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Trade Elasticity, Gravity and The Gains from Trade: Evidence from the Food Industry

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Abstract

This paper estimates the elasticity of trade flows to trade barriers from gravity equations, using different econometric methods, with the aims to simulate the trade gains from the elimination of tariffs. Specifically, we compare a benchmark OLS fixed effects specification with three emerging estimation methods: the Heckman correction for selection bias; the Eaton and Tamura Tobit estimator, to solve limited-dependent variable issues; and, finally, the Poisson pseudo-maximum-likelihood (PPML) technique, to correct for the presence of heteroskedasticity. The paper achieves two goals. First it provides estimates of the trade elasticity for eighteen food industries. Second, it gives a dimension to the trade reduction effect induced by existing border protection, by simulating the effects of a full trade liberalization scenario, computing the standard errors of predicted values. The estimates reveal interesting variations in the elasticity of substitution across products and procedures. The simulation indicates that trade liberalization will strongly increase agro-food trade, especially from high income and emerging countries.

JEL Classification: F1, F13, F14
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1. Introduction

In the last decade there has been a growing interest in the use of gravity equations to explain bilateral trade flows, an interest largely driven by the sounder 'micro-foundation' of the gravity equation (see, e.g, Eaton and Kortum, 2002; Anderson and van Wincoop, 2004; Melitz, 2003; Helpman et al. 2008). Indeed, an important class of international trade models – from neoclassical with perfect competition to the most recent trade models with monopolistic competition and firms heterogeneity – shares as a common feature a gravity-like explanation of bilateral trade flows.

As a consequence of the growing popularity of gravity equations, a great deal of controversy and uncertainty has emerged over the *correct* estimation method (see, e.g., Schaefer et al. 2008, Santo Silva and Tenreyro 2008, Helpman et al. 2008). An influential paper by Santos Silva and Tenreyro (2006) criticised the standard estimation approach that fails to properly account in log linear model for both heteroskedasticity and the presence of zero-value in the dependent variables. As an alternative approach they recommended the Poisson Pseudo Maximum-Likelihood (PPML) estimator.

However, Martin and Pham (2008) have shown that the PPML approach produces biased results when used in the presence of a large fraction of zero trade flows, a situation consistent with recent trade models with firms heterogeneity (Melitz 2003; Helpman et al. 2008) and very frequent working at a disaggregated product level. As an alternative to the PPML method they propose the Eaton and Tamura (1994) Tobit estimator and the Heckman procedure. The first appears more consistent in the presence of limited dependent-variable issues, when the heteroskedasticity problem is dealt with; the second, by adding a variable that adjusts for sample selection issues overcomes the omitted variable bias, and is a good estimation procedure whether *true* identify restrictions are available.

In the Santos Silva and Tenreyro (2006) and the Martin and Pham (2008) papers the bias in the gravity estimation is discussed focusing especially on the 'correct' magnitude of two important coefficients of the gravity equation: the distance and the GDP coefficients. However, what about the sensitivity to other gravity parameters?

The present paper aims at contributing to the literature by estimating the elasticity of trade flows to trade barriers under different estimation techniques. Indeed, a key

potential of the gravity theory is the possibility of identifying the trade elasticity to variable trade barriers, an elasticity that represents the *key* behavioural parameter for capturing the general equilibrium response of trade flows to falling trade barriers (Lai and Zhu, 2004; Lai and Trefler, 2004; Bergstrand et al., 2007; Arkolakis et al., 2009).

Thus, the first objective of the paper is to estimate these trade elasticities by analyzing their sensitivity of using different econometric techniques recently highlighted in the literature. Specifically, we compare a benchmark OLS fixed effects specification *a* la Feenstra (2002), with three emerging estimation methods: the standard Heckman correction for selection bias (Heckman, 1979), to account for zero trade flows; the Eaton and Tamura (1994) Tobit estimator recently proposed by Martin and Pham (2008) to solve limited-dependent variable issues; and, finally, the PPML technique first proposed by Santos Silva and Tenreyro (2006), to correct for the presence of heteroskedasticity.

Our second goal is to use our 'preferred' gravity equations, with their trade elasticity values, to simulate the gains from trade liberalization in 18 food industry, dealing with the problem of uncertainty in the estimation values. Specifically, we performed a Monte Carlo like simulation to compute the confidence intervals around the trade liberalization effects.

This paper is related to the large literature estimating the determinants of bilateral trade and the gains from trade liberalization, a literature too large to summarize here. However, within this literature our paper is most closely in spirit to Lai and Trefler (2004) and Ghazalian et al (2007). Lai and Trefler (2004) using dynamic panel methods were able to estimate static and dynamic versions of the elasticity of substitutions at 3-digits (ISIC) level. Then, they used these estimated elasticities to measure the welfare gains from the elimination of tariffs, with results in the range of actual figures from CGE models.[1] Our analysis depart from this paper in two main respects. First, we work at more disaggregated level (4-digits vs. 3-digits) focusing on food sectors, and using a cross-sectional regression approach. Second, we consider a

[1] Also Eaton and Kortum (2002) estimate the gains from trade liberalization using a gravity-like model. Their strategy to estimate the trade elasticity is to use price differences across goods between countries as a proxy for trade frictions. However, this approach is problematic. First because the sample size of prices (about 50) is small relative to the number of goods in the economy, generating an underestimation of trade frictions, and thus an overestimation of trade elasticity (see Simonovska and Waugh 2010). Second because using prices to measures trade friction introduces several potential measurement errors, as they include also cost elements not linked to border protection.

very larger countries sample of both developed and developing countries.[2] Notwithstanding these differences, our (aggregated) estimate of food trade elasticity is impressivly similar to their value.

Our aim of estimating the trade effects from tariff elimination using gravity, in the context of food industries, is shared by Ghazalian et al. (2007) who provide in-depth analysis of the trade gains from cattle and meat sectors, taking also in consideration their vertical linkages. We depart from this paper in many aspects, like the econometric approach and the countries and sectors coverage. However, the simulated increase in meat (cattle) trade after the elimination of tariffs is very close in the two studies (24% vs. 22%).

The paper is organised as follows. Section 2 justifies and presents the three econometric approaches to properly estimate the gravity equation. Section 3 describes the variables used and the data sources. Section 4 discusses the regression results and the mis-specification tests. The results from our free trade simulation exercise is reported in section 5. Finally, section 6 concludes.

2. The empirical framework

The standard CES monopolistic competition trade model with iceberg trade costs introduced by Krugman (1980) represents the 'benchmark' from which we derive the gravity-like equations estimated in this paper. Specifically, we rely on Lai and Zhu (2004) who show that adding a rich set of international asymmetries to the standard monopolistic competition trade model helps us to identify the key structural parameters, namely the elasticity of substitution (σ). In the estimable version of their model the bilateral trade flow from *j* to *i* can be summarized by the following log-linear bilateral trade equation:

$$(1) \qquad \log M_{ij} = \beta_0 + \lambda_j + \chi_i + (1-\sigma)\gamma \log D_{ij} + (1-\sigma)\log \tau_{ij} + u_{ij},$$

with λ_j and χ_i the exporter and importer fixed effects to control for the unobserved number of varieties (firms) and the price term of the exporter, and for the expenditure and the unobserved price term of the importer. D_{ij} are the transport costs proxy by distance between *i* and *j*; τ_{ij} is the *ad valorem* bilateral tariff; $\sigma > 1$ is the elasticity of

[2] Specifically, Lai and Trefler (2004) work with 14 importers and 36 exporters, differently our sample comprise 99 importers and 193 exporters (see Table A.4 in Appendix).

substitution between home and foreign goods; finally u_{ij} is an error term. We are first interested in the unbiased estimation of the trade elasticity to bilateral tariffs, the parameter $\beta_2 = (1 - \sigma)$ in equation (1), from which we will infer the derived elasticity of substitution, $\sigma = 1 - \beta_2$.

When equation (1) is applied at the disaggregated level, the first problem that emerges is the presence of a high number of zero bilateral trade flows. One of the most common methods of dealing with zero trade is the Heckman (1979) two stage selection correction: i) a Probit equation where all the trade flows determinants are regressed on the indicator variable, T_{ij}, equal to 1 when *j* exports to *i* and 0 when it does not; ii) an OLS second-stage with the same regressors as the Probit equation, plus the inverse Mills ratio from the first stage, correcting the biases generated by the sample selection problems. Following the modification suggested by Helpman et al. (2008) and supported by Martin and Pham (2008), we omitted in the OLS an independent variable associated with the fixed trade costs of establishing trade flows[3].

Since the logarithm of zero is not defined, another way to solve for zero trade flows in the log linear gravity equation is to use a Tobit estimator. Thus, following Martin and Pham (2008), we implemented the Eaton and Tamura (1994) Tobit estimation procedure. Here, to derive the maximum likelihood function, the bilateral trade flows, M_{ij}, are modeled as follows:

$$(2) \qquad \log(M_{ij}^{*} + A) = \beta_0 + \lambda_j + \chi_i + (1-\sigma)\gamma \log D_{ij} + (1-\sigma)\log\tau_{ij} + u_{ij}$$

where $M_{ij} = M_{ij}^{*}$ if $M_{ij}^{*} > 0$, and $M_{ij} = 0$ otherwise

Equation (2) specifies that the right-hand side has to reach a minimum threshold (A) before bilateral trade takes a positive value. A is a parameter to be estimated (see Eaton and Tamura, 1994). Moreover, due to the very large sample of our database, we introduced the adjustment for heteroskedasticity recently proposed by Martin and Pham (2008). They improved the performance of the E-T Tobit model using the adjustments proposed by Maddala (1985), specifying the error variance by the process $\sigma_i^2 = (\xi + \delta\ (x_i\ \beta))^2$, where ξ and δ are parameters estimated together with the parameters of interest.

[3] Martin and Pham (2008) noted that the Heckman sample selection estimators gave poor results when estimated with the same variables in the selection and estimation equation.

Finally, the last estimation technique is the Poisson Pseudo-Maximum-Likelihood estimator. For several reasons, this method has met with success in gravity literature since the important contribution of Santos Silva and Tenreyro (2006). Indeed these authors suggest that, as a consequence of Jensen's inequality, $E(\ln y) \neq \ln E(y)$. Thus, the standard practice of interpreting the parameters of a log-linearized model estimated by OLS as elasticity can be highly misleading in the presence of heteroskedasticity (Santos Silva and Tenreyro 2006, 641). The PPML estimator is very simple to implement with standard econometric programs, as with this method the gravity equation is estimated in its multiplicative form, thus with the dependent variable in levels, representing also a natural way to deal with zero trade flows.

3. The data

Our gravity model includes trade among 193 exporter and 99 importer countries, of 18 food industry sectors. The number of countries is limited by the availability of importer bilateral tariff data that precludes the possibility of squaring the dataset. We used the UN Comtrade database for bilateral trade at the HS-96 6-digit level, reported by the importer countries, then aggregated at the 4-digit ISIC industry classification. To partially reduce the zero data of one year's observations, we used the average value of trade for the years 2002-03-04. However, more than the 70% of the 222,457 observations in our dataset are zero trade flows (see Figure 1). As suggested by Martin and Pham (2008), some of the zero reflects errors, omissions and, rarely, rounding error due to reported low trade values. However, it appears that most of the zero trade flows between country pairs reflects a true absence of trade.

Output data come from the UNIDO data and are for the most part based on ISIC rev. 3 at 4-digits (code from 1511 to 1600), supplemented by the UNIDO ISIC rev. 2 data in the case of missing values. Transport costs are proxied by bilateral distances between countries, calculated considering the average bilateral distances between the biggest cities of two countries weighted by the share of the city in the country's overall population (Head and Mayer, 2002). Data on distance, with dummies for other trade costs normally used in similar exercises (contiguity, language, colony, and common colonizer), are taken from CEPII (Centre d'Etude Prospectives et d'Informations Internationales).

Bilateral tariff data come from the MAcMap database jointly developed by ITC (UNCTAD and WTO, Geneva) and CEPII (Paris). It includes *ad-valorem*, as well as specific components of each bilateral tariff line at the six digit level of the Harmonized System. Average tariffs are computed starting from the HS 6-digit bilateral tariffs, then aggregated at the ISIC 4-digit level using import weights based on the reference group method of Bouët et al. (2007).

4. Estimation results

We estimate equation (1) to examine the trade elasticity to bilateral tariffs, using two sets of gravity estimates: one pooled over the 18 food industries (Table 1), the other considering each of the 4-digit food sectors separately (Table 2). Table 1 is structured as follows: column 1 reports the OLS benchmark; column 2 the first stage Probit for the Heckman procedure; column 3 the second Heckman' stage; column 4 the E-T Tobit model results; and finally column 5 the PPML estimates using only the sub-sample of positive trade pairs.[4]

Starting from the pooled regression results (Table 1), the first point to note is that the trade elasticity to bilateral tariffs (the tariff coefficient), always negative and highly statistically significant, is remarkably similar in the OLS and Heckman procedures. The derived elasticity of substitution[5] for food industry products ranges between 2.56 and 2.61, thus very close to the 2.53 value estimated by Lai and Trefler (2004) for food trade, using a more complex panel method.

The Probit results strongly confirm that the same variables that impact export volumes also affect the probability that country *j* exports to country *i*, and the impact is in the same direction. Indeed, the presence of tariffs reduces the probability of registering positive trade flows by more than 50%.[6] At the end, when we consider overall food trade, both the Eaton-Tamura and the Poisson results show that bilateral tariffs play a smaller role compared with OLS estimates. Moreover, the PPML

[4] Poisson estimates using the whole sample present very similar results; the tariff coefficients are always slightly lower than in Poisson with only positive trade.

[5] Remember that from equation (1) the tariff coefficient is equal to $(1 - \sigma)$, thus the substitution elasticity estimates are equal to the absolute tariff coefficients plus 1.

[6] Note that, for the second stage estimation, Martin and Pham (2008) suggested excluding variables that affect fixed trade costs but do not variable trade costs. Following other authors, we selected common language and common colonizer, both variables that have substantial explanatory power for the formation of trading relationships, and statistically significant in the first-stage probit equation.

estimates indicate that sharing a common language and having colonial relationship does not influence the volume of trade flows.

This preliminary evidence gives a broad confirmation to the Santos Silva and Tenreyro' (2006) findings, namely that estimating the gravity model with the PPML technique tends to produce lower (absolute) estimated coefficients of distance and other trade costs parameters. The innovation here is that a similar effect also applies to the bilateral tariff coefficient, from which we can infer our structural parameter of interest, the elasticity of substitution. Thus, at the aggregate level, the PPML approach displays lower substitution elasticity than other estimation methods.

Table 2 shows estimates of the substitution elasticities, and their *t*-values, obtained from the tariff coefficients of gravity regressions estimated for each 4-digit ISIC sector separately. The specification is identical to the regressions of Table 1, except for the exclusion of importer and exporter production values that now are subsumed in the importer and exporter fixed effects.[7] As expected, the results at the product level show that bilateral tariffs generally affect trade flows significantly more, but with strong heterogeneity across industries. This result is in line with the notion that the (absolute) magnitude of the trade elasticity estimate tends to increase with the level of the disaggregation of the analysis (see Anderson and van Wincoop, 2004). All the derived estimated elasticises of substitution are positive and > 1, as predicted by the theory. Moreover, across different econometric procedures, not less than 15 out of 18 tariff coefficients are statistically significant at the 5% level or more. The estimated values across all methods range from 1.5 to 14, with mean and median values equal to 4.32 and 3.48, respectively. These figures are broadly comparable with previous evidence (see, e.g., Hummels, 2001; Hertel et al 2004), although direct comparison is problematic as our level of disaggregation is significantly higher than in the previous exercises based on a similar approach.

Useful comparison can be made with the results of Broda and Weinstein (2006), who estimated import substitution elasticities at a very disaggregated level using the Feenstra' (1994) import demand equations approach. Aggregating their elasticity estimates at the ISIC 4-digits level (from SITC 4-digits) we have mean and median

[7] Working at single product level, the omission of country production variable (due to importers and exporters fixed effects) increases the number of trading countries and, consequently, the presence of zero trade. The zero trade represents 50% of trade in results of table 1, and up to 77% in estimations of table 2.

values of 4.49 and 5.48 respectively, which, as expected, are just slightly higher than our estimate. Thus, we conclude that our estimates appear broadly within the range of existing evidence.

Next, by comparing the results across different estimation methods, several interesting differences emerge. In the OLS benchmark, the average magnitude of the elasticity across products is 4.2, ranging from 2.4 (spirits) to 9.2 (fish), thus significantly higher than the previous pooled regression. Differently, when we correct for selection bias (column 2) the elasticities decrease, on average, by 16%, while with the E-T Tobit model the reduction is about 34%. By contrast, using the PPML approach (column 4), we observe a remarkable increase in the estimated elasticities of about 70%, associated with a generalized lower distance elasticity (not reported). Interestingly, for many products, the elasticity estimates with the PPML method is more than two times the benchmark OLS value. Thus, the PPML results at the product level go exactly in an opposite direction with respect to what happen at aggregated level, suggesting that some form of *aggregation bias* are driving the results.

The rank correlation between trade elasticities obtained with different econometric methods adds further considerations to the analysis. Indeed, a strong positive correlation exists between the OLS and the Heckman techniques (0.91); the correlation drops to 0.51 on passing to the E-T Tobit model.[8] By contrast, the Poisson's substitution elasticities present a significant lower rank correlation with both the OLS (0.28), and the other methods. This evidence seems to suggest that, at the disaggregated level, the difference between PPML and other methods is largely driven by the large fraction of zero trade flows, more than by heteroskedasticity problems.

4.1 The 'best' estimation strategy

The heterogeneity in the results discussed above raises the question about which is the best estimation strategy to reach the second goal of our paper, namely the simulation of the trade effect induced by a complete tariff removal. To deal with, we performed two formal tests: a mis-specification test and a goodness-of-fit test. Mis-specification can cause significant bias and efficiency problems in econometric models. Thus

[8] Despite the *average* substitution elasticities of the E-T procedure being absolutely similar when estimated with the classical procedure, and with the Martin and Pham (2008) heteroskedasticity correction (2.346 *vs.* 2.335), the rank correlation between OLS and E-T Tobit classical procedure presents a higher value (0.83 *vs.* 0.51).

following Santos Silva and Tenreyro (2006) we checked the adequacy of the estimated models with the RESET test (Ramsey, 1969). The test is performed by adding an additional regressor, constructed as $(x'b)^2$ where b is a vector of estimated parameters, and testing for its significance.

Considering the regression results pooled over the 18 food industries, the corresponding *p*-values of the RESET tests are reported at the bottom of Table 1. It shows that, with the exclusion of the Heckman and PPML methods, all other 'aggregated' gravity models are mis-specified.[9] On the other hand, applying the RESET test at the product level (see Table A.1 in the Appendix), there emerges a strong heterogeneity in the results, suggesting that when zero trade flows represent a large fraction of the data, not surprising, misspecification issues are definitely more severe. The *p*-values for the tests are extremely small in both the OLS and the E-T Tobit models for almost all sectors, indicating serious mis-specification issues. By contrast, most product estimates obtained using the Heckman and the PPML procedure pass the test, and this is particularly true for the Heckman method.

Next, to select our 'preferred' gravity equation we also performed a second test, computing the Theil's *U*-statistic (see Martinez-Zarzoso et al. 2007), a measure of forecast accuracy suggested by Henry Theil (1961). It is measured as the square root of the sum of the squared deviations of the predicted from the actual values, divided by the square root of the sum of the squared actual values. The *U*-statistic reaches its lowest boundary of zero for perfect forecasts. The values obtained at the product level (see Table A.2) show that OLS and the Heckman procedure give better forecast accuracy than Tobit and Poisson, in most of food sectors considered. Exceptions to this rule are bakery production and macaroni, noodle and couscous products, where the PPML Theil's statistics are lower than those obtained with the other methods. Finally, figure 2 plots the correlation between actual and predicted trade flows, from aggregated regressions of Table 1. One again, the 'superiority' of the OLS and the Heckman procedure in term of forecast accuracy, emerges clearly from an inspection of the graphs.

Summarizing, our two tests of misspecification taken together, suggest that the 'best' estimation method for our purpose is the Heckman two stages procedure, a conclusion in line with recent empirical evidence (see Helpman et al. 2008, Martin and

[9] Note that low *p*-values mean rejection of null hypothesis that the models are correctely specified.

Pham 2008). Thus we chose to use the Heckman second stage results to conduct our simulation exercise of the elimination of tariffs.

5. The trade effect of the elimination of tariffs

In this section we deal with the economic implications of our model by simulating the extent to which bilateral tariffs restrict the volume of trade. More specifically, following Lai and Zhu (2004), we simulated an hypothetical trade liberalization effect as the percentage change in trade due to the full elimination of tariffs, using the estimates of the Heckman procedure for the 18 food sectors (see Table A.3).

The trade shocks generated by tariffs removal induce two trade effects. The first is direct, through the trade costs function; the second is indirect, through the multilateral resistance terms (MTR). As our gravity models are based on a fixed effect specification, the MTR terms are not retrieved, thus we are forced to measure only the direct (first order) effect of trade liberalization.

In analysing the simulation results it is important to keep in mind that they are subject to estimation uncertainty, due to the uncertainty of the parameters used for calculations. This is an important advantage of the econometric approach to trade liberalization over CGE models. Indeed, as emphasized by Lai and Trefler (2004), if the estimates of the gains from trade liberalization have appeared in the CGE literature, but rarely in the econometric literature, then the estimates of the uncertainty about the expected gains from trade liberalization are even rarer.[10]

To deal with this uncertainty, we compute the confidence intervals of trade liberalization effects, using Monte Carlo like simulation to convert the raw output of the statistical procedure into simulation results.[11] More specifically, the procedure starts from the point estimates and the variance–covariance matrix of the gravity equations. The central limit theorem guarantees that, for a large enough sample, one can randomly draw (simulate) the coefficient value from a multivariate normal distribution, with mean equal to the point estimated coefficients and variances equal to the variance-covariance matrix of the point estimates (King et al. 2000). Thus, by random drawing, we can obtain the 'estimated coefficients' (the result of one

[10] An exception is Ghazalian et al. (2007) who built confidence intervals around predicted trade flows induced by trade liberalization using bootstrap methods.
[11] The Monte Carlo like simulations are implemented using the package *Clarify* in STATA (see Tomz, Wittenberg and King 2003).

simulation) that can be multiplied by the value of its corresponding explanatory variable (i.e. bilateral tariffs). The simulated coefficients variability translates in variability in the expected value of trade (the dependent variable), while the effects of the other independent variables are held constant at their means.

By repeating this procedure 1000 times for each of the 18 food sectors, we generated 1000 expected values of the status quo, and 1000 expected value of full liberalization scenario. Then, we calculated the 1000 expected trade variations induced by the elimination of tariffs, sorting them from the lowest to the highest. The 25th and 976th positions represent, respectively, our lower and upper bounds of a 95-percent confidence interval.

5.1 Simulation results

Because most trade is among 'rich' countries, especially European countries, and the highest tariffs are among 'poor' countries (developing and emerging), we selected three exporting country groups to better evaluate and summarize the results of the trade liberalization effects. The first two groups are those of high income and low to medium income, as defined by the World Bank, and are labelled as 'high income' and 'developing' countries, respectively. The last group considers the 'emerging' countries, selected on the basis of the FTSE group classification.[12]

Table 3 shows results of the estimated full liberalization exercise, revealing that actual trade barriers reduce food industry world trade, on average, by 33% in the observed period.[13] This figure appears higher than the results of Francois et al. (2005) who, using global computable general equilibrium model, find a full liberalization increase of agricultural and food trade of 21%.

The simulated effect of the elimination of tariffs is particularly important for 'high income' and 'emerging' country groups. In the former, where exports represent more than two third of world food trade, exports increase by about 41%, while in the later increase by 38%. By contrast, 'developing' countries food export grows by only 17%.

[12] The FTSE group is an independent company owned by the Financial Times and the London Stock Exchange. Emerging markets are identified as those developing countries with superior growth prospects. See http://www.ftse.com/index.jsp. Note that using other classifications for emerging countries does not to any degree affect the qualitative results and conclusions of the analysis.

[13] The overall food-industry *trade effect* is obtained by averaging the liberalization effects simulated for each product, weighted by the respective trade share.

Not surprisingly, these aggregated effects mask substantial heterogeneity at product level. Indeed, as malt, grain mill and livestock products have among the highest protection rates, it is not surprising that, after trade liberalization, their world trade will increase more than other agro-food products, *ceteris paribus*. Specifically, the highest increase is detected on malt industry products, where trade volume is almost doubled, driven especially by 'high income' countries exports. Developed countries benefit from tariffs removal by increasing 1.2 times malt exports, and realizing an impressive growth in their world market share.

The meat products industry, the most important food traded product representing about 16% of the world food trade, increases its world exports by about 22%. As expected, this effect is higher than that obtained by Hertel and Keeney (2006) in a partial liberalization scenario, who find for 'cattle' and 'other' meat products an increase of 10.3% and 10.8%, respectively, using GTAP. At the same time, it is very close to the increase of 24% obtained by Ghazalian et al. (2007) using a gravity-like model accounting for the vertical linkages between primary and processed cattle/beef products. In line with their results, we find that 'high income' countries stand to benefit the most in value terms from tariffs removal, increasing their meat exports especially within themselves (+29%). However, the country group that experiences the higher increase in their meat exports is the one of 'emerging' countries, with an overall growth of 29%, that reach the 49% towards the 'high income' countries.

Other products that show a strong increase in trade after the elimination of tariffs are cocoa and chocolate, where world exports increase by 85% due to the increase especially of the 'high income' and 'emerging' countries exports. On the contrary, it appears at odd the trade effect of sugar products. Indeed, despite these products have the highest protection rate among foods, trade liberalization have a nil effect. A potential explanation for this counterintuitive result, comes from the EU prohibitive tariffs existing to prevent any imports beyond the trade preferences given to developing countries, as well as in the MAcMap computation of the equivalent tariffs in presence of tariff rate quotas.[14] Indeed, we observe that developing countries with

[14] Indeed, with the idea that the *ad valorem* tariff should reflect the marginal level of protection, tariff is calculated as equal to the out-quota tariff rate when imports are higher than quota, or in the case of missing data about the quota level and its fill rate, and equal to the lower in-quota tariff when the fill rate is less than 90% (see Bouët et al. 2008).

EU preferential access present the higher tariffs as well as the higher volume of trade with the EU than with other countries.[15]

Figure 3 displays the simulation results of table 3, plotting the upper and lower value around the core estimates at the sector level. As we can see, what may be assimilated to the 95 percent confidence interval, contributed to better qualify the nature of our findings. For example, with some notable exceptions like sugar, the results tend to show that greater is the predicted impact of liberalization on trade flows, the larger is the 'confidence interval' around the predicted values. Indeed, sectors like Malt, Cocoa and Bakery, that display the highest trade effects, have also the largest quantitatively uncertainty of the results. Note that, as highlight by Ghazalian et al. (2007), given the multiplicative relationship between parameters in gravity models, it is not surprising that the biggest estimated impacts also have the larger confidence intervals.

Another interesting feature of these results is that four of the eighteen sectors, have their lower bound estimate of the trade effect closed to zero or even negative, with a variation from two to four times around the core effect. Thus, the analysis appears very useful to investigate the robustness of our findings showing that, i.e, for Macaroni, Sugar, Spirits and Animal feed the trade effect of tariff removal is not robust at all.

6. Conclusions

A key potential of the 'gravity theory' is the possibility to identify the import substitution elasticity between home and foreign varieties, an elasticity that represents the key behavioural parameter for capturing the general equilibrium response of trade flows to falling trade barriers. In this paper, we show that the estimated values of these elasticities are very sensitive to both the level of aggregation in trade data and, especially, the econometric technique. In contrast to the influential paper of Santos Silva and Tenreyro (2006) our results at disaggregated level show that the standard Heckman sample-selection two step estimators, when properly specified, perform well and this appears especially true when the estimated model is used for statistical

[15] Indeed, we observe high sugar export volumes to European countries often associated to import tariffs higher than 100%. This explain also the puzzle of the insignificant value in estimated tariff coefficients used to derive the substitution elasticity (see table 2).

simulation. By contrast, the PPML approach works very well at the aggregate level, but appears dominated by the Heckman procedure at disaggregate level, and often also in term of forecasts performance.

Our substitution elasticity estimates are in the range of the most recent evidence confirming the validity of gravity-like models to identify this important structural parameters. At food industry 4-digit level our preferred substitution elasticity estimates have a mean and median value of 3.69 and 3.26, respectively. Finally we show that a very simple simulation of an hypothetical full trade liberalization scenario produces bilateral trade effects, and their confidence intervals, that are not so far from actual evidence based on more complex approaches, confirming the validity of using gravity models as starting point for counterfactuals. From this point of view, we conclude that more investments in econometric work to estimate the gains from trade liberalization could represent an interesting avenue for future research.

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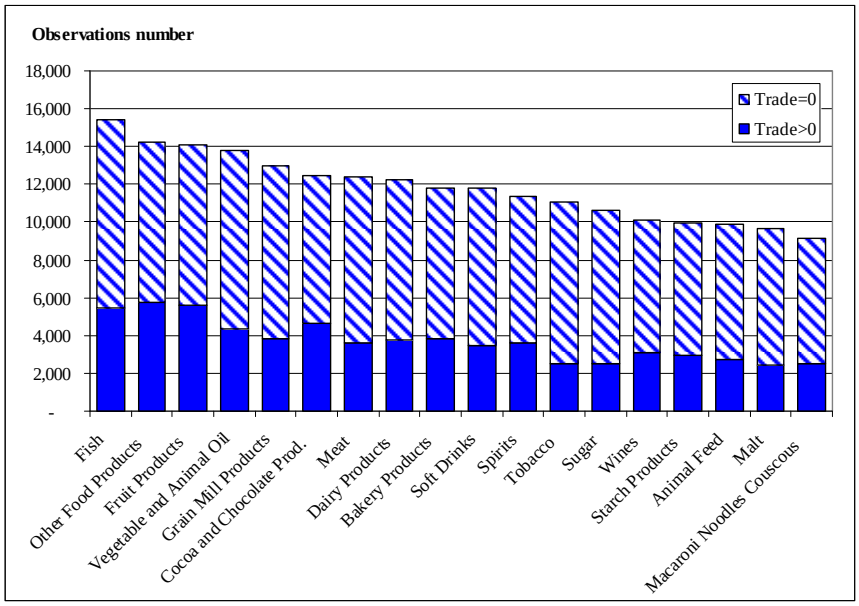

Figure 1. Observations with positive and zero trade flows (4-digit ISIC)

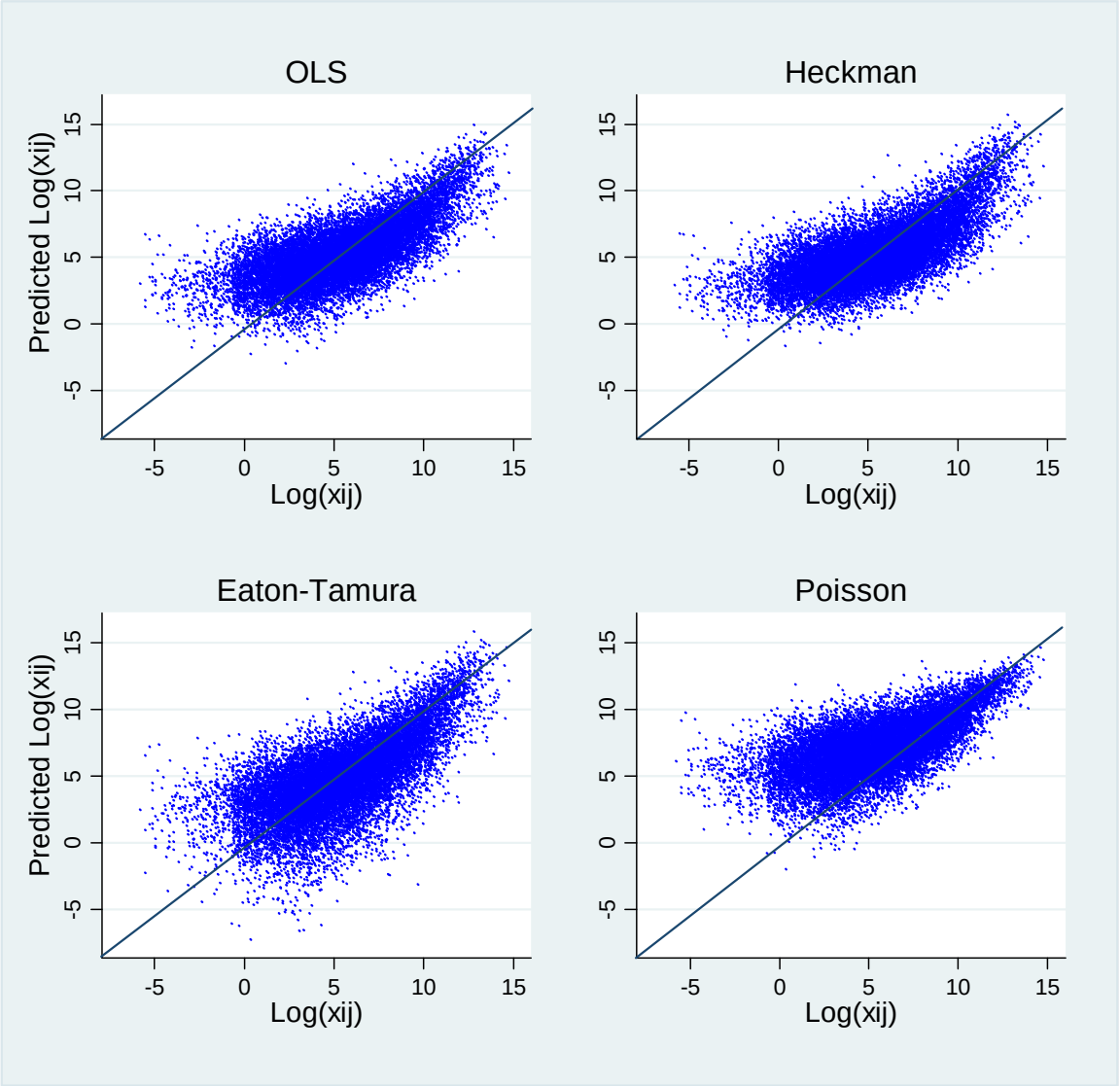

Figure 2. Model fit: actual versus predicted trade flows

Notes: the graphs are obtained from gravity equations of Table 1. The correlation coefficients between actual and predicted values are as follow: OLS (0.709), E-T (0.682), Heckman (0.707), and PPML (0.656).

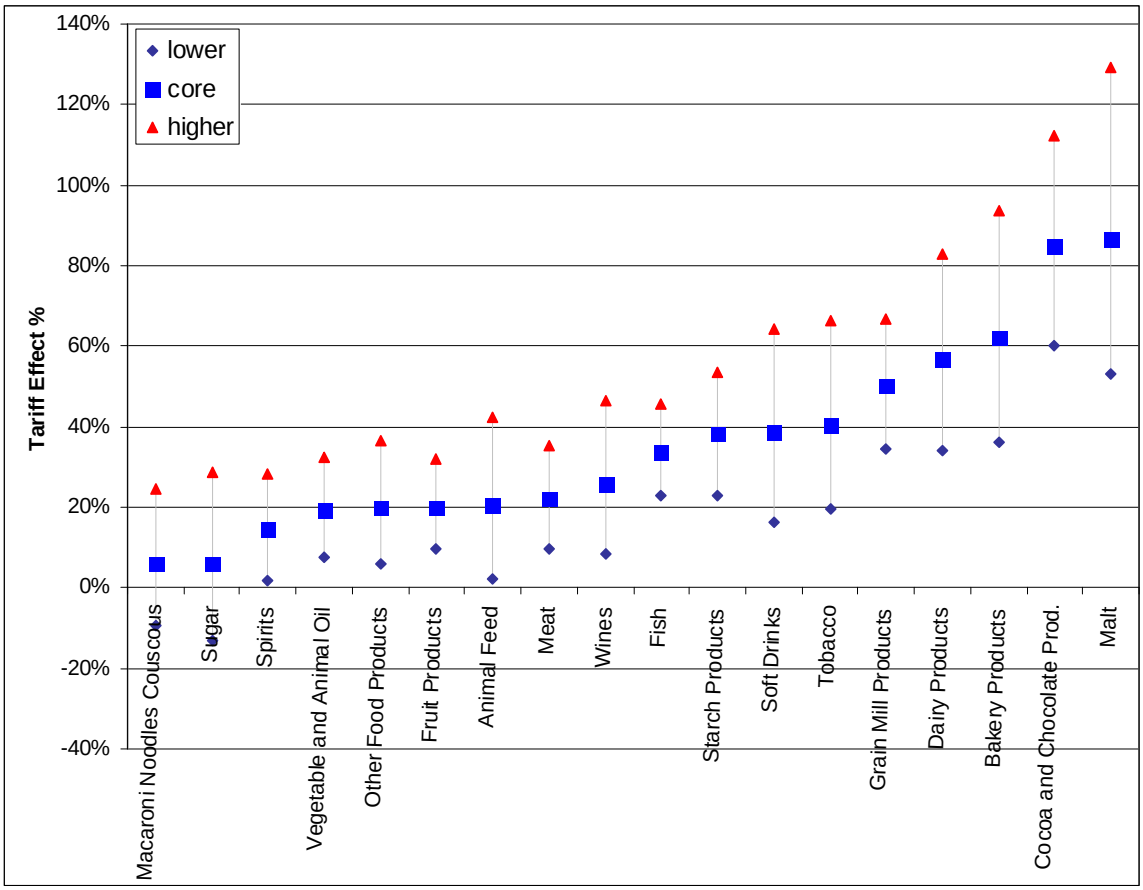

Figure 3. Trade liberalization effects (%) and their confidence interval at 95%. (See text)

Table 1. Gravity Equations Pooled across products

	OLS	***Probit***	**Heckman**	**E-T Tobit**	**PPML>0**
Log(production)i	-0.049	**-0.057**	**-0.073**	**-0.126**	-0.191
	(0.03)	(0.01)	(0.03)	(0.02)	(0.10)
Log (production)j	**0.643**	**0.200**	**0.719**	**0.793**	**0.810**
	(0.03)	(0.01)	(0.03)	(0.02)	(0.06)
Log Distance	**-1.361**	**-0.770**	**-1.604**	**-1.678**	**-1.065**
	(0.06)	(0.02)	(0.09)	(0.03)	(0.07)
Log (1+ tariff)	**-1.561**	**-0.526**	**-1.607**	**-1.550**	**-1.199**
	(0.24)	(0.06)	(0.22)	(0.11)	(0.44)
Common Language	**0.300**	**0.292**		**0.566**	0.244
	(0.15)	(0.05)		(0.07)	(0.13)
Common Border	**1.025**	**0.683**	**1.226**	**0.656**	**0.511**
	(0.13)	(0.09)	(0.14)	(0.08)	(0.14)
Colonial Relationship	**0.768**	**0.843**		**0.893**	0.220
	(0.17)	(0.08)		(0.08)	(0.15)
Common Colonizer	**1.615**	**1.102**	**2.082**	**2.624**	**1.604**
	(0.28)	(0.05)	(0.31)	(0.11)	(0.33)
Mills ratio			**1.123**		
			(0.18)		
A				**2.585**	
				(0.10)	
Observations	16,095	31,105	16,095	31,105	16,095
RESET test p-value	0.000		0.628	0.000	0.892
U-Theil coeff.	0.210		0.209	0.232	0.556

Notes: Exporter, Importer and 3-digit industry fixed effects included in each regression. Marginal effects at sample means reported for Probit. Standard errors in parentheses. Pseudo R-squared reported for Probit and Poisson. Number in Bold (*Italic*) when the significant level is higher than 5% (10%).

Table 2. Substitution Elasticities from Gravity Equation at ISIC 4-digits Level

	OLS	Heckman	E-T Tobit Heterosc.	PPML>0	Obs Trade>0 Tot.trade
Meat	**3.050**	**2.424**	1.016	2.083	3,621
1511	(3.36)	(2.48)	(0.05)	(1.25)	12,389
Fish	**9.190**	**7.128**	**3.266**	**12.540**	5,447
1512	(5.78)	(4.70)	(2.59)	(2.97)	15,445
Fruit Products	**4.234**	**3.132**	**2.420**	**8.695**	5,619
1513	(3.72)	(2.64)	(3.26)	(6.42)	14,122
Vegetable and Animal Oil	**4.766**	**4.129**	**2.614**	2.007	4,373
1514	(2.48)	(2.38)	(1.81)	(0.56)	13,769
Dairy Products	**5.011**	**3.933**	**2.357**	**3.989**	3,728
1520	(5.43)	(4.34)	(3.31)	(4.32)	12,258
Grain Mill Products	**3.700**	**3.382**	**2.332**	**4.590**	3,850
1531	(4.84)	(4.52)	(4.44)	(7.67)	12,969
Starch Products	**4.440**	**3.855**	**2.078**	**3.409**	2,979
1532	(5.53)	(4.77)	(2.61)	(4.62)	9,949
Animal Feed	**4.758**	*3.068*	0.781	*4.007*	2,753
1533	(3.39)	(1.86)	(0.31)	(1.77)	9,901
Bakery Products	**5.187**	**5.417**	**5.655**	**14.160**	3,827
1541	(2.45)	(2.60)	(7.46)	(7.09)	11,793
Sugar	*1.790*	1.214	**0.208**	**3.313**	2,521
1542	(1.94)	(0.52)	(2.05)	(4.28)	10,633
Cocoa and Chocolate Prod.	**7.633**	**7.214**	**6.527**	**14.150**	4,661
1543	(5.70)	(5.87)	(8.83)	(6.31)	12,457
Macaroni Noodles Couscous	1.822	1.507	**2.602**	**6.886**	2,501
1544	(0.82)	(0.50)	(2.47)	(4.80)	9,149
Other Food Products	**3.533**	*3.131*	**2.117**	**8.707**	5,752
1549	(2.14)	(1.85)	(1.96)	(4.02)	14,214
Spirits	**2.401**	2.077	0.566	3.199	3,607
1551	(2.08)	(1.64)	(1.11)	(1.62)	11,374
Wines	**2.791**	**2.448**	**2.183**	**9.448**	3,113
1552	(2.38)	(2.10)	(3.09)	(2.94)	10,076
Malt	**4.916**	**5.605**	**6.485**	**6.717**	2,449
1553	(6.02)	(6.27)	(8.54)	(3.48)	9,691
Soft Drinks	**4.295**	*4.034*	**2.628**	*6.113*	3,449
1554	(1.92)	(1.79)	(2.71)	(1.73)	11,785
Tobacco	**2.539**	**2.692**	**3.426**	**5.387**	2,533
1600	(2.31)	(2.52)	(6.22)	(2.81)	11,094

Notes: The table reports substitution elasticities, and their *t-value*, obtained from the tariff coefficients of the gravity equations. Each regression includes: Exporter and Importer fixed effects, as well as all the variables used in regressions of Table 1. Absolute *t*-statistic in parentheses. The adj R-squared of the OLS regressions range from 0.45 to 0.68. Number in Bold (*Italic*) when the significant level higher than 5% (10%).

Table 3. Trade Liberalization Effect (%) and their Confidence Interval at 95%

Product		Exporter: High Income	Emerging	Developing	World
1511	Meat	24	29	15	22
	[95% Conf. Interval]	[*10* *40*]	[*12* *50*]	[*6* *25*]	[*10* *35*]
1512	Fish	49	49	14	34
		[*32* *68*]	[*32* *67*]	[*10* *19*]	[*23* *46*]
1513	Fruit Products	27	26	10	20
		[*13* *44*]	[*13* *43*]	[*5* *15*]	[*10* *32*]
1514	Vegetable and Animal Oil	25	23	8	19
		[*9* *43*]	[*9* *40*]	[*3* *14*]	[*8* *32*]
1520	Dairy Products	62	64	40	57
		[*38* *90*]	[*39* *93*]	[*25* *56*]	[*34* *83*]
1531	Grain Mill Products	44	72	37	50
		[*31* *59*]	[*49* *100*]	[*26* *50*]	[*35* *67*]
1532	Starch Products	39	51	20	38
		[*25* *54*]	[*32* *73*]	[*13* *27*]	[*23* *53*]
1533	Animal Feed	21	23	13	21
		[*2* *46*]	[*2* *51*]	[*1* *26*]	[*2* *42*]
1541	Bakery Products	70	70	41	62
		[*41* *107*]	[*41* *106*]	[*25* *60*]	[*36* *94*]
1542	Sugar	5	8	6	6
		[*-10* *22*]	[*-17* *41*]	[*-13* *31*]	[*-13* *29*]
1543	Cocoa and Chocolate Prod.	104	103	45	85
		[*71* *143*]	[*70* *141*]	[*32* *59*]	[*60* *112*]
1544	Macaroni Noodles Couscous	7	6	3	6
		[*-11* *28*]	[*-11* *26*]	[*-5* *12*]	[*-10* *25*]
1549	Other Food Products	25	24	13	20
		[*7* *47*]	[*7* *45*]	[*4* *24*]	[*6* *37*]
1551	Spirits	20	16	6	15
		[*3* *41*]	[*2* *33*]	[*1* *12*]	[*2* *28*]
1552	Wines	29	28	17	26
		[*10* *52*]	[*10* *49*]	[*6* *30*]	[*8* *46*]
1553	Malt	124	85	27	87
		[*75* *185*]	[*53* *122*]	[*18* *36*]	[*53* *129*]
1554	Soft Drinks	48	44	25	39
		[*22* *80*]	[*21* *73*]	[*12* *39*]	[*16* *64*]
1600	Tobacco	45	52	26	40
		[*21* *74*]	[*24* *87*]	[*13* *41*]	[*20* *66*]
15-16	*Processed Food (WM)*	*41*	*38*	*17*	*33*

Notes: Tariff effect is calculated using *Clarify* with the Heckman correction second stage procedure for the 18 food sectors (see text). Processed Food is calculated as weighted mean on trade (WM) of single product.

Appendix

Table A.1. RESET test (*p*-value)

	Estimation procedure			
Food industry sector	OLS	Heckman	E-T Tobit	PPML
Meat-1511	0.000	0.064	0.001	0.038
Fish -1512	0.000	0.861	0.001	0.000
Fruit Products-1513	0.000	0.621	0.034	0.200
Vegetable and Animal Oil-1514	0.143	0.036	0.000	0.000
Dairy Products-1520	0.001	0.118	0.041	0.352
Grain Mill Products-1531	0.021	0.961	0.000	0.000
Starch Products-1532	0.005	0.800	0.000	0.978
Animal Feed-1533	0.000	0.569	0.008	0.008
Bakery Products-1541	0.000	0.535	0.030	0.363
Sugar-1542	0.000	0.011	0.000	0.000
Cocoa and Chocolate Prod.-1543	0.000	0.166	0.316	0.698
Macaroni Noodles Couscous-1544	0.000	0.032	0.000	0.002
Other Food Products-1549	0.000	0.062	0.002	0.000
Spirits-1551	0.001	0.132	0.001	0.966
Wines-1552	0.000	0.044	0.562	0.013
Malt-1553	0.163	0.459	0.000	0.000
Soft Drinks-1554	0.003	0.519	0.000	0.064
Tobacco-1600	0.063	0.084	0.000	0.000

See text.

Table A.2. U-Theil statistic

	Estimation procedure			
Food industry sector	OLS	Heckman	E-T Tobit	PPML
Meat-1511	0.3375	0.3358	0.4069	0.4521
Fish -1512	0.3324	0.3309	0.3915	0.4421
Fruit Products-1513	0.3364	0.3386	0.3689	0.3843
Vegetable and Animal Oil-1514	0.3670	0.3678	0.4391	0.5984
Dairy Products-1520	0.3478	0.3453	0.4156	0.4280
Grain Mill Products-1531	0.4033	0.4033	0.4777	0.4151
Starch Products-1532	0.3762	0.3756	0.4317	0.3931
Animal Feed-1533	0.3411	0.3397	0.3957	0.3195
Bakery Products-1541	0.3870	0.3901	0.4363	0.2396
Sugar-1542	0.4455	0.4449	0.7533	0.6243
Cocoa and Chocolate Prod.-1543	0.3568	0.3554	0.4018	0.2981
Macaroni Noodles Couscous-1544	0.4336	0.4372	0.5059	0.2715
Other Food Products-1549	0.3609	0.3555	0.3980	0.4104
Spirits-1551	0.3943	0.3911	0.4770	0.4317
Wines-1552	0.3697	0.3692	0.4548	0.3368
Malt-1553	0.4022	0.4059	0.4700	0.4632
Soft Drinks-1554	0.4272	0.4295	0.4873	0.4318
Tobacco-1600	0.4424	0.4373	0.5840	0.4446

See text.

Table A.3. II Stage Heckman Gravity Equations used in the Simulation

	lnd	lnt	Contiguity	Common colony	Mills ratio	Constant	Observ.	Adjusted R-squared
Meat	**-1.951**	**-1.424**	**0.809**	**1.670**	**1.012**	**10.251**	3,621	0.580
1511	(0.09)	(0.58)	(0.20)	(0.24)	(0.16)	(0.59)		
Fish	**-1.444**	**-6.128**	**1.014**	**1.265**	**1.213**	**10.156**	5,447	0.585
1512	(0.08)	(1.30)	(0.21)	(0.20)	(0.15)	(0.57)		
Fruit Products	**-1.507**	**-2.132**	**1.235**	**1.573**	**0.804**	**8.467**	5,619	0.630
1513	(0.07)	(0.81)	(0.18)	(0.18)	(0.15)	(0.46)		
Vegetable and Animal Oil	**-1.704**	**-3.129**	**0.970**	**0.969**	**0.625**	**9.731**	4,373	0.536
1514	(0.09)	(1.32)	(0.20)	(0.19)	(0.16)	(0.70)		
Dairy Products	**-1.882**	**-2.933**	**1.271**	**1.205**	**1.306**	**8.209**	3,728	0.582
1520	(0.10)	(0.68)	(0.22)	(0.24)	(0.20)	(0.66)		
Grain Mill Products	**-1.701**	**-2.382**	**1.434**	**0.802**	**0.530**	**10.966**	3,850	0.507
1531	(0.11)	(0.53)	(0.24)	(0.26)	(0.16)	(1.07)		
Starch Products	**-1.570**	**-2.855**	**1.162**	**1.337**	**0.706**	**11.189**	2,979	0.568
1532	(0.10)	(0.60)	(0.19)	(0.32)	(0.19)	(0.78)		
Animal Feed	**-1.723**	*-2.068*	**0.966**	**1.224**	**1.220**	**7.122**	2,753	0.535
1533	(0.10)	(1.11)	(0.23)	(0.34)	(0.18)	(0.63)		
Bakery Products	**-2.055**	**-4.417**	**1.570**	**1.377**	**0.838**	**15.954**	3,827	0.593
1541	(0.11)	(1.70)	(0.18)	(0.24)	(0.18)	(0.67)		
Sugar	**-1.755**	-0.214	**0.723**	**0.154**	**1.119**	**11.549**	2,521	0.457
1542	(0.21)	(0.41)	(0.28)	(0.37)	(0.34)	(1.30)		
Cocoa and Chocolate Prod.	**-1.956**	**-6.214**	**0.723**	**1.584**	**1.189**	**10.203**	4,661	0.607
1543	(0.10)	(1.06)	(0.19)	(0.26)	(0.20)	(0.64)		
Macaroni Noodles Couscous	**-1.650**	-0.507	**1.478**	**0.931**	**0.713**	**8.843**	2,501	0.503
1544	(0.13)	(1.01)	(0.24)	(0.26)	(0.21)	(1.29)		
Other Food Products	**-1.862**	*-2.131*	**1.036**	**0.898**	**1.154**	**15.109**	5,752	0.587
1549	(0.09)	(1.15)	(0.18)	(0.18)	(0.18)	(0.65)		
Spirits	**-1.505**	-1.077	**1.201**	**1.896**	**1.237**	**10.113**	3,607	0.565
1551	(0.13)	(0.66)	(0.24)	(0.30)	(0.21)	(0.86)		
Wines	**-1.345**	**-1.448**	**1.096**	**2.658**	**1.427**	**6.401**	3,113	0.662
1552	(0.10)	(0.69)	(0.23)	(0.38)	(0.18)	(0.77)		
Malt	**-1.230**	**-4.605**	**1.845**	**2.066**	**0.467**	**10.569**	2,449	0.521
1553	(0.12)	(0.73)	(0.21)	(0.32)	(0.22)	(0.65)		
Soft Drinks	**-1.560**	*-3.034*	**1.771**	**1.311**	**0.544**	**8.137**	3,449	0.556
1554	(0.09)	(1.70)	(0.19)	(0.25)	(0.13)	(0.56)		
Tobacco	**-1.965**	**-1.692**	**0.886**	**1.933**	**1.506**	**9.648**	2,533	0.512
1600	(0.12)	(0.67)	(0.24)	(0.33)	(0.25)	(1.25)		

Notes: Regressions include: Exporter and Importer fixed effects. Standard errors in parentheses. Number in Bold (*Italic*) when the significant level higher than 5% (10%).

Table A. 4. Countries and Groups considered in the analysis

Developing Countries		
Aruba	Gambia	Oman
Afghanistan	Guinea-Bissau	Panama
Angola	Grenada	Papua New Guinea
Albania	Guatemala	Korea, democratic people's republic of
Netherlands Antilles	Guyana	Paraguay
Armenia	Honduras	Romania
Antigua and Barbuda	Croatia	Saudi arabia
Azerbaijan	Haiti	Sudan
Burundi	Iran (islamic republic of)	Senegal
Benin	Iraq	Solomon Islands
Burkina faso	Jamaica	Sierra Leone
Bangladesh	Kazakhstan	El Salvador
Bulgaria	Kenya	Somalia
Bahrain	Kyrgyzstan	St. Pierre and Miquelon
Bosnia and Herzegowina	Cambodia	Suriname
Belarus	Kiribati	Slovakia (slovak republic)
Belize	Lao people's democratic republic	Swaziland
Bolivia	Lebanon	Seychelles
Barbados	Liberia	Syrian Arab republic
Bhutan	Libyan Arab Jamahiriya	Turks and Caicos Islands
Botswana	Saint lucia	Togo
Central African republic	Sri lanka	Tajikistan
Cote d'Ivoire	Lithuania	Tokelau
Cameroon	Latvia	Turkmenistan
Congo	Moldova, republic of	Tonga
Cook Islands	Madagascar	Trinidad and Tobago
Cape Verde	Maldives	Tunisia
Costa Rica	Marshall Islands	Tanzania, United republic of
Cuba	Macedonia, the former yugoslav republic of	Uganda
Djibouti	Mali	Ukraine
Dominica	Myanmar	Uruguay
Dominican republic	Mongolia	Uzbekistan
Algeria	Mozambique	Saint Vincent and the Grenadines
Ecuador	Mauritania	Venezuela
Eritrea	Mauritius	Virgin Islands (british)
Estonia	Malawi	Viet Nam
Ethiopia	Namibia	Vanuatu
Fiji	Niger	Samoa
Gabon	Nigeria	Yemen
Georgia	Nicaragua	Congo, Dem. Rep.
Ghana	Nepal	Zambia
Guinea	Nauru	Zimbabwe

Emerging Countries	**High Income Countries**	
Argentina	Andorra	Japan
Brazil	Australia	Kuwait
Chile	Austria	Luxembourg
China	Bahamas	Netherlands
Colombia	Belgium	New Caledonia
Czech republic	Bermuda	New Zealand
Egypt	Brunei Darussalam	Norway
Hungary	Canada	Portugal
Indonesia	Cayman Islands	Qatar
India	Cyprus	Singapore
Jordan	Denmark	Slovenia
Korea, republic of	Falkland Islands (Malvinas)	Spain
Morocco	Faroe Islands	St. Helena
Mexico	Finland	Sweden
Malta	France	Switzerland, Liechtenstein
Malaysia	French Polynesia	Taiwan
Pakistan	Germany	United Arab Emirates
Peru	Greece	United Kingdom
Philippines	Greenland	USA
Poland	Hong Kong	
Russian Federation	Iceland	
Thailand	Ireland	
Turkey	Israel	
Southern African Customs Union	Italy	

Group (exporters - importers)	**Food Export**	**Food Import**
Developing (126 - 53)	6.8%	7.8%
Emerging (24 - 20)	25.2%	13.5%
High Income (43 - 26)	68.0%	78.7%
World (193 -99)	100.0%	100.0%