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Gravity Estimation of the Intensive and Extensive Margins of Trade: An Alternative Procedure with Alternative Data

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Abstract

Helpman, Melitz and Rubinstein (2008) derive gravity equations to estimate effects of trade barriers on the intensive and extensive margins of trade. They exploit the frequency of zeros in aggregate bilateral trade data to identify effects on the extensive margin and to obtain controls for firm level heterogeneity and sample selection on the intensive margin. By using data on the number of bilaterally traded products we improve on identification and allow estimation of the extensive margin when data contain only positive trade flows. We also control for the pervasive presence of heteroscedasticity in trade data. The heterogeneity and selection biases are shown to be small and unimportant whereas the heteroscedasticity bias is large and important.

JEL-Code: F100, F120, F140.

Keywords: gravity estimation, heteroscedasticity in data, intensive and extensive margin.

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1 Introduction

Until recently, most empirical research made no distinction between effects of trade barriers on the intensive margin – the volume of trade by current exporters and importers – and effects on the extensive margin – the entry or exit of exporters and importers. This was quite natural, since standard models of international trade assumed firms to be identical. However, empirical research by Roberts and Tybout (1997), Eaton, Kortum and Kramarz (2004) and subsequently by many others find considerable heterogeneity of firms with respect to their propensity to export. Spurred by these findings, Eaton and Kortum (2002) and Melitz (2003) developed theoretical models that take account of firm heterogeneity and allow a distinction between effects of trade barriers on the intensive and extensive margins.

Based on the Melitz (2003) model, Helpman, Melitz and Rubinstein (2008; henceforth HMR) extended the gravity equation of Anderson and van Wincoop (2003) and developed an estimation procedure to obtain the effects of trade barriers on the intensive and extensive margins of trade. The lack of bilateral trade data at the firm level has been a major difficulty in identifying effects on the two margins empirically. HMR solve the problem by exploiting the presence of zero trade flows in aggregate bilateral trade data. Nearly half of the potential bilateral trade flows in their data have a value of zero.[1] In a first step, they derive an equation for the probability of trade at the firm level based on firms' decisions and use it to estimate effects on the extensive margin. In the second step, they estimate effects on the intensive margin using predicted probabilities from the first step to correct for bias caused by firm heterogeneity and sample selection.

The HMR estimation procedure has limitations. One limitation is that effects of trade barriers on the extensive margin are identified by zero and positive bilateral trade flows in the data. This is a limitation, first, because the fixed cost of becoming an exporter may be different when no firm is exporting than when some firms already are exporting to a particular destination, and, second, because only a small part of the variation on the external margin is exploited, namely the variation between zero and

[1] The proportion is much higher than the proportion in our own data – 14 per cent – and makes us suspect that a considerable part of the zeros actually represent missing data. Many poorer countries do not report trade and it is therefore not uncommon to find that neighboring countries are reported not to trade with each other.

positive trade but not across positive trade flows. A second limitation is that the estimation procedure does not take account of the considerable heteroscedasticity that is present in trade data, as shown in Figure 1. Silva and Tenreyro (2009) have demonstrated that the assumption of homoscedasticity of the error terms in HMR leads to serious misspecification. In their view "… the presence of heteroscedasticity in the data seems to preclude the estimation of *any* model that purports to identify the effects of the covariates in the intensive and extensive margins …" (italics added).

Ideally, one would like to have bilateral trade data at the firm level for many countries to be able to estimate the intensive and extensive margins directly. Such data exist only for a few countries and would not yield results that are generally valid. The next best approach, we argue, is the use data on the *total number of bilaterally traded products at the 6-digit level of the Harmonized System*. Such data are readily available from the UN COMTRADE database. Our proposed estimation procedure makes two contributions. First, we improve on identification of the extensive margin by using data on the total number of products in bilateral trade. This means that we are able to exploit the variation in trade on the external margin not only by the difference between zero and some positive level of trade, but at all levels and in much more detail. In particular, we can identify effects on the external margin also when all bilateral trade flows are positive. Second, we can control for heteroscedasticity by using the Poisson Pseudo Maximum Likelihood estimator, as first suggested by Silva and Tenreyro (2007), (as well as controlling for the firm level heterogeneity and sample selection bias that HMR focus on).[2] The presence of heteroscedasticity in trade data is pervasive, as is evident from the plots shown in Figure 1.

We find that the biases caused by firm heterogeneity and sample selection are small and economically unimportant. The bias introduced caused heteroscedasticity is on the other hand large and economically important.

In addition to eliminating the limitations of the HMR estimation procedure, we contribute by controlling for tariffs and trade preferences in great detail. We have calculated the weighted average tariffs levied by each country on imports from the

[2] Standard estimation of log-linearized gravity equations must exclude observations of zero bilateral trade and therefore give rise to sample selection bias.

exporting country and on imports from all other countries based on tariffs at the 8- and 10-digit level of the Harmonized System, i.e. the most detailed level available.

Section 2 sketches the derivation of HMR's gravity equations and describes their and our estimation procedure. Section 3 presents our empirical specifications and data sources. Section 4 presents and discusses our results. Section 5 provides a summary.

2 The HMR gravity equations and their and our estimation procedures

The HMR gravity model is an extension of the gravity model by Anderson and van Wincoop (2003) and takes account of the empirical facts that firms in a typical industry are heterogeneous in terms of efficiency, that only a fraction of them export and that exporters tend to be more productive than non-exporters (see e.g. Eaton et al , 2004). Without control for heterogeneity, estimates of the effects of trade barriers on firm level exports will be confounded with their effects on the number of firms that export, and without control for zero bilateral trade flows, estimates will be affected by selection bias.

The details of the HMR model and its derivation can be found in Helpman et al (2008). For our purposes, it is sufficient to outline the basic steps and to replicate the estimating equations.

On the demand side, consumers maximize utility from consumption of a bundle of domestic and imported symmetric differentiated products. Utility maximization yields demand for each product as a function of its price relative to the index of all other product prices and of the country's income, assumed to be equal to its expenditure. The elasticity of substitution between products and the elasticity of demand for a given product are assumed to be identical across products and countries.

On the supply side, each firm transforms a bundle of inputs into units of a single output. Firms differ with respect to the efficiency of this transformation. The distribution of firms with respect to efficiency is identical across countries, but the cost of the input bundle per unit of output is specific to each country, reflecting differences in factor prices. The product market is characterized by monopolistic competition. Each firm sets a price equal to production cost plus a markup, which depends on the elasticity of demand. If a firm exports, it adds a margin that will at least cover the fixed and variable costs of exporting. The variable transport costs are of the melting iceberg specification. Fixed and variable trade costs are specific but not necessarily symmetric to each pair of trading countries. Whether or not it is profitable to export depends on the firm's efficiency, given prices and costs. An efficient firm will be able to set a competitive price in the export market and make a profit, except for the marginal firm, whereas an inefficient firm will be unable to cover its costs. All firms that can at least cover their costs will export. The model allows for zero unidirectional trade, which is important empirically.

The HMR model provides a mapping from exogenous income levels, exogenous numbers of domestic firms and exogenous costs, all specific to each country, an exogenous and identical distribution of firms with respect to efficiency across countries, exogenous and country-pair specific fixed and variable costs of trade, on to prices, the proportion of firms that export and the volume of unidirectional trade. The resulting gravity equation can be written in log-linear form (their equation (9) and notation) as

(1) $$m_{ij} = \beta_0 + \lambda_j + \chi_i - \gamma d_{ij} + \omega_{ij} + u_{ij}$$

where m_{ij} is exports from country *j* to country *i*, β_0 is a constant, λ_j is a fixed effect of the exporting country, χ_i is a fixed effect of the importing country, d_{ij} is the distance between *i* and *j*, ω_{ij} controls for the fraction of firms (possibly zero) that export from *j* to *i*, and u_{ij} is the error term, $u_{ij} \sim \mathrm{N}(0, \sigma_u^2)$.

The main difference between the HMR and the Anderson and van Wincoop gravity equations is the addition of the term ω_{ij} that controls for the fraction of firms that export from *j* to *i*. Its value is determined by the marginal profitability of exporting from *j* to *i*. Without this control, estimation of the standard gravity equation confounds the effects of trade barriers on the intensive and extensive margins at the firm level.

In addition, the gravity equation (1) allows for zero trade flows. It has been common to exclude observations of zero bilateral trade when estimating a log-linear version of the gravity equation. Country pairs with positive trade flows despite high observed trade barriers have low unobserved trade barriers (high u_{ij}), while country pairs with the same high observed trade barriers that do not trade, due to negative country pair specific shocks, have high unobserved trade barriers (low u_{ij}). This selection effect induces a positive correlation between the error terms and the independent variables and a downward bias in the trade barrier coefficient. Various alternatives of including zero trade flows, such as replacing zeros with unit values or using a Tobit estimator, will generally lead to inconsistent estimators (Silva and Tenreyro, 2007).

The HMR gravity equation also allows for unbalanced trade; trade can for example be positive in one direction and zero in the other. The ω_{ij} term controlling for firm heterogeneity need not be symmetric with respect to the direction of trade and the same country should normally have different importer and exporter fixed effects.

Consistent estimation of equation (1) requires controls for both the selection of firms into export markets, i.e. a consistent estimate of ω_{ij}, and the selection of country pairs into trading partners, i.e. a consistent estimate of u_{ij}. The selection of firms into export markets is a function of firm-level decisions about the profitability of exporting, which in turn is a function of firm efficiency, fixed and variable costs, trade barriers, demand and the elasticity of substitution between symmetric products. HMR derive a selection equation on the log-linear form (their equation (11) and notation)

(2) $z_{ij} = \gamma_0 + \xi_j + \zeta_i - \gamma d_{ij} - \kappa\phi_{ij} + \eta_{ij}$

where z_{ij}, the ratio of the export profits of the most efficient firm to the common fixed export cost for exporters from *j* to *i*, is a latent variable of which the selection of firms into export markets is a monotonic function (exports are zero when z_{ij} = 0), ξ_j is an exporter fixed effect, ζ_i is an importer fixed effect, ϕ_{ij} is a country-pair specific fixed trade cost and η_{ij} is an IID error term consisting of u_{ij} plus unmeasured fixed export costs. Since z_{ij} is unobserved but is observed positive when trade is positive, the following Probit equation (equation (12) in HMR) can be estimated

(3) $\rho_{ij} = \Phi(\gamma_0^* + \xi_{j_j}^* + \zeta_i^* - \gamma^* d_{ij} - \kappa^*\phi_{ij})$,

where ρ_{ij} is the probability of positive exports from *j* to *i*. Predicted ρ_{ij} can be used to obtain predicted values of the latent variable, and the predicted values can be used to obtain consistent estimates of ω_{ij} and u_{ij}.

HMR claim that a transformation of gravity equation (1) that will give consistent estimates is

(4) $$m_{ij} = \beta_0 + \lambda_j + \chi_i - \gamma d_{ij} + \hat{\bar{z}}^*_{ij} + \hat{\bar{z}}^{*2}_{ij} + \hat{\bar{z}}^{*3}_{ij} + \beta_{u\eta}\hat{\bar{\eta}}^*_{ij} + e_{ij},$$

where the polynomial in $\hat{\bar{z}}^*_{ij} \equiv \hat{z}^*_{ij} + \hat{\bar{\eta}}^*_{ij}$ ($\hat{z}^*_{ij} = \Phi^{-1}(\hat{\rho}_{ij})$) is an approximation of an arbitrary increasing function of the latent variable z_{ij}, which in turn controls for firm-level heterogeneity.[3] The inverse Mills ratio $\hat{\bar{\eta}}^*_{ij} = \phi(\hat{z}^*_{ij} / \Phi(\hat{z}^*_{ij})$ is the standard Heckman correction for sample selection and addresses the biases generated by the unobserved country-pair level shocks u_{ij} and η_{ij}. The error term, e_{ij}, is assumed distributed IID.

HMR use a two-stage procedure to obtain estimates of the effects of trade barriers. In the first stage, they estimate the Probit equation (3) to obtain the estimated probability of exporting and the effects of various trade barriers on the extensive margin of trade. In the second stage, they estimate equation (4) to obtain estimates of the effects of trade barriers on the intensive margin, using predicted probabilities from the first stage to control for firm heterogeneity and sample selection.

We use a different two-stage procedure. In the first stage, we obtain estimates for the extensive margin of trade by estimating equation (2), substituting the total number of bilaterally exported products for the latent variable z_{ij}. We are thereby making the assumption that each exported product is produced by a single firm in a single country. Hence, products that have the same classification in the Harmonized System but are produced in different countries are assumed to be symmetric differentiated products, which is in line with the model of monopolistic competition. In the second stage, we estimate equation (4) to obtain estimates for the intensive margin. We substitute the predicted number of exported products from the first stage for the term ω_{ij} in equation (1) that controls for the fraction of firms (possibly zero) that export from *j* to *i*. The term is non-linear, reflecting the fact that firm productivity is not uniformly distributed. Instead of a polynomial in ω_{ij} we use a polynomial in predicted n_{ij}.

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[3] Equation (4) is the same as equation (14) in HMR except for the polynomial in $\hat{\bar{z}}^*_{ij}$. HMR make a particular assumption regarding the distribution of firm heterogeneity that gives a non-linear term controlling for firm heterogeneity in (4), which makes it necessary to estimate (4) by NLS. Later, they drop the particular distribution assumption and find that a polynomial that approximates any monotonic increasing function of z_{ij} yields very similar estimates. We use the latter specification for simplicity.

We need a valid and relevant instrumental variable in the first stage in order not to let the identification of the extensive margin estimates depend solely on the normality assumption for unobserved trade costs. The variable we use is the time typically spent to take care of regulations and procedures for the exporter and the importer of a standard container of goods (as estimated by the World Bank, 2007). We argue that it takes considerable more time for first time exporters and importers than experienced exporters and importers. Note that this variable is specific to each country pair.

In order to control for both sample selection and heteroscedasticity, we employ a Poisson Pseudo Maximum Likelihood (PPML) estimator in the first and second stage, as suggested by Silva and Tenreyro (2007). The PPML estimator allows for the inclusion of observations of zero trade (the dependent variable is not transformed to log form). Thus, the Heckman correction for sample selection in the second stage is not needed.

3 Empirical specification and data

3.1 Specification

In the first step, we estimate equation (2), where the dependent variable z_{ij} has a value of zero when bilateral trade is zero and is an increasing monotone function of the selection of firms into export markets. We use the total number of bilaterally exported products as a proxy for z_{ij}.

Equation (2) contains exporter and importer fixed effects. However, inclusion of such effects gives rise to considerable colinearity. Instead, we include the GDP of the exporter and importer respectively. This should capture a large part of the exporter and importer fixed effects and provides a basis for comparison with estimates of GDP effects in other studies.

In addition, we need to control for the potential number of products in each country's exports, since small and less developed countries can be expected to have a smaller capacity to produce a large number of different products than large and developed countries. We therefore include each country's total number of exported products in aggregate exports, which is an exporter fixed effect. (GDP is not a good proxy for export variety; the correlation between the exporter's GDP and the number of products in aggregate exports is only 0.35.)

As for trade frictions, we add several variables to geographic distance: common land border, common language, common colonial history, whether the two countries were part of the same country in 1945, the importer's tariffs against the exporter, and the importer's tariffs against the exporter's competitors (all other exporters). The calculation of tariffs on the extensive margin poses a challenge, since we are faced with the question of tariffs on the exporter's and its competitors' *potential* exports. Appendix A describes the construction of the various average tariff rates in detail.

In the second stage, we estimate equation (4). For the same reasons as in the first stage, we proxy the exporter and importer fixed effects by the exporter's and importer's GDPs. We use the same pair-specific trade frictions as in the first step. As already explained, firm heteroscedasticity is controlled for by a polynomial in predicted z_{ij} and there is no need to control for sample selection since observations of zero trade are included by virtue of the PPML estimator.

3.2 Data

The number of bilaterally traded products is extracted from the United Nations Commodity Trade Statistics Database (COMTRADE), accessed through WITS.[4] The number of bilaterally traded products is measured from the import side. The exported number of products from China to the US is thus measured as the imported number reported by the US rather than the exported number reported by China. We prefer import statistics since governments have tax revenue incentives to record imports more accurately than exports. The number of traded products is derived from the import matrix at the 6-digit level of the Harmonized Commodity Description and Coding System. We use cross-section data on the aggregate value and on the number of products in unidirectional bilateral trade from the UN Comtrade database in 2005 for 90 countries with 137 of their trade partners. The 90 countries are those that report tariffs and their 137 trading partners are those that report the time required for administrative procedures

[4] WITS is a software developed by the World Bank in collaboration with the United Nations Conference on Trade and Development (UNCTAD). WITS provides access to the (i) the COMTRADE database maintained by UNSD; (ii) the TRAINS database maintained by UNCTAD and (iii) the IDB and CTS databases maintained by WTO.

to export and import a container of goods.[5] The potential number of unidirectional trade flows at the country level is 90 x 137 = 12 330. Of these, 1 768 or 14 per cent are zero.[6]

Data on distance, border contiguity, common language and colonial history, and whether the countries were part of the same country in 1945 are extracted from Centre d`Etudes Prospectives et d'Informations Internationales (CEPII) database.[7] The distance between two countries is measured as the distance in kilometers (in logs) between the economic centers of the trade partners, typically the capitals. For some countries the economic center may be another major city, such as Frankfurt in the case of Germany and São Paolo in the case of Brazil. Data on the required time needed for administrative procedures when exporting and importing are extracted from the World Bank publication *Doing Business*.

The GDP data are extracted from UNSTAT´s National Accounts Main Aggregates Database, complemented with national sources for countries that are not included in the database (e.g. Taiwan).

We have constructed tariff data at the country level from data on effective tariffs reported at the 8- or 10-digit level in the Harmonized System. Two different tariffs are constructed: the average, country level tariff applied by the importer against the exporter taking all tariff preferences into account, and the average, country-level tariff applied by the importer against the exporters´ competitors for the same bundle of goods and taking all tariff preferences into account. The construction of the country level tariffs involves taking account of more than 600 tariff schedules for the 90 reporting countries, i.e. an average of seven preferential agreements per country. (The European Union alone has 37 tariff schedules, including MFN duties, rates for EEA countries that are not members of the Union, and schedules for a large number of bilateral and regional trade agreements.) A detailed description of the construction of the country level tariffs can be found in Appendix A.

[5] Countries are listed in Appendix B, including which countries report tariffs.
[6] The potential number of traded products at the 6-digit level of the Harmonized System is 12,330 x 5,015 ≈ 62 million. However, it is difficult if not impossible to handle this number of observations.
[7] http://www.cepii.fr/anglaisgraph/bdd/distances.htm

4 Results

Table 1 shows the basic results. Estimates for the extensive and intensive margins are shown in columns (1) and (2) respectively. All estimates have expected signs and most are highly significant. Estimates for the extensive margin are uniformly smaller in value than estimates for the intensive margin. Geographical distance is a barrier to trade on both margins, but a common land border promotes trade only on the intensive margin. Cultural and historical links stimulate trade on both margins. Tariffs are estimated to have strong effects on both margins. Note the strong positive effect on exports of tariffs levied on the exporter's competitors. Both the exporter's and importers' GDP have positive effects on both margins. The exporter's GDP is a fixed effect and a proxy for supply capacity on both margins, and the importers' GDP is a fixed effect and a measure of demand. The total number of different products in aggregate exports on the extensive margins, which controls for capacity to supply different products, is estimated to be quite important.

Our instrumental variable for the number of bilaterally exported products is the time it typically takes to take care of official regulations and procedures when exporting and importing a container of goods. The variable has a significant negative effect on the extensive margin, see column [1], but not on the intensive margin (not shown), and the F-test of its explanatory power has a value of 202, all of which indicates that it is a valid and exogenous instrument.

Firm heterogeneity is controlled for in the second stage estimation – for the intensive margin – by a polynomial based on the predicted number of exported products in the first stage estimation. The estimated signs on the polynomial are consistent with the assumed Pareto distribution of firm productivity, namely that it is decreasing at a decreasing rate, starting with the most productive firm. This is confirmed by the nonlinearity in the data plotted in Figure 1, panel b), showing the relation between the number of (log) exported products, $Ln(N_{ij})$, and the force of gravity, $Ln(GDP_i \times GDP_j / D_{ij})$. The concave relation corresponds to the probability density function of the distribution function. Many firms start to export at the lowest level of gravity, few firms start at the highest level, and the rate of increase in the number of exporters is decreasing with gravity.

Columns [3] and [4] are included for comparison. They show estimates for aggregate bilateral exports, i.e. for the extensive and intensive margins combined. Note that the PPML estimates for aggregate exports in column [3] are identical in sign and similar in size to the estimates for the intensive margin. The OLS estimates for aggregate exports in column [4] suffer from several biases (more on this below). They have the same signs as the PPML estimates but are uniformly larger in size (mainly due to selection bias; observations of zero trade are excluded).

Table 2 shows effects of different kinds of bias. Columns [1] and [2] replicate the basic estimates for the extensive and intensive margin from Table 1. Columns [3] and [4] show the effect of selection bias due to exclusion of all observations of zero bilateral exports. The estimates are nevertheless quite similar to the corresponding unbiased estimates in columns [1] and [2]. In fact, we cannot reject the hypothesis that about half of the estimates for the extensive margin with and without observations of zero trade are the same (at the 5 per cent level). Our finding of a small selection bias echoes those of both HMR and Silva and Tenreyro (2009), but it should be pointed out that the share of zero trade observations is much smaller in our data than in those of HMR.

Columns [5] and [6] show effects of not controlling for firm heterogeneity in estimating the intensive margin. The extensive margin estimates in column [5] are identical to those in column [1]. The non-linear terms in the polynomial controlling for firm heterogeneity have been dropped in column [6] (but not the predicted number of exported products). A comparison of the estimates in column [2] and [6] reveals that they have the same signs and significance and that they are quite similar in magnitude.

The estimates in column [7] and [8] are affected by both sample selection and heterogeneity bias. They are nevertheless very similar to the estimates in column [5] and [6] – which are affected by heterogeneity bias – and quite similar to the estimates in columns [3] and [4] – which are affected by selection bias – and also to the unbiased estimates in column [1] and [2].

Finally, columns [9] and [10] contain OLS estimates that are affected by heteroscedasticy as well as sample selection and heterogeneity bias. All estimates have the expected sign and are highly significant, but their overall magnitudes differ substantially from those in columns [7] and [8] without heteroscedasticity bias.

In summary, we find that the biases caused by sample selection and firm level heterogeneity are small and economically unimportant, but that the bias caused by heteroscedasticity in trade data is large and economically important. The same conclusions regarding sample selection and heteroscedasticity bias were reached by Silva and Tenreyro (2007, 2009).

Inspection of data plots can explain our findings. Figure 1 shows the relation between basic gravity – caused by economic mass and geographical distance – on one hand and exports in the aggregate and on the extensive and intensive margins on the other. The plots in panel a) for aggregate exports and panel c) for the intensive margin are very similar. It is therefore not surprising that estimates for aggregate exports and the intensive margin exports also are very similar in magnitude. Figure 1 also makes clear that heteroscedasticity is pervasive in the data and consequently that standard estimation of log-linearized gravity equations can be expected to yield severely biased estimates

The heteroscedasticity for the extensive margin shown in panel (b) is especially striking. The number of exported products defined at the HS 6-digit level varies from one to more than 4 000 (of a maximum of about 5 000) for a given value of gravity and over a wide range, but is relatively small at low and very high levels of gravity. .

Based on these findings, one may ask whether the standard practice of estimating gravity equations on aggregate trade really yields grossly misleading estimates. Table 1 suggests that this is not the case: the estimates for aggregate trade in column [3] and those for the intensive margin in column [2] have the same signs and are very similar in magnitude. This suggests that the intensive margin is much more important quantitatively than the extensive margin. Figure 2 supports such a conclusion. It shows that the share in total exports of the largest export product as defined at the HS 6-digit level is almost 50 per cent on average, of the ten largest 80 per cent, and of the largest 100 products 95 per cent on average. An additional product adds less and less to total trade. When the number of products has reached 1 000, an additional product adds almost nothing to aggregate bilateral trade. This explains why the extensive margin is relatively unimportant on average.

Our results that changes on the intensive margin are much more important with respect to trade barriers are confirmed by Santos and Tenreyro (2009) and by Berman et al (2009) on French micro data. Bernard, Redding and Schott (2010), reach a different conclusion, however. They use U.S. micro data and define the average volume of exports per firm-product as the intensive margin, and the number of firm-product observations as the extensive margin. They find that the average volume does not decline with distance, whereas the number of firm-products does (their Table 2), and therefore draw the conclusion that the observed decline in aggregate exports with distance is due to the extensive and not the intensive margin. This apparently contradicts our results. However, it seems that the fact that the number of exporters declines with distance and that the attrition primarily hits small exporters has not been controlled for. A different definition of the intensive margin that takes account of the size distribution of firms with respect to distance would presumably result in a different result, namely that the volume per product and firm does decrease with distance, and that the effects on the intensive margin dominate the effects on the extensive margin.

5 Summary

Helpman, Melitz and Rubinstein (2008) have derived gravity equations that control for firm heterogeneity and sample selection and are able to estimate effects of trade barriers on both the intensive and extensive margins of trade. Confounding effects on the two margins at the firm level and not controlling for sample selection will cause biased estimates. They exploit the presence and frequency of zero trade flows to estimate the probability of starting to trade with respect to various trade barriers. These estimates are interpreted as effects on the extensive margin of trade. The estimated probabilities are then used to construct controls for firm heterogeneity and selection bias and to estimate effects on the intensive margin of trade.

We exploit the gravity equations derived by HMR plus data on the total number of bilaterally traded products as defined by at the 6-digit level of the Harmonized System. This allows us to use a different estimation procedure to control for sample selection and heterogeneity bias. HMR did not control for heteroscedasticity in the data. We show that heteroscedasticity is pervasive in trade data, and control for the heteroscedasticity data by using Poisson Pseudo Maximum Likelihood estimation as suggested by Silva and Tenreyro (2007).

One additional advantage of our procedure is that effects on the extensive margin can be identified not only by the step from zero to positive bilateral trade but by changes in the number of traded products at all levels of trade. Another advantage is that this allows estimation of both margins even when all trade flows are positive.

We find that all estimates for the extensive and intensive margin of trade have the expected sign, that most are highly significant, and that the biases caused by excluding observations of zero trade and firm heterogeneity are rather small and economically unimportant. In contrast, not controlling for heteroscedasticity causes substantial bias. We also find that the extensive margin is relatively unimportant in quantitative terms. Estimation of a gravity equation that explains the sum of the extensive and intensive margins produces estimates that are quite similar to those for the intensive margin.

Tariffs are usually absent in gravity equations because of the difficulty of collecting and aggregating data. We have constructed average tariffs faced by the exporter as well as tariffs faced by the exporter's competitors in the importing country. The tariff data were aggregated from the 8- and 10-digit level of the Harmonized System and include preferential treatment. Our estimates indicate that existing tariffs constitute significant and important barriers to trade.

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Appendix A

The tariff data are extracted from UNCTAD´s database TRAINS, accessed through WITS. The WITS software allows extraction of import-weighted tariff rates at the aggregate level of trade, accounting for any preferential rates that may be granted by the importer to the exporter. However, in cases where there is no trade in the base year, WITS reports missing values for the average tariff rate. This is a problem since we need data also on the tariff rate facing non-exporting countries on their marginal exportables. Since we do not know the identities of these products, we assume that the potential export basket to a potential trade partner mirrors the existing composition of total exports.

We also need data on the tariff rate facing competing suppliers (which enters the price index in the denominator in the gravity equation). Since about 50 percent of world trade is within free trade areas and preferential trade agreements, tariffs on the same products may differ quite substantially depending on the supplying country. This is particularly true for food, textiles, apparel and other sensitive commodities where the standard MFN rate applied between members of the WTO may exceed 10 percent, thereby giving free trade partners a significant advantage. We calculate the competitors' tariff rate by aggregating tariff data at the 6-digit HS-level over the bundle of goods exported by country *j* to country *i*, using the export weights of *j* to *i*. If *j* does not export anything to *i*, we use as a substitute the export weights of *j* to the world market.

For the purpose of these calculations, we have downloaded some 600 tariff schedules from TRAINS and match tariffs with import data at the 6-digit product level. We assume that countries make use of the most favorable tariff rates available to them. For trade partners that have a Preferential Trade Agreement (PTA), duties are exempted on most products. For example, no duties are collected between the members of the European Union. However, for other PTA:s, including NAFTA, some exemptions may apply on "sensitive" products. (The WTO rules on PTAs only require that "substantially all the trade" is covered, where the unofficial threshold is 90 percent). The most common exemption is food and textiles. For example, agricultural and fish is only partially covered in the trade agreement between Norway and the EU. Exports from developing to developed countries are granted preferential rates under the Generalized System of Preferences (GSP). The GSP includes particularly favorable rates – mostly zero – for the least developed countries. However, the preferential rates are not always available in reality since donors apply strict rules of origin in order to prevent "trade deflection" (transshipment by countries that are not eligible for preferences). Lacking data on what tariff rates are actually paid, we assume that the best available statutory rates are used by the eligible countries.

Appendix B

List of countries

Albania (R)	Georgia	New Zealand (R)
Angola	Germany (R)	Niger (R)
Argentina (R)	Ghana	Nigeria
Armenia (R)	Greece (R)	Norway (R)
Australia (R)	Guinea	Oman (R)
Austria (R)	Guinea-Bissau	Pakistan (R)
Azerbaijan	Hong Kong (R)	Paraguay (R)
Bangladesh	Hungary (R)	Peru (R)
Belarus	Iceland (R)	Philippines (R)
Belgium (R)	India (R)	Poland (R)
Benin (R)	Indonesia (R)	Portugal (R)
Bhutan	Iran	Romania (R)
Bolivia (R)	Iraq	Russian Federation (R)
Bosnia and Herzegovina (R)	Ireland (R)	Rwanda
Botswana	Israel (R)	Sao Tome and Principe
Brazil (R)	Italy (R)	Saudi Arabia (R)
Brunei Darussalam	Japan (R)	Senegal (R)
Bulgaria (R)	Jordan (R)	Serbia and Montenegro
Burkina Faso	Kazahkstan	Sierra Leone
Cambodia	Kenya	Singapore (R)
Cameroon (R)	Korea, South (R)	Slovakia (R)
Canada (R)	Kuwait	Slovenia (R)
Cape Verde	Kyrgyzstan	South Africa (R)
Central African Republic (R)	Laos	Spain (R)
Chad	Latvia (R)	Sri Lanka (R)
Chile (R)	Lebanon	Sudan
China (R)	Lesotho	Swaziland
Colombia (R)	Liberia	Sweden (R)
Comoros	Lithuania (R)	Switzerland (R)
Congo, Dem. Rep.	Luxembourg (R)	Syria
Congo, Rep.	Macedonia (R)	Taiwan (R)
Côte d'Ivoire (R)	Madagascar (R)	Tajikistan
Croatia (R)	Malawi	Tanzania (R)
Czech Republic (R)	Malaysia (R)	Thailand (R)
Denmark (R)	Maldives (R)	Togo (R)
Djibouti	Mali	Tunisia (R)
Ecuador (R)	Mauritania	Turkey (R)
Egypt	Mauritius (R)	Uganda (R)
Equatorial Guinea	Mexico (R)	Ukraine (R)
Estonia (R)	Moldova (R)	United Kingdom (R)
Ethiopia	Mongolia (R)	United States of America (R)
Fiji	Morocco (R)	Uruguay (R)
Finland (R)	Mozambique (R)	Venezuela (R)
France (R)	Namibia (R)	Viet Nam (R)

Gabon (R)	Nepal	Yemen
Gambia	Netherlands (R)	Zambia (R)

(R) = Reporting tariffs and trade in 2005.

Table 1 Basic results

	[1]	[2]	[3]	[4]
Estimation procedure	PPML	PPML	PPML	OLS
Variables	Extensive margin	Intensive margin	Total trade (ext.+int.)	Total trade (ext.+int.)
Distance	-0.34***	-0.52***	-0.48***	-0.90***
	(0.01)	(0.09)	(0.05)	(0.03)
Common land border	0.04	0.39***	0.30**	1.08***
	(0.05)	(0.12)	(0.13)	(0.13)
Common language	0.29***	0.48***	0.44***	0.84***
	(0.03)	(0.11)	(0.10)	(0.07)
Common colonizer	0.38***	0.87***	0.92***	1.30***
	(0.07)	(0.27)	(0.26)	(0.11)
Same country in 1945	0.91***	1.72***	1.78***	1.71***
	(0.11)	(0.48)	(0.49)	(0.15)
Importer tariff against exporter	-3.31***	-6.08***	-6.12***	-7.72***
	(0.45)	(1.46)	(1.45)	(0.75)
Importer tariff against other countries	3.48***	4.29***	4.27***	4.92***
	(0.45)	(1.44)	(1.32)	(0.79)
Exporter GDP	0.32***	0.78***	0.73***	1.01***
	(0.01)	(0.08)	(0.03)	(0.02)
Importer GDP	0.22***	0.80***	0.79***	1.07***
	(0.00)	(0.05)	(0.03)	(0.01)
Time cost of exporting plus importing	-0.12***			
	(0.02)			
Total number of exported products	1.77***		0.45***	0.95***
	(0.05)		(0.14)	(0.06)
Predicted number of exported products		-0.56***		
		(0.08)		
Square of predicted number		0.17***		
		(0.03)		
Cube of predicted number		-0.01***		
		(0.00)		
Observations	12,330	12,330	12,330	10,562
(Pseudo) R-square	0.85	0.87	0.87	0.72

Notes: PPML = Poisson Pseudo Maximum Likelihood estimator in columns [1], [2] and [3], OLS in column [4]. Column [3] shows estimates for aggregate bilateral trade (both margins combined). Column [4] shows OLS estimates for aggregate trade for comparison with the PPML estimates for aggregate trade in column [3]. Robust standard errors in parentheses,
*** p<0.01, ** p<0.05, * p<0.1.

Table 2 Bias decomposition

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Estimation procedure	PPML	PPML	PPML	PPML	PPML	PPML	PPML	PPML	OLS	OLS
Bias	No bias	No bias	Sample selection		Heterogeneity		Sample selection & heterogeneity		All three biases	
Variables	Extensive	Intensive	Extensive	Intensive	Extensive	Intensive	Extensive	Intensive	Extensive	Intensive
Distance	-0.34***	-0.52***	-0.34***	-0.53***	-0.34***	-0.39***	-0.34***	-0.40***	-0.52***	-0.84***
	(0.01)	(0.09)	(0.01)	(0.09)	(0.01)	(0.06)	(0.01)	(0.06)	(0.01)	(0.03)
Common land border	0.04	0.39***	0.04	0.40***	0.04	0.29**	0.04	0.28**	0.76***	0.90***
	(0.05)	(0.12)	(0.05)	(0.12)	(0.05)	(0.13)	(0.05)	(0.13)	(0.08)	(0.13)
Common language	0.29***	0.48***	0.29***	0.50***	0.29***	0.36***	0.29***	0.37***	0.52***	0.68***
	(0.03)	(0.11)	(0.03)	(0.10)	(0.03)	(0.10)	(0.03)	(0.10)	(0.04)	(0.07)
Common colonizer	0.38***	0.87***	0.37***	0.86***	0.38***	0.83***	0.37***	0.83***	0.33***	1.19***
	(0.07)	(0.27)	(0.07)	(0.27)	(0.07)	(0.26)	(0.07)	(0.26)	(0.06)	(0.12)
Same country in 1945	0.91***	1.72***	0.90***	1.81***	0.91***	1.57***	0.90***	1.63***	0.99***	1.68***
	(0.11)	(0.48)	(0.11)	(0.47)	(0.11)	(0.48)	(0.11)	(0.47)	(0.11)	(0.16)
Importer tariff against exporter	-3.31***	-6.08***	-3.07***	-6.36***	-3.31***	-5.30***	-3.07***	-5.49***	-1.83***	-6.39***
	(0.45)	(1.46)	(0.44)	(1.37)	(0.45)	(1.44)	(0.44)	(1.40)	(0.35)	(0.77)
Importer tariff against other countries	3.48***	4.29***	3.29***	4.63***	3.48***	3.50***	3.29***	3.71***	1.97***	3.86***
	(0.45)	(1.44)	(0.45)	(1.30)	(0.45)	(1.33)	(0.45)	(1.25)	(0.38)	(0.80)
Exporter GDP	0.32***	0.78***	0.32***	0.79***	0.32***	0.66***	0.32***	0.66***	0.53***	1.15***
	(0.01)	(0.08)	(0.01)	(0.08)	(0.01)	(0.05)	(0.01)	(0.05)	(0.01)	(0.02)
Importer GDP	0.22***	0.80***	0.21***	0.81***	0.22***	0.74***	0.21***	0.74***	0.38***	0.97***
	(0.00)	(0.05)	(0.00)	(0.05)	(0.00)	(0.04)	(0.00)	(0.04)	(0.01)	(0.01)
Time cost of exporting plus importing	-0.12***		-0.12***		-0.12***		-0.12***		-0.69***	
	(0.02)		(0.02)		(0.02)		(0.02)		(0.03)	
Total number of exported products	1.77***		1.70***		1.77***		1.70***		0.70***	
	(0.05)		(0.05)		(0.05)		(0.05)		(0.03)	
Predicted number of exported products		-0.56***		-0.74***		0.24***		0.23***		0.90***
		(0.08)		(0.10)		(0.07)		(0.08)		(0.10)
Square of predicted number		0.17***		0.20***						
		(0.03)		(0.03)						
Cube of predicted number		-0.01***		-0.01***						

Observations	12330	12330	12,330	12,330	10,562	10,562	10,432	10,432	10,562	10,562
(Pseudo) R-squared	0.85	0.87	0.83	0.86	0.85	0.87	0,83	0,86	0.76	0.70

Notes: PPML = Poisson Pseudo Maximum Likelihood estimator in columns [1- [8], OLS in column [9] and [10]. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Columns [1] and [2] show unbiased estimates for the extensive and intensive margin respectively. Columns [3] and [4] show estimates affected by selection bias, i.e. all zero observations of the dependent variable are omitted. Columns [5] and [6] show estimates affected by heterogeneity bias, i.e. heterogeneity across firms with respect to productivity is not controlled for. Columns [7] and [8] show estimates affected by both selection and heterogeneity bias. Columns [9] and [10] show OLS estimates affected by selection, heterogeneity and heteroscedasticity bias, i.e. OLS does not control for heteroscedasticity in the data.

Figure 1

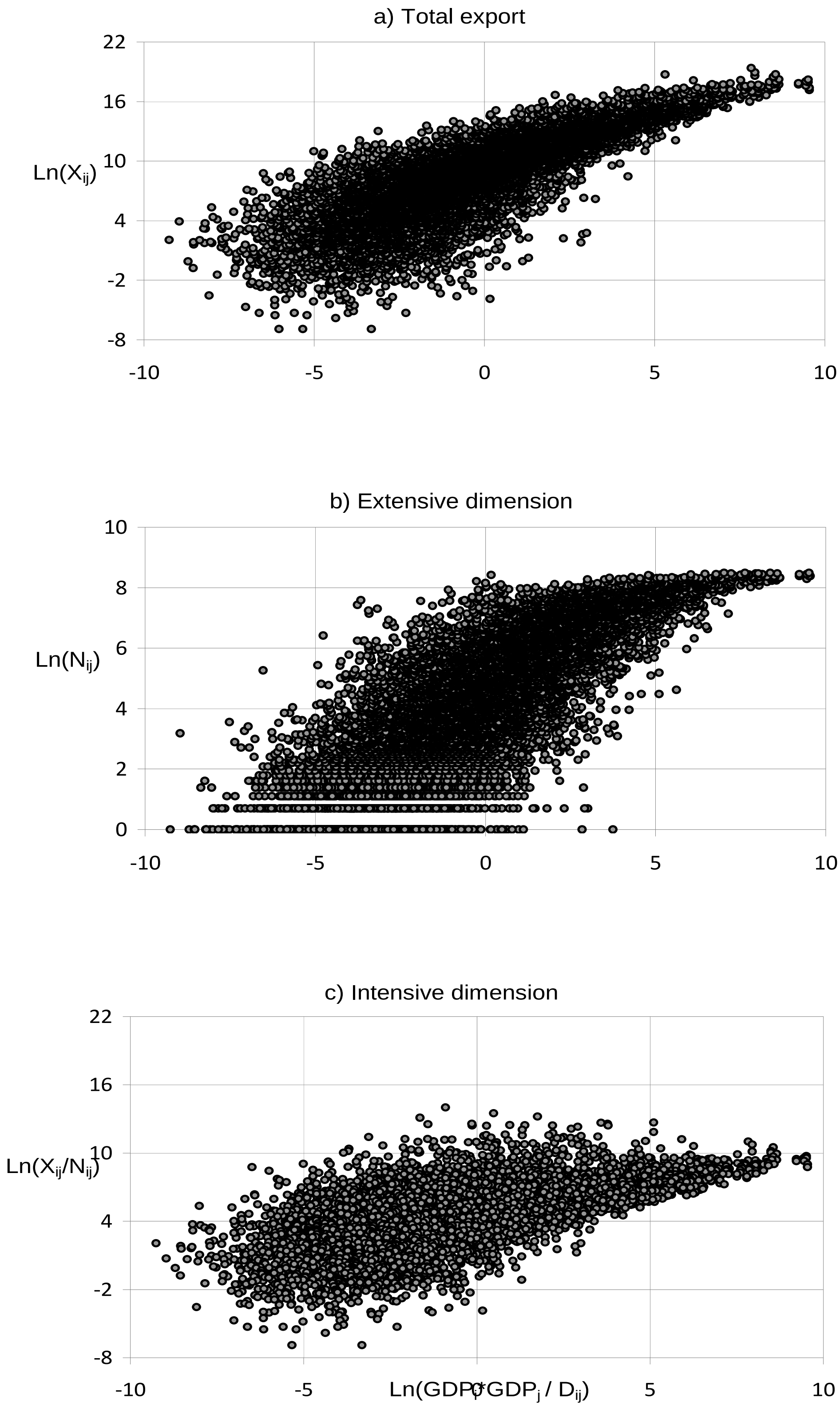
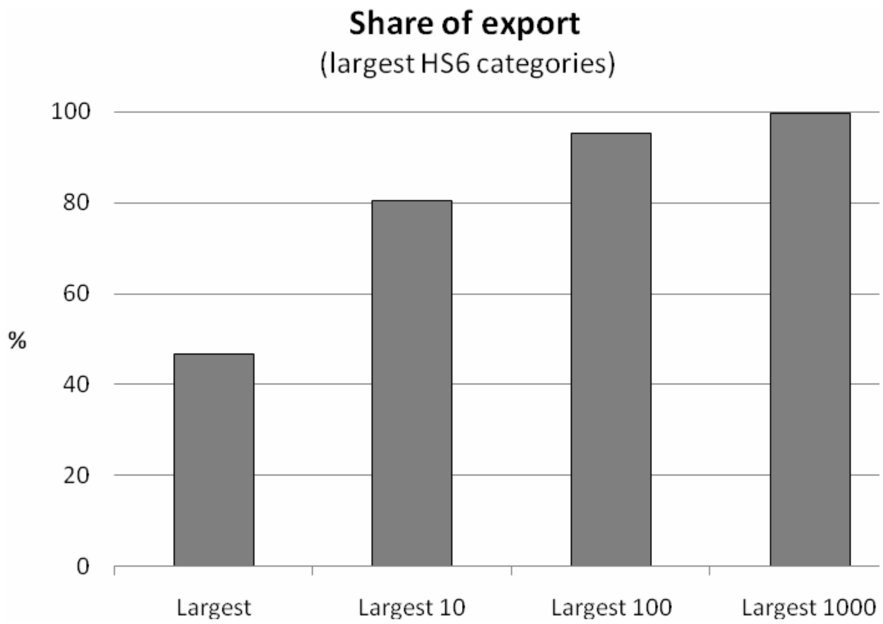

a) Total export
Ln(X_ij)
22
16
10
4
-2
-8
-10
-5
0
5
10
b) Extensive dimension
Ln(N_ij)
10
8
6
4
2
0
-10
-5
0
5
10
c) Intensive dimension
Ln(X_ij/N_ij)
22
16
10
4
-2
-8
-10
-5
0
5
10
Ln(GDP_i*GDP_j / D_ij)

Figure 2


Share of export
(largest HS6 categories)
100
80
60
40
20
0
%
Largest
Largest 10
Largest 100
Largest 1000