Trade costs in bilateral trade flows:
Heterogeneity and zeroes in structural gravity models

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Abstract

This paper contributes to the explanation of international trade flows with structural gravity models taking heterogeneity and excess zeroes into account. We introduce a more general hypothesis on the structure of trade costs in Helpman et al. (2008) theoretical model that is capable of explaining over-dispersion in trade data. Zero inflated negative binomial models are considered to analyze the impact of trade costs, measured in terms of geographical distance and contiguity effects. An analysis related to a sample of 37 countries trade flows, with heterogeneous effects across sectors and trade integrated areas, such as APEC and EU, is presented. The size of exporting and destination economies, cultural and institutional factors are considered as influencing both the extensive and the intensive margin of trade.

Keywords: zero-inflated negative binomial estimator, heterogeneous firms, multilateral resistance

JEL classification: F12, F14, F15.

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1. Introduction

A large empirical literature using firm and plant-level data has documented the presence of firm's heterogeneity in productivity and fixed costs, implying productivity thresholds for firms to be capable to export[1]. An important corollary is that trade is determined along an extensive (number of firms) as well as an intensive (average exports per firm) margin. The extensive margin exists because less-productive firms that cannot cover their fixed costs will not export at all. Traditional theory generating gravity models (e.g. Anderson and van Wincoop, 2003) assume homogeneous firms and love for variety in consumption to ensure that all goods are traded everywhere, therefore they do not show any extensive margin and all changes occur along the intensive margin. To rationalize zeroes in trade flows, fixed costs of export and productivity heterogeneity are to be assumed as in Helpman et al. (2008) and Baldwin and Harrigan (2011). The selection mechanism due to productivity differences across firms determines which firms export in a country, how much goods are supplied by each exporter in foreign markets and therefore the amount of each country's aggregate exports.

This paper contributes to the explanation of international trade flows with structural gravity models taking heterogeneity and excess zeroes into account. We show how a gravity relationship with over-dispersion in trade flows arises from an extended version of Helpman et al. (2008) structural trade model in which unobserved heterogeneity in trade costs is explicitly modeled. This extension dictates a negative binomial rather than a Poisson estimator and zero-inflated models. Our estimation approach builds on Santos Silva and Tenreyro (2006) and Burger et al. (2009).

The paper is organized as follows. In section 2 a generalized version of Helpman et al. (2008) model with over-dispersion in trade costs is proposed and the corresponding econometric specification with excess zeroes and over-dispersion is presented in section 3. Sections 4 and 5 report evidence on a sample of 37 countries from NBER-UN database (Feenstra et al., 2005) and

[1] See Greenaway and Kneller (2007) for a recent survey of the micro econometric evidence.

section 6 concludes with some final comments.

2. Theory

A gravity equation can be derived from models with firms' heterogeneity. For the purpose of our paper, we report the model developed by Helpman et al. (2008) that considers the self-selection process of firms on the basis of their productivity levels, and the influence that they have on international trade flows. This model is also capable to account for the probability that two countries may trade or not. This model therefore includes all possible combinations: i) zero values of the bilateral flows between country *j* and country *i*; ii) positive flows in one direction (e.g. from *j* to *i*) and no flows in the other one (e.g. from *i* to *j*); iii) positive flows in both directions.

The authors consider a number of countries *J*, indexed by $j = 1, 2, ..., J$, and an indeterminate group of final goods, whose markets operate in a monopolistic competition framework. Each country includes N_j firms, each of which produces a single differentiated good. It follows that there are $N = \sum_{j=1}^{J} N_j$ products worldwide.

Any country *j* 's firm produces output at a cost $c_j a$, where a measures the amount of input required for the production of a unit of output, and c_j is the unit cost of inputs. The cost c_j varies across countries, reflecting international differences in production costs, and a across firms, thereby reflecting differences in productivity levels among firms even within the same country. The cumulative distribution of these levels of efficiency is represented by the function $G(a)$, identical in all countries, in which the two extremes are defined as $a_H > a_L > 0$.

The selling price of good *l* from country *j* is given by the cost of production multiplied by the mark-up, $1/q$:

$$p_j(l) = \frac{c_j a}{q} \quad [1]$$

International trade implies that a firm located in country j sells its product in country i and incurs a fixed cost of access, $c_j f_{ij}$, and a transport cost equal to τ_{ij}. For the latter cost, the "melting iceberg" specification is assumed, that is τ_{ij} units of a product have to be shipped from country j to i for one unit to arrive. We assume that $f_{jj} = 0$ for every j and $f_{ij} > 0$ for $i \neq j$, and $\tau_{jj} = 1$ for every j and $\tau_{ij} > 1$ for $i \neq j$. Note that the fixed cost coefficients f_{ij} and the transport cost coefficients τ_{ij} depend on the identity of the importing and exporting countries, but not on the identity of the exporting producer. In particular, they do not depend on the producer's productivity level.

The selling price of good l from country j to country i is therefore equal to

[2] $$\breve{p}_j(l) = \tau_{ij} \frac{c_j a}{q}$$

Using [2] we can define the quantity demanded by country i with the following equation:

[3] $$x_i(l) = \frac{\breve{p}_j(l)^{1-\varepsilon} Y_i}{P_i^{1-\varepsilon}}$$

where Y_i identifies country i's income, and P_i its price index.

Using [2] and [3] we can determine the profit arising from j 's sales to i:

[4] $$\pi_{ij}(a) = (1-q)\left(\tau_{ij} \frac{c_j a}{q P_i}\right)^{1-\varepsilon} Y_i - c_i f_{ij}$$

The level of efficiency, $1/a_{ij}$, is derived from the zero profit condition and indicates the threshold above which a firm can achieve positive profits and then it is profitable to sell its product to foreign consumers:

[5] $$(1-q)\left(\tau_{ij} \frac{c_j a}{q P_i}\right)^{1-\varepsilon} Y_i = c_i f_{ij}$$

The zero profit condition [5] shows that only the fraction $G(a_{ij})$ of the N_j firms of country j export to country i. We now proceed to the determination of bilateral flows.

Given the price function [2] and the demand function [3], we can derive the value of imports of country i from country j:

[6] $$M_{ij} = \left(\frac{c_j \tau_{ij}}{q P_i}\right)^{1-\varepsilon} Y_i N_j V_{ij}$$

where

[7] $$V_{ij} = \begin{cases} \int_{a_L}^{a_{ij}} a^{1-\varepsilon} dG(a) & if\ a_{ij} \geq a_L \\ 0 & otherwise \end{cases}$$

As in Helpman et al. (2008) we assume that firm productivity $1/a$ is Pareto distributed, truncated to the support $[a_L, a_H]$. In this case we have

[8] $$G(a) = \frac{a^k - a_L^k}{a_H^k - a_L^k},\ k > (\varepsilon - 1).$$

Then expression [7] becomes

[9] $$V_{ij} = \frac{k a_L^{k-\varepsilon+1}}{(k-\varepsilon+1)(a_H^k - a_L^k)} W_{ij}$$

where W_{ij} represents the firms' export share from country j to country i and is defined as follows:

[10] $$W_{ij} = max\left\{\left(\frac{a_{ij}}{a_L}\right)^{k-\varepsilon+1} - 1, 0\right\}$$

In this way, Helpman et al. (2008) obtain a gravity model, that includes the process of firm selection through the value of V_{ij}, to study the influence of costs and productivity levels on trade flows. The selection process of companies in foreign markets, represented by the variable W_{ij}, is then determined by the value of the "cutoff" a_{ij}, obtained from the zero profit condition in equation [5]. The trade equation can be written as

[11] $$M_{ij} = AA_iA_j\tau_{ij}^{1-\varepsilon} max\left\{\left[\frac{a_{ij}}{a_L}\right]^{k-\varepsilon+1} - 1, 0\right\}$$

Information on a_{ij} and a_L is typically not available. To overcome this problem, Helpman et al. (2008) define a latent variable Z_{ij}, which represents the value of the more productive firm's profit (with productivity $1/a_L$) compared to the fixed cost of exporting from *j* to *i*:

[12] $$Z_{ij} = \frac{(1-q)\left(\frac{qP_i}{c_j\tau_{ij}}\right)^{1-\varepsilon} Y_i a_L^{1-\varepsilon}}{c_i f_{ij}}$$

Trade flows are positive when $Z_{ij} > 1$. In this case, given equations [5] and [8], W_{ij} is a monotone function of Z_{ij}:

[13] $$W_{ij} = Z_{ij}^{(k-\varepsilon+1)/(\varepsilon-1)} - 1$$

By assuming i.i.d normal distributed errors on the random components of the model and by defining

T_{ij} = 1 if country *j* exports to *i* (and T_{ij} = 0 otherwise) they obtain the probability to have export flows from j to i as a probit model and they estimate the trade equation for the positive observations of M_{ij}, by using a procedure to account for the sample-selection issue. We instead propose to assume a more general form for random trade cost components, with the objective of modelling unobserved heterogeneity in trade flows across country pairs.

Specifically, we assume that the unobserved components of transport cost τ_{ij} and fixed cost to have access to foreign markets f_{ij} are gamma distributed.

The transport cost depends on the geographical distance D_{ij} from *i* to *j* and on the u_{ij} disturbance, which is distributed i.i.d. gamma:

[14] $$\tau_{ij} = D_{ij}^{\gamma} e^{-u_{ij}}$$

In this case trade equation [11] can be re-written as

$$M_{ij} = AA_i A_j D_{ij}^{-\gamma} max\left\{\left[\frac{a_{ij}}{a_L}\right]^{k-\varepsilon+1} - 1,0\right\} e^{u_{ij}}$$

For fixed costs f_{ij}, we assume that they are stochastic due to frictions or impediments related to trade. They depend on trade barriers imposed by the importing country to all countries (IM_j), on export-related fixed costs (EX_i) and on any additional fixed cost of each specific country pair (χ_{ij}). Specifically,

[15] $$f_{ij} = EX_j^{\zeta} IM_i^{\varsigma} \chi_{ij}^{k} e^{-\upsilon_{ij}}$$

where we assume that the unobserved residual v_{ij} is distributed i.i.d. gamma as transportation costs, differently from other contributions.

Given trade equation [11] and fixed costs equation [15], the latent variable Z_{ij} can be expressed as follows:

[16] $$Z_{ij} = BB_i B_j \chi_{ij}^{-k} D_{ij}^{-\gamma} e^{\eta_{ij}}$$

where

$$B \equiv (1-q) q^{1-\varepsilon} a_L^{1-\varepsilon} ,$$

$$B_i \equiv \frac{P_i^{1-\varepsilon} Y_i}{c_i IM_i^{\varsigma}} \ ,$$

$$B_j \equiv \frac{EX_j^{-\zeta}}{c_j}$$

and $\eta_{ij} \equiv u_{ij} + v_{ij}$, is gamma distributed when u_{ij} and v_{ij} are assumed to be independent[2]. In this case the density function of the error term is

[17] $$g(\eta_{ij}) = \frac{\delta^{\delta}}{\Gamma(\delta)} \eta_{ij}^{\delta-1} e^{-\eta_{ij}\delta}$$

with $E(\eta_{ij})= (1)$ and $V(\eta_{ij})=1/\delta = \alpha$.

Given a consistent estimate of Z_{ij}, named $Z_{ij}^{*} = BB_i B_j \chi_{ij}^{-k} D_{ij}^{-\gamma}$, it is easy to show that the export flow M_{it} may be written as

[18] $$M_{ij} = T_{ij} AA_i A_j D_{ij}^{-\gamma} \left\{ \left[Z_{ij}^{*} e^{\eta_{ij}} \right]^{\frac{k-\varepsilon+1}{\varepsilon-1}} - 1 \right\} e^{u_{ij}}$$

with the indicator $T_{ij} = 1$ if country j exports to i and $T_{ij} = 0$ otherwise.

For the positive observations of M_{ij} we can take the logs of both sides of [18] to obtain

[19] $$m_{ij} = a + a_i + a_j - \gamma d_{ij} + \ln\left[e^{\delta\left(z_{ij}^{*} + \eta_{ij}\right)} - 1 \right] + u_{ij}$$

where $\delta = \frac{k-\varepsilon+1}{\varepsilon-1}$ and lower-case letters indicate the logs of the quantity corresponding to the same upper case letters. Besides bilateral trade barriers between country i and j (τ_{ij}), modeled in equation [14], two other components of trade resistance can be identified: i's resistance to trade with other countries (a_i) and j's resistance to trade with other countries (a_j). In our structural gravity model, this is done to account for the "relative" attractiveness of origin-destination pairs and therefore to fully explain trade frictions from a general equilibrium perspective (Anderson and van Wincoop, 2003).

[2] The gamma distribution has been used by Eaton et al. (2012) to model heterogeneity in a gravity model with a discrete choice structure. The authors exploit this characteristics with reference to the number of firms which trade internationally.

3. Structural gravity models with over-dispersion and excess zeroes

The empirical literature on zeroes in bilateral trade data includes Santos Silva and Tenreyro (2006), Helpman et al. (2008), and Eaton et al. (2012) among others. As presented in the previous section, the analysis of trade flows is to be corrected for the probability of positive trade in gravity models. Helpman et al. (2008) consider the Heckman selection model, where the selection equation determines whether or not bilateral trade between two countries is observed, while the regression model concentrates on the analysis of bilateral trade determinants. This model requires some restrictive assumptions of homoskedastic random components. Despite the fact that the Heckman selection model deals with zero counts, the bias created by the logarithmic transformation in the regression part of the model poses a problem in the presence of heteroskedasticity, even when controlling for fixed effects. Santos Silva and Tenreyro (2006) propose a Poisson pseudo-maximum likelihood (PPML) estimator to be applied to the gravity model in the multiplicative specification given by Helpman et al. (2008). However, they observe that this estimator does not take full account of the heteroskedasticity in the model and all inference has to be based on an Eicker-White robust covariance matrix operator[3]. In this view, we directly estimate the gravity model in the multiplicative specification, to avoid the problems associated to Helpman et al. (2008) estimation procedure in the presence of heteroskedasticity, We also take into account the presence of zeroes in the data, along the lines developed by Burger et al. (2009).

With reference to trade equation [18] we can summarize all observables by the vector $X_{ij} = \left(a_i, a_j, b_i, b_j, ln\chi_{ij}, d_{ij}\right)$, such as geographical distance, language, cultural and institutional variables. In addition, importer and exporter fixed effects respectively control for inward and outward multilateral resistance variables (Anderson and van Wincoop, 2003).

[3] Other contributions in estimating gravity models consider the PPML approach. See for example Westerlund and Wilhelmsson (2011), Liu (2009), and Henderson and Millimet (2008).

In this case, the conditional mean of trade flow between country *i* and country *j* when T_{ij} = 1 can be written as a function of the vector of covariates and of an unobserved term for each (*i*, *j*) country pair:

$$E(M_{ij}|X_{ij},\eta_{ij}) = \mu_{ij}\eta_{ij} = exp^{(X'_{ij}\beta)}\eta_{ij} \quad [20]$$

Interestingly, given the gamma distribution for trade (fixed and variable) costs, we have the nice feature that if we do not condition on η_{ij} - which we cannot do in practice since it is not observed - the trade flow M_{ij} is distributed negative binomial. More specifically, conditional on both X_{ij} and η_{ij}, the dependent variable M_{ij} is Poisson distributed with probability

$$\mathrm{P}(M_{ij} = I_{ij}|X_{ij},\eta_{ij}) = \frac{e^{-\mu_{ij}\eta_{ij}}(\mu_{ij}\eta_{ij})^{I_{ij}}}{I_{ij}!} \quad [21]$$

However, conditional on only X_{ij}, M_{ij} is distributed as a negative binomial

$$\mathrm{P}(M_{ij} = I_{ij}|X_{ij}) = \frac{\Gamma(I_{ij}+\alpha^{-1})}{I_{ij}!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\mu_{ij}+\alpha^{-1}}\right)^{\alpha^{-1}}\left(\frac{\mu_{ij}}{\mu_{ij}+\alpha^{-1}}\right)^{I_{ij}} \quad [22]$$

where E(M_{ij}) = μ_{ij} and V(M_{ij})= $\mu_{ij}(1+\alpha\,\mu_{ij})$.

Negative binomial and Poisson models are nested because the negative binomial converges to Poisson, as α converges to 0. The negative binomial distribution tests for the presence of *unobserved* heterogeneity in the sample, while the Poisson model assumes equi-dispersion and therefore is able to account for *observed* heterogeneity only. If the estimation procedure does not correct for over/under-dispersion, results are consistent but inefficient (with spuriously large z-values and small p-values due to downward standard errors).

The negative binomial distribution emerges when M_{ij} is strictly positive. However, no bilateral trade can exist as well, then both T_{ij} = 1 and T_{ij} = 0 alternatives must be considered in our estimation strategy. This can be done by considering a zero-inflated version of the negative binomial model.

The zero-inflated model considers two kinds of zero-valued trade flows: countries that never trade and countries that do not trade now but potentially could trade in the future, based on a positive latent probability to trade obtained by some determinants such as distance, institutional proximity, etc. In this view, this model accounts for unobserved heterogeneity in the population with a zero count.

Then the estimation process consists of two parts. The first equation contains a logit (or probit) regression of the probability that there is no bilateral trade at all. With reference to the structural model presented in section 2, no trade occurs when $Z_{ij}\leq 1$. The second part contains a negative binomial regression of the probability of each count for the group that has a non-zero probability or interaction intensity other than zero.

Formally we have:

[23] $$Pr[T_{ij}=0] = (1-\chi_{it}) + \chi_{it}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_{ij}}\right)^{\alpha^{-1}}$$

[24] $$Pr[M_{ij}=I_{ij}\mid T_{ij}=1] = \chi_{it}\,\frac{\Gamma(I_{ij}+\alpha^{-1})}{I_{ij}!\,\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_{ij}}\right)^{\alpha^{-1}}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_{ij}}\right)^{I_{ij}}$$

where the mean value μ_{ij} has been defined in equation [20].

Santos-Silva and Tenreyro (2006) suggest that heteroskedasticity is responsible for the main differences in trade data. To control for heteroskedasticity in the gravity equation, Helpman et al. (2008) introduce fixed effects in a log-linear gravity model and take account of zero observations. Alternatively, Santos-Silva and Tenreyro (2006) consider a Poisson PML estimation technique of the gravity model in the multiplicative (level) form with fixed effects, but cannot separate the extensive margin from the intensive one.

Helpman et al. (2008) consider a two-equation model based on Heckman (1979) sample selection estimator, which allows the covariates to affect the conditional distribution of M in two different ways, separately modeling the probability of observing zero and non-zero observations. The authors propose several estimators, but all of them are not able to capture all the heteroskedasticity that is present in trade data. The log-linearized OLS estimator will generally deliver inconsistent estimates for betas, as well explained by Santos-Silva and Tenreyro (2006).

Specifically, the *general* gravity model can be expressed in levels as in [20]

[25] $$M_{ij} = exp(X'_{ij}\beta) + \varepsilon_{ij} = exp(X'_{ij}\beta)\eta_{ij}$$

or in the log form

[26] $$\ln(M_{ij}) = X'_{ij}\beta + ln\eta_{ij}$$

where $\eta_{ij} = 1 + \varepsilon_{ij}exp(-X'_{ij}\beta)$, $E[\varepsilon_{ij}|X_{ij}] = 0$ and $E[\eta_{ij}|X_{ij}] = 1$. The errors of the level model are mean-independent of the covariates.

Helpman et al. (2008) consider the following model (HMR model):

[27] $$Pr[T_{ij} = 1|X_{ij}] = Pr(X'_{ij}\gamma_{HMR} + e_{1ij} > 0|X_{ij})$$

$$for\ T_{ij} = 1\text{: } \ln(M_{ij}) = X'_{ij}\beta_{HMR} + e_{2i}$$

where $$\begin{bmatrix} e_{1i} \\ e_{2i} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{HMR}\sigma_{HMR} \\ \rho_{HMR}\sigma_{HMR} & 1 \end{bmatrix}\right)$$

However, the assumption of i.i.d errors is not met. Indeed, when comparing the HMR model and the general log one, e_{2ij} corresponds to $ln\eta_{ij}$. It is easy to see that this error is a function of the covariates and ε_{ij}, violating the condition for consistency of OLS. Moreover, the non-linear least squares estimator is considerably inefficient, since excessive weight is given to observations with large variance.

Santos-Silva and Tenreyro (2006, 2009) propose a one-equation specification with an exponential conditional expectation function. This specification requires minimal distributional assumptions at the estimation stage of the level model and presents consistency in the presence of heteroskedasticity, but the extensive margin cannot be disentangled from the intensive margin. In Poisson Pseudo Maximum Likelihood (P-PML) technique $Pr[M_{ij} = I_{ij}|X_{ij}]$ is Poisson distributed and the variance is proportional to the mean, $E(M) \propto V(M)$. When this hypothesis is not satisfied, P-PML estimates are consistent but inefficient (Santos- Silva and Tenreyro, ????)

Alternatively, by proposing zero-inflated models, we are able to treat corner-solutions by means of two-equation models and estimate the gravity equation in the multiplicative form. Specifically, we consider a Negative Binomial PML (NB-PML) estimator - as in Burger et al. (2009) – for the following model

[28] $$Pr[T_{ij} = 0|X_{ij}] = \varphi(X'_{ij}\gamma)$$

$$for\ T_{ij} = 1: E[M_{ij}|X_{ij}, T_{ij} = 1] = exp(X'_{ij}\beta)[1 - \varphi(X'_{ij}\gamma)]$$

$Pr[M_{ij} = I_{ij}|X_{ij}, T_{ij} = 1]$ is distributed as a negative binomial and $V(M)$ is a quadratic function of $E(M)$. A negative binomial distribution can be regarded as a gamma mixture of Poisson random variables. This estimator is generally appealing because it is meant to increase efficiency. However, as shown by Bosquet and Boulhol (2014), NB-PML estimator does not improve efficiency upon P-PML when applied to continuous dependent variables, such as trade data. In this vein, the proposal of such technique is exclusively meant to separately explain the economic determinants of the intensive and extensive margins of trade.

4. Estimating structural gravity models from sector data

The analysis of trade flows of 37 countries in 2000 has been performed by using the NBER-UN data set, described in Feenstra et al. (2005), for sectors in the 4-digit Standard International Trade Classification (SITC4), Revision 2. The sample consider 30 OECD countries and 7 non-OECD countries (China, Israel, Romania, Russian Federation, Singapore, Slovenia, South Africa). See table 2 for a complete list of countries. For each sector 37×36 country pairs (*i, j*) trade flows are recorded and the number of zero observations is high (72% on total observations). To model trade costs, two variables connected to distance are considered. The geographical distance between the capital cities of each country pair captures variable trade costs, which are increasing with the distance. Its effect on trade volume is expected to be negative. A contiguity variable is connected to fixed trade costs and is equal to 1 when two countries share a common border. Its effect on trade volume is expected to be positive. Since it is argued that the geographical distance is not able to capture all the economics barriers to trade, the analysis often considers other gravity variables. As to other explanatory variables, we have: a language dummy, which is equal to one when two countries share the same language; a history dummy which is equal to one when two countries had a colonial link or were the same country in the past. All these variables are from CEPII. Country i's log GDP and country j's log GDP (Source: Penn Table) are used to consider exporter supply and importer demand size; four free trade agreement dummies are equal to one when two countries join the same free trade area (APEC, EFTA, EU, NAFTA). The existence of free trade agreements is expected to give positive effects on trade. By simply considering the number of zero trade flows, smaller frequencies are observed for them than the corresponding value calculated for the all countries sample. To model multilateral resistance effects, exporter fixed effects and importer fixed effects have been introduced, as proposed by Feenstra (2002)[4]. Moreover, fixed effects allow for other unobservable country/product characteristics.

Given the presence of a large number of zero bilateral trade flows with disaggregated data, Santos-Silva and Tenreyro (2009) show that the truncation of trade flows at zero biases the standard OLS approach. In addition, they argue that not accounting for trade data heteroskedasticity in the log-linear OLS regressions produces inconsistent coefficient estimates. To account for heteroskedasticity and to utilize the information carried by the zero trade flows, they suggest estimating the gravity equation in multiplicative form using the Poisson pseudo-maximum-likelihood (PPML) estimator. As detailed in the previous section, we instead proceed by considering the two step procedure of zero inflated models, which allow to separately evaluate the economic effects of the explanatory variables on both the extensive and the intensive margins of trade.

Our approach models a selection stage where exporters must pay some fixed costs to enter a market. In this way, we can control for unobserved heterogeneity (the proportion of exporting firms) and for

[4] Several studies use this approach (among many others, Henderson and Millimet, 2008). An alternative solution is to include a remoteness variable (Head and Mayer, 2000). Anderson and van Wincoop (2003) use observables to obtain multilateral resistance indices, but their method is non linear and highly data consuming. To avoid non-linear estimates Baier and Bergstrand (2009) consider a first-order Taylor series expansion.

sample selection. At the second stage, an intensive margin gravity model is estimated in the multiplicative form. Specifically, a zero-inflated negative binomial estimator has been considered to account for both the extensive margin, expressed in terms of the probability to have a zero trade flow between country pairs, and the intensive margin of trade. The zero-inflated technique estimates the econometric specification (28) for each class of commodities in our sample. However, in order to test the robustness of our findings, we also experiment with (cluster-robust) log-linear OLS regressions. The first one considers OLS estimates with reference to the logarithmic variable ln(Value) for which zero observations are dropped, and the second one refers to the logarithmic variable ln(Value+0.01) for which zero observations are maintained. Results, presented in table 2, can be directly compared with the intensive margin estimates obtained by zero inflated models. With reference to OLS estimates, most variables have the expected sign and are highly statistically significant for the log-normal specification. Trade intensity decreases with geographical distance, and increases when countries share the same language and with their size. However, the coefficients of the determinants of trade in the OLS gravity equation are biased, as they confound the effect of these variables on the intensive margin of trade with their indirect effect on the probability to have positive export flows. The results of the estimation of the log-normal model with zero valued flows show the same signs, but differ substantially in size (50% or more).

Alternatively, the zero-inflated model generates two sets of parameter estimates (both reported in table 2): one set for the logit model, which identifies members of the group of pairs of countries always having zero values (pairs of countries that never trade), and one set for the negative binomial part, which predicts the probability of a count belonging to the group of countries that have theoretically non-zero trade flows. The correct model choice depends on the extent to which over-dispersion and excess zeroes are empirically relevant. To test the null hypothesis of the α parameter of over-dispersion equal to zero a likelihood ratio test has been performed rejecting the null in all specifications. With reference to excess zeroes, a Vuong test shows that a positive value in favor of the zero-inflated model cannot be rejected.

As to the intensive margin of trade, the geographical distance coefficient is negative, while size of the trading economies, common language, contiguity, and past colonial ties have positive effects. The sign of coefficients in the logit model, which considers the probability to have no trade flows, present opposite signs as expected. Free trade agreement dummies capture the reduction of non-tariff barriers due to the existence of such agreements: we find positive effects on trade intensity and negative ones on the probability of zero flows. When estimating the same model with heterogeneous coefficients across APEC and EU countries (table 3), some differences emerge: contiguity positively affects trade intensity within APEC area in a stronger way than across EU countries, while the effect on the extensive margin is homogeneous across areas. Past colonial ties coefficient is not significant and exporter's GDP is less important in APEC trade intensity.

Santos-Silva and Tenreyro coefficients are a combination of both intensive and extensive margins effects.

A description of importer and exporter fixed effects is then proposed. Anderson and van Wincoop (2003) introduce them in terms of outward and inward 'multilateral resistance' terms, respectively, to indicate the incidence of the global set of bilateral trade costs. So fixed effects indicate the change in exporting intensity due to such trade costs. High (low) trade costs imply low (high) fixed effects terms and low (high) export intensity. Both inward and outward multilateral resistance values vary across countries. Figure 1 shows exporter and importer fixed effects with reference to the intensive margin regression, measured as deviations from the corresponding value for USA (which is the excluded country in our gravity estimations) and reported in an increasing order.

The pattern of inward and outward multilateral resistance variation makes economic sense. More `remote' nations, geographically and in terms of economic development, face larger buyers' and sellers' incidence implying lower intensity of exporting. Thus developing countries and some former Soviet republics are consistently among the countries with the highest buyers' incidence. In contrast, all developed countries show the lowest ones.

The majority of the developing countries show the highest sellers' incidence. In contrast, the majority of the developed countries are among the regions with the lowest sellers' incidence. Moreover, our estimates capture the emerging importance of Asian countries, as can be seen from figure 1, where three of nine countries with the lowest outward multilateral resistance values (and the highest fixed effects) are Japan, Singapore and South Korea, sharing the best positions with rich countries such as Germany and USA.

It is worth noting that several contributions that have analyzed determinants of trade flows stress the importance of a sector-based picture. Evidence on industry level data can be found in Baldwin and Taglioni (2006), Chen and Novy (2011), Martínez-Zarzosoa and Pérez-Garcíab (2008). Given the empirical recognition of a link between exporting and productivity and of heterogeneous trade costs across sectors, a deeper investigation of export decisions by taking into account the intensity of productivity enhancing activities is developed in next section.

5. Does technology influence the link between trade costs and exports?

When firms undertake investments that lead to both higher productivity and higher export propensity, the role of other determinants of export decisions may be influenced. By taking into account the intensity of productivity enhancing activities we expect to find differences in the coefficient of export determinants and in sellers' and buyers' incidence.

To admit likely differences in technology intensity we classify the 37 sectors into four macro-sectors according to the OECD classification based on technology content: high-tech, medium-high tech, medium-low tech and low-tech macro-sectors. In addition, the S3 SITC sector related to mineral fuels, lubricants and related material is considered separately from the other ones (otherwise included in the medium-low tech group). When simply analyzing the number of zero observations, we observe that medium-low and low tech industries show the highest frequencies.

That is, for a country it is easier to domestically produce medium-low tech goods than high tech ones.

By admitting heterogeneity across sectors in slope coefficients, we assume heterogeneous effects of trade costs, captured by the same set of explanatory variables used in section 4 and sector-specific multilateral resistance terms. Results are presented in table 4. Overall, our estimates are comparable to those obtained with homogeneous slopes, however we also reveal some important differences and additional insights.

With reference to the propensity of exporting, the lowest effect of geographical distance is related to high tech sectors. Conversely, the intensity of exporting is homogeneously affected by distance across sectors (with the exception of mineral fuels, where distance strongly influences both propensity and volume flows). The other variable with heterogeneous effects across technology sectors is related to supply conditions (exporter's GDP level). Both the propensity and the intensity of exporting are positively related to the exporter's dimension (remember that the extensive margin regression estimates the probability of no-exporting). This effect is stronger, the higher is the technology content. Moreover, the intensity of exporting is positively related to the exporter's dimension, though in medium-low and low sectors this effect is smaller than other sectors. This result can be interpreted with the existence of scale economies in advanced sectors, which are more important than in low technology ones.

Colonial links affect the extensive margin differently across free trade areas, but not across sectors. As to free trade areas, few differences emerge across sectors. The export propensity is not affected by the existence of preferential economic agreements in the mineral fuels sector. In all other sectors, they promote trade among members with some specificities in European and non-European countries. The former group is not able to exploit the existence of preferential economic ties to influence export propensity, while they improve volume flows. Conversely, APEC and NAFTA pacts positively affect trade both along the intensive and the extensive margins, with moderate differences across sectors.

Inward and outward multilateral resistance indexes also vary across industries in 2000 trade data. The pattern of variation makes good sense for the most part, when considering sector specific exporter's average barriers to trade and importer's average barriers in details. Again, high (low) trade costs imply low (high) fixed effects terms and low (high) export intensity.

As in the pooled analysis, geographically distant and developing countries face large buyers' incidence implying low intensity of exporting in all sectors, with few exceptions. While the Russian Federation shows the highest buyers' incidence values for all sectors, Hungary shows a low value in the high tech group and South Korea in medium-high and medium-low sectors. Within developed countries, buyers' incidence costs decrease from high tech to low tech sectors for Italy. The reverse is true for Ireland.

More heterogeneous fixed effects emerge when considering sellers' incidence and the relative position of developing and developed countries is affected by the technology content of traded commodities. In high tech sectors, developed countries are the most important trading leaders. Specifically, several European countries (Ireland, Finland, Switzerland, Sweden, Netherlands, Denmark, Germany, UK) are accompanied by two former Soviet republics (Hungary and Slovenia), Israel and Singapore. In low tech sectors, China, USA and Italy show the smallest sellers' incidence values. The Russian Federation shows low sellers' incidence in medium low and mineral fuels sectors only.

6. Concluding remarks

This paper has contributed to the explanation of international trade flows by the specification of a structural gravity model taking heterogeneity and excess zeroes into account. A generalized version of Helpman et al. (2008) trade model with heterogeneous firms' productivities, fixed costs to access foreign markets and trade variable costs between trading partners has been proposed. It is capable of explaining over-dispersion in trade data in addition to zero trade flows between some pairs of countries and larger numbers of exporters to larger destination markets. In the presence of unobserved heterogeneity in fixed and variable trade costs, trade flows are negatively binomial distributed and the probability of zero outcomes may be studied. The estimation strategy connected to our structural gravity model allows us to identify the effects of trade determinants along the intensive and the extensive margin by a two-equation system (zero-inflated negative binomial model).

Empirically, the approach has been applied to NBER-UN data (4-digit SITC sectors, 37 countries in 2000). Trade costs affect both intensive and extensive margins as predicted by the theory. The impact of trade costs measured in terms of geographical distance and contiguity, the size of exporting and destination economies, cultural and institutional factors such as common language, free trade agreement and colonial ties have been considered in influencing both the extensive and the intensive margin of trade. Other global trade barriers are captured by inward and outward multilateral resistance terms. Heterogeneous trade costs characteristics emerge across trade integrated areas, such as APEC and EU, and across sectors, classified according to their technological content. When considering the technological content of export flows, costs connected to geographical distances are less important while economies of scale are more important in high tech than in low tech sectors. As to global multilateral costs, heterogeneous patterns emerge especially from the supply side. European developed and Asian emerging countries are leaders in exporting high tech products for their capacity of lowering their multilateral non-tariff barriers. Some former Soviet countries are also emerging on the world trade scene. In medium-low and low sectors other countries, such as China, USA and Italy, show low global export resistance with a positive effect on their export intensity.

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Table 1: List of countries

EU members	APEC members
Austria	Australia
Belgium-Lux	Canada
Czech Rep	China
Denmark	Chile
Finland	Japan
France	Korea Rep.
Germany	Mexico
Greece	New Zealand
Hungary	Russian Federation
Ireland	Singapore
Italy	USA
Netherlands	
Poland	
Portugal	**Other countries**
Romania	Iceland
Slovakia	Israel
Slovenia	Norway
Spain	South Africa
Sweden	Switzerland
UK	Turkey

Table 2: Gravity estimates, homogeneous slope coefficients across sectors

	Robust OLS Ln(Value)	**Robust OLS** Ln(Value+0.01)	**Negative binomial** Intensive margin	**Negative binomial** Extensive margin
Geographical distance	-0.33***	-0.90***	-0.28***	0.63***
Contiguity	0.50***	1.32***	0.52***	-0.52***
Common language	0.11***	0.52***	0.03**	-0.34***
Colonial links	0.12***	0.44***	0.25***	-0.33***
GDP importer	0.28***	0.68***	0.52***	-0.50***
GDP exporter	0.29***	0.89***	0.23***	-0.74***
APEC dummy	0.41***	0.82***	0.75***	-0.53***
EFTA dummy	0.13**	0.11**	-0.30***	-0.37***
EU dummy	0.17***	0.20***	0.29***	-0.11***
NAFTA dummy	0.82***	1.96***	0.89***	-0.57***
Constant	-7.80***	-36.96***	-7.97***	33.40***

Estimates with importer, exporter and (1 digit SITC) sector fixed effects; *** 1%, ** 5%, * 10% significant coefficient. Parameter $\alpha = 2.56$ (p-value: 0.00), Vuong test 209.12 (p-value: 0.00).

Table 3: Gravity estimates, homogeneous slope coefficients across sectors

	All countries		EU27		APEC	
	Extensive margin	Intensive margin	Extensive margin	Intensive margin	Extensive margin	Intensive margin
Geographical distance	0.63***	-0.28***	0.72***	-0.47***	0.94***	-0.42***
Contiguity	-0.52***	0.52***	-0.54***	0.39***	-0.54***	0.96***
Common language	-0.34***	0.03**	-0.08**	0.11***	-0.55***	-0.24***
Colonial links	-0.33***	0.25***	-0.29***	0.19***	1.14***	-0.09
GDP importer	-0.50***	0.52***	-0.66***	0.68***	-0.37***	0.68***
GDP exporter	-0.74***	0.23***	-0.90***	0.63***	-0.69***	0.39***
Constant	33.40***	-7.97***	41.46***	-23.41***	25.88***	-15.53***
Number of obs	1028304		293360		69480	
Nonzero obs	295159		116615		29016	
Zero obs	733145	71.3%	176745	60.2%	40464	58.2%

Estimates with importer, exporter, and (1 digit SITC) sector fixed effects; free trade areas fixed effects are also considered in the all countries sample. *** 1%, ** 5%, * 10% significant coefficient. All countries: parameter $\alpha = 2.56$ (p-value: 0.00), Vuong test 209.12 (p-value: 0.00). EU27: parameter $\alpha = 2.28$ (p-value: 0.00), Vuong test 137.15 (p-value: 0.00); APEC: parameter $\alpha = 3.11$ (p-value: 0.00), Vuong test 69.24 (p-value: 0.00).

Figure 1: Inward and outward multilateral resistance terms, intensive margin

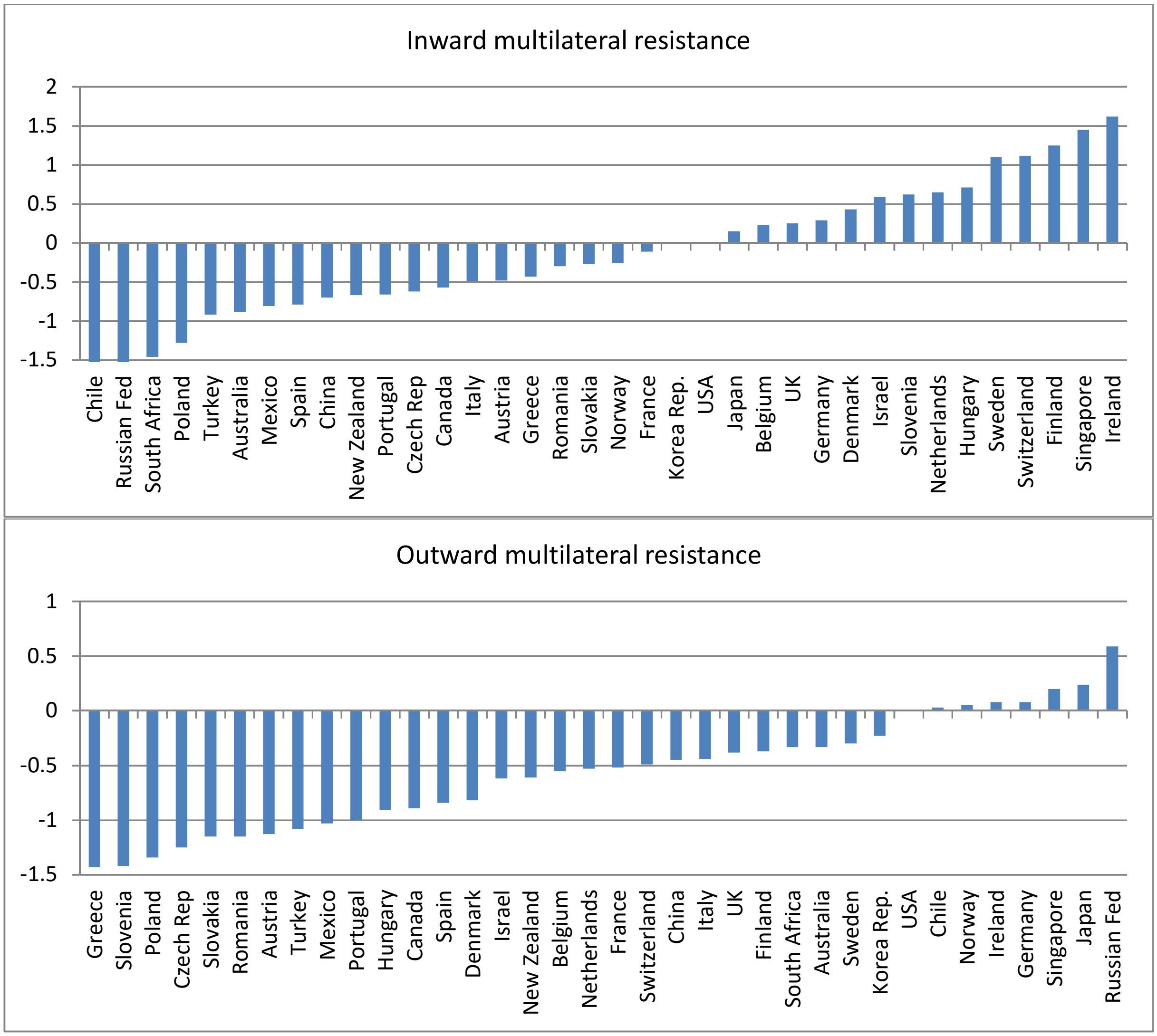


Table 4: Sector gravity estimates by technology intensity

Extensive margin	High-tech	Medium-high tech	Medium-low tech	Mineral fuels, lubricants and related material	Low tech
Geographical distance	0.36***	0.67***	0.64***	1.01***	0.66***
Contiguity	-0.58***	-0.53***	-0.43***	-0.73***	-0.59***
Common language	-0.41***	-0.38***	-0.28***	-0.12	-0.39***
Colonial links	-0.28***	-0.32***	-0.41***	-0.36***	-0.31***
GDP importer	-0.49***	-0.57***	-0.50***	-0.49***	-0.46***
GDP exporter	-0.84***	-0.89***	-0.71***	-0.86***	-0.64***
APEC dummy	-0.65***	-0.42***	-0.67***	-0.59***	-0.64***
EFTA dummy	-0.30*	-0.41***	-0.44***	0.62	-0.42***
EU dummy	0.06	-0.01	-0.01	-0.04	-0.27***
NAFTA dummy	-0.80***	-0.64***	-0.44***	0.19	-0.63***
Constant	34.44***	37.48***	32.01***	34.22***	28.62***
Number of obs	75924	285048	279720	26640	358308
Nonzero obs	30277	102946	63828	3878	94192
Zero obs	45647	182102	215892	22762	264116

Intensive margin	High-tech	Medium-high tech	Medium-low tech	Mineral fuels, lubricants and related material	Low tech
Geographical distance	-0.27***	-0.40***	-0.30***	-0.86***	-0.28***
Contiguity	0.26***	0.42***	0.62***	0.39***	0.60***
Common language	0.17***	0.10***	-0.13***	0.06	0.14***
Colonial links	0.24***	0.14***	0.31***	0.43***	0.26***
GDP importer	0.58***	0.54***	0.49***	0.42***	0.48***
GDP exporter	0.72***	0.53***	0.17***	0.53***	0.10***
APEC dummy	0.82***	0.55***	0.63***	0.95***	0.88***
EFTA dummy	-0.25	-0.15	-0.57***	-1.09	0.03
EU dummy	0.19***	0.25***	0.41***	-0.42**	0.34***
NAFTA dummy	0.94***	1.19***	0.59***	-0.57*	1.03***
Constant	-25.94***	-18.74***	-6.34***	-12.71**	-5.20***
Number of obs	75924	285048	279720	26640	358308
Nonzero obs	30277	102946	63828	3878	94192
Zero obs	45647	182102	215892	22762	264116

Estimates with importer, exporter and (1 digit SITC) sector fixed effects; *** 1%, ** 5%, * 10% significant coefficient. HT: parameter α = 2.42 (p-value: 0.00), Vuong test 69.51 (p-value: 0.00). MHT: parameter α = 2.35 (p-value: 0.00), Vuong test 124.21 (p-value: 0.00); MLT: parameter α = 2.34 (p-value: 0.00), Vuong test 95.01 (p-value: 0.00). Mineral fuels, lubricants and related material: parameter α = 3.10 (p-value: 0.00), Vuong test 12.38 (p-value: 0.00). LT: parameter α = 2.27 (p-value: 0.00), Vuong test 120.48 (p-value: 0.00).

Figure 2: Inward multilateral resistance terms by technology intensity, intensive margin

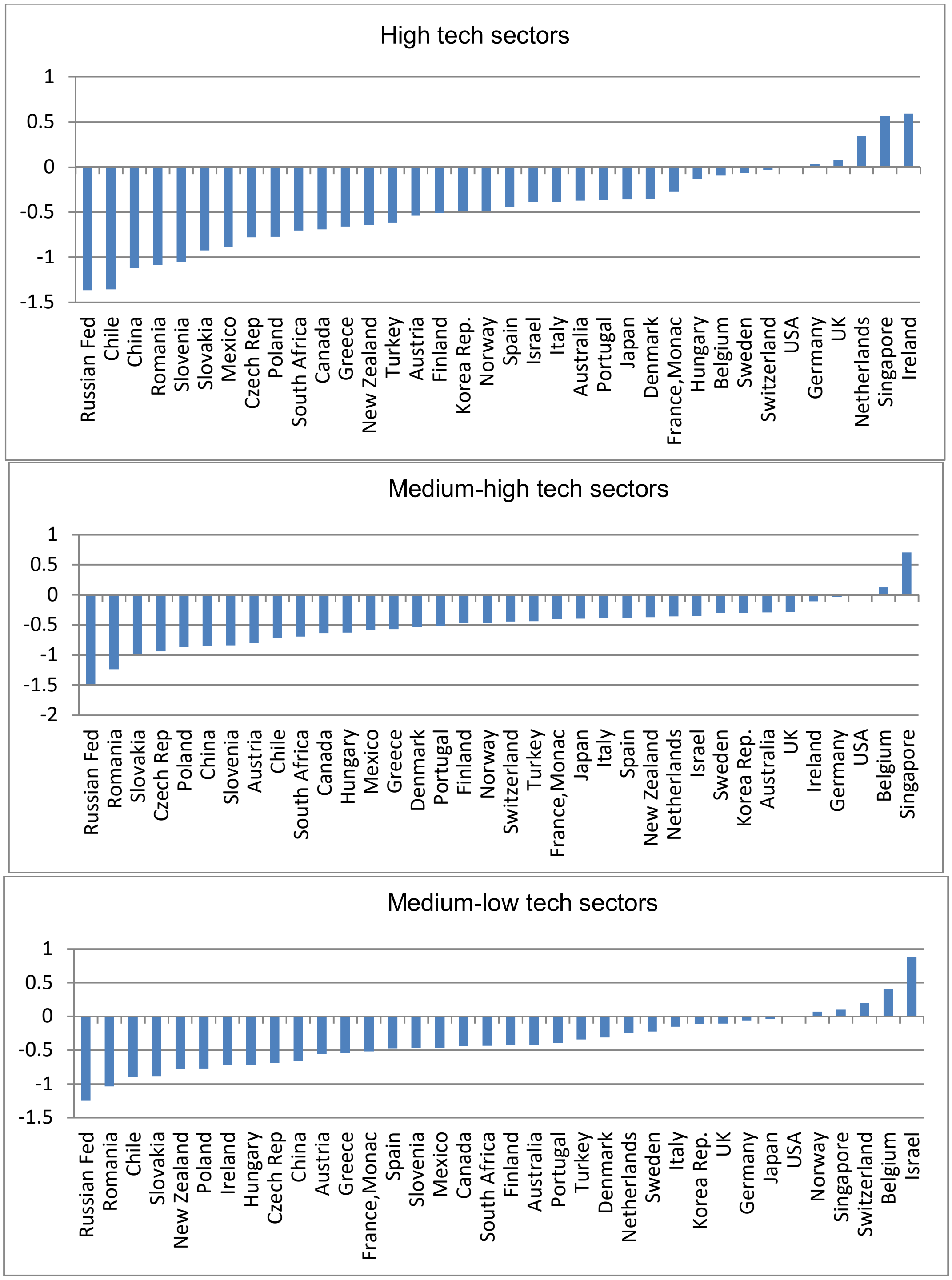
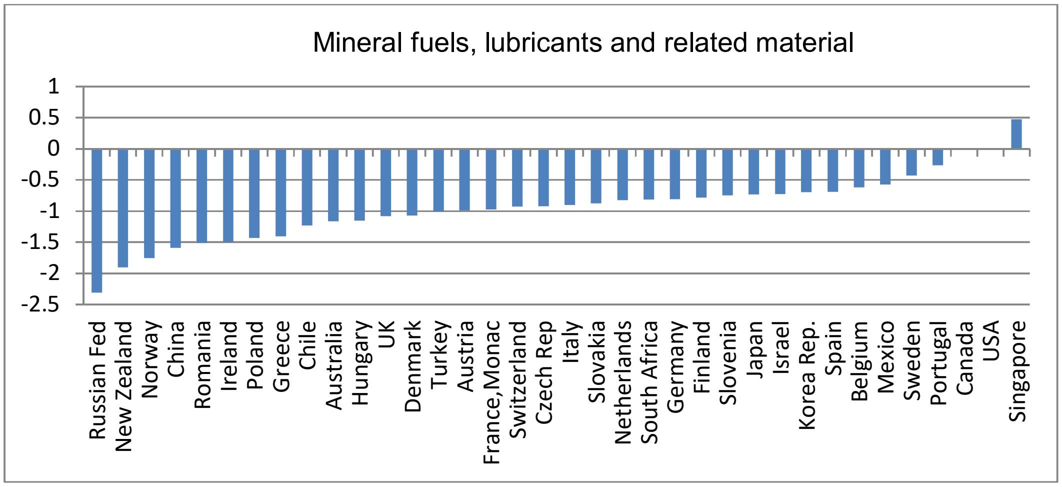


Figure 2(continue): Inward multilateral resistance terms by technology intensity, intensive margin



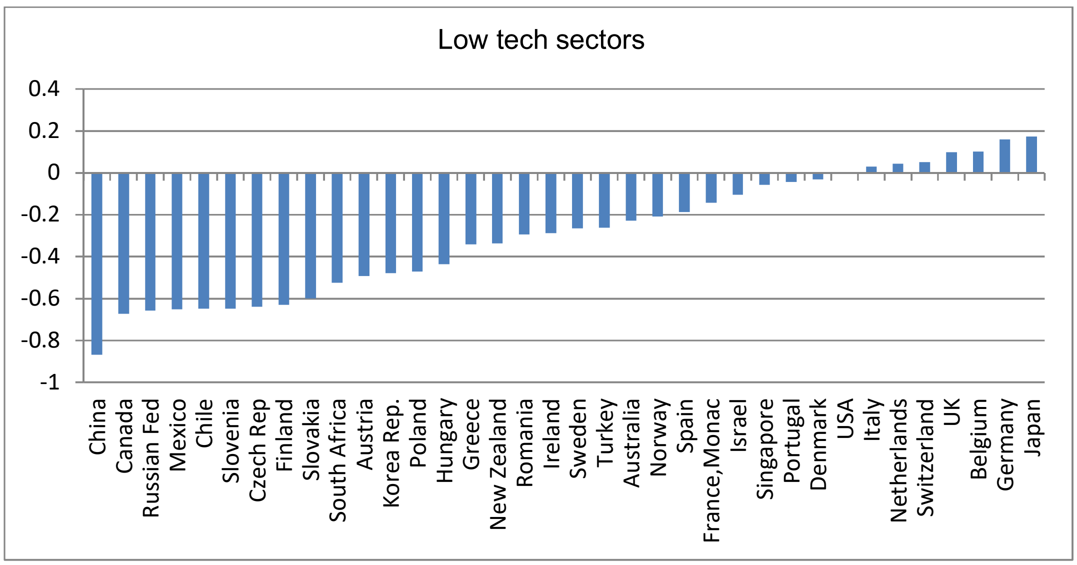
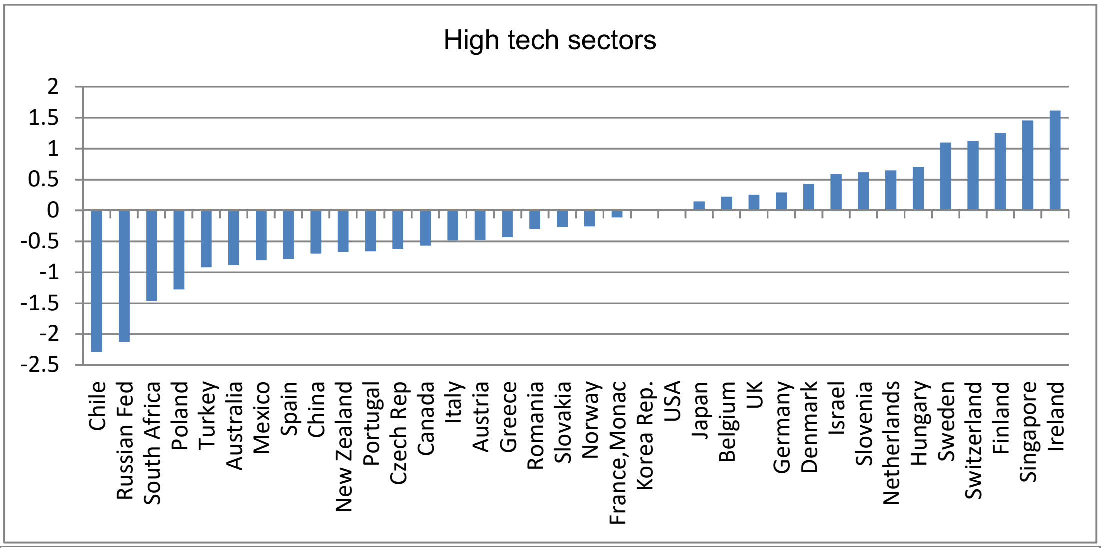
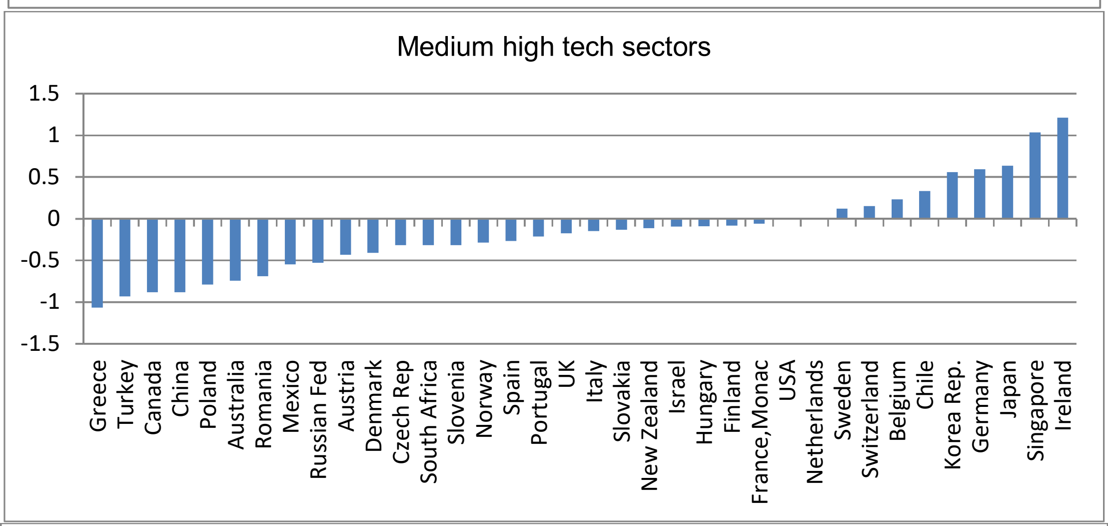


Figure 3: Outward multilateral resistance terms by technology intensity, intensive margin





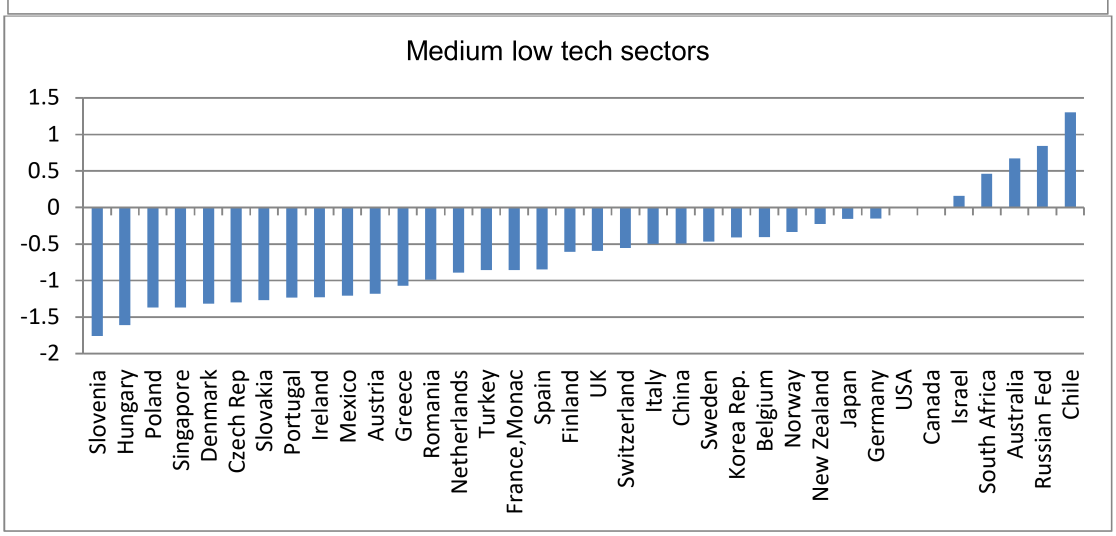


Figure 3 (continue): Outward multilateral resistance terms by technology intensity, intensive margin