UMR 225 IRD - Paris-Dauphine

DOCUMENT DE TRAVAIL DT/2015-02

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Joaquim GUILHOTO
Jean-Marc SIROËN
Ayçil YÜCER

UMR DIAL 225
Place du Maréchal de Lattre de Tassigny 75775 • Paris Cedex 16 •Tél. (33) 01 44 05 45 42 • Fax (33) 01 44 05 45 45
• 4, rue d'Enghien • 75010 Paris • Tél. (33) 01 53 24 14 50 • Fax (33) 01 53 24 14 51
E-mail : dial@dial.prd.fr • Site : www.dial.ird.fr

THE GRAVITY MODEL, GLOBAL VALUE CHAIN AND THE BRAZILIAN STATES

Joaquim GUILHOTO
Department of Economics, FEA,
University of São Paulo,
NEREUS and CNPq Scholar
guilhoto@usp.br

Jean-Marc Siroën
PSL, Université Paris-Dauphine,
LEDa, IRD UMR DIAL, 75016 Paris, France,
Universidad Javeriana Cali, C. 18 # 1-18, Cali
jean-marc.siroen@dauphine.fr

Ayçil Yücer
University of Dokuz Eylül,
Department of Economics, Izmir 35160 Turkey
PSL, Université Paris-Dauphine,
LEDa, IRD UMR DIAL, 75016 Paris, France
ayicily@gmail.com

Document de travail UMR DIAL
Janvier 2015

Abstract

The WTO and the OECD along with many other organizations, suggest trade in value-added is a "better" measuring system than gross value in order to better understand the impact of trade on employment, growth and production . When it comes to the "domestic" value chain and internal specializations, internal trade statistics are rarely available. In this work we use a gravity model based on the estimation of exports of the Brazilian states, considered as trade entities, both in traditional terms of gross value and in terms of value-added. Our method is based on an Input-Output table for 2008. The results of the bilateral gravity model for the Brazilian states' exports show that the main determinants (GDP, distance etc.) are fairly similar when exports are estimated in gross or value-added terms.

Key words: Vertical Specialization, Global supply-chain, Input-Output Analysis, Brazil, Intra-national trade.

Résumé

L'OMC et l'OCDE ainsi que de nombreuses organisations internationales, suggèrent que l'évaluation du commerce en valeur ajoutée est «meilleure» que celle en valeur brute car elle permet de mieux saisir l'impact du commerce sur l'emploi, la croissance et la production. Quand il s'agit de la chaîne de valeur "domestique" les statistiques commerciales internes sont rarement disponibles. Dans ce travail, nous utilisons un modèle de gravité qui estime les exportations des États brésiliens, considérés comme des entités commerciales, à la fois en termes traditionnels de valeur brute et en termes de valeur ajoutée. Notre méthode est basée sur une table d'entrées-sorties pour 2008. Les résultats du modèle de gravité pour les exportations des États brésiliens montrent que les principaux déterminants du commerce (PIB, distance, etc.) ont des élasticités similaires lorsque les exportations sont estimées en valeur brute ou en valeur ajoutée.

Mots Clés : Spécialisation verticale, chaîne globale de valeur, analyse Input-Output, Brésil, Commerce international.

JEL Code : F12, F14, F15, F63, R12, R15

I. Introduction

Trade is commonly evaluated in gross terms whereas the contribution of exports to exporting country's growth, employment and balance of trade depends solely on the content in domestic value-added. Due to the increasing fragmentation of the "international supply chain", countries are now specialized in "tasks" (design, assembly, transport, distribution, etc.) rather than in goods (cars, computers, etc.). For example, if China is perceived as being specialized in exports of laptops, the country is, in fact, far more specialized in the assembly of the final product that results in imports of technology and components.

The value of goods exported by a country may thus be divided into imported and domestic value-added and here we have several indications for certain specific goods. For example, the 1998 WTO Annual Report estimated that a mere 37% of the production value of a typical American car was generated in the US. More recent case studies are available on the iPod, iPhone and iPad, the Nokia N95 (Yrkkö *et al.*, 2011), and even … Barbie dolls (WTO-IDE-JETRO, 2011; Maurer *et al.*, 2010; World Economic Forum, 2012). However, this measurement of import content in specific exported goods cannot be generalized to aggregate the total import content of exports either across the industry as a whole or the entire country or region. International input-output tables are commonly used as indirect measurements of the import or domestic value content of exports (for example, Hummels *et al.*, 2001). Indeed some international organizations are currently supporting the making of international input-output matrices based on the method introduced by Leontief (see OECD-WTO, 2012).

At the same time, the gravity model, frequently used in empirical analyses of international trade, is becoming debatable in the light of the evolution in the "international supply chain". The model estimates trade in terms of gross value and hence ignores the share of import content in exports, which is not at all the same for all countries. Moreover, demand concerns not only final consumption, but also intermediate consumption. This raises questions about the use of the importer's GDP as a demand indicator in the model (Baldwin & Taglioni, 2011).

Brazil's rate of trade openness is low compared to other large emerging countries such as China. The domestic value-added content of Brazilian exports is probably higher (or the import content lower) as the Brazilian states specialize in tasks in the early stages of the supply chain, such as producing raw materials, while China is specialized in the final stages (assembly) of the production process (Koopman *et al.*, 2008). Brazil's poor performance in terms of openness does not imply a low level of specialization through the domestic supply chain. Considering the high heterogeneity of Brazilian regions in terms of natural resources, location and factor endowment, there is room for large specialization differences throughout Brazil.

The purpose of this article is to correctly estimate the determinants of the Brazilian states' external trade, whose structure also depends on the inter-state trade structure, notably the domestic value chain. We estimate the Brazilian states' gross exports to the rest of the world, first using a bilateral gravity model inspired by a traditional approach and then new measurements of exports in value-added terms. Section II develops the theoretical and empirical implications of the move from trade in gross value to trade in value-added. Section III specifically focuses on gravity models applied to the Brazilian states' exports. Section IV compares the results given by the gravity model when we alternately use exports in gross value and exports in value-added. We show that when we control the model correctly, results are quite comparable.

II. Trade Analysis and Dynamics of "Domestic" Vertical Specialization

The Made in the World Initiative (MiWi) launched by the WTO is sub headed *A Paradigm Shift to Analyzing Trade*. Gene Grossman and Esteban Rossi-Hansberg (2006) highlight a change in the structure of trade and call it "trade in tasks". The increasing dominance of task specialization over product specialization has many implications that may be interpreted as a "paradigm shift" though the phenomenon is not exactly new.

Two events explain why, only in recent years, international institutions have turned their attention to the practical repercussions of this trend in international trade statistics and their interpretation[1]:

1) The collapse of international trade from mid-2008 to mid-2009 dramatically amplified the worldwide recession. For example, in just nine months[2] exports fell by 38% in the World and a massive 53% in China. One explanation for this is that vertical specialization results record the value-added of a component several times in trade statistics, i.e. each time it crosses the border for use in a new stage of the production process. In this case, a $100 drop in national exports in the final product could cause a drop of $200, $300 or more in world exports[3].
2) The proliferation of case studies which explains the origin of the value-added of specific final goods exported outward also reveal very surprising results. These case studies find a spectacularly weak share of domestic value-added in the value of national exports. The most striking case was probably the iPod 30 gigabit valued at US$300 in the United States, previously exported by China for US$150, but with a Chinese value-added focused on assembly tasks of just US$4 (Dedrik *et al.*, 2009).

The phenomenon is defined more precisely by Hummels *et al.* (1998) as, "*Vertical specialization occurs when a country uses imported intermediate parts to produce goods it later exports". Thus, three conditions need to be held:

(1) Goods must be produced in multiple sequential stages.
(2) Two or more countries have to specialize in producing some but not all stages.
(3) At least one stage must cross an international border more than once.

Although the definition of Hummels *et al.* (1998) explains vertical specialization as a specific pattern of international trade, its dynamic is also at work in domestic markets which are characterized by their relatively good trade integration, favorable to the components trade. Under the classical assumptions of traditional trade theories, with factors of production being perfectly mobile inside national markets, endowments are uniform in space. If that were true, all the regions in a country would have similar product and/or task specialization and a company would gain nothing, except face extra costs from splitting up the production chain across the country.

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[1] For example, WTO&IDE-JETRO published a report on the issue in 2011. The Organization of Economic Cooperation and Development supports the position of the World Trade Organization (WTO) in this area (OECD-WTO, 2002) with the publication of new estimations of trade in value added (TiVA) in May 2013.
[2] WTO statistics.
[3]See, for example, Escaith *et al*. (2010)

However, neither production factors nor goods markets are really "perfectly" integrated, and a country's regions may differ in terms of their specializations and production costs. Trade in tasks (or vertical specialization) may therefore occur inside a country when differences in its regions' factor endowments and/or production technology give them the comparative advantage in a specific task. This is especially true for developing and emerging markets, such as Latin American countries, India and China, where regional differences are considerable. Yet, this internal dimension of specialization, driven by trade openness, has not been studied in depth as international organizations prioritize inter-country vertical specialization.

Lastly, trade in tasks is expected to occur relatively more in the exporting sectors of a country, since the gain from economies of scale is another important factor, leading to the proliferation of large plants, clusters or Special Economic Zones dedicated to exports of goods and services coming from highly specialized tasks. Meanwhile, intra-country vertical specialization may also occur in a closed economy where internal demand is large enough to benefit from economies of scale. In this case, trade openness may be a further incentive to broaden this type of specialization and create a dual dynamic of domestic vertical specialization.

Previously used cross trade measures, which are quite suitable in the context of "horizontal" specialization, are becoming more and more unreliable in a world where the final good is produced in more than one country or more than one geographic location, as in the case of intra-country trade. In particular, bilateral trade balances measured in gross trade terms provide very little information on the supply or demand side and hence raise questions about the gravity model. Measuring trade using the "value-added" approach enables us to approximate the true origin of exports. This may also be used to determine the value-added contribution at each stage and hence track the value chain right through to the end of the production process.

III. Gravity model and Global Value Chain

Incidentally, the recognition of vertical specialization prompts a series of questions on the consistency of conventional statistical tools and/or on the general concepts of trade literature, including the gravity model. The notion of "home" or "origin" of goods is dissociated from the notion of "exporter" and the notion of "destination" from "importer". Gross export values no longer reflect the competitiveness of the exporting entity, but the entire product chain, especially when the exporter is situated at the final step of the production process. The use of bilateral gross trade statistics is not appropriate for demand side analysis, since exports to the import country are driven mostly by the demand of third countries.

The intermediate goods trade ("middle products" in Sonyal and Jones, 1982; "multi-stage production" in Dixit and Grossman, 1982; "vertically related markets" in Spencer and Jones, 1989) has been discussed at length especially from the view of "effective protection". However, only recently, has gravity modeling of the intermediate goods trade become of interest. As mentioned in Yi (2010), "*In reality, most goods are produced in multiple, sequential stages. …., the single stage assumption is not taken to be literally true; rather, the production function can be thought of as a reduced-form amalgam of a multiple, sequential stage process. However, the maintained assumption is that the nature of production, the mapping of production stages to regions, for example –is invariant to changes in trade costs*". He calibrates a multi-stage production model and estimates a gravity model with calibrated trade flows over trade costs. The multi-stage model explains border effects better than the one-stage model by controlling the multiple times intermediate goods bear trade costs during their exportation.

Egger and Bergstrand (2010) show, by means of a general equilibrium theory, bilateral final goods trade flows, intermediate trade flows and FDI flows are all driven by a “common process” and the impact of key economic determinants (GDPs and friction) is similar for the final and intermediate goods trade between developed countries (sample of 24 OECD countries). Moreover, their empirical model also gives comparable results for trade between non-OECD countries. Egger and Egger (2005) also estimate a gravity model of the intermediate goods trade between 12 European countries.

According to Baldwin and Taglioni (2011), standard specification performs well when data is pooled from a wide range of countries, as for many, trade in intermediate goods is proportional to trade in final goods. However, when intermediate goods trade is high, GDPs only loosely reflect the structure of trade. In their gravity model estimates for Asian countries, Baldwin and Taglioni (2011) find the interactive term of GDPs with the intermediate goods trade share has a negative and significant impact. This result explains the smaller explanatory power of GDP values on the intermediate goods trade. On the other hand, the interactive term of "distance variable" with the intermediate goods trade share shows a higher impact of distance on the intermediate goods trade. Trade volumes depend on, in the theoretical and empirical work of Basher and Westbrock (2014), an entire network structure of trade connections. In other words, the intermediate goods trade between two countries “*increases in the size and productivity of a third country and declines in each of the two countries trade costs to it*”. They call this relation “gravity” of a third country which finally contradicts the common theoretical literature of the final goods trade where third country “gravity”, or in traditional terms, lower multilateral resistance, decreases bilateral trade (Anderson and van Wincoop, 2003).

The gravity model, in its standard form, is derived from a consumer expenditure system in which the price term is eliminated using the general equilibrium structure of the theoretical model. In Anderson and van Wincoop (2003), the demand for the products of *i* by entity *j*, derived by maximizing the CES utility function of the consumer *j*, is as follows:

$$x_{ij} = \left(\frac{\beta_i p_i t_{ij}}{P_j}\right)^{1-\sigma} Y_j \qquad \textbf{(1)}$$

where p_i is the supply price of i, t_{ij} the iceberg trade costs and P_j the consumer price index in *j*. The aggregate exports of *i* to all partners *j* are equal to the total output of *i:*

$$Y_i = \sum_j x_{ij} \qquad \textbf{(2)}$$

The above market clearance condition is then used to eliminate the relative price term (p_i) in expenditure equation (1). The equilibrium prices are then:

$$(\beta_i p_i)^{1-\sigma} = \frac{Y_i}{\sum_j (t_{ij}/P_j)^{1-\sigma} Y_j} \qquad \textbf{(3)}$$

Hence, trade from *i* to *j* in equilibrium is:

$$x_{ij} = \frac{Y_i}{\Omega_i}\left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} Y_j \qquad \textbf{(4)}$$

Where,

$$\Omega_i = \sum_j \left(t_{ij}/P_j\right)^{1-\sigma} Y_j \qquad \textbf{(5)}$$

The above model relies on the assumption that the products exported from *i* to *j* are produced solely in *i*. In empirical gravity literature, x_{ij} is measured as the gross exports of *i* to *j*, while Y_i is measured on a value-added basis by the GDP of entity *i*. However, under vertical specialization, the origin of the value-added and the exporter of the goods are no longer the same and the volume of aggregate gross exports is much higher than the amount of domestic value-added due to the import content of exports or, in other words, intermediate goods imported and re-exported after being processed. Another problem in the theoretical model concerns the measurement of *j*'s expenditure. The model assumes that the demand of *j* is for final consumption. Therefore, *j's* expenditure is its total income, which again is measured by the GDP of entity *j*. However, if *j* is not the final demand market, but is solely the point where the goods are transformed before being re-exported, then *j's* GDP does not reflect its expenditure on imported goods.

As discussed by Baldwin and Taglioni (2011), GDP can be used to measure gross output provided the import content of exports is similar across entities and over time. This is understandable since, in this case, the ratio of imported intermediate goods in exports may be considered as a constant in econometric estimations as long as it is fixed for the whole sample. Nevertheless, trade relation dependencies are not uniform across countries and world trade today is characterized by a varied range of trade in tasks among trade partners. Furthermore, trade in intermediate goods has grown sharply in recent years.

The studies presented above use either calibrated data or gross intermediate goods trade volumes where data is available. Thankfully, nowadays, we have better statistics to trace the value chain. Bilateral trade flows, estimated on net value, are corrected incidentally for the statistical bias created by the multiple accounting of imported intermediate goods and components embodied in exports. In this way, we can understand the supply and demand side determinants of trade, such as the "revealed" competitiveness and comparative advantages of geographic entities that participate at different stages of production. The estimates in VA also illustrate that estimated trade in tasks is different from trade in final goods and if this is so, the gravity model suffers from a bias when estimated in gross trade terms.

IV. Model and Data

We aim to measure the impact of exporter state characteristics on their exports assuming an inter-state vertical specialization. However, we would first like to estimate the structure of the Brazilian states' gross exports with the rest of the worlds' by using a traditional gravity approach in cross section. To this end, we have taken the exports of 27 states with 81 countries in 2008 (see Appendix 3).

In Model I, we take up the proposal put forward by Baldwin and Taglioni (2011) and replace traditional gravity variables (GDP and Remoteness) with exporter and importer fixed effects, which include the influence of determinants specific to each country and considered in previous studies to be a good proxy of "multilateral resistance". We then estimate the following bilateral trade equation which should provide a "benchmark" model for the Brazilian states' trade structure under the assumption of inter-state vertical specialization:

$$\ln X_{sj} = \beta_0 + \beta_1 \ln D_{sj} + \beta_2 Cont_{sj} + \alpha_s + \alpha_j + \varepsilon \qquad \textbf{Model Ia}$$

where X_{sj} is gross exports from exporter state s to destination country j, $\ln D_{sj}$ is the natural logarithm of the bilateral distance and $Cont_{sj}$ is a dummy variable as a control for a common border between state s and partner country j. α_s and α_j are, respectively, the exporter fixed effects of the state s and importer fixed effects of country j. Model Ia then assumes that the characteristics of the production chain are satisfactorily controlled by fixed effects as being specific to the exporter s and to the importer j. This structure should provide a better measurement of the impact of bilateral distance on bilateral gross exports.

Model Ia assumes that impact of bilateral variables (distance, contiguity etc.) on the intermediate goods trade is similar to their impact on the final goods trade (Yi; 2010). However, the impact of gravity estimates of distance on the intermediate goods trade shows evidence to the contrary (Baldwin and Taglioni; 2011). Empirically, this bias may occur, for example, if vertical specialization is more probable between close trade partners[4]. We therefore expect to get higher export values between close partners since they are not solely trading for final consumption but also for re-export. In this case, if vertical specialization is not controlled for, the impact of the bilateral distance variable will be overestimated since the real destination of the gross exports is, in part, another more distant country. However in this structure, exporter-importer fixed effects being collinear with unilateral characteristics (GDP, landlocked, etc.), it is impossible to estimate the impact of exporter and importer idiosyncratic characteristics on trade.

Another way of solving the disassociation between the origin of exported goods and the exporter is to find another measurement of trade focusing on the origin of exports. This means dropping the value-added originating in other states, otherwise included in the gross exports from state i to country j. These values are calculated using the Inter-State Input-Output Table for 2008. In Model Ib below, we construct the benchmark model by replacing the gross measures of trade with value-added exports.

$$\ln V_{sj} = \beta_0 + \beta_1 \ln D_{sj} + \beta_2 Cont_{sj} + \alpha_s + \alpha_j + \varepsilon \qquad \textbf{Model Ib}$$

Model Ib is similar to Model Ia , the only difference being the dependent variable which is not gross exports, but the value-added produced and exported by state s to destination country j (V_{sj}).

In Model II and III, we assess the impact of idiosyncratic characteristics on trade by introducing unilateral variables instead of fixed effects. We continue to estimate each model in gross trade terms (IIa and IIIa) and value-added terms (IIb and IIIb) in order to understand if the estimates in value-added terms differ from the estimates in gross terms.

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[4]For example, according to Wolf (1997) due to the spatial non-linearities of transaction costs the production of tasks will be spatially concentrated, instead of being spread out geographically, and trade in intermediate goods will take place among close entities.

Model II includes exporter characteristics while keeping, as before, importer fixed effects. Model IIa estimates the exporter state characteristics as if it is the "origin" of the gross export value. However Model IIa, in gross trade terms, does not control for the domestic vertical specialization of the Brazilian states with their supplier states. Then, we estimate Model IIb with the exported value-added of states s (value-added produced and exported by the states s) to destination countries j (V_{sj}):

$$\ln X_{sj} = \beta_0 + \beta_1 \ln D_{sj} + \beta_2 Cont_{sj} + \beta_3 \ln GDP_s + \beta_4 \ln R_{sj} + \beta_5 LL_s + \alpha_j + \varepsilon \quad \textbf{Model IIa}$$

$$\ln V_{sj} = \beta_0 + \beta_1 \ln D_{sj} + \beta_2 Cont_{sj} + \beta_3 \ln GDP_s + \beta_4 \ln R_{sj} + \beta_5 LL_s + \alpha_j + \varepsilon \quad \textbf{Model IIb}$$

where X_{sj} denotes gross exports from Brazilian exporter state *s* to destination country *j*, and V_{sj} the value-added produced and exported by state *s* to destination country *j*. GDP_s is the gross domestic product of state *s*. LL_{sj} is a dummy variable whose value is one when state *s* is landlocked. Importer characteristics, as well as their role in the production chain from importer country *j* onwards until the final destination (the consumption market), are controlled with importer fixed effects (α_j). R_s is the remoteness of state *s* from the rest of the world ($m \neq j$, aside from its partner country *j*). This is measured in keeping with Head (2003) by[5]:

$$R_{sj} = 1/\sum_{m \neq j} [GDP_m / D_{sm}]$$

The higher R_{sj}, the more distant state *s* from importer countries *m* ($m \neq j$) and other states *s* and/or the closer to countries and states whose *GDP*s are relatively small. The more remote the state, the higher trade can be expected to be between *s* and its partner *j* since exporter state *s*'s access to other markets is limited. The inverse is also plausible when trade is in intermediate goods as the better access of state *s* to third markets can increase trade between *s* and *j*.

Model III goes further to estimate exporter and importer characteristics without any fixed effects.

$$\ln X_{sj} = \beta_0 + \beta_1 \ln D_{sj} + \beta_2 Cont_{sj} + \beta_3 \ln GDP_s + \beta_4 \ln R_{sj} + \beta_5 LL_s + \beta_6 MIG_{sj} + \beta_7 \ln GDP_j + \beta_8 \ln R_{js} + \beta_9 LL_j + \varepsilon$$

Model IIIa

$$\ln V_{sj} = \beta_0 + \beta_1 \ln D_{sj} + \beta_2 Cont_{sj} + \beta_3 \ln GDP_s + \beta_4 \ln R_{sj} + \beta_5 LL_s + \beta_6 MIG_{sj} + \beta_7 \ln GDP_j + \beta_8 \ln R_{js} + \beta_9 LL_j + \varepsilon$$

Model IIIb

Where MIG_{sj} is a dummy variable which controls for the immigration and language links of the Brazilian states with their partner countries (See Appendix 4). $\ln(R_{js})$ is calculated reciprocally to the remoteness index $\ln(R_{sj})$.

[5] We have also tested the model with a remoteness index calculated in line with McCallum (1995). However, the results do not differ a lot.

Model III, even when estimated in value-added terms (Model IIIb) cannot control the product chain on the importer side as a result of our methodology in calculating states' exported value-added.[6] Unfortunately, our methodology does not trace the final destination. It will return biased estimates when the importer country imports intermediate goods to export to a third country. However, we believe Model IIIb has useful insights on the comparability of the models' estimates in value-added and in gross value.

We estimate the three models above in cross-section for 2008. For the purpose of comparison, we use two types of estimator: Ordinary Least Square (OLS) and Pseudo Poisson Maximum Likelihood (PPML), which have been widely used in literature since Santos Silva and Tenreyro (2006). The PPML model is a better tool for estimating gravity models in the way it deals with the model's existing estimation bias due to heteroskedasticity in trade data. Another advantage of PPML is that the model estimates the gravity equation in its multiplicative form and hence better deals with zero trade values. The log-linearization procedure in OLS returns zero trade values for missing data points, which can cause a bias when they are not random.

National GDP values are given in current dollars and are drawn from the World Bank's *World Development Indicators* database. GDP values for the Brazilian states are provided by the IBGE (*Instituto Brasileiro de Geografia e Estatística)* in local currency units. They are converted into current dollars by applying the exchange rate taken from WDI. The distance variable is calculated using the geographical coordinates of the capitals of the states and the countries as provided by the *World Gazetteer* website.

The Brazilian inter-state input-output system for 27 regions (26 states and the Federal District) for 2008 was estimated based on a combination of different sources of data and methodologies. We first explain the data available in order to estimate the Brazilian input-output table and then address the construction of the inter-state input-output system.

The most recent input-output system released by the Brazilian Statistical Office (IBGE) refers to 2005 (IBGE, 2008). However, using the information available in the Brazilian System of National Accounts (IBGE, 2010) and the methodology presented by Guilhoto and Filho (2005) (2010), we can estimate an input-output system for 2008 (see Yücer *et al.*, 2014 and appendix 1). The estimated national input-output system was then used as the basis to estimate the inter-state system for Brazil based on the methodology presented in Guilhoto and Filho (2010).

Table 1 shows the results for the benchmark gravity model with dependent variables: the states' bilateral gross exports (Model Ia) and bilateral exported value-added (Model Ib). For ease of reading, we present the models that are similar in terms of their explanatory variables side by side. The third column assesses the χ^2 statistics value in order to test the zero hypothesis of equality of coefficients estimated for gross exports and for value-added exports. We follow the methodology of Clogg, Petkova and Haritou (1995) which tests the equality of variables when they are estimated separately from two different samples. In our estimations, we also use two samples of dependent variable, namely samples of gross exports and value-added exports.

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[6] See Yücer *et al.*, 2014.

Table 1: Benchmark model with Exporter and Importer fixed effects

Model:	(Ia)	(Ib)	(Ia) *vs.* (Ib)	(Ia)	(Ib)	(Ia) *vs.* (Ib)
	Gross Exports	**Value-added**	***Test of Equality***	**Gross Exports**	**Value-added**	***Test of Equality***
Estimator:	***OLS***	***OLS***	***H0***	***PPML***	***PPML***	***H0***
ln D_{sj}	-0.307	-0.259	$\chi^2(1) = 2.49$	-0.833	-0.768	$\chi^2(1) = 0.40$
	[0.337]	[0.328]	$Prob > \chi^2 = 0.114$	[0.338]**	[0.386]**	$Prob > \chi^2 = 0.526$
$Cont_{sj}$	1.027	1.031	$\chi^2(1) = 0.00$	-0.399	-0.418	$\chi^2(1) = 0.03$
	[0.662]	[0.630]	$Prob > \chi^2 = 0.944$	[0.422]	[0.511]	$Prob > \chi^2 = 0.874$
Constant	13.887	13.145		19.333	18.400	
	[2.986]***	[2.913]***		[2.995]***	[3.414]***	
Exporter fixed effects	Yes	Yes		Yes	Yes	
Importer fixed effects	Yes	Yes		Yes	Yes	
Observations	1692	1670		2187	2187	
R-squared	0.64	0.64				

*Robust standard errors are in parentheses: All inferences are based on a Huber-White sandwich estimate of variance. Pseudo R^2 in the table is calculated for PPML estimates by McFadden's Pseudo R^2 and are not comparable with OLS R^2. ***p<0.1; **p<0.05; * p<0.01*

Estimates for Model Ia – with Distance and Contiguity variables – are shown in the first and fourth column of the table, the former in OLS and the latter in PPML. In keeping with research literature, both estimators show that bilateral distance drives down the states' gross exports to countries. The contiguity impact is not significantly different from zero and has different signs under OLS and PPML.

In Model I, the distance variable is larger in absolute terms when estimated by PPML and is significant at 1%. It is smaller and non-significant when estimated by OLS. This may appear surprising at first since the PPML estimator, compared to OLS, generally estimates a smaller impact of bilateral distance on exports. In our sample, however, as the Brazilian states are very close to each other and thus have similar distances from the rest of the world, the bilateral trade barriers vary more by importer country than by exporter state and are hence taken into account, in part, by the importer fixed effects. Apparently, PPML better manages to isolate the impact of bilateral distance from the importer fixed effects while OLS estimates a smaller impact of distance on exports. This may be explained by the PPML estimator's ability to solve the bias due to the heteroskedasticity in the data.

For each estimator (OLS and PPML), equality test results comparing Model Ia and Model Ib are given in a third column. We fail to reject the null hypothesis which assumes the equality of coefficients and this result holds for both estimators (PPML or OLS). The impact of the distance variable is the closest to being significantly unequal when estimated in gross exports and value-added. However the probability of failure by rejecting the hypothesis of equality is more than 10% ($Prob > \chi^2 = 0.114$).

Table 2 presents the gravity estimates of exporter characteristics (GDP, landlocked etc.) for Model IIa and IIb, differently from Table 1 where we have exporter fixed effects. Results show that the PPML estimator is once again more in line with literature. All variables show the expected signs. The landlocked variable also has an expected negative sign but not significantly different from zero. Remoteness has a positive impact as expected and χ^2

statistics show that the remoteness impact is similar in gross and value-added terms. The distance variable estimate by PPML shows a slightly smaller impact for the model with exported value-added (IIb *versus* IIa).On the contrary, the GDP impact is slightly higher as highlighted by Baldwin and Taglioni (2011). However, the test of equality of coefficients shows that the coefficient estimates are not significantly different between Model IIa and Model IIb.

Table 2: Impact of Exporter Characteristics

Model:	**(IIa)**	**(IIb)**	**(IIa) *vs.* (IIb)**	**(IIa)**	**(IIb)**	**(IIa) *vs.* (IIb)**
	Gross Exports	**Value-added**	***Test of Equality***	**Gross Exports**	**Value-added**	***Test of Equality***
Estimator:	**OLS**	**OLS**	***H0***	**PPML**	**PPML**	***H0***
ln GDP_s	1.330	1.312	$\chi^2(1) = 2.44$	0.915	0.923	$\chi^2(1) = 0.20$
	[0.069]***	[0.068]***	$Prob > \chi^2 = 0.118$	[0.052]***	[0.058]***	$Prob > \chi^2 = 0.654$
ln R_{sj}	6.686	6.496	$\chi^2(1) = 1.32$	2.164	1.878	$\chi^2(1) = 0.56$
	[0.948]***	[0.951]***	$Prob > \chi^2 = 0.25$	[1.134]*	[1.284]	$Prob > \chi^2 = 0.453$
LL_s	-0.132	-0.174	$\chi^2(1) = 2.46$	-0.018	0.020	$\chi^2(1) = 1.25$
	[0.130]	[0.131]	$Prob > \chi^2 = 0.116$	[0.135]	[0.153]	$Prob > \chi^2 = 0.263$
ln D_{sj}	0.001	0.042	$\chi^2(1) = 1.01$	-0.704	-0.657	$\chi^2(1) = 0.29$
	[0.348]	[0.335]	$Prob > \chi^2 = 0.315$	[0.292]**	[0.296]**	$Prob > \chi^2 = 0.593$
$Cont_{sj}$	1.732	1.674	$\chi^2(1) = 0.26$	-0.199	-0.300	$\chi^2(1) = 1.39$
	[0.700]**	[0.637]***	$Prob > \chi^2 = 0.612$	[0.382]	[0.392]	$Prob > \chi^2 = 0.238$
Constant	143.853	138.817		56.712	48.957	
	[23.156]***	[23.191]***		[26.338]**	[29.642]*	
Exporter fixed effects	No	No		No	No	
Importer fixed effects	Yes	Yes		Yes	Yes	
Observations	1692	1670		2187	2187	
R-squared	0.51	0.52				

*Robust standard errors are in parentheses: All inferences are based on a Huber-White sandwich estimate of variance. Pseudo R^2 in the table is calculated for PPML estimates by McFadden's Pseudo R^2 and are not comparable with OLS R^2. ***p<0.1; **p<0.05; * p<0.01*

In Model III, we estimate the model without exporter and importer fixed effects in order to make a detailed comparison of the determinants. Table 3 shows the results.

Table 3: Impact of Exporter and Importer Characteristics

Model:	(IIIa)	(IIIb)	(IIIa) *vs.* (IIIb)	(IIIa)	(IIIb)	(IIIa) *vs.* (IIIb)
	Gross Exports	**Value-added**	***Test of Equality***	**Gross Exports**	**Value-added**	***Test of Equality***
Estimator:	**OLS**	**OLS**	***H0***	**Poisson**	**Poisson**	***H0***
ln GDP_s	1.366	1.344	$\chi^2(1) = 3.94$	0.982	0.975	$\chi^2(1) = 0.20$
	[0.068]***	[0.067]***	$Prob > \chi^2 = 0.047$	[0.064]***	[0.070]***	$Prob > \chi^2 = 0.655$
ln R_{sj}	5.183	5.024	$\chi^2(1) = 1.43$	0.539	0.586	$\chi^2(1) = 0.02$
	[0.855]***	[0.861]***	$Prob > \chi^2 = 0.232$	[1.059]	[1.327]	$Prob > \chi^2 = 0.885$
LL_s	-0.082	-0.124	$\chi^2(1) = 2.29$	-0.007	0.032	$\chi^2(1) = 0.76$
	[0.134]	[0.135]	$Prob > \chi^2 = 0.13$	[0.163]	[0.187]	$Prob > \chi^2 = 0.382$
ln D_{sj}	-0.631	-0.637	$\chi^2(1) = 0.06$	-0.956	-0.917	$\chi^2(1) = 1.17$
	[0.120]***	[0.120]***	$Prob > \chi^2 = 0.805$	[0.191]***	[0.198]***	$Prob > \chi^2 = 0.279$
$Cont_{sj}$	1.995	1.875	$\chi^2(1) = 1.31$	0.289	0.121	$\chi^2(1) = 5.26$
	[0.677]***	[0.620]***	$Prob > \chi^2 = 0.252$	[0.393]	[0.392]	$Prob > \chi^2 = 0.022$
MIG_{sj}	0.741	0.743	$\chi^2(1) = 0.00$	0.221	0.242	$\chi^2(1) = 0.38$
	[0.209]***	[0.212]***	$Prob > \chi^2 = 0.950$	[0.196]	[0.203]	$Prob > \chi^2 = 0.539$
ln GDP_j	0.677	0.691	$\chi^2(1) = 4.39$	0.658	0.659	$\chi^2(1) = 0.00$
	[0.043]***	[0.043]***	$Prob > \chi^2 = 0.036$	[0.118]***	[0.152]***	$Prob > \chi^2 = 0.969$
ln R_{js}	0.118	0.089	$\chi^2(1) = 1.73$	0.208	0.202	$\chi^2(1) = 0.03$
	[0.111]	[0.110]	$Prob > \chi^2 = 0.188$	[0.152]	[0.175]	$Prob > \chi^2 = 0.869$
LL_j	-0.453	-0.456	$\chi^2(1) = 0.01$	-0.413	-0.539	$\chi^2(1) = 3.42$
	[0.340]	[0.336]	$Prob > \chi^2 = 0.916$	[0.296]	[0.318]*	$Prob > \chi^2 = 0.064$
Constant	99.529	94.684		8.682	8.700	
	[20.526]***	[20.687]***		[25.195]	[31.729]	
Exporter fixed effects	No	No		No	No	
Importer fixed effects	No	No		No	No	
Observations	1692	1670		2187	2187	
R-squared	0.45	0.45				

*Robust standard errors are in parentheses: All inferences are based on a Huber-White sandwich estimate of variance. Pseudo R^2 in the table is calculated for PPML estimates by McFadden's Pseudo R^2 and are not comparable with OLS R^2. ***p<0.1; **p<0.05; * p<0.01*

Contiguity ($Cont_{sj}$) and Landlocked variables (LL_s and LL_j) are not significant at 5% but have expected signs. Sharing a common border increases the gross exports and value-added exports between exporter state s and the importer country j. Migration variable (MIG_{sj}) increases trade but its impact is not significant. The remoteness variable of s increases slightly when the model is estimated in value-added by PPML while the remoteness of j indicates the inverse. Table 3 highlights the fact that the variable estimates are still very similar (we do not reject the equality of coefficients) estimated in value-added or in gross terms[7].

These results reinforce the idea that, in this specific case, trade in intermediate goods and final goods is driven by a similar process (Bergstrand and Egger, 2010) and when the sample countries are large enough, the gravity model works well (Baldwin and Taglioni, 2011). Another point is the very special trade structure of the Brazilian states. As shown in Yücer *et al.* (forthcoming), the Brazilian states' exported domestic value-added share and gross exports share in total Brazilian exports are similar.

V. Conclusion

Our work discusses the implications of the "new trade paradigm" – reflected in the geographical fragmentation of the production process– in the traditional statistical and empirical trade analysis tools and, specifically, in the gravity model. We take a theoretical approach to show that measuring exports in value-added terms might be more appropriate for gravity model estimates and this model should therefore be extended as a control for the multilateral nature of vertical specialization.

We use the Brazilian Inter-State Input-Output table for 2008, to calculate states' value-added directly and indirectly via other states. The results of the bilateral gravity model for the Brazilian states' value-added exports are very similar to the traditional estimates in gross terms. The coefficients for distance and remoteness are smaller and less significant when their impact is estimated for exported value-added. However, the test of equality of coefficients emphasizes the similarity of two models (model of value-added exports and gross exports). These findings are not contradictory with the findings of literature. However, they need to be interpreted with care because this sample only covers Brazilian states' exports. We must therefore be very cautious in generalizing this evidence of similarity.

Brazil is one specific case of a country specialized in primary goods which "mechanically" leads to similar values between the two export measures. This stance does not mean that Brazil is not concerned by vertical specialization, but processing activities are mainly oriented to the supply of goods to the domestic market instead of foreign markets (see also Yücer *et alii*, 2014). The structure of this model, where the exporters comprise uniquely the Brazilian states, amplifies the consequences of the Brazilian specificity on our results.

[7] As discussed above due to the limitations of our methodology; states' exported value-added is not calculated for the final destination country but for the apparent importer. We are aware that even the model estimated in value-added (Model IIIb) will include some bias in the estimation of importer characteristics.

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Appendix 1 -Estimating the Inter-State Input-Output System for Brazil for 2008

The steps followed for the estimation of the inter-state system for Brazil can be summarized as follows (see Yücer & *alii*, 2014):

- Using information from the IBGE surveys of Agriculture, Industry, Trade, Transport, Services, and Civil Construction, a first estimate is made of total output of 56 industries and 110 commodities for each of the Brazilian states;
- These initial estimates are then balanced to match the total output of 17 industries presented in the Brazilian Regional Accounts (IBGE);
- These output estimates are also used to estimate the supply tables for each of the Brazilian states. The states' supply tables are estimated in such a way as to be consistent with the national supply table;
- The tax, imports, and the input-output system's final demand components are estimated for the 56 industries for each of the Brazilian states, which are also consistent with the value-added components in the national input-output table[8].
- Using cross-industry location quotients for intermediate consumption and simple location quotients for final demand, a first estimation is made of flows of goods and services between the Brazilian states;
- Using the work done by Vasconcelos and Oliveira (2006), which estimates the flow of goods between Brazilian states for 1999, and taking into consideration the growth of the states from 1999 to 2008, a second estimation is made of flows of goods and services between the Brazilian states;
- The third and final estimation of flows of goods and services between the Brazilian states is made taking into consideration the following: a) the inter-state input-output system should be consistent with the national table; b) the change in inventories should be zero when they are zero in the national table; c) the change in inventories in each state, when related to the total output of the corresponding sector should be in a range no greater than 30% of this relation found in the national table;
- The third estimation produces a commodity-by-industry inter-state input-output system for Brazil. The supply tables for each of the states are then used to obtain the industry-by-industry inter-state system used in this work.

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[8]Sources and information are: imports and exports by state: Ministry of Development, Industry and External Trade; tax collection in each state, government spending: Ministry of Finance and the State Secretaries of Finance, IBGE; payments to workers by industry and state: Ministry of Labor and IBGE Household Survey; household spending: *Household and Household Consumption Patterns surveys*; value-added generated at the level of 17 industries, by state: *Brazilian Regional Accounts*, IBGE; investment is based on the level of the Civil Construction in each state (IBGE).

Appendix 2: List of Countries and Brazilian states

Angola	Ghana	Philippines
United Arab Emirates	Greece	Poland
Argentina	Guatemala	Puerto Rico
Australia	Hong Kong. China	Portugal
Austria	Croatia	Paraguay
Belgium	Indonesia	Qatar
Bangladesh	India	Romania
Bulgaria	Ireland	Russian Federation
Bahrain	Israel	Saudi Arabia
Canada	Italy	Senegal
Switzerland	Jamaica	Singapore
Chile	Jordan	El Salvador
China	Japan	Slovenia
Colombia	Korea. Rep.	Sweden
Costa Rica	Kuwait	Syrian Arab Republic
Cuba	Lebanon	Thailand
Cyprus	Libya	Trinidad and Tobago
Germany	St. Lucia	Tunisia
Denmark	Morocco	Turkey
Dominican Republic	Mexico	Taiwan
Algeria	Malaysia	Ukraine
Ecuador	Nigeria	Uruguay
Egypt. Arab Rep.	Netherlands	United States
Spain	Norway	Venezuela. RB
Finland	Pakistan	Vietnam
France	Panama	Yemen. Rep.
United Kingdom	Peru	South Africa

Appendix 3 List of Brazilian states and their abbreviations:

ACRE	AC	PARA	PA
ALAGOAS	AL	PERNAMBUCO	PE
AMAZONAS	AM	PIAUI	PI
AMAPA	AP	PARANA	PR
BAHIA	BA	RIO DE JANEIRO	RJ
CEARA	CE	RIO GRANDE DO NORTE	RN
DISTRITO FEDERAL	DF	RONDONIA	RO
ESPIRITO SANTO	ES	RORAIMA	RR
GOIAS	GO	RIO GRANDE DO SUL	RS
MARANHAO	MA	SANTA CATARINA	SC
MINAS GERAIS	MG	SERGIPE	SE
MATO GROSSO DO SUL	MS	SAO PAULO	SP
MATO GROSSO	MT	TOCANTINS	TO
PARAIBA	PB		

Appendix 4: Migration flows and Language criteria (*MIGsj*)

MIG_{sj}	Germany	Austria	Switzerland	Italy	Japan	Netherland	Belgium	Jordan	Lebanon
AC	0	0	0	0	0	0	0	0	0
AL	0	0	0	0	0	0	0	0	0
AM	0	0	0	0	0	0	0	0	0
AP	0	0	0	0	0	0	0	0	0
BA	0	0	0	0	0	0	0	0	0
CE	0	0	0	0	0	0	0	0	0
DF	0	0	0	0	0	0	0	0	0
ES	1	1	1	1	0	0	0	0	0
GO	0	0	0	0	0	0	0	0	0
MA	0	0	0	0	0	0	0	0	0
MG	1	1	1	1	0	0	0	1	1
MS	0	0	0	0	0	0	0	0	0
MT	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0
PB	0	0	0	0	0	0	0	0	0
PE	0	0	0	0	0	1	1	0	0
PI	0	0	0	0	0	0	0	0	0
PR	1	1	1	1	1	0	0	0	0
RJ	0	0	0	1	0	0	0	1	1
RN	0	0	0	0	0	0	0	0	0
RO	1	1	1	0	0	0	0	0	0
RR	0	0	0	0	0	0	0	0	0
RS	1	1	1	1	0	0	0	0	0
SC	1	1	1	1	0	0	0	0	0
SE	0	0	0	0	0	0	0	0	0
SP	1	1	1	1	1	1	1	1	1
TO	0	0	0	0	0	0	0	0	0

MIG_{sj} variable is constructed by authors with the criteria of different immigration flows and language families across Brazilian states.

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