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Missing data in the structural gravity: estimation bias of preferential trade agreements due to the omission of internal trade[#]

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Abstract: In the last decade, there has been an intense development in trade models aiming to explain the determinants of bilateral trade. A seminal theoretical and methodological contribution is Anderson and van Wincoop (2003), who introduced the concept of multilateral resistance and structural gravity. However, there is still an important gap between the theoretical developments of the structural gravity model and its empirical applications. Two main issues come from the presence of zeros in bilateral trade and missing data for internal trade flows (own production oriented to the own market). The presence of zero trade flows has been considered in Santos Silva and Tenreyro (2006) and Helpman, Melitz and Rubinstein (2008). The consequences of omitting internal transactions have not been much studied, even when its relevance may be greater due to a significant heterogeneity across countries' openness. The objective of the paper is to analyze and characterize the consequences from omitting internal trade in the estimation of trade proximities (inverse trade costs) and on the values of multilateral resistances, which in turn will affect the comparative statics effects derived from different trade policy measures.

Key Words: Structural gravity, Zero trade, Missing data.
Codes JEL: F10, F17

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I. Introduction

The gravity model of trade goes back to the contributions of Tinbergen (1962) and Pöyhönen (1963). Despite its high power to explain bilateral trade flows, it was not until Anderson (1979) that the model finds its first theoretical support. During the 1980s and 1990s it is possible to find further contributions (Bergstrand, 1985 y 1989; Deardorff, 1998) aimed at providing theoretical support for a very successful empirical model, but it was not until Eaton and Kortum (2002) and mostly Anderson and van Wincoop (2003)[4] that the gravity model found a strong microeconomic foundation.

In what is now widely known as the "structural gravity model", the main contribution of AvW (2003) is to show that bilateral trade flows depend not only on bilateral trade costs among two countries, but also on what the authors defined as multilateral resistances (MR). The idea behind the concept of MR is that what matters is the bilateral trade cost relative to trade costs with all other countries, either as an exporter or seller (outward MR, OMR) or as an importer or buyer (inward MR, IMR). Also, after AvW (2003) it became clear that the gravity model of trade is a general equilibrium model, where a country's supply (measured by the value of its production) is equal to the sum of all countries' demands of the country's production, including in the later the part of the domestic production that is demanded domestically.

These two characteristics of the structural model meant a challenge for its empirical application. AvW (2003) proposed a nonlinear least squares estimator, while Head and Mayer (2015)[5] developed an iterative estimator imposing the restrictions that arise from the general equilibrium nature of the model (SILS). Earlier, Feenstra (2004) and Redding and Venables (2004) proposed to control for IMRs and OMRs through the inclusion of exporter and importer fixed effects. This strategy greatly simplifies the estimation process, and became a standard practice that popularized the adoption of the structural gravity in empirical applications.

However, the use of importer and exporter fixed effects does not guarantee the fulfillment of the general equilibrium conditions of the model, impeding also the use of

[4] Hereafter AvW (2003).
[5] Hereafter HM (2015).

time-invariant variables that are specific to exporter and importer countries (Hornok, 2012). Another suggestion for empirical applications, the use of country-pair fixed effects has the drawback of rendering impossible including time-invariant variables that are specific to each country-pair (e.g. distance, common language, etc.). This second issue can be recovered using a two steps procedure.

The estimation of the structural gravity model faces two main information problems. First, the zero trade flows, a high proportion of censored observations in which there is no trade between two countries (or because the value is so small that statistics agencies approximate them to zero). Second, information on internal trade is frequently missing since sales of own production in the domestic market are excluded from most world trade databases. As internal trade is usually greater than any bilateral trade flow, this can be seen as a truncation in the right tail of the trade values' distribution.

The zero trade flow problem received two different solutions in the literature. Helpman, Melitz and Rubinstein (2008)[6] proposed a micro founded model with heterogeneous firms (*à la* Melitz, 2003), developing a two-stage estimator where the first stage provides information on the extensive margin and this information is used in the second stage. Instead, Santos Silva and Tenreyro (2006)[7] proposed to use a Poisson Pseudo Maximum Likelihood (PPML) estimator in the model in levels, an estimator that is consistent in the presence of heteroscedasticity and provides an alternative to HMR (2008) on how to handle the zero trade cases. Fally (2015) has shown that the inclusion of exporter and importer fixed-effects makes the SST (2006) estimator satisfy the structural gravity general equilibrium conditions, as derived by AvW (2003).

The missing data problem has received a very scant treatment in the literature. In the theoretical developments of the structural gravity model, internal trade flows are included and treated equally to any flow between two different countries. However, in the empirical applications they are usually left aside, working with datasets in which the observations are omitted.[8] This reveals an important gap between the contributions on

[6] Hereafter HMR (2008).

[7] Hereafter SST (2006).

[8] Trade data between a sample of *C* countries, either at the aggregate level or for a specific sector, can be represented by a square *CxC* matrix in which origin countries are represented in the rows (exports) and

the theoretical foundations of the model on the one hand and the empirical applications based on those models on the other hand.

There are some exceptions, and authors like Dai, Yotov, and Zylkin (2014) or Bergstrand, Larch, and Yotov (2015) do include internal trade flows in their estimations. Recently Baier, Yotov, and Zylkin (2019) pay specific attention to the issue of including internal trade in their study of the impacts of FTAs.[9] The main result is that including internal trade in the estimation should lead to positive, significant and larger coefficient estimates on the effects of free trade agreements (FTA). However, no results are reported about the effect of excluding internal trade flows in the estimation of MRs.

The empirical evidence shows that countries exhibit quite a deal of heterogeneity in terms of the relation between internal trade and total production or consumption of tradable goods. In a groundbreaking contribution, Arkolakis, Costinot, and Rodríguez-Clare (2012) have shown the theoretical relevance of this share, proving that several micro-foundations of the gravity model lead to a common expression for the extent of the gains from trade, which can be expressed as a reduced form that depends on such variable. Moreover, the degree of openness of an economy depends on different variables, such as its size, its geographical location, the magnitude of trade liberalization policies, among other factors.

Thus, missing data are far from being randomly distributed in the sample. Instead, they respond to a determinist pattern with deep theoretical implications. Together with the fact that these flows represent most of the transactions in tradable goods, one can confidently assume that their omission from empirical analysis introduce a bias in the estimated coefficients, as well as in the magnitudes of MR, which in turn call into question the results of any comparative static analysis that might be derived from the estimates.

The aim of our paper is to contribute to the analysis of the effects of missing values, specially looking at the case when the structural gravity model is estimated without information on internal trade. This is important because the omission of the internal

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destinations are represented in the columns (imports). Observations in the main diagonal correspond to internal trade.

[9] Hereafter BYZ (2016).

trade can have significant impacts on the estimated parameters of the model, and so on the values of MR, which are a central piece if we are interested in conducting any static comparative exercise. Additionally, we also provide a new way of interpreting the structural gravity model, viewing it as a relation between the trade network and the network of trade proximities (inverse of trade costs).

II. Model and Methodology

The gravity model can be rationalized from the relationship between two unipartite directional networks of countries $\left(\mathbf{C} = (1, \ldots, c)\right)$. Each network relates nodes by a different type of link: trade flows and proximity. The trade network $\left(\mathbf{N}^T(X, \mathbf{C})\right)$ collects information from the trade flows matrix, which is the adjacency matrix of this network $(X_{c\times c})$. Each link is weighted by the traded value and is oriented: there is an origin node i and a destination node (x_{ij}). Countries' productions $\left(y_i = \sum_j x_{ij} = X\iota'\right)$ and expenditures $\left(x_j = \sum_i x_{ij} = \iota' X\right)$ are centrality indicators in the trade network.[10]

The proximity network $\left(\mathbf{N}^P(\phi, \mathbf{C})\right)$ links the country nodes according to the proximity of node i and node (ϕ_{ij}), admitting the possibility of asymmetric proximities $(\phi_{ij} \neq \phi_{ji})$. Proximity is a (inverse) function of trade cost (τ_{ij}).[11] The gravity model explains links in $\mathbf{N}^T$ (bilateral trade flows) given the nodes' centralities in $\mathbf{N}^T$ (origin's production and destination's expenditure), links in $\mathbf{N}^P$ (inverse trade costs), and centralities in $\mathbf{N}^P$ (multilateral resistances). Multilateral resistances are centrality indicators in the proximity network, since they give a (duly weighted) measure of the average proximity to all partners, both as a seller (Ω_i) and a buyer (Φ_j). Hence, the structural gravity is summarized as:

$$x_{ijt} = S_{it} M_{jt} \phi_{ijt} = \frac{y_{it}}{\Omega_{it}} \frac{x_{jt}}{\Phi_{jt}} \phi_{ijt} \tag{1}$$

[10] Where ι is a *Cx1* vector of ones.

[11] Proximity is related inversely with trade costs $\phi_{ij} = \left(\tau_{ij}\right)^{1-\sigma}$=$\left(1 + t_{ij}\right)^{1-\sigma}$, where $(1-\sigma)$ is the trade elasticity to trade costs, with $\sigma > 1$. If ϕ_{ij} is one then proximity is maximum and trade cost is zero, if ϕ_{ij} tends to zero then the trade cost tends to infinite.

$$\Omega_{it} = \sum_l \frac{x_{lt}}{\Phi_{lt}} \phi_{ilt} \quad (2)$$

$$\Phi_{jt} = \sum_l \frac{y_{lt}}{\Omega_{lt}} \phi_{ljt} \quad (3)$$

OMR for country i (Ω_{it}) is the weighted sum of proximities within the set of buyer markets, as shown in equation (2). The weight is usually called importing capacity (M_{lt}), and is defined as the ratio between the centrality as a buyer (x_{lt}) and the IMR (Φ_{lt}). IMR for country j (Φ_{jt}) is the weighted sum of proximities within the set of providing countries (3). The weight is called export capacity (S_{lt}), and is defined as the ratio between the centrality as a seller (y_{lt}) the OMR (Ω_{lt}).

In the structural gravity model, the OMRs are derived from the condition that the sum of a country's sales to all destinations (including the own market) should equal its total production (seller centrality in $\mathbf{N}^T$). Then it is shown that the OMR depends on proximities (trade costs) to all other nodes, each one characterized by its capacity as a buyer (expenditure over IMR). Similarly, the IMRs are derived from the condition that the sum of what countries buy from all possible origins is total expenditure (buyer centrality in $\mathbf{N}^T$). Then it is shown that the IMR depends on proximities (trade costs) to all other nodes, each one characterized by its capacity as a seller (production over OMR).

AvW (2003) rationalize the gravity model in the framework of monopolistic competition model with product differentiation by origin.

$$x_{ijt} = x_{jt} \left(\frac{\beta_i p_{it} \tau_{ijt}}{P_j} \right)^{1-\sigma}; \qquad \sigma > 1 \quad (4)$$

where $P_{jt} = \left[\sum_i \left(\beta_i p_{it} \tau_{ijt} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$ is a price index of the buyer country j; σ is the elasticity of substitution among varieties in a Dixit-Stiglitz utility function. Using the market clearing condition for supply (centrality restriction) it is possible to show that:

$$x_{ijt} = \frac{y_{it} x_{jt}}{y_t^w} \left(\frac{\tau_{ijt}}{\Pi_{it} P_{jt}} \right)^{1-\sigma} \quad (5)$$

$$\Pi_{it}^{1-\sigma} = \sum_j \varpi_{jt} \left(\frac{\tau_{ijt}}{P_{jt}} \right)^{1-\sigma} \quad (6)$$

$$P_{jt}^{1-\sigma} = \sum_i \theta_{it} \left(\frac{\tau_{ijt}}{\Pi_{it}} \right)^{1-\sigma} \quad (7)$$

where: $\theta_{it} = \frac{y_{it}}{y_t^w}$; $\varpi_{jt} = \frac{x_{it}}{y_t^w}$; and Π_{it} is the seller's price index.[12]

See that the system defined by equations (6) and (7) is an alternative way to specify the gravity model. In this case the average weighted proximity of each node (as a seller and as a buyer) in the $\mathbf{N}^P$ network is a function of the price indices as a seller and as a buyer. If average proximity is high (MR high) then price indices are low and so is bilateral trade (given some bilateral proximity).

Typically the gravity model estimations use three different transformations of variables. First by dividing supply and demand by world supply, both multilateral resistance terms have the scale of a price index. The second normalization is related with trade costs, considering the theoretical restriction that bilateral trade cost factors τ_{ijt} should always be greater than one. Then, trade costs must be divided by own trade costs τ_{iit} (assumed to be the minimum trade cost for each country). As the gravity system is homogeneous of degree zero in trade costs this transformation is inconsequential: estimation can only identify relative trade costs. The third transformation normalizes trade data in terms of the expenditure of one particular country (the one that trades with the largest number of countries is preferred).

III. Empirical Strategy

Two families of empirical approaches emerged after the structural gravity became the conventional practice for modelling trade flows. One controls for import and export capacities using fixed effects, while the other is based on computing IMRs and OMRs for all countries in the sample. The main references supporting the use of fixed effects were already mentioned, and this literature gained relevance in the context of the increasingly used Poisson estimators (SST, 2006). After AvW's (2003) nonlinear estimator, a method to compute MRs was proposed by HM's (2015) Structurally Iterated Least Squares (SILS) estimator. SILS uses the structure of the gravity model to obtain bilateral proximities, which are used to find a fixed point solution to equations (6) and

[12] AvW (2003) refers to Π_{it} and P_{jt} as the OMR and IMR, while here we identify them as $(\Pi_{it})^{1-\sigma}$ and $\left(P_{jt}\right)^{1-\sigma}$, respectively.

(7). The resulting MRs are then used to obtain a new estimation for proximities, and iteration goes on until convergence. We use here a combination of both approaches that was recently proposed by Larch, Wanner, Yotov and Zylkin (2018) in the context of panel data.[13]

LWYZ (2018) develop a procedure that overcomes the computational restrictions that can arise when including bilateral fixed effects. Their method also identifies the existence of bilateral permanent trade frictions, as proximity (ϕ_{ijt}) is split into a permanent component $(\breve{\phi}_{ij})$, and a time-dependent one $(\tilde{\phi}_{ijt})$. The latter is assumed to be mainly related with Preferential Trade Agreement (PTA) effects, so we define $\tilde{\phi}_{ijt} = \exp(\mathrm{b}' w_{ijt})$ where w_{ijt} is a vector of time-varying proximity variables including the existence of an agreement for the bilateral relation in period t. The impact of these variables is measured by vector b, and thus a stochastic version of equation (1) is given by:

$$x_{ijt} = \frac{y_{it} x_{jt}}{y_t^w} \frac{\breve{\phi}_{ij} \exp(\mathrm{b}' w_{ijt})}{(\Pi_{it})^{1-\sigma} (P_{jt})^{1-\sigma}} + \varepsilon_{ijt} \quad (8)$$

The method is iterative as in HM (2015) and in each step it obtains a new PPML estimator. Using the first order conditions of the PPML estimator, LWYZ (2018) estimate the following system:

$$0 = \sum_i \sum_j \sum_t \left[x_{ijt} - \frac{y_{it} x_{jt}}{y_t^w} \frac{\breve{\phi}_{ij} \exp(\mathrm{b}' w_{ijt})}{(\Pi_{it})^{1-\sigma} (P_{jt})^{1-\sigma}} \right] w_{ijt} \quad (9)$$

$$(\Pi_{it})^{1-\sigma} = \sum_j \frac{x_{jt}/y_t^w}{(P_{jt})^{1-\sigma}} \breve{\phi}_{ij} \exp(\mathrm{b}' w_{ijt}) \quad (10)$$

$$(P_{jt})^{1-\sigma} = \sum_i \frac{y_{it}/y_t^w}{(\Pi_{it})^{1-\sigma}} \breve{\phi}_{ij} \exp(\mathrm{b}' w_{ijt}) \quad (11)$$

$$\breve{\phi}_{ij} = \frac{\sum_t x_{ijt}}{\sum_t \frac{y_{it} x_{jt}}{y_t^w} \frac{\exp(\mathrm{b}' w_{ijt})}{(\Pi_{it})^{1-\sigma} (P_{jt})^{1-\sigma}}} \quad (12)$$

Starting from initial guesses for proximities and multilateral resistances, usually a world without trade frictions: $(\Pi_{it})^{1-\sigma} = (P_{jt})^{1-\sigma} = \breve{\phi}_{ij} = 1$, a solution for $\hat{\mathrm{b}}$ is obtained using a PPML estimator in equation (9). Then the system from equations (10)

[13] Hereafter LWYZ (2018).

and (11) is solved, obtaining multilateral resistances.[14] Finally, permanent proximity effects $\breve{\phi}_{ij}$ are calculated using equation (12).[15] The method implies an iterative process, until convergence is achieved, where in each iteration the values of $(\Pi_{it})^{1-\sigma}$, $(P_{jt})^{1-\sigma}$ and $\breve{\phi}_{ij}$ from the previous iteration are used to obtain a new estimation of vector $\hat{\mathrm{b}}$. LWYZ (2018) applied the method in a sample without internal trade, where expenditure is proxied by total imports and production by total exports of each country. In this case they do not impose any restriction to own proximity ϕ_{ii} because there is not internal trade. However this is the same as to impose that $\phi_{ii} = 0$. LWYZ (2018) follow French (2016) in arguing that either approach (with and without internal trade) is compatible with structural gravity.

IV. Dataset

The database presented by Yotov, Piermartini, Monteiro, and Larch (2016) covers the period 1986-2006 and includes three main types of information: aggregated bilateral trade of manufacturing products, geographic variables, and data on PTAs. The distinctive feature of this database is it presents information for the observations in which the origin and destination are the same country.

We performed two important changes to YPML's (2016) database, updating the information until 2014 and improving PTA variables, as detailed hereunder.

The source of trade data for the period 2007-2014 is CEPII's BACI database, including all bilateral trade flows for the 69 countries considered in YPML (2016). BACI is, in turn,

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[14] The following normalization rule is used:

$$\bar{\Pi}_{it}^{1-\sigma} = \Pi_{it}^{1-\sigma} / \left(\sum_i \Pi_{it}^{1-\sigma} \Big/ \sum_i P_{it}^{1-\sigma}\right)^{1/2}$$

$$\sum_i \bar{\Pi}_{it}^{1-\sigma} = \sum_i \left(\Pi_{it}^{1-\sigma} / \left(\sum_i \Pi_{it}^{1-\sigma} \Big/ \sum_i P_{it}^{1-\sigma}\right)^{1/2}\right) = \left(\sum_i \Pi_{it}^{1-\sigma} \sum_i P_{it}^{1-\sigma}\right)^{1/2}$$

$$\bar{P}_{it}^{1-\sigma} = P_{it}^{1-\sigma} \left(\sum_i \Pi_{it}^{1-\sigma} \Big/ \sum_i P_{it}^{1-\sigma}\right)^{1/2}$$

$$\sum_i \bar{P}_{it}^{1-\sigma} = \sum_i P_{it}^{1-\sigma} \left(\sum_i \Pi_{it}^{1-\sigma} \Big/ \sum_i P_{it}^{1-\sigma}\right)^{1/2} = \left(\sum_i \Pi_{it}^{1-\sigma} \sum_i P_{it}^{1-\sigma}\right)^{1/2}$$

[15] Maximum proximity is chosen for each country. In the aggregated version of the model with internal trade: $\phi_{ii} = \bar{\phi}_{ii} = max_j(\bar{\phi}_{ij}) = max_j(\bar{\phi}_{ji})$. Then after the estimation of bilateral permanent frictions in proximity (12), the normalization is $\bar{\bar{\phi}}_{ij} = \frac{\bar{\phi}_{ij}}{\phi_{ii}}$.

based on COMTRADE original data (United Nations Statistical Division), and has three main advantages compared to other possible sources. First, it reconciles the information provided by the exporter and the importer, allowing to considerably reducing the number of missing trade flows. Second, insurance and freight costs are estimated and removed from all the trade values reported, which is a useful feature when estimating gravity models. Third, trade flows are highly disaggregated at the product level, and this enables an aggregation for manufacturing products, as in YPML (2016).[16]

The most challenging issue in updating the data is to find domestic sales of domestically produced manufacturing goods for each of the countries in the sample. This kind of data is reported in some specific databases, but none of them matched our needs. The World Bank's Trade, Production, and Protection database (TPP) is interrupted in 2004, CEPII's TradeProd database ends in 2006, and UNIDO's INDSTAT data has up-to-date information for a country sample that does not have a good matching with YPML's country list.[17] Lacking a suitable source of information, we needed to estimate these values based on the information on trade. The method we use to calculate the values of internal trade for 2010 and 2014 consists of the following steps:

i. We use data on the evolution of manufacturing value added in current dollars for the period 2006 to 2014, and for each of the countries in the sample (World Bank Open Data).
ii. We calculated average growth rates for the period 2006-2010 and for the period 2010-2014.
iii. Assuming that each country's ratio of value added over gross production remains constant, the growth rates are applied to the 2006 production data to obtain the

[16] We follow the standard definition of manufacturing products, encompassing divisions 15 to 37 of the International Standard Industrial Classification (ISIC), Revision 3.1, from the United Nations Statistics Division. Since BACI disaggregates goods using 6 digits of the Harmonized System (HS 2002), the identification of manufacturing products required to apply a product concordance between ISIC and HS, which was taken from the World Integrated Trade Solution website (wits.worldbank.org/product_concordance.html).

[17] Even if INDSTAT has a wide country coverage (166 countries), missing data are widespread and especially prevalent in the most recent years (for this reason we lose ARG, CMR, CHL, ISL, MWI, MMR, NPL, NER, NGA, TTO, and TUN). Moreover, in the case of many small countries we reach a sum of exports to all destinations in CEPII that is greater than the value of manufacturing production reported in INDSTAT, leading to a nonsense negative figure for domestic sales (this problem occurs for BEL, BOL, CRI, CYP, ECU, HKG, IRL, KWT, MAC, MLT, NLD, NOR, PAN, PHL, QAT, SGP, TZA).

values for 2010, then with the second sub-period growth rates we obtain the values for 2014.

iv. Using the values obtained in the previous step, we subtract the value of exports to obtain the values of internal trade.

Information on PTAs in YPML (2016) presents some problems. On the one hand, many country pairs having a PTA are assigned a value of zero, because their estimation strategy identifies the effect of PTA's based on changes of status, so country pairs that had an agreement during the whole period do not contribute to the estimation of PTA effects. On the other hand, their PTA variables signal the existence of agreements for many country pairs in which there is a partial agreement between developing countries (as those existing between the countries of the group of 77). We are not interested in these shallow kinds of agreement, since we want to consider Free Trade Agreements (FTA) or deeper kinds of integration.

In order to solve these problems we use of an alternative source for PTA's, resorting to the most established database on the topic, as is the one recorded by Jeffrey Bergstrand and available in his website (https://www3.nd.edu/~jbergstr/). This database provides information for all the YPML's (2016) countries, but its last version ends in 2012 (April 2017 version). We kept the information on PTAs unchanged for 2013 and 2014. The main variable in Bergstrand's database distinguishes between six levels of economic integration (Non reciprocal PTA, PTA, FTA, Customs Union, Common Market, and Economic Union). We define as having a preferential trade relationship if countries i and j are involved in a FTA, Customs Union, Common Market, or Economic Union.

V. PTA Effects

The way we model proximities between countries, or trade costs, is at the center of the gravity model of trade. Trade costs can be permanent or subject to changes over time. Empirically, permanent trade costs have been identified using bilateral fixed effects, and they can be assumed symmetric or asymmetric. Among time-varying trade costs, the evolution of PTAs has an important role. The most common approach is to assume trade agreements are bilateral, and deep in terms of the coverage of goods and services as well as in terms of the reduction of trade barriers: free trade areas, customs unions, economic unions are different integration schemes considered in the literature. In all these cases, the empirical strategy is the use of a dummy variable that takes the value one if two countries have an agreement, and zero otherwise. As a result, we obtain a measure of trade costs for country pairs having a trade agreement relative to pairs with no agreement or with a shallower one.

The signature of a trade agreement changes the relative costs of trade with different origins (including oneself), which leads to substitution effects known as "trade creation" and "trade diversion". The latter occurs when, for example, an agreement between countries i and j increases trade between each other at the expense of trade with extra-zone countries z. This substitution takes place because the agreement reduces the relative cost of country j importing from country i *vis à vis* importing from country z. Instead, the second type of substitution is between the domestic production sold in the own market and imports from the country the agreement is signed with. In this second case, the signature of a trade agreement means a change in the costs of country j importing from country i *vis à vis* the own production.[18] The outcome of a new trade agreement is a combination of these two effects, which depends on different characteristics such as countries' sizes, the degree of trade complementarity/substitutability between trade partners, etc. However, in the end, what matters is if openness changes or not, if imports increase their share to domestic demand (ratio between imports/expenditure).

In the extreme case of trade diversion, we should not expect that new trade agreements significantly affect the degree of trade openness (exports/production or imports/expenditure). However, it could involve a negative dynamic effect if the level of production/expenditure falls due to the costs of trade protection. On the other extreme, trade creation changes the degree of openness, even if it has almost no effect on the

[18] In a model with monopolistic competition in which each variety is produced by a single firm, neither trade diversion nor trade creation can arise; instead we refer to trade modification. On the one hand, instead of trade diversion we have that varieties imported from z are substituted by the consumption of varieties imported from the new partner i. On the other hand, instead of trade creation, the consumption of domestic varieties are substituted by the consumption of varieties produced by country i.

structure of trade with non-partner countries. In this case the expected dynamic effects are positive and stem from the increased gains from trade.

When omitting internal trade, most empirical applications of the gravity model lack the necessary information to obtain potentially consistent estimates of the effects of PTAs. We argue that as the outcome of PTAs depends on the particular balance between trade creation and trade diversion, the omission of domestic transactions can have important effects in terms of the magnitude of the estimates, in particular providing an underestimation of such effects.

Another issue that the literature has given attention to is the "domino theory of regionalism", proposed by Baldwin (1993). As explained by the author, the rationale behind the domino effect is that when a triggering event happens (e.g., the signature of a new trade agreement), *it harms the profits of nonmember exporters, thus stimulating them to boost their pro-membership political activity. The extra activity alters the political equilibrium, leading some countries to join. This enlargement further harms nonmember exporters since they now face a disadvantage in a greater number of markets. This second round effect brings forth more pro-membership political activity and a further enlargement of the bloc*. Grossman and Helpman (1995) propose instead another framework, in which the decision to sign an agreement is the result of a political game in which the gains derived from the access to the partner's market, which benefit local exporters, are balanced against the losses suffered by import-competing sectors due to the access granted to foreign firms in the domestic market. Grossman and Helpman (1995) describe an equilibrium with trade diversion resulting from the lobby of inefficient exporters located in both countries, and without trade creation, because these sectors are excluded from the agreement to reduce political opposition.[19]

A large body of literature has been inspired by the two previous contributions. Baldwin (2006) also includes the impact that own trade barriers have on access to the partner's market as a result of reciprocal trade liberalization. Exporters can get better

[19] The sectors excluded from the agreement are those that create more trade to the extent that the interests of producers who have the capacity to influence governments are affected. On the other hand, in trade-diverting sectors liberalization tends to be successful, consolidating trade flows. In these sectors, there are no interests of negatively affected producers, but there are the interests of exporters who would benefit from the agreement, and so lobby for it. The ones who pay the costs are the consumers with little or no capacity to put pressure on the definition of trade policy by the government.

access to the partner's market if the country reduces its barriers. Lobbying in favor of a reduction of domestic barriers is a way to obtain lower barriers by the partner country. This process, which he calls the "juggernaut effect", results in a trajectory of liberalization that deepens as tariffs are reciprocally reduced. A similar argument is suggested by Krishna and Mitra (2000), which they call "reciprocated unilateralism". A large country can open up other countries' markets, or manage to include a new trade agreement agenda, if opening its own market changes the political equilibria in the other countries favoring their exporting sectors. The result, again, is a more open equilibrium.

The evolution of the influences of exporting sectors shows the political economy incentives toward a more open trade policy, which should reflect in higher levels of openness. Other complementary trade policies (trade facilitation, special regimes, policies directed to facilitate foreign direct investment, etc.), should then align with the predominance of the exporting sector in the political economy game. All these dynamic effects should be reflected in the effects of PTAs.

One way to proxy this preference for openness is looking at the information regarding the stock of PTAs, which should inform about the level of trade openness granted to other countries as well as openness received from them.

As a final step of this preliminary empirical analysis, we estimate a gravity model using data for our sample of 69 countries and the years 1986, 1990, 1994, 1998, 2002, 2006, 2010, and 2014. In addition to the standard approach of including a dummy variable to control for the existence of a preferential trade relationship, we also include the number of preferential relationships a country has in force in a given year. Also, in line with the theoretical discussion above, we run our model with and without including internal trade observations. The general form of our model is specified as follows:

$$X_{ijt} = exp\Big(s_{it} + n_{jt} + \mu_{ij} + \delta_1 PTA_{ijt} + \delta_2\big[PTA_{ijt} \times NPTA_{it}\big] + \delta_3\big[PTA_{ijt} \times NPTA_{jt}\big] + \delta_4\big(NPTA_{it} \times NPTA_{jt}\big)\Big) \quad (13)$$

where s_{it} is an exporter-time fixed effect, n_{jt} is an importer-time fixed effect, μ_{ij} is a country-pair fixed effect, PTA_{ijt} is a dummy that equals 1 if countries i and j are in a preferential relationship at time t, $NPTA_{it}$ is the number of PTAs country i is involved in at time t (excluding the one that may have with country j), and $NPTA_{jt}$ is the number of PTAs country j is involved in at time t (excluding the one that may have with country i).

As reported in Table 1, when the effect of a PTA on trade is restricted to be homogenous the estimated coefficient is positive, either when internal transactions are excluded (column 1) or when they are included (column 3). However, when internal trade observations are dropped the magnitude of the parameter is much lower (13% of the value obtained when internal trade is included). Typically a PTA implies a reduction in trade costs among members, and so an increase in proximity and trade. This effect results from a substitution from expensive origins to cheaper ones. However, as argued before, a second type of substitution is also expected to take place, that of domestic production by imports coming from the new preferential partners. This second substitution effect is not captured when internal trade is excluded from the sample, and so it is not a surprise the estimated coefficient is lower in that case.

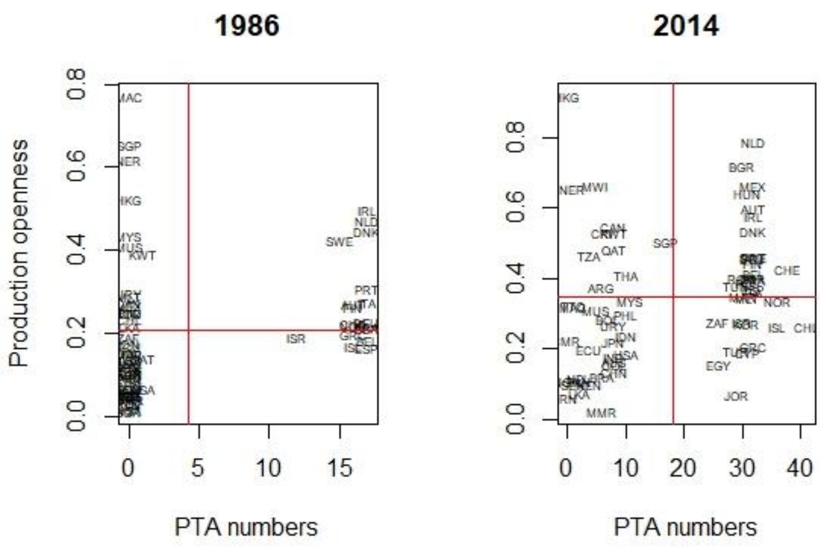
A problem with the baseline specification is that the PTA variable is the only one which is potentially time varying for each country-pair, so it could be capturing the effects of other pair-specific factors that are also varying in time. However, a pattern that emerges clearly from the analysis of the data is that countries with a larger number of PTAs tend to trade more with all countries and not only with those with which they have an agreement.

Having both information on international and internal transactions, we can obtain measures of trade openness. In particular we measure openness in two ways, openness in terms of expenditure as $1 - (internal\ trade\ /total\ expenditure)$, and openness in terms of production as $1 - (internal\ trade\ /\ total\ production)$. Graph 1 relates, across countries, their number of bilateral preferential trade relationships and the degree of openness in terms of production, both in 1986 and 2014. As it is clear, there are two well-differentiated groups. A group with a considerably higher number of PTAs is predominantly composed by the European Union countries. In 1986 our sample had a mean of 4 preferential relationships, and a level of production openness of about 21%, in 2014 the mean of preferential relationships increased to 18 and the level of openness to 34%.

Graph 2 shows that openness in terms of expenditure is positively correlated with openness in terms of production. A higher export specialization of the domestic production is associated with a higher share of imports in the domestic demand. Both at the beginning and at the end of the period the average level of expenditure openness is higher than production openness. In 2014 the average expenditure openness was 43%, significantly higher than the 28% observed in 1986. Between 1986 and 2014 both openness measures experienced an increase, but the rate was higher in terms of production (66%) than in terms of expenditure (49%).

In Graph 2 country names colored in red are those with a number of preferential relationships above the mean. In line with our conjecture, the number of preferential relationships appears to be positively associated to the preference for openness, potentially determined by the interests of exporting sectors in the design of trade policy (defined more broadly than just by the number of preferential relationships).

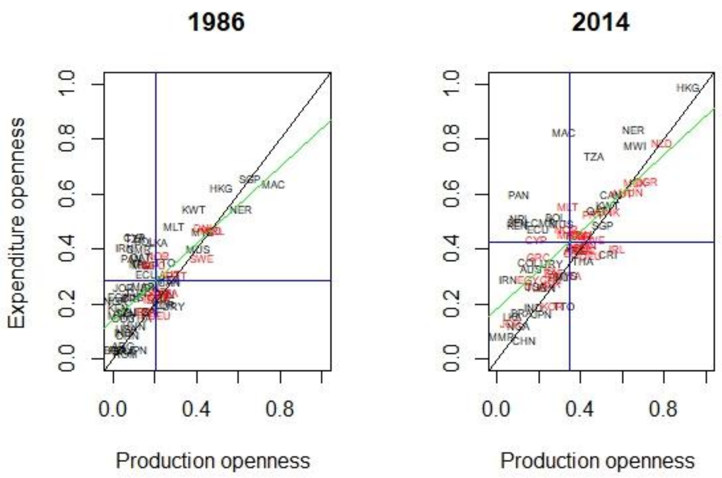
Graph 1: Number of preferential trade relationships and export orientation of production (exports/production) in 1986 and 2014.



Source: Own elaboration based on manufacturing trade database.

To account for these findings, we include the last three regressors in equation (13). Two of them allow the effect of PTAs to vary depending on the number of PTAs each member of the country-pair already signed at a given time. In this specification the effect of a PTA is not only identified by coefficient δ_1, which is the same for all PTAs, but also by δ_2 and δ_3, which capture the heterogeneity of the PTA effects according to the preferences each member has over trade liberalization.[20] Additionally, since countries with more PTAs tend to trade more with all partners regardless of the existence of a bilateral agreement, a third variable is included, defined as the interaction of the number of PTAs each member of the pair has at a given time. A positive estimated coefficient could be understood as a "globalization effect".[21] The results from the complete specification of equation (13) are reported in columns (2) and (4) of Table 1.

Graph 2: Trade liberalization - import penetration (expenditure openness) and export orientation (production openness) in 1986 and 2014



Source: own based on manufacturing trade database.

The direct impact of a PTA, measured by coefficient δ_1, is still lower when internal trade is excluded, but it is much closer to the estimation reached with the full sample. However, estimation of δ_1 alone does not fully capture the marginal effect of PTA on bilateral trade any more. Allowing for heterogeneity in terms of the number of PTAs already signed, the impact of a PTA falls as the countries involved have higher numbers of PTAs in place (coefficients δ_2 and δ_3 are both negative).

[20] Note that the marginal effect of PTA on trade is now equal to $\delta_1 + \delta_2 NPTA_{it} + \delta_3 NPTA_{jt}$.

[21] A usual way to capture the globalization phenomenon is to include a set of year dummy variables that take the value one when i is different form j. However, this option has, at least, two drawbacks. First, it is agnostic with regards to the sources behind the evolution of bilateral trade besides the PTA effect. Second, and more important, they cannot be included when internal trade is excluded from the sample.

Table 1: The effects of PTA effects on bilateral trade (with and without internal trade)

	Without internal trade		With internal trade	
	(1)	(2)	(3)	(4)
$\delta_1(PTA_{ijt})$	0.0541*** (0.020)	0.2521*** (0.031)	0.4138*** (0.036)	0.3285*** (0.067)
$\delta_2(PTA_{ijt} \times NPTA_{it})$		-0.0057*** (0.002)		-0.0046 (0.003)
$\delta_3(PTA_{ijt} \times NPTA_{jt})$		-0.0086*** (0.002)		-0.0071** (0.004)
$\delta_4(NPTA_{it} \times NPTA_{jt})$		-0.0000 (0.000)		0.0011*** (0.000)
Observations	37,376	37,376	37,928	37,928
s_{it}, n_{jt}, and μ_{ij} F.E.	YES	YES	YES	YES

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The effects of the stock of PTAs signed by each partner can be interpreted as a decreasing marginal effect of new PTAs. When using the full sample the fall of the impact takes place at a slower pace (both δ_2 and δ_3 are lower in absolute values). Also, the inclusion of internal trade observations shows that the decreasing marginal effect of PTAs is irrelevant on the side of the exporter (δ_2 loses statistical significance). The negative values we obtain for coefficients δ_2 and δ_3 might be explained by the fact that as the number of PTA a country has increases, there is less scope for a reallocation of trade flows with countries with which there already are preferential agreements toward/from the new preferential partner. However, the lower absolute values of both coefficients when internal transactions are included, could be explained because in this case the new trading partner can still become a substitute for the domestic transactions of the countries involved in the new agreement, on the one hand with the exporter redirecting its domestic production to the new partner, and on the other hand the importing country replacing consumption of its own production with imports from the new partner. Finally, the positive and significant value for the coefficient δ_4 when internal transactions are included is evidence that countries that are more open tend to trade more internationally than with themselves. The number of trade agreements captures the multilateral effect on an MFN basis of signing preferential trade agreements. These agreements, in addition to the preferences themselves, also involve changes that “clean up” trade policy of other instruments that hinder trade. Additionally, the number of agreements reveals a country’s preference for trade openness, and how export interests overcome those of import-substituting sectors. In this sense, they capture the trade preference effect that globalization variables had already identified. The difference is that, instead of being captured as a general trend common across countries, they capture the heterogeneity with which the phenomenon manifests itself at the level of each individual country. This effect is only possible to be captured in the sample with domestic trade, since the substitution shown is between international and domestic trade, therefore it informs about how the degree of trade openness of each country evolves.

A way to look at our results is through the marginal effect of a PTA. Considering our empirical specification we have:

$$\frac{\partial X_{ijt}}{\partial PTA_{ijt}} / X_{ijt} = \delta_1 + \delta_2 NPTA_{it} + \delta_3 NPTA_{jt} \tag{14}$$

In Table 2 we report the evolution of the marginal effects for country pairs that at a given year do not have a PTA.[22] Two results emerge from Table 2. Firstly, the exclusion of internal transactions underestimate the impact of new PTAs, secondly even when in both cases the marginal effects show a declining tendency, which is not surprisingly due to the proliferation of PTAs in the last decades, the decline is less marked when internal transactions are included into the model. Thus, the underestimation due to the omission of internal transactions has increased with time. Once again, this result could be due to the fact that including internal sales allows to account for trade creation effects of the PTAs, while this cannot be capture when the model is estimated using only international trade flows. For instance, considering the average number of preferential trade relationships in 2014, which was 18 for our sample, the marginal impact associated to signing a new trade agreements would be 0.117 when internal trade is included and -0.005 when it is excluded.

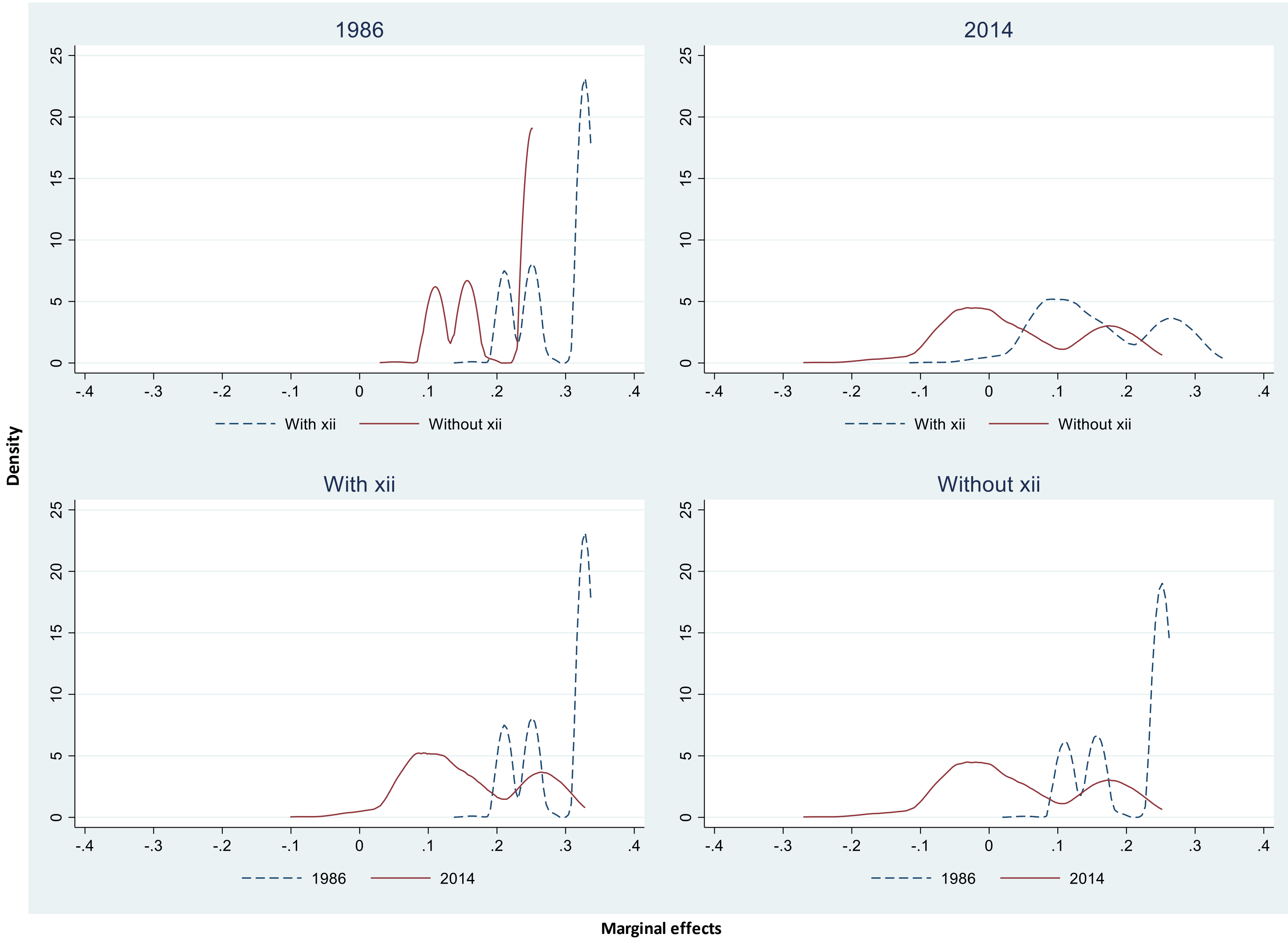
[22] It is important to point out that even when $\frac{\partial X_{ijt}}{\partial PTA_{ijt}} / X_{ijt} = \delta_1 + \delta_2 NPTA_{it} + \delta_3 NPTA_{jt}$ takes into account the heterogeneity of the PTA effects, it is still a partial equilibrium measure, since it does not consider that new PTAs will also have an impact on the multilateral resistances terms, and so also on bilateral flows of countries which are not affected by the new agreements. We deal with this issue in section V.2.

Table 2: Average marginal effects of "new PTAs" on bilateral trade flows (with and without internal trade)

Year	Without internal trade	With internal trade
1986	0.2023	0.2876
1990	0.1981	0.2841
1994	0.1715	0.2623
1998	0.1481	0.2431
2002	0.1145	0.2156
2006	0.0751	0.1833
2010	0.0514	0.1638
2014	0.0455	0.1590

In Graph 3 we report the kernel densities for country pairs without a PTA. When comparing the first and last year of our sample, 1986 and 2014, the general picture that emerges is, as expected, that the distribution of the marginal effects have displaced to the to the left. This is not an odd result given the proliferation of trade agreements that took place during the period covered by our study, and the negative value we obtained for the variables that control for the number of preferential trade relationships (coefficients $\delta_2$and δ_3). Also, and in line with the average values reported in Table 2, the distribution obtained when internal trade is excluded is to the left of the one obtained when internal transactions are taken into account. Since the proliferation of trade agreements has not been homogeneous across countries, marginal effect values show a wider range in 2014 than in 1986. Finally, with fewer countries having agreements in 1986 than in 2014, the distribution shows in the first case higher densities for a few ranges of marginal effects, while in 2014, even though the density function appears bimodal, it is smoother than the obtained for 1986.

Graph 3: distribution of marginal effects for country pairs without a PTA



V.1. Internal trade omission and multilateral resistances

As argued before, the omission of internal transactions should provide a downward biased estimate of the preferential trade agreements, but what are the effects on the magnitude of multilateral resistances.

Leaving aside the error term, when internal transactions are included, exports from *i* to *j* are given by:

$$x_{ijt} = \frac{y_{it}x_{jt}}{y_t^w} \frac{\breve{\phi}_{ij}\exp(\mathrm{b}'w_{ijt})}{(\Pi_{it})^{1-\sigma}(P_{jt})^{1-\sigma}} \tag{15}$$

while when internal transactions are excluded, we have:

$$x_{ijt} = \frac{e_{it}m_{jt}}{e_t^w} \frac{\breve{\phi}_{ij}\exp(\mathrm{b}'w_{ijt})}{(\Pi_{it})^{1-\sigma}(P_{jt})^{1-\sigma}} \tag{16}$$

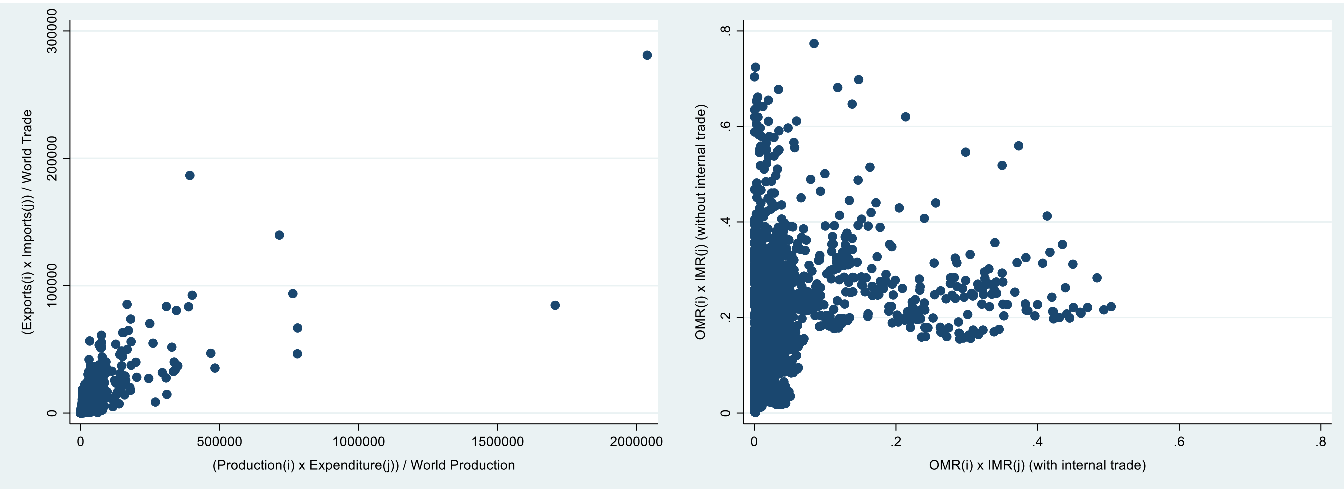
where e_{it}, m_{jt} and $e_t^w (= m_t^w)$ are, respectively, country *i*'s total exports, country *j*'s total imports, and world trade. Since in both cases, the model needs to predict observed values as accurately as possible, any bias in the estimation of vector **b** needs to be compensated by changes in the other parameters of the model $\left\{\breve{\phi}_{ij}, (\Pi_{it})^{1-\sigma}, (P_{jt})^{1-\sigma}\right\}$, as well as to compensate for the differences that may be due to the fact that expenditure and production data is replaced with imports and exports. Graphs 4 to 6 show these very clearly.

On the left of Graph 4 we can observe clearly, for the year 2014, that the for each country-pair we have $\frac{y_{it}x_{jt}}{y_t^w} > \frac{e_{it}m_{jt}}{e_t^w}$. Additionally, this pattern is exacerbated by the differences in the product between multilateral resistances $(\Pi_{it})^{1-\sigma}$ and $(P_{jt})^{1-\sigma}$, which is almost always larger when internal transactions are excluded. A similar way to look at this results is by looking at the products between export and import capacities depending on internal trade is or not considered, once again, as reported in Graph 5, there are important differences.

The question that follows is how these differences translate in terms of the general equilibrium effects of new PTAs. We deal with this issue next.

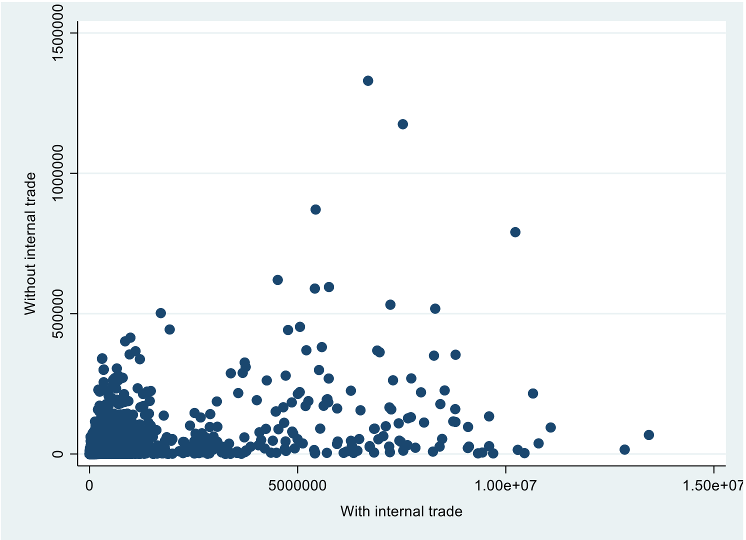
In summary, we can observe that the effects working through the multilateral resistances go in the direction of underestimating the levels of international flows when internal transactions are not included into the model. Then, in order to correctly predict observed flows, the model needs to overestimate the part working through proximities. This is clearly observed in Graph 6. On the left side graph we have that the permanent component of proximity is substantially larger when internal trade is excluded, which in turn translate into larger values of overall proximity (right side graph), even when for most country pairs the time-varying component is larger when internal transactions are included.

Graph 4



Source: own calculations. Data correspond to year 2014.

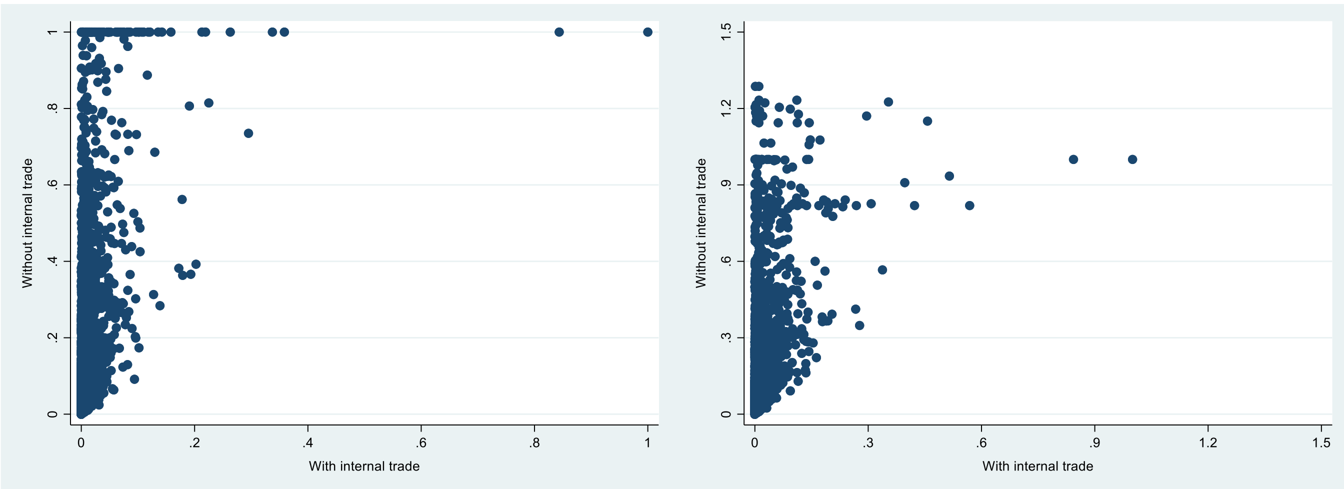
Graph 5: Export and import capacities[23] (with and without internal trade)



Source: own calculations. Data correspond to year 2014.

Graph 6: Permanent and time-varying proximities (with and without internal trade)

Permanent proximity: $\breve{\phi}_{ij}$ **Overall proximity:** $\breve{\phi}_{ij}\exp(\mathbf{b}'w_{ijt})$



Source: own calculations. Data correspond to year 2014.

[23] When internal trade is included, export and import capacities are measured by $y_{it}/(\Pi_{it})^{1-\sigma}$ and $x_{jt}/(P_{it})^{1-\sigma}$, while when excluded they are $e_{it}/(\Pi_{it})^{1-\sigma}$ and $m_{jt}/(P_{it})^{1-\sigma}$. The product of both measures are normalized by world expenditure when internal trade is considered and by world trade when is not.

V.2. Some comparative static exercises

Among the objectives for obtaining consistent and unbiased estimates, is the possibility of being able to provide some advice on the potential effects of alternative trade policies. To quantify the bias induced by the exclusion of internal transactions from the estimation of the structural gravity model, we run three counterfactual scenarios: the Non-Mercosur which assumes that the agreement was not in place in 2014, and the EU-Mercosur and EFTA-Mercosur scenarios, which look at the hypothetical cases that these two agreements were in force in 2014.

As pointed out by HM (2015), a point made by AvW (2003) is that multilateral resistances change when trade costs change. Thus, merely exponentiating the coefficients on dummy variables may not give a reliable estimate of the full impact on trade, moreover AvW (2003) also state that taking into account the changes in multilateral resistances should lead to smaller trade impacts of changes in trade costs. Due to the modular nature of the structural gravity model, holding production and expenditure levels constant, the ratio between the post- and pre-change scenarios is given by:

$$\frac{x_{ijt}^{1}}{x_{ijt}^{0}} = \exp\left(\mathbf{b}'\left(w_{ijt}^{1} - w_{ijt}^{0}\right)\right)\left(\frac{\Pi_{it}^{0}P_{jt}^{0}}{\Pi_{it}^{1}P_{jt}^{1}}\right)^{1-\sigma} \tag{17}$$

where the superscripts 0 and 1 refer to the pre- and post-change scenarios. Given an estimated vector $\hat{\mathrm{b}}$ and of the time-invariant part of trade proximities $\left(\hat{\phi}_{ij}\right)$, the new set of multilateral resistances $\left\{(\Pi_{it}^{1})^{1-\sigma}, \left(P_{jt}^{1}\right)^{1-\sigma}\right\}$ can be obtained by solving the following system:

$$\left(\Pi_{ij}^{1}\right)^{1-\sigma} = \sum_{j} \frac{x_{jt}/y_{t}^{W}}{\left(P_{jt}^{1}\right)^{1-\sigma}} \hat{\phi}_{ij} \exp\left(\hat{\mathrm{b}}' w_{ijt}^{1}\right) \tag{18}$$

$$\left(P_{ij}^{1}\right)^{1-\sigma} = \sum_{i} \frac{y_{it}/y_{t}^{W}}{\left(\Pi_{it}^{1}\right)^{1-\sigma}} \hat{\phi}_{ij} \exp\left(\hat{\mathrm{b}}' w_{ijt}^{1}\right) \qquad (19)[24]$$

[24] In the case of the estimation without internal transactions, countries' production and expenditure and world production, are replaced with countries exports and imports, and world trade, respectively.

Table 3 reports the results from the three exercises in terms of the changes in international transactions within and between different trade blocks. As expected, in the three cases the simulated changes are larger when the model is estimated using internal transactions, moreover, in some cases the omission of such data produce a change with the opposite sign as expected. Another interesting result is that changes in trade flows between country pairs in which one of the countries belong to the new agreement being considered and the other country does not belong, also increases. However this is not always the case when internal transactions are excluded.

Looking individually at the three counterfactual exercises, in the Non-Mercosur case when internal transactions are not used in the estimation of the model, the magnitude of the effect on intra-Mercosur trade is about 50% less than when internal transactions are used. Moreover, the Non-Mercosur scenario would also meant a reduction of trade between Mercosur and the RoW. This result could be explained because if Mercosur had not existed its members would have also been more closed toward other economies, and so trade would have been lower. Instead, excluding internal transactions from the estimation of the model predicts trade would have increased.

For the Mercosur-EU counterfactual, when internal transactions are included in the estimations, the results show an increase in trade flows between country pairs in which one of the countries belong to Mercosur and the other one to the EU. Even when with lower magnitudes, there could be expected an increase of international trade within each of the two original trade blocks, as well as between countries that belong to the new agreement and the ones that are left aside. However, when internal transactions are not take into account at the moment of estimation, the results could take quite different forms. The model would predict a reduction in international trade within each of the original trade blocks, while trade between blocks would increase by much lower magnitudes. A potential reason for the differences in the results is that an agreement between Mercosur and the EU would have a strong component of trade creation, something the model without internal transaction is not able to capture. Another striking difference is that when considering internal sales in the estimation, the model predict an important increase of trade flows between Mercosur and the RoW.

For the case of the Mercosur-EFTA agreement, international transactions between blocks would increase when internal transactions are considered in the estimation, but this would not be the case with exports from Mercosur to EFTA's members if internal sales are excluded. In addition to some differences in the signs of the predicted changes, excluding internal transactions reduces the magnitude of the expected impacts.

In summary, while the inclusion of internal transactions at the moment of estimation provides with effects that are theoretically reasonable, the same is not the case when internal transactions are not considered. And in those cases in which the direction of the effects are the same, including internal transactions at the moment the model is estimated produces, as expected, larger effects.

Table 3. Percentage changes in international trade flows due to counterfactual scenarios (*)

Agreement Mercosur and EU				**Agreement Mercosur and EFTA**				**Non-Mercosur**		
(a) Gravity model with internal transactions										
Destiny	**Origin**			**Destiny**	**Origin**			**Destiny**	**Origin**	
	EU	**MCS**	**RoW**		**EFTA**	**MCS**	**RoW**		**MCS**	**RoW**
EU	10.5	125.2	1.6	**EFTA**	17.5	15.2	4.9	**MCS**	-23.69	-2.33
MCS	90.7	30.4	16.3	**MCS**	38.7	-0.5	3.7	**RoW**	-3.88	0.01
RoW	0.3	45.5	-0.2	**RoW**	4.6	7.4	-0.1			
(b) Gravity model without internal transactions										
Destiny	**Origin**			**Destiny**	**Origin**			**Destiny**	**Origin**	
	EU	**MCS**	**RoW**		**EFTA**	**MCS**	**RoW**		**MCS**	**RoW**
EU	-0.6	3.9	1.3	**EFTA**	-1.2	-5.3	0.1	**MCS**	-11.90	2.03
MCS	7.1	-15.8	0.7	**MCS**	21.1	-2.5	-0.1	**RoW**	3.12	-0.04
RoW	0.8	4.2	-0.3	**RoW**	-0.3	0.8	0.0			

(*) To avoid the influence of estimation errors, percentage changes are calculated using predicted values for the observed (*obs*) and counterfactual (*cf*) scenarios: $\left(\frac{\hat{x}_{ijt}^{cf}}{\hat{x}_{ijt}^{obs}}-1\right)*100$. Source: own based on models (2) and (4) of Table 1.

VI. Conclusions

The gravity model of trade is now well developed on strong theoretical foundations. Similarly, there has been groundbreaking contributions on the development of econometric tools that allow the use a very large sets of fixed effects on nonlinear models, such as the case of the PPML approach pioneered by SST (2006). However, there still an important lag in terms of the availability of suitable data to properly estimate the structural model, this is the case of statistics on internal transactions that are coherent with statistics on international transactions. Because of this issue, it still is standard the estimation of the gravity model relying only on international trade, which as we reported in this research may have important costs in terms of obtaining consistent and unbiased estimates of the parameters of the model, which then in turn translate to into incorrect predictions of the effects of trade policy. These findings require the need for appropriate data for the tasks to be performed, or the development of tools that, based on the general equilibrium nature of the structural gravity model, allow internal transactions to be retrieved from international trade data. This need will acquire more importance as the fragmentation of production moves further, increasing the already large difference between gross and net values.

References

Anderson J. and Yotov, Y. 2010. Specialization: Pro- and Anti-globalizing, 1990-2002. NBER Working Papers, 16301, National Bureau of Economic Research, Inc.

Anderson, J. (1979). A Theoretical Foundation for Gravity Equation. American Economic Review. 69, 106-116.

Anderson, J. and Yotov, Y. 2010a. The changing incidence of geography. American Economic Review, 100, 2157-2186.

Anderson, J. and Yotov, Y. 2010b. Specialization: Pro- and Anti-Globalizing, 1990-2002. NBER Working Paper 14423.

Anderson, J., Milot, C. and Yotov, Y. (2011). The Incidence of Geography on Canada's Services Trade. NBER Working Paper, 17630.

Anderson, J. and van Wincoop, E. 2003. Gravity with Gravitas: A Solution to the Border Puzzle. The American Economic Review, 93, 170-192.

Anderson, J. and Yotov, Y. 2011. Terms of trade and global efficiency effects of free trade agreements, 1990-2002. NBER Working Paper, 17003.

Arkolakis, C., Costinot, A. and, Rodriguez-Clare, A. 2012. New Trade Models, Same Old Gains? American Economic Review, 102, 94-130.

Baier, S., Yotov, Y. and Zylkin, T. 2019. On the widely differing effects of free trade agreements: Lessons from twenty years of trade integration. Journal of International Economics, 116, 206-226.

Baier, S. and Bergstrand, J. 2007. Do free trade agreements actually increase members' international trade? Journal of International Economics, 71, 72-95.

Bergstrand, J. 1985. The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical. The Review of Economics and Statistics, 67, 474-481.

Bergstrand, J. 1989. The Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade. The Review of Economics and Statistics 71, 143-153.

Bergstrand, J., Larch, M. and Yotov, T. 2015. Economic Integration Agreements, Border Effects, and Distance Elasticities in the Gravity Equation. European Economic Review, 78, 307-327.

Dai, M., Yotov, Y. and Zylkin, T. 2014. On the trade-diversion effects of free trade agreements. Economics Letters, 122, 321-325.

Deardorff, A. 1998. Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical Framework? In J. A. Frankel (ed.) The Regionalization of the World Economy, University of Chicago Press: Chicago.

Eaton, J. and Kortum, S. 2002. Technology, Geography, and Trade. Econometrica, 70, 1741-1779.

Fally, T., 2015. Structural Gravity and Fixed Effects. NBER Working Paper, 21212.

Feenstra, R. 2004. Advanced International Trade: Theory and Evidence. Princeton University Press, Princeton, New Jersey.

Grossman, G. and Helpman, E. (1995). The Politics of Free-Trade Agreements. American Economic Review, 85, 667-90.

Head, H. and Mayer, T. 2015. Gravity Equations: Workhorse, Toolkit, and Cookbook. In G. Gopinath, E. Helpman y K. Rogoff (Eds.) Handbook of International Economics, Volumen 4. North Holland: Oxford.

Helpman, E., Melitz, M. and Rubinstein, Y. 2008. Estimating Trade Flows: Trading Partners and Trading Volumes. Quarterly Journal of Economics, 123, 441-487.

Hornok, C. 2012. Gravity or Dummies? The Limits of Identification in Gravity Estimations. CEU Working Papers 2002-11, Department of Economics, Central European University.

Jensen, P. and Yotov, Y. 2011. Agriculture, Gravity and Welfare. Manuscript, Drexel University.

Larch, M., Wanner, J., Yotov, Y. and, Zylkin, T. 2018. Currency Unions and Trade: A PPML Re-assessment with High-dimensional Fixed Effects. Oxford Bulletin of Economics and Statistics, 81, 487-510.

Melitz, M. 2003. The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. Econometrica, 71, 1695-1725.

Pöyhönen, P. 1963. A Tentative Model for the Volume of Trade between Countries. Weltwirtschaftliches Archiv (Review of World Economics), 90, 93-100.

Redding, S. and Venables, T. 2004. Economic Geography and International Inequality. Journal of International Economics 62, 53-82.

Santos Silva, J. and Tenreyro, S. 2006. The Log of Gravity. The Review of Economics and Statistics, 88, 641-658.

Tinbergen, J. 1962. Shaping the World Economy: Suggestions for an International Economic Policy. Twentieth Century Fund, New-York.

Wolf, H. 2000. Intranational Home Bias in Trade. Review of Economics and Statistics, 82, 555-63.

Yotov Y., Piermartini, R., Monteiro, J. and Larch, M. 2016. An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model. World Trade Organization y UNCTAD Virtual Institute. Brookings Institution Press.

Appendix: A (still incomplete) proposal to recover internal transactions

In this appendix we lay out the general steps in order, through an iterative method, recovering the values of internal transactions, starting from the estimation of a model in which they are not available.

The model with internal transactions (w) is:

$$x_{ijt} = y_{it} x_{jt} \frac{\phi_{ijt}^{w}}{\Omega_{it}^{w} \Phi_{jt}^{w}} = y_{it} x_{jt} \frac{\breve{\phi}_{ij}^{w} \tilde{\phi}_{ijt}^{w}}{\Omega_{it}^{w} \Phi_{jt}^{w}} = \frac{y_{it}}{\Omega_{it}^{w}} \frac{x_{jt}}{\Phi_{jt}^{w}} \breve{\phi}_{ij}^{w} \tilde{\phi}_{ijt}^{w} = E_{it}^{w} I_{jt}^{w} \breve{\phi}_{ij}^{w} \tilde{\phi}_{ijt}^{w} \quad \text{(A.1)}$$

where:

x_{ijt} : exports from *i* to *j* at time *t*,

y_{it} : total production of *i* at time *t*,

x_{jt} : total expenditure of *j* at time *t*,

ϕ_{ijt} : total proximity from *i* to *j* at time *t*,

$\breve{\phi}_{ij}$: the constant part of total proximity from *i* to *j*,

$\tilde{\phi}_{ijt}$: the variable part of total proximity from *i* to *j* at time *t*,

Ω_{it} : multilateral resistance of *i* as exporter at time *t*,

Φ_{jt} : multilateral resistance of *j* as importer at time *t*.

The empirical form is:

$$x_{ijt} = \exp\left(s_{it}^{w} + n_{jt}^{w} + \mu_{ij}^{w} + b^{w}{}' w_{ijt}\right) \quad \text{(A.2)}$$

On the other hand, the model without internal transactions (*wo*) is specified as follows:

$$x_{ijt} = e_{it} m_{jt} \frac{\phi_{ijt}^{wo}}{\Omega_{it}^{wo} \Phi_{jt}^{wo}} = e_{it} m_{jt} \frac{\breve{\phi}_{ij}^{wo} \tilde{\phi}_{ijt}^{wo}}{\Omega_{it}^{wo} \Phi_{jt}^{wo}} = \frac{e_{it}}{\Omega_{it}^{wo}} \frac{m_{jt}}{\Phi_{jt}^{wo}} \breve{\phi}_{ij}^{wo} \tilde{\phi}_{ijt}^{wo} = E_{it}^{wo} I_{jt}^{wo} \breve{\phi}_{ij}^{wo} \tilde{\phi}_{ijt}^{wo} \quad \text{(A.3)}$$

where e_{it} and m_{jt} are total exports and imports. The empirical form is:

$$x_{ijt} = \exp\left(s_{it}^{wo} + n_{jt}^{wo} + \mu_{ij}^{wo} + b^{wo}{}' w_{ijt}\right) \quad \text{(A.4)}$$

Step 1:

Using the estimates from (A.4), we obtain the estimated total proximities $\left(\hat{\phi}_{ijt}^{wo}\right)$, and their constant $\left(\hat{\bar{\phi}}_{ij}^{wo}\right)$ and variable $\left(\hat{\tilde{\phi}}_{ijt}^{wo}\right)$ components.

Step 2:

Using estimates of the constant component of the proximities $\left(\hat{\bar{\phi}}_{ij}^{wo}\right)$, we run a gravity-like model:

$$\hat{\bar{\phi}}_{ij}^{wo} = f(...) \quad \text{(A.5)}$$

and then we make out-of-sample predictions for internal proximities $\left(\bar{\phi}_{ii}\right)$.

Step 3:

From the gravity equation is possible to derive the following expression:

$$\left(\frac{x_{ijt}x_{jit}}{\phi_{ijt}\phi_{jit}}\right) = \frac{x_{iit}}{\phi_{ii}}\frac{x_{jjt}}{\phi_{jj}} = \left(\frac{y_{it}}{\Omega_{it}}\frac{x_{it}}{\Phi_{it}}\right)\left(\frac{y_{jt}}{\Omega_{jt}}\frac{x_{jt}}{\Phi_{jt}}\right) \quad \text{(A.6)}$$

So, we construct an auxiliary variable $\hat{x}_{ijt}^{b} = \frac{\hat{x}_{ijt}^{wo}\hat{x}_{jit}^{wo}}{\hat{\phi}_{ijt}^{wo}\hat{\phi}_{jit}^{wo}}$, where $\hat{x}_{ijt}^{wo}$ are the estimated international trade flows. The auxiliary variable is regressed on a sets of dummy variables:

$$\hat{x}_{ijt}^{b} = \exp\left(\eta_{it} + \varphi_{jt}\right) \quad \text{(A.7)}$$

where η_{it} is a dummy variable equal to 1 whenever country *i* is present at time *t*, and φ_{jt} is a dummy variable equal to 1 whenever country *j* is present at time *t*. Because the way $\hat{x}_{ijt}^{b}$ is defined, which means $\hat{x}_{ijt}^{b} = \hat{x}_{jit}^{b}$, in the estimation of (A.7) we uses only half of the sample.

Step 4:

Using the out-of-sample predictions for internal proximities $\left(\bar{\phi}_{ii}\right)$ and the estimates from (A.7), we compute the set of internal transactions:

$$\bar{x}_{iit} = \bar{\phi}_{ii} \exp\left(\hat{\eta}_{it}\right) \qquad \text{(A.8)}^{25}$$

Step 5:

We then combine the internal transactions obtained through (A.8) with the data for international trade flows, and obtain a partially simulated dataset $\left(x_{ijt}^{s}\right)$ that includes internal transactions. We use this dataset to estimate a new gravity equation.

Then, we iterate over steps (1) to (5) until convergence is achieved for the parameters of interest. It is important to note that once the iterations are started, all estimations and other operations are done using the estimates $\left(\hat{\phi}_{ijt}^{s}, \hat{\bar{\phi}}_{ij}^{s}\right)$ and predictions $\left(\hat{x}_{ijt}^{s}\right)$ that emerge from using the partially simulated x_{ijt}^{s} obtained in step 5 of the previous loop.

At the moment of writing this draft, we are still in the process of finding the best way to approximate the values of the internal proximities $\left(\bar{\phi}_{ii}\right)$, which are crucial to achieve the desired convergence. However, in order to look at if our proposal is methodologically sound, we have taken advantage that we have data on internal transactions to obtain a pseudo-observed measure of the border effect, which then help to obtain a more accurate approximation of internal proximities. The process involves the same steps as before, with the exception of step 2, which now is as follows:

[25] From (A.6) and for *i=j*, we have: $\frac{x_{iit}}{\phi_{ii}}\frac{x_{iit}}{\phi_{ii}} = \left(\frac{y_{it}}{\Omega_{it}}\frac{x_{it}}{\Phi_{it}}\right)\left(\frac{y_{it}}{\Omega_{it}}\frac{x_{it}}{\Phi_{it}}\right) = \exp\left(\eta_{it}+\eta_{it}\right)$. Then, solving for x_{iit}, we obtain: $x_{iit} = \sqrt{x_{iit}x_{iit}} = \sqrt{\exp\left(\eta_{it}+\eta_{it}\right)}\sqrt{\phi_{ii}\phi_{ii}} = \phi_{ii}\exp\left(\eta_{it}\right)$.

Step 2 (bis):

Using the estimates from the sample with internal transactions, we define an adjustment factor *f* as:

$$f_{it} = \frac{\hat{\phi}_{ii}^{w}}{\hat{\phi}_{imt}^{w}} \quad \text{(A.9)}$$

where $\hat{\phi}_{imt}^{w} = \max_{j \neq i}\left(\hat{\phi}_{ijt}^{w}\right)$ is the value of the proximity to the closest neighbor for exporter country *i* at time *t*. The interpretation of *f* is none other than the inverse of the border effect, since it measures the relationship between the proximity that a country has with itself and the proximity to its nearest neighbor. Then, $\bar{\phi}_{iit}$ is calculated as follows:

$$\bar{\phi}_{iit} = f\,\hat{\phi}_{imt}^{wo} \quad \text{(A.10)}$$

where $\hat{\phi}_{imt}^{wo} = \max_{j \neq i}\left(\hat{\phi}_{ijt}^{wo}\right)$ is the proximity to the closest neighbor for exporter country *i* at time *t* when the gravity equation is estimated without internal transactions. It is important to note that since the proximity to the closest neighbor can change over time, also can $\bar{\phi}_{iit}$

As before, once we have obtained our first set of internal transactions $\left(x_{iit}^{s}\right)$, in the following iterations all estimations and other operations are done using the estimates $\left(\hat{\phi}_{ijt}^{s}, \hat{\bar{\phi}}_{ij}^{s}\right)$ and predictions $\left(\hat{x}_{ijt}^{s}\right)$ that emerge from using the partially simulated dataset obtained in step 5 of the previous loop. The only exemption is the adjustment factor *f* which is kept constant at each iteration.

As reported in Table A.1, starting from a good first guess of the internal proximities helps the process to approximate to the true values of the parameters of interest.

Table A.1

	With x_{iit}	Without x_{iit}	Iterations				
			1	2	3	4	5
$\delta_1(PTA_{ijt})$	0.3285	0.2521	0.2260	0.3815	0.3658	0.3584	0.3571
$\delta_2(PTA_{ijt} \times NPTA_{it})$	-0.0046	-0.0057	-0.0088	-0.0091	-0.0078	-0.0073	-0.0073
$\delta_3(PTA_{ijt} \times NPTA_{jt})$	-0.0071	-0.0086	-0.0111	-0.0114	-0.0094	-0.0090	-0.0090
$\delta_4(NPTA_{it} \times NPTA_{jt})$	0.0011	0.0000	0.0012	0.0013	0.0012	0.0011	0.0011