than those for the intensive margins. Of all the variables used, only those reflecting the size of the market and some proxies for communications infrastructure had a robustly significant effect on the intensive margin, with these variables having negative effects. And to the extent that these communications networks can reduce the fixed costs associated with trade, these results are also consistent with the model.

1 Introduction

One of the longest-standing and most robust empirical results in international economics is the existence of a negative relationship between aggregate exports and distance. This relationship is usually estimated as part of a gravity relationship for trade, a log-linear specification linking trade flows to the GDP of trading partners and the geographical distance between them.[1] More recent research on exporting activity at the firm level has established an apparently equally robust result—few firms export, and exporting firms usually sell in a limited number of markets.[2] This has led to the development of new models of trade that focus on firm-level exporting decisions. The most influential of these has been Melitz's (2003) model, which is based on assumptions of firm heterogeneity in productivity and fixed costs. This combination implies the existence of a productivity threshold for each country that firms must exceed if they are to export to that country.

An important implication of the threshold-productivity prediction is that it results in both an extensive (number of firms) and intensive (average exports per firm) margin to total trade. The extensive margin exists because firms that cannot export enough to cover their fixed costs will not export at all. This contrasts with the predictions of popular models used to generate the gravity relationsip, such as Anderson and van Wincoop (2003), which assume homogenous firms within each country and consumer love of variety ensures that all goods are traded everywhere. There is no extensive margin in these models and all adjustment to changes in trade costs should therefore occur in the intensive margin.

This paper uses data from the US Census Bureau, detailing exports and numbers of exporting firms from the US to 156 destination markets, to decompose total exports into number of firms and average export sales per firm. We use this decomposition to show how GDP as well as distance and a range of other proxies for trade costs have different impacts on both the extensive and intensive margins. Regressions of the sort discussed in this paper were recently reported by Bernard, Jensen, Redding and Schott (2007). This paper goes beyond their analysis in two important respects.

First, Bernard, Jensen, Redding and Schott used this decomposition into extensive and intensive margins to examine only the effects of GDP and distance. However, the literature

[1]The gravity relationship for trade dates back at least as far as Isard (1954) and has been estimated econometrically many times over the years. See Disdier and Head (2008) for a useful summary.

[2]See for instance, Bernard and Jensen (1995, 2004), Eaton, Kortum and Kramarz (2004), Bernard, Jensen, Redding and Schott (2007), and Lawless (2007).

on gravity models has identified a large number of proxies for trade costs in addition to distance. This paper thus extends the extensive and intensive margin regressions by adding variables such as common language, influences of internal geography, and infrastructure. In addition, we use new data from the World Bank on the costs associated with importing procedures (Djankov, Freund and Pham, 2008). These include financial costs coming from customs and port fees as well as less tangible costs such as the length of time it takes for imports to be processed and the complexity of the importing procedure, measured by the number of documents that have to be completed for each container-load.

Second, we provide a theoretical framework within which the results of the decompositions can be interpreted. In particular, we use a variant of the Melitz (2003) model to derive predictions for how various factors will affect the two margins. The Melitz model predicts that the extensive margin is negatively affected by both fixed and variable trade costs. There is no such clear prediction for the intensive margin however. For example, an increase in variable costs will reduce the sales of all firms exporting to a given country, but may also result in some of the lowest sales firms exiting the market, thus resulting in an ambiguous effect for *average* sales per firm. In addition, the model predicts that sales per firm should be *positively* related to fixed trade costs. Thus, the model predicts that variables such as GDP, which might be expected to be correlated with fixed trade costs, should have a positive effect on sales per firm, while those variables that impact on variable trade costs should have a clear effect on the extensive margin (number of firms), and perhaps have little effect on the intensive margin (sales per firm).

The results from our analysis largely confirm the model's prediction. We find that most of the variables used in our analysis affect exports largely through their influence on the extensive margin. Distance has a negative effect on both margins, but the magnitude of the coefficient is considerably larger for the extensive margin. All of the variables capturing language, internal geography, and import cost barriers have significant and appropriately signed effects on the extensive margin. However, almost none of these variables are found to have a statistically significant relationship with the intensive margin. The results show that the only factor to consistently affect the intensive margin is the size of the market.

The remainder of the paper is organised as follows. Section 2 presents a simple model of exporting with heterogeneous firms and fixed costs and discusses the model's implications for the intensive and extensive margins. Section 3 discusses the data. Section 4 presents the results for the basic and augmented gravity model. Section 5 concludes.

2 Model with Heterogeneous Firms and Fixed Trade Costs

In this section, a simple version of the model first presented by Melitz (2003) is used to derive expressions for the number of exporters and average exports in each destination and analyse how these depend upon trade costs and GDP.[3] The key features of the model are that firms are heterogeneous in their productivity and face both fixed and variable costs in order to export. We begin with a general formulation of the productivity distribution and then show the results are affected when the distribution is assumed to be Pareto. The Melitz structure has often been used to model bilateral trade flows across a range of sectors and countries. However, as the data used later in the paper are for exports from a single country, we will describe a model with firms from a single exporting country and therefore we suppress the home country subscript to simplify the notation.

2.1 Assumptions and Productivity Threshold

We assume that each country produces a continuum of separate differentiated products, and that consumers in the foreign country j have a utility function across the goods produced in all countries that takes the form

$$U_j = \left[\int x_j(k)^{\frac{\epsilon-1}{\epsilon}} dk \right]^{\frac{\epsilon}{\epsilon-1}} \tag{1}$$

Thus, the demand for good i in country j is

$$x_j(i) = \frac{p_j(i)^{-\epsilon} Y_j}{P_j^{1-\epsilon}} \tag{2}$$

where $p_j(i)$ is the price charged in country j for good i, Y_j is real income in country j and P_j is the Dixit-Stiglitz price level defined by

$$P_j = \left[\int p_j(k)^{1-\epsilon} dk \right]^{\frac{1}{1-\epsilon}} \tag{3}$$

We assume that our exporting country produces a continuum of separate differentiated products of unit mass. Each firm produces a single product according to a Ricardian

[3] Chaney (2008) has also reported theoretical results relating to intensive and extensive margins of trade. However, he defines these margins differently to this paper and focuses only on the effects of the elasticity of substitution between goods.

technology with cost-minimizing unit cost $\frac{c}{a}$, where c relates to the exporting country's cost level and a is the firm-specific productivity parameter. The productivity parameter a is assumed to be randomly drawn from a distribution $G(a)$ with probability density function on the support $[0, \infty]$.

There are two types of trade costs associated with exporting to country j. First, there are fixed costs F_j. These can be viewed as related to bureaucratic paperwork costs associated with exporting, to marketing costs, and to the costs of running a wholesale and retail distribution chain. It is likely that each of these costs increase with the scale of exports; however, it is also likely that many of these costs need to be incurred independent of the scale of subsequent export sales. Second, there are variable costs, which are modeled with the iceberg specification so that τ_j units have to be shipped from our country of interest to country j for one unit to arrive. These can be viewed as transport costs, tariffs, and the variable costs associated with marketing and distribution.

The assumptions about market structure and trade costs imply that the optimal selling price to country j for a good produced with technology level a is

$$p_j(a) = \frac{\epsilon}{\epsilon - 1} \frac{\tau_j c}{a} \tag{4}$$

This implies profits generated by this product in country j are given by

$$\pi_j(a) = \mu \left(\frac{P_j a}{\tau_j c} \right)^{\epsilon - 1} Y_j - F_j \tag{5}$$

where $\mu = (\epsilon - 1)^{\epsilon - 1} \epsilon^{-\epsilon}$. Thus, profits generated by exporting this product to country j are positive as long as

$$a > \left(\frac{F_j}{\mu Y_j} \right)^{\frac{1}{\epsilon - 1}} \frac{\tau_j c}{P_j} \tag{6}$$

This defines a cut-off level of productivity necessary for entry into country j as

$$\bar{a}_j = \left(\frac{F_j}{\mu Y_j} \right)^{\frac{1}{\epsilon - 1}} \frac{\tau_j c}{P_j} \tag{7}$$

so that only firms with productivity above this level will sell in country j. As would be expected, this cut-off level of productivity is increasing in both types of trade costs and in domestic cost levels, while it is negatively affected by export country GDP and the price level in country j.

2.2 Intensive and Extensive Margins of Trade

To calculate the model's predictions for the intensive and extensive margins, we begin with the expression for the exports of firm i to country j, which are

$$s_{ij} = p_{ij} x_{ij} = \left(\frac{P_j}{p_{ij}}\right)^{\epsilon-1} Y_j \tag{8}$$

Inserting the formula for the optimal price, this gives us

$$s_{ij} = \left(\frac{\epsilon-1}{\epsilon} \frac{P_j a_i}{\tau_j c}\right)^{\epsilon-1} Y_j \tag{9}$$

Thus, sales of an individual good depend positively on productivity, on the export country's GDP and price level, and negatively on variable trade costs. Once the firm has become an exporter, fixed costs do not have any impact on the level of sales. Total sales to country j are obtained by integrating across all productivity levels above the cut-off level for participation $\bar{a}$:

$$S_j = \int_{\bar{a}_j}^{\infty} s_j(a) G(a) \tag{10}$$

The change in total exports due to a change in any type of trade costs, x is given by:

$$\frac{\partial S_j}{\partial x} = \int_{\bar{a}_j}^{\infty} \frac{\partial s_j(a)}{\partial x} G(a) da - s_j(\bar{a}_j) G(\bar{a}_j) \frac{\partial \bar{a}_j}{\partial x} \tag{11}$$

Total exports to j are affected by a change in trade costs through two channels - the first part of the expression is the change in sales of firms already above the productivity threshold and the second part gives the change in the threshold itself. An increase in variable trade costs affects both parts of the expression, by reducing the sales of current exporters and also increasing the productivity level needed to export. Fixed costs do not affect the sales of current exporters but will still impact total sales as it is included in determining the threshold productivity, an increase in which may result in some firms exiting the market.

The number of firms exporting to each market is derived using the formula for the productivity cut-off:

$$N_j = \int_{\bar{a}_j}^{\infty} G(a) da \tag{12}$$

The change in the number of firms due to a change in trade costs, x is given by

$$\frac{\partial N_j}{\partial x} = -G\left(\bar{a}_j\right) \frac{\partial \bar{a}_j}{\partial x} \tag{13}$$

This shows the negative relationship between trade costs and number of exporters. As increases in trade costs shift upward the threshold level of productivity needed to export, fewer firms are above the bar and the number of exporters falls.

Finally, the expressions for total exports and number of exporters can be combined to give the average exports per firm:

$$\frac{S_j}{N_j} = \frac{\int_{\bar{a}_j}^{\infty} s_j(a)G(a)da}{\int_{\bar{a}_j}^{\infty} G(a)da} \tag{14}$$

Average exports are affected by trade costs according to:

$$\frac{\partial\left(\frac{S_j}{N_j}\right)}{\partial x} = \frac{\frac{\partial S_j}{\partial x}N_j - S_j\frac{\partial N_j}{\partial x}}{N_j^2} \tag{15}$$

The total change in the intensive margin depends on how the change in trade costs affects both total sales and the number of firms. Fixed and variable trade costs have quite different effects on average sales. In the case of a change in fixed costs, the effect is unambiguous. An increase in F_j will not affect the sales of continuing exporters, so from equation (11), we get

$$\frac{\partial S_j}{\partial F_j} = -s_j(\bar{a}_j)G(\bar{a}_j)\frac{\partial \bar{a}_j}{\partial F_j} \tag{16}$$

Inserting this and the expression for $\frac{\partial N_j}{\partial F_j}$ (following 13) into the expression implied by equation (15) and we get

$$\frac{\partial\left(\frac{S_j}{N_j}\right)}{\partial F_j} = \frac{-s_j(\bar{a}_j)N_jG(\bar{a}_j)\frac{\partial \bar{a}_j}{\partial F_j} + S_jG\left(\bar{a}_j\right)\frac{\partial \bar{a}_j}{\partial F_j}}{N_j^2} \tag{17}$$

$$= \frac{\left(S_j - s_j(\bar{a}_j)N_j\right)G(\bar{a}_j)\frac{\partial \bar{a}_j}{\partial F_j}}{N_j^2} \tag{18}$$

Because $S_j - s_j(\bar{a}_j)N_j > 0$ (total sales are greater than if all firms sold the same as the thereshold firm), $G(\bar{a}_j) > 0$ (continuous distribution) and $\frac{\partial \bar{a}_j}{\partial F_j} > 0$ (higher fixed costs raise the threshold), the effect of fixed costs on sales per firm can be signed as positive. By increasing the productivity threshold required to export, the increase in F_j eliminates low-sales firms while keeping high-sales firms and this raises the average sales per firm.

In the case of an increase in variable trade costs, there is also an increase in the productivity threshold for exporting (in the same way as fixed costs), removing some marginal exporters from the market. However, variable costs also have an effect on the exports of firms that remain in the market. The expression for the effect of a change in variable costs on average exports is given by

$$\frac{\partial\left(\frac{S_j}{N_j}\right)}{\partial\tau_j} = \frac{\left(\int_{\bar{a}_j}^{\infty}\frac{\partial s_j(a)}{\partial\tau_j}G(a)da - s_j(\bar{a}_j)G(\bar{a}_j)\frac{\partial\bar{a}_j}{\partial\tau_j}\right)N_j + S_jG\left(\bar{a}_j\right)\frac{\partial\bar{a}_j}{\partial\tau_j}}{N_j^2} \tag{19}$$

$$= \frac{\left(\int_{\bar{a}_j}^{\infty}\frac{\partial s_j(a)}{\partial\tau_j}G(a)da\right)N_j + \left(S_j - s_j(\bar{a}_j)N_j\right)G(\bar{a}_j)\frac{\partial\bar{a}_j}{\partial\tau_j}}{N_j^2} \tag{20}$$

The first term in the numerator of this expression is the change in export sales of existing exporters as a result of a change in variable trade costs, and this term is negative. The second term relates to the raising of the threshold bar (it is identical in form to the expression for fixed trade costs) and thus is positive. Without additional assumptions about the form of the productivity distribution, $G(a)$, the overall effect cannot be signed, leaving us with an ambiguous effect of τ on average sales. The same expression can also be derived for changes in export market GDP. This raises the sales of all continuing firms but also introduces marginal low-sales firms. Note, though, that higher GDP may also contribute to raising the fixed costs associated with exporting to that market, so this may offset the threshold-bar effect and contribute to a positive effect.

The predictions of the model can be summarized as follows.

- The number of firms exporting to a market should depend positively on the market's GDP and negatively on factors that affect the fixed and variable trade costs associated with the market.
- The model has more ambiguous predictions for sales per firm. Factors that reduce variable trade costs tend to increase sales of existing firms but reductions in fixed and variable trade costs also allow more marginal producers into the market, thus implying an ambiguous effect on sales per firms for a range of variables expected to impact upon trade costs.
- Export market GDP has an ambiguous direct effect on sales per firm but will have a positive effect if it raises fixed trade costs.

2.3 Pareto Productivity Distribution Example

Before moving on to our empirical analysis, we think it is worth pointing out that more definite predictions for the impact of variable trade costs on sales per firm can be derived if more specific assumptions are made about the form of heterogeneity in productivity. Specifically, the model produces clean analytical results if, following Helpman, Melitz and Yeaple (2004) and Chaney (2008), one assumes that the productivity parameter a is randomly drawn from a Pareto distribution with probability density function $G(a) = \gamma a^{-\gamma-1}$ on the support $[1, \infty]$ (meaning c has the interpretation of the cost of the minimum-productivity technology). Beyond analytical convenience, there is empirical evidence that important firm-level distributions, such as for firm size, follow a Pareto distribution.[4] In addition, Gabaix (1999) has shown that Pareto distributions can be generated from an aggregation of random micro-level exponential growth shocks to each of the individual units, while Kortum (1997) has shown that the upper tail of productivity distributions needs to be Pareto if steady-state growth paths are to be sustained.

As before, the extensive margin is given by integrating above the productivity cut-off point, giving the expression:

$$N_j = \int_{\bar{a}_j}^{\infty} G(a)da = \bar{a}_j^{-\gamma} = \left(\frac{P_j}{\tau_j c}\right)^{\gamma} \left(\frac{\mu Y_j}{F_j}\right)^{\frac{\gamma}{\epsilon-1}} \tag{21}$$

The number of firms is increasing in the GDP and price level of the destination market and is negatively related to both fixed and variable trade costs.

Total export sales to country j are now given by:

$$S_j = \left(\frac{\epsilon-1}{\epsilon}\frac{P_j}{\tau_j c}\right)^{\epsilon-1} Y_j \int_{\bar{a}_j}^{\infty} a^{\epsilon-1} G(a)da \tag{22}$$

$$= \frac{\gamma}{\gamma-\epsilon+1}\left(\frac{\epsilon-1}{\epsilon}\frac{P_j}{\tau_j c}\right)^{\epsilon-1} Y_j \bar{a}_j^{\epsilon-\gamma-1} \tag{23}$$

Again we note that once it has been decided that a product will be exported, its subsequent sales are independent of the fixed cost but that variable costs have a negative impact.[5] The

[4] See Axtell (2001) for evidence on size distributions of US firms.

[5] Note from this last calculation that it is necessary to assume $\gamma > \epsilon - 1$. Higher values for γ implies that the distribution of productivity levels falls off faster. If this parameter is assumed to be too small, then firms with high productivity (and thus high sales) would become so important that the integral for total sales would not converge to a finite value.

average value of exports per product can now be calculated directly as

$$\frac{S_j}{N_j} = \frac{\gamma}{\gamma - \epsilon + 1} \left(\frac{\epsilon - 1}{\epsilon} \frac{P_j}{\tau_j c} \right)^{\epsilon - 1} Y_j \bar{a}_j^{\epsilon - 1} \tag{24}$$

This can be simplified by inserting the formula for the cutoff value of productivity. In this case, all of the terms involving Y_j, P_j, τ_j and c cancel out, leaving the formula:

$$\frac{S_j}{N_j} = \frac{\gamma\epsilon}{\gamma - \epsilon + 1} F_j \tag{25}$$

We obtain a prediction that sales per firm are directly proportional to fixed trade costs but do not depend at all on the effect of variable trade costs or foreign market GDP. We have shown already that an increase in τ_j reduces the exports of all firms that choose to continue to sell to market j but also eliminates some marginal low-sales firms from the market. These calculations show that when productivity is drawn from a Pareto distribution, these two counteracting forces exactly offset each other.

This example shows that for a reasonable calibration of the productivity distribution, it is possible for some variables to have significant effects on the number of firms exporting to a market but to have *no effect* on sales per firm in that market.

3 Data

We use data from 2006 on the number of US firms and their average export sales to each destination market. These data come from the US Census Bureau's Profile of Exporting Firms (US Census Bureau, 2008). The data is based on detailed export documentation used to compile the official U.S. trade statistics. The number of destinations used in this analysis is limited to 156 countries due to availability of data on explanatory variables. Table 1 shows the known value of exports[6] and number of exporting firms to the top 25 foreign markets as published by the Census Bureau. The largest destination is Canada with over 87,000 firms from the US exporting there; the number of firms exporting to each market decreases rapidly, with half of the number of firms exporting to Mexico (the next most popular destination for US exports) as to Canada. The 25^{th}-largest market, Saudi Arabia, has less than one-tenth of the number of exporters as Canada.

[6] Only data on exports that could be linked to firms is used, thereby slightly understating the total exports to any individual destination but giving a more accurate figure for average export sales.

This data can be used to demonstrate the importance of the role of the extensive margin by decomposing the variation in total exports to different markets into the contributions of variation in the number of firms, the average exports per firm and a term related to the covariance of these two elements.

$$Var(lnS_j) = Var(lnN_j) + Var(ln\frac{S_j}{N_j}) + 2Cov(lnN_j, ln\frac{S_j}{N_j}) \tag{26}$$

We find that the variation in number of firms contributes over half (0.52) of the total variation in exports, variation in average export sales contributes 0.14 to the total and the remaining 0.34 is due to the covariance between the two terms. The strong positive covariance is in agreement with the predictions of the model, which suggests that GDP likely has a positive effect on both margins.

The explanatory variables at the country level come from a number of sources and are listed in Table 2. The standard gravity variables of destination GDP (in US dollars) comes from the World Bank's World Development Indicators database and distance between capital cities comes from Jon Haveman's website.[7]

Data on administrative costs of international trade come from the Doing Business Survey, undertaken by the World Bank in 2005 (for a detailed description see Djankov, Freund and Pham, 2008). The costs detailed in this dataset relate to customs inspections, storage and handling at the port and documentation required in the importing country. The costs are compiled on the basis of a homogeneous import good; specifically, the cost is that of processing a dry-cargo, 20-foot container requiring no special treatment such as refrigeration or environmental safety standards. Three variables are used to capture the administrative costs of trade: The first is the number of documents that must be filled to import the container into the country, the second is the average length of time in days it takes for all the technical and customs procedures to be completed and the third is the cost of all the fees associated with customs clearance and handling at the port (but does not include taxes or tariffs). The importance of time delays in trading and the associated costs of storage and depreciation (particularly of time-sensitive products such as fresh produce) has been examined by Hummels (2001), who estimated that each day saved in transporting manufactured goods is worth 0.8 percent ad-valorem.

Ability to communicate in a common language is predicted to reduce the costs of trade. We use a dummy variable representing English as a common language if it is (one of the)

[7] http://www.macalester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources/Data/Gravity/dist.txt

official language(s) in the destination market, also from the Haveman website. To capture effects of internal geography and level of development, we use a number of infrastructural and access variables from World Bank World Development Indicators. In terms of communications infrastructure, access to information on the market can make it easier for a firm to investigate the market and to conduct business (Anderson and van Wincoop, 2004). We use the extent of telephone and computer usage to proxy for the ease of information gathering and running a business abroad.

To augment the market size variable, we use two additional measures to capture how easily the exporting firm can gain access to this market. The physical size of the country (area in square kilometres) is used to proxy for internal transportation costs. The population density is also used as an indicator of internal geography that might make it easier for the exporter to reach a large proportion of the market without having to set up a very large distribution network.

4 Gravity Model of Intensive and Extensive Margins

This section presents the results of an econometric gravity model for total trade, separating the effects of explanatory variables into those relating to the number of firms exporting and those relating to average exports per firm. The first subsection describes the empirical specification and the results of the basic gravity formulation using market size and distance. The second subsection then augments the model by adding further variables that may influence the costs of exporting, such as common language, infrastructure indicators and bureaucracy measures.

4.1 Empirical Specification and Benchmark Results

As in Bernard, Jensen, Redding and Schott (2007), the aggregate export sales S to country j are decomposed into the number of firms exporting to the destination, N_j and the average exports per firm S/N. This decomposition can be expressed in log form as:

$$lnS_j = lnN_j + ln\frac{S_j}{N_j} \tag{27}$$

Each of the three components (total exports, number of firms and average exports) are regressed on a range of variables that might be expected to have an effect on the costs of trading internationally:

$$lnZ_j = \alpha + \beta lnD_j + \gamma lnGDP_j + \delta X_j + \epsilon_j \tag{28}$$

where Z represents either total sales, number of exporters or average exports per firm, D is bilateral distance, GDP is gross domestic product in the destination market and X is a range of other factors proxying for trade costs. The gravity model generally includes both importer and exporter income as explanatory variables: however, as we use data on exporting from a single source country, its income level will be picked up in the regression constant. As is standard in the gravity literature, all the variables are expressed in logs, allowing us to interpret the coefficients as elasticities. Using OLS means that the coefficients on number of firms and average sales per firm will sum to give the coefficient on total exports.

The benchmark gravity model, using just GDP and distance as explanatory variables, is presented in Table 3. The results for total exports show, as expected, a significant negative relationship between trade and distance and a significant positive coefficient on destination GDP. The distance coefficient on total trade is -1.32. This is slightly higher than the average distance elasticity of -0.9 found by Disdier and Head (2008) in a meta-analysis of 103 gravity model papers. They found that 90% of estimates were between -0.28 and -1.55, so our result is well within the standard range.

Splitting the total trade into the number of firms and average exports shows that most of the distance effect is working through inhibiting entry: The coefficient on the extensive margin is -1.06, approximately four-fifths of the total effect. The effect on average exports is also negative but is considerably smaller. These results are consistent with our theory which predicts that trade costs, which distance affects, have ambiguous effects on sales per firm. It should be expected that its effect on the intensive margin therefore appears weaker than on the extensive margin, where trade costs work in a single direction.

The decomposition of the GDP effect is somewhat more equal across the two margins than the distance effect, but it still works mainly through the extensive margin: The total effect of 0.94 is made up of a coefficient of 0.65 on the extensive margin and 0.29 on the intensive margin. As noted above, the positive effect of GDP on sales per firm may reflect the its effect on fixed trade costs. Regarding the fit of the model, a feature of all our specifications is that the R^2 is always higher, sometimes considerably so, for number of firms compared to average exports. In the benchmark case, the R^2 for number of firms is 0.77 and for average sales per firm it is 0.56. Again this is consistent with our theoretical framework, which suggests systematic relationships across countries between numbers of firms and explanatory variables but which suggests ambiguous and possibly weak relationships for average sales per firm.

This benchmark regression can be compared to the results of Bernard et al. (2007) who use a sample of 175 countries for the year 2000. As one would expect, the results are almost identical. They report a total effect for GDP of 0.98 comprising a extensive margin effect of 0.71 and an intensive margin effect of 0.27. Their distance effect was -1.36 for total exports, divided into an effect of -1.14 for the extensive margin and -0.22 for the intensive margin.[8] The slight variation in the coefficients is most likely to be due to sampling differences, e.g. their data refer to 2000 rather than 2006.

4.2 Infrastructure Variables and Costs of Trade

This section augments the gravity model by including additional variables that might be expected to affect the costs of trading internationally. Supplementing the distance proxy for costs of getting to the country, we now add costs incurred at the border. The Doing Business Survey, conducted by the World Bank, provides the measures for costs of import processing in the destination country, both financial and in terms of the burden of paperwork and time. As the measures are all relatively highly correlated, they are entered into the specification separately, the results of which are presented in Table 4. The administrative complexity of the importing process, as measured by the number of documents that need to be completed, is negatively associated with total trade and with the number of firms exporting to the market. The length of time required to fulfill all the necessary requirements has a similar effect. Finally, the total financial cost of import restrictions, also has a negative impact on total trade and the number of exporters, and is the variable associated with the highest R^2 for the number of firms. None of these trade costs measures have any discernible impact on average sales. This evidence is consistent with the model's prediction of an ambiguous effect of trade costs on average export sales.

Table 5 adds measures of common language and communications infrastructure to the

[8] Bernard et al. actually report three margins as they divide the intensive margin into two components - the number of products per firm and the average sales per product. I have combined the coefficients of these two components to compare like with like, as the data used in this paper does not contain product information.

basic gravity specification. The dummy variable for English as an official language is positively related to total trade. Again, we find that this effect works entirely through the extensive margin, with the coefficient on the English dummy having a statistically insignificant effect on the intensive margin. This table also presents results using measures of the extent of telephone and internet networks as indicators both of the ease of transacting business for firms in the market and also for accessing information prior to an entry decision. Both of the measures have positive and significant effects on total trade, with the number of fixed and mobile telephones per hundred people performing somewhat better in terms of model fit. Telephone and internet networks also have a positive relationship with the number of firms.

Perhaps surprisingly, however, both phone and internet coverage have a negative impact on average exports per firm. That said, these results are still consistent with the model's ambiguous prediction about the effect of trade costs on average exports. From the model outlined earlier, we know that the effect of a change in trade costs on average exports will depend on the relative strength with which the change affects the threshold for entering the market and the sales of continuing exporters. In some cases, as appears to be the case with the import cost variables, these effects appear to be offsetting. In other cases, they may not be. For instance, the model predicts that if good phone and internet networks reduce fixed trade costs, then they may be associated with lower average sales per firm.

The distance coefficient captures the costs of transportation to the foreign market. Further costs of transportation are likely to be incurred within the country and Table 6 presents results for two proxies for internal geography that may influence these costs. The first is the physical area of the country, which should increase the costs of supplying that market and, as one would expect, it has a negative coefficient on total trade. This is not a perfect measure of course, as population is rarely evenly distributed within a country. For this reason, we also add a measure of population density (people per square kilometre). Markets where consumers are relatively highly concentrated may be more accessible for exporters with lower transportation costs and possibly also lower costs for marketing and administration in general. Population density indeed has a positive effect on total exports. Again, the division of the effects of these internal geography measures shows that both work entirely through the extensive margin of trade. The area and density measures have no significant effect on the intensive margin.

Drawing all of the elements together, Table 7 presents results for an extended gravity model that includes a range of trade cost variables in addition to the standard elements of GDP and distance. The results remain comparable to when the costs are entered separately, with statistically significant coefficients in the regression for the number of firms and not in the regression for average exports per firm. The exception is the measure of the telephone network, which again has a negative and significant coefficient in the average exports regression. The fit of this extended model is higher than that the benchmark model that contained just GDP and distance. The R^2 for the total trade column has increased slightly from 0.82 to 0.85. The extra trade cost variables do particularly well in explaining the variation in the number of firms; the R^2 of the extended model is 0.84 compared to 0.77 for the benchmark. On the other hand, there is very little improvement in the fit of the average firm exports regression (0.58 in the extended model compared to 0.56 in the benchmark). The lack of improvement in fit and the generally insignificant coefficients for the average exports regressions are consistent with the predictions of the model, because the impact of trade costs were shown to have an ambiguous effect on this intensive margin.

5 Conclusions

The gravity model relating trade flows to GDP and proxies for trade costs is one of the most empirically successful in international economics. This paper decomposes the gravity model into a extensive (number of firms) and intensive (average export sales per firm) margin. We begin by using a variant of the Melitz (2003) model of firm exports—which incorporates firm heterogeneity in productivity and fixed trade costs for each export market—to generate predictions for how trade costs should impact on the two margins of trade. The model gives a clear prediction that the extensive margin is negatively affected by both fixed and variable trade costs, but the prediction for the intensive margin contains counteracting terms whose overall sign is unclear. Lowering trade costs tend to raise the sales of continuing exporters but also leads to the introduction of new more marginal exporters with lower average sales.

We then apply the gravity model specification to the extensive and intensive margins in US exports across 156 countries, examining the effect of a range of variables commonly shown to impact on the cost of exporting. In addition to the standard gravity variables of size and distance, we add factors such as common language, internal geography and communications infrastructure. Furthermore, we use new data from the World Bank on the costs associated with importing procedures, including both financial costs coming from customs and port fees, the length of time it takes for imports to be processed and the complexity of the importing procedure.

The results strongly confirm the predictions of the Melitz theoretical framework and run counter to popular models of the gravity relationship, such as Anderson and van Wincoop (2003), which feature homogenous firms and no extensive margin. Most of the variables relating to trade costs affect US exports only through their influence on the extensive margin. In addition, regressions for the extensive margin have a much better fit than those for the intensive margins. Of all the variables used, only those reflecting the size of the market and some proxies for communications infrastructure had a robustly significant effect on the intensive margin, with these variables having negative effects. And to the extent that these communications networks can reduce the fixed costs associated with trade, these results are also consistent with the model.

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Table 1: Exports and Exporting Firms to Top 25 Markets

	Exports ($millions)	Number Firms
Canada	178,507	87,554
Mexico	118,174	44,204
Japan	55,984	26,648
China	51,902	25,873
United Kingdom	40,861	39,684
Germany	37,722	29,416
South Korea	29,657	19,184
Netherlands	29,293	16,370
Singapore	22,584	18,278
France	22,463	17,674
Taiwan*	21,610	16,754
Belgium	20,158	10,635
Brazil	18,024	13,465
Australia	15,578	24,553
Hong Kong	16,139	21,765
Switzerland	12,965	10,195
Italy	11,487	17,344
Malaysia	11,987	9,479
United Arab Emirates	11,169	11,055
Israel	8,003	12,806
India	9,404	13,774
Venezuela	8,346	9,200
Ireland	7,933	7,882
Thailand	7,734	9,775
Saudi Arabia	6,938	7,709

* Not included in this paper's analysis due to a lack of data on explanatory variables

Table 2: Variable Definitions and Sources

Variable	Definition	Source
Distance	Distance in kilometres from Washington DC to destination's capital city	Jon Haveman International Trade Data website[a]
GDP	Gross Domestic Product in US dollars	World Bank World Development Indicators (WDI)
English	Dummy variable = 1 if English is an official language	Jon Haveman International Trade Data website
Phones	Fixed line and mobile phone subscribers (per 100 people)	World Bank WDI
Internet	Internet users (per 100 people)	World Bank WDI
Area	Surface area in square kilometres	World Bank WDI
Density	Population per km^2 (Data for 2005)	United Nations World Population Prospects
Documents	Number of documents required to process imports as port of entry	Doing Business Survey
Time	Number of days taken to process imports	Doing Business Survey
Costs	Cost in US dollars of all fees and charges at port of entry (excluding tariffs)	Doing Business Survey

(a): Available at

http://www.macalester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources/Data/Gravity/dist.txt

Table 3: Benchmark Gravity Model

	Dependent Variable		
	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports
Ln Distance	-1.32***	-1.06***	-0.26***
	(0.17)	(0.14)	(0.08)
Ln GDP	0.94***	0.65***	0.29***
	(0.04)	(0.03)	(0.02)
R^2	0.82	0.77	0.56
Observations	156	156	156

Notes: Robust standard errors in parentheses.

*** indicates significance at 1% level, ** at 5% and * at 10%.

Table 4: Procedures and Costs of Trade

	Dependent Variable								
	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports
Ln Distance	-1.24***	-0.96***	-0.27***	-1.24***	-0.96***	-0.28***	-1.32***	-1.07***	-0.25***
	(0.18)	(0.14)	(0.08)	(0.17)	(0.13)	(0.08)	(0.15)	(0.12)	(0.08)
Ln GDP	0.92***	0.62***	0.30***	0.89***	0.58***	0.31***	0.90***	0.60***	0.30***
	(0.04)	(0.03)	(0.02)	(0.04)	(0.03)	(0.02)	(0.04)	(0.03)	(0.02)
Ln Import Documents	-0.67**	-0.82***	0.16						
	(0.30)	(0.23)	(0.15)						
Ln Import Time				-0.46**	-0.61***	0.15			
				(0.18)	(0.14)	(0.10)			
Ln Import Cost							-0.80***	-0.86***	0.06
							(0.18)	(0.12)	(0.11)
R^2	0.83	0.78	0.56	0.83	0.80	0.56	0.84	0.82	0.56
Observations	156	156	156	156	156	156	156	156	156

Notes: Robust standard errors in parentheses. *** indicates significance at 1% level, ** at 5% and * at 10%.

Table 5: Language and Communications Infrastructure

	Dependent Variable								
	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports
Ln Distance	-1.34***	-1.09***	-0.25***	-1.19***	-0.85***	-0.34***	-1.25***	-0.91***	-0.34***
	(0.18)	(0.15)	(0.08)	(0.18)	(0.13)	(0.08)	(0.18)	(0.14)	(0.08)
Ln GDP	0.96***	0.67***	0.29***	0.88***	0.55***	0.33***	0.91***	0.58***	0.33***
	(0.04)	(0.03)	(0.02)	(0.04)	(0.03)	(0.02)	(0.04)	(0.03)	(0.02)
English Dummy	0.48**	0.57***	-0.09						
	(0.20)	(0.18)	(0.11)						
Ln Phones				0.22**	0.36***	-0.14**			
				(0.09)	(0.07)	(0.05)			
Ln Internet							0.11	0.26***	-0.15***
							(0.09)	(0.06)	(0.05)
R^2	0.83	0.78	0.56	0.83	0.80	0.57	0.82	0.79	0.58
Observations	156	156	156	156	156	156	156	156	156

Notes: Robust standard errors in parentheses. *** indicates significance at 1% level, ** at 5% and * at 10%.

Table 6: Accessibility

	Dependent Variable					
	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports
Ln Distance	-0.27***	-1.00***	-0.27***	-1.35***	-0.109***	-0.25***
	(0.17)	(0.12)	(0.08)	(0.16)	(0.13)	(0.08)
Ln GDP	1.02***	0.75***	0.27***	0.93***	0.64***	0.29***
	(0.05)	(0.03)	(0.03)	(0.04)	(0.03)	(0.02)
Ln Area	-0.13**	-0.17***	0.03			
	(0.05)	(0.04)	(0.03)			
Ln Population Density				0.14*	0.16**	-0.01
				(0.08)	(0.06)	(0.04)
R^2	0.83	0.79	0.56	0.83	0.78	0.56
Observations	156	156	156	156	156	156

Notes: Robust standard errors in parentheses. *** indicates significance at 1% level, ** at 5% and * at 10%.

Table 7: Extended Gravity Model

	Dependent Variable		
	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports
Ln Distance	-1.36***	-1.01***	-0.35***
	(0.16)	(0.11)	(0.07)
Ln GDP	0.89***	0.53***	0.36***
	(0.10)	(0.06)	(0.08)
English Dummy	0.50***	0.58***	-0.08
	(0.18)	(0.15)	(0.12)
Ln Phone	0.05	0.24**	-0.19*
	(0.16)	(0.09)	(0.11)
Ln Density	0.10	0.14**	-0.04
	(0.12)	(0.07)	(0.09)
Ln Area	0.04	0.07	-0.04
	(0.11)	(0.07)	(0.09)
Ln Cost	-0.76***	-0.72***	-0.04
	(0.18)	(0.11)	(0.12)
R^2	0.85	0.84	0.58
Observations	156	156	156

Notes: Robust standard errors in parentheses.

*** indicates significance at 1% level, ** at 5% and * at 10%.