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# Competing-Destinations Gravity Model Applied to Trade in Intermediate Goods\*

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## Abstract

The competing-destinations formulation of the gravity model ensues from the fact that unlike the classic version, this approach explicitly acknowledges the interdependence of the flows between a set of alternative countries. This paper applies the competing-destinations gravity model to the analysis of trade in intermediate goods. The results of the model were then tested empirically with an international input-output dataset and using the PPML estimator. The empirical results suggest that the analytical model can explain trade in intermediate goods. Indeed, as predicted, import of intermediate goods is increasing in the importing country's demand for inputs, in the competitiveness of the exporting country, and decreasing in distance and competition posed by alternative countries.

*JEL Classification:* C31; F14

*Keywords:* Gravity Model, Trade in Intermediate Goods, Poisson Regression

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## 1 Introduction

One of the distinctive characteristics of the current globalization process is the emergence of global value chains. Within global value chains and international production networks, not only final goods are traded internationally, but also intermediate goods (parts, components, and semi-finished goods) and services. Exports of final goods are no longer an appropriate

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indicator of the competitiveness of countries, as following the emergence of global value chains, final goods increasingly include a large proportion of intermediate goods that have been imported into the country. This trend greatly alters the economic relationships between countries and casts increasing doubt on empirical indicators such as trade and Foreign Direct Investment (FDI), which are traditionally used to measure globalization. In that regard, this paper sets up a competing-destinations gravity model to characterize trade in intermediate goods.

The gravity model has more recently acquired a range of micro-founded theoretical bases. These analytical approaches are important to policy researchers because they affect the data, specification, and econometric technique used to estimate the gravity model. Use of a theoretically-grounded gravity model can lead to interpretations that are substantially different from those obtained via an intuitive formulation, and high quality policy research and advice increasingly needs to be based on a rigorously established methodology. The literature provides a variety of theoretically-grounded gravity models (Anderson, 1979, Bergstrand, 1985, Anderson and van Wincoop, 2003, 2004, Baier and Bergstrand, 2001, 2009, Evenett and Keller, 2002, Feenstra, 2004). It is only recently that Eaton and Kortum (2002), Baldwin and Taglioni (2011), and Johnson and Noguera (2012) show how gravity models can be adjusted to accommodate trade in intermediate products and global value chains. Although there are important differences among the exact forms of gravity produced by these models, they all retain some fundamental similarities to the basic model.

The version of the competing destinations gravity model that we employ is proposed in de Mello-Sampayo (2007, 2009, 2016, 2017) and summarily described in Section 2. In short, the competing destinations version of the gravity model adds to the classic version a competition factor that captures the gravity of the other trading countries. The competition factor allows treating trade directed to one specific country as interdependent with trade decisions concerning alternative countries. Anderson and van Wincoop (2003) demonstrate that the traditional gravity equation is mis-specified and coefficient estimates are likely biased owing to omission of nonlinear multilateral resistance terms. However, these multilateral resistance variables capture the dependence only on trade costs of the trade flows between trading countries across all possible trading suppliers. Conversely, the competition factor proposed in this paper captures the gravity of the competing countries since it is the sum, weighted by economic distance, of all other supplier countries' characteristics in supplying inputs.

In our analytical model firms are assumed to purchase some of their inputs from other firms, paying the required transport costs and accounting for the spatial structure of trading partners in a geographical system. The analytical model reveals that imports of intermediate goods are increasing in the importing country's demand for inputs, in the competitiveness of the exporting country, and decreasing in distance and competition posed by alternative countries. We use an international input-output dataset to test the derived competing-destinations gravity equation using the Poisson pseudo-maximum-likelihood (PPML) estimator since from the entropy maximization, we built a probabilistic input demand function or conditional logit model, with a Poisson outcome. The empirical results support the find-

ings of the analytical model. By suggesting that trade in intermediate goods depends not only on the push factors, pull factors, and spatial factors but crucially on the geographical pattern, the overall empirical results corroborate the use of the competing-destinations of the gravity model to the analysis of trade in intermediate goods.

The paper is structured as follows. In Section 2 we derive a gravity equation for trade in intermediate goods based on the entropy maximization problem. In Section 3 we discuss the estimation strategy, and present the estimation results in Section 4. We conclude in Section 5.

## 2 Theoretical Framework

The analytical model follows Fujita, Krugman and Venables (1999), but we concentrate on the behavior of producers and go one step further by applying our model to the intermediate sector and by using the entropy approach. Consider the world economy to be divided into final good producing countries  $i$ ,  $i = 1, 2, \dots, I$ , and input suppliers' countries,  $j = 1, 2, \dots, J$ . However, some countries might produce both the final goods and intermediate goods. Let  $M = \sum_{vij} m_{vij}$  be defined as the total number of input interactions, and we wish to model the interaction pattern between countries, i.e.  $m_{vij}$  the flow of input  $v$  between country  $i$  and  $j$ . Thus, final good firms located in country  $i$  may buy some of their inputs from country  $j$ , paying the required transport costs.

We start characterizing the countries without the subscripts  $i$  and  $j$ . The economy consists of two sectors of activity: final good firms, which employ labor ( $L$ ) and a set of inputs ( $m_v$ ) to produce a unique consumption good ( $y$ ); intermediate good firms, which have monopoly power over the production of their input. The technology to produce final goods is represented by:

$$Y = L_y^{1-\alpha} \int_0^n m_v^\alpha dv, \quad (1)$$

where  $m_v$  is the quantity of the input  $v$ ,  $n$  is the measure of inputs available,  $L_y$  is the fraction of labor used in the production of good  $y$ , and  $\alpha$  gives the intensity of the preference for inputs' variety,  $0 < \alpha < 1$ . This specification stretches back to Dixit and Stiglitz (1977). The additive separability of the function implies that the inputs are different, although they are neither intrinsically better nor worse. The marginal product of each input is decreasing but there are constant returns to the number of inputs,  $n$ , which can be regarded as the level of technological knowledge. That is, there are increasing returns to scale to the rivalrous inputs,  $m_v$ , and  $n$  taken together. The final good firms maximize the following profit function:  $\Pi = Y - \int_0^n p_v m_v dv - w_y L_y$ , where  $w_y$  denotes the salary in the final sector, and  $p_v$  is the price of the variety  $v$  of intermediate input. The final product is the numeraire. From the profits' maximization of the representative firm in the competitive final sector, we obtain the following input demand function:

$$p_v = \alpha L_y^{1-\alpha} m_v^{\alpha-1}, v \in [0, n]. \quad (2)$$

The marginal cost of producing any inputs is equal to  $w_v$ . The intermediate firms maximize their profits:  $\Pi_v = p_v m_v - w_v m_v$ , subject to the demand function as given by Equation (2), to obtain the input supply function:

$$m_v = \alpha^{\frac{1}{1-\alpha}} L_y p_v^{\frac{1}{\alpha-1}}, \quad (3)$$

where  $p_v = \frac{w_v}{\alpha}$ . Equation (3) can be substituted into equation (1) to obtain the corresponding optimum sales,  $Y^*$ .

Assume that the optimum sales,  $Y^*$ , will exceed the observed sales,  $Y^{obs}$ , emerging from the observed flows,  $m_{vij}^{obs}$ . This divergence could be due to imperfect information available to the firms, differences in technology between the so-called identical firms, and differences in strategic objectives. If we have enough commodity flow data to evaluate the actual realized sales, the resulting total sales can never be greater than the results of the maximization solution, and will often be less. Thus, we investigate the entropy approach for gravity (Roy, 2004) to cope with this divergence. Let  $S$  be the number of ways that distinct observed shipments from region  $j$ ,  $M_{vj}^{obs}$ , can be allocated in groups  $m_{vij}$  to the country  $i$  and the number of ways the  $M_{vi}$  shipments arriving at country  $i$  can be arbitrarily allocated to the  $D_i$  distinct receiver firms:

$$S = \frac{\prod_j M_{vj}^{obs}!}{\prod_i m_{vij}! \prod_i D_i^{M_{vi}}}. \quad (4)$$

The log-linearized form of Equation (4) is determined, the Stirling approximation applied, and constant terms omitted, then the entropy  $S$  comes out as:

$$S = - \sum_{vij} m_{vij} [\ln(\frac{m_{vij}}{D_i}) - 1]. \quad (5)$$

Now, assume that we are going to reproduce the observed input flows  $M_{vj}^{obs}$  of each input  $v$  out of each country  $j$ , which the firms at country  $i$  compete for. Maximize Equation (5) under the key behavioral constraint,  $Y^{obs} = \sum_i Y_i$ , with multiplier  $\beta$ , and iceberg type transport costs ( $\tau_{ij}$ ) with multiplier  $\varphi$ , and competition factor ( $c_{ij}$ ) with multiplier  $\delta$ , making use of Equation (3), and imposing that the predicted total interaction flow leaving each origin should equal the observed value, i.e.  $M_{vj}^{obs} = \sum_i m_{vij}$  to obtain:

$$m_{vij} = \frac{M_{vj}^{obs} D_i e^{\beta \left(\frac{\alpha n_j}{w_{vj}}\right) + \varphi \tau_{ij} + \delta c_{ij}}}{\sum_i D_i e^{\beta \left(\frac{\alpha n_j}{w_{vj}}\right) + \varphi \tau_{ij} + \delta c_{ij}}}, \quad (6)$$

which has a form similar to a conditional logit model (probabilistic input demand function)

and where  $\beta$ ,  $\varphi$ , and  $\delta$  are parameters to be estimated. The parameters  $\beta$  and  $\varphi$  reflect the perception of supplier countries' attractiveness and distance as determinants of interactions. The balance of total flows are ensured by  $M_{vj}^{obs} / \sum_i D_i e^{\beta \left( \frac{\alpha n_j}{w_{vj}} \right) + \varphi \tau_{ij} + \delta c_{ij}}$ . The variable  $\frac{\alpha n_j}{w_{vj}}$  measures the country  $j$ 's competitiveness for supplying inputs, since the higher are the intensity of the preference for inputs' variety ( $\alpha$ ) and the level of technological knowledge ( $n_j$ ), and the lower the cost of producing any inputs ( $w_{vj}$ ), the more capable country  $j$  is to supply inputs. We expect  $\beta$  to be positive, indicating that as the competitiveness of country  $j$  increases, the volume of interactions between  $i$  and  $j$  increases. Conversely, we expect  $\varphi$  to be negative: as the economic distance between country  $i$  and region  $j$  increases, the volume of interaction between them decreases.

Countries are viewed as competing with each other for interaction, and when a variable measuring such competition is included in the gravity framework, the resulting interaction models are known as competing destinations or origins models (Fotheringham, 1983). One possible measure of interaction interdependencies is the competition factor, a composite variable that seeks to capture the gravity of the competing countries (see de Mello-Sampayo, 2007, 2009, 2016):

$$c_{ij} = \sum_{k \neq j} \frac{\beta \left( \frac{\alpha n_k}{w_{vk}} \right)}{\varphi \tau_{ik}}, \quad (7)$$

where  $c_{ij}$  is the sum, weighted by economic distance, of all other supplier countries' characteristics (except country  $j$ ) in supplying inputs to  $i$ . The variable  $\frac{\alpha n_k}{w_{vk}}$  represents the competitiveness of supplier country  $k$ ;  $\tau_{ik}$  represents the economic distance between country  $i$  and supplier country  $k$ ;  $\beta$  and  $\varphi$  are defined as in the gravity model given by Equation (6). Often they are set to one in the competition formulation (Roy, 2004) and so becomes  $c_{ij} = \sum_{k \neq j} \frac{\alpha n_k}{w_{vk} \tau_{ik}}$ . A negative value of  $\delta$  in Equation (6) demonstrates the presence of competition or congestion forces. The above model structure represents a step forward in recognition of interdependencies in spatial choice.

In the context of same type origin-destination gravity models, Fotheringham (1983) proposed a potential accessibility measure:

$$a_{ij} = \sum_{k \neq i, j} \frac{\alpha n_k}{w_{vk} \tau_{kj}}, \quad (8)$$

where  $a_{ij}$  represents the accessibility of country  $j$  in relation to all other countries. The higher the competitiveness of countries  $k$ , and the closer these countries are to  $j$  (i.e., the smaller is  $\tau_{kj}$ ), the lower is the flow expected from  $i$  to  $j$  since there is a spatial concentration of opportunities in the neighborhood of  $j$ . In this situation the access measure  $a_{ij}$  models competition effects since it will be high but the flow low, so that this type of accessibility has a negative impact on flows if several countries with large masses are close to each other. Alternatively, it may model agglomeration effects if the higher the competitiveness of countries  $k$ , and the closer these countries are to  $j$ , the higher is the flow expected from

$i$  to  $j$  since there is a spatial concentration of opportunities in the neighborhood of  $j$ . In this situation the access measure  $a_{ij}$  will be high and the flow high, so that it has a positive impact on flows if several areas with large masses are close to each other.

In de Mello-Sampayo (2017) we compare Equation (6) to a deterministic model, in which firms trade inputs to reduce the overall cost of production, and intermediate sales are encouraged by low distance costs and low competition from alternative input sources. Even if the gravity equations look similar, we show that their underlying structures are different, and that the type of gravity equation has significant implications for the estimation technique adopted.

### 3 Data and Estimation Strategy

We use an input-output dataset that has been taken from the Institute of Developing Economies, Japan External Trade Organization, IDE-JETRO, for Brazil, China, Europe, India, Japan, Russia, and the United States, for 2005. The Input-Output Database shows transactions, wherever possible, in industry-by-industry symmetric tables at basic prices. The imported intermediate inputs' dataset is disaggregated into seven sectors: agriculture, livestock, forestry, and fishery; Mining; Manufacturing; Electricity, gas, and water supply; Construction; Trade and transport; and Services.

Regarding the explanatory variables, total expenditure on inputs have been taken from input-output datasets from IDE-JETRO. To proxy technological level, the Technological Environment and Intellectual Property Rights (IPR) are from the *Profils Institutionnels* database of CEPII. Distances come from the GeoDist database of CEPII. We use bilateral distance in kilometers between the two capitals, and distance weighted by the share of the city in the overall country's population developed by Eaton and Kortum (2002). We also use cost insurance and freight (CIF) from IDE-JETRO. As suggested by our model, a country's wage is endogenous, we follow Eaton and Kortum (2002) and use the Population Density and Total Workforce to proxy labor costs from World Bank. Population density proxies (inversely) for productivity. Given its technology, a country with more workers has a lower wage.

To control for geographical patterns we use the competition factor as given by Equation (7), and a potential accessibility measure, see Equation (8). The competition factor is a composite variable that seeks to capture the gravity of the competing destinations and is the sum, weighted by economic distance, of all other countries' characteristics (except country  $i$ ) for supplying inputs. The potential accessibility measure represents the accessibility of country  $j$  in relation to all other countries. This type of access measure may model competition and agglomeration effects. In order to avoid multicollinearity problems, IPR to proxy technological level, total workforce to proxy wages, and CIF to proxy transport costs are used only to compute the competition factor and the accessibility measure. Due to the difficulty in gathering data on the intensity of the preference for inputs' variety, we had to set  $\alpha$  to unity.

The conditional logit model as given by Equation (6) for the matrix of input flows,  $m_{vij}$ , from country  $j$  to country  $i$ , may be specified in terms of Poisson sampling (Guimaraes, Figueiredo and Woodward, 2003):

$$m_{vij} \sim \text{Poisson}(\mu_{vij}), \quad i = 1, 2, \dots, 7; \quad j = 1, 2, \dots, 7, \quad v = 1, 2, \dots, 7 \quad (9)$$

where the Poisson mean is predicted by:

$$\hat{\mu}_{vij} = D_i : \alpha n_j / w_{vj} : \tau_{ij} : c_{ij}. \quad (10)$$

The dependent variable,  $m_{vij}$ , is the number of inputs  $v$  imported by country  $i$  from country  $j$ ,  $\tau_{ij}$  is the distance between country  $i$  and country  $j$  measured in kilometers,  $D_i$  is the importing country's total expenditure on inputs,  $\frac{\alpha n_j}{w_{vj}}$  represents the competitiveness of supplier country  $i$ ,  $\alpha$  the intensity of the preference for inputs' variety,  $n_j$  is the exporting country's level of technological knowledge,  $w_{vj}$  is the exporting country's labor costs,  $c_{ij}$  is the competition factor or an index that yields the gravity faced by country  $j$  from all other country  $j$ 's trading partners.

## 4 Results

Table 1 reports to the estimation of the gravity equation as given by Equations (9) and (10). All PPML specifications include industry and country fixed effects. Table 1 is arranged in two main sections. The first is composed of columns (1) to (4), and corresponds to the estimation of the benchmark gravity equation, and the other composed of columns (5) to (8), which correspond, in a robustness check, to the extended gravity equation when we disaggregate  $\frac{\alpha n_j}{w_{vj}}$  and add countries' population density ( $w_{vj}$ ) and technological level ( $n_j$ ) separately as pull factors determining trade in intermediate goods. Columns (3)-(4) and (7)-(8) show the results for the estimation of the probabilistic gravity equation when the competition factor,  $c_{ij}$ , in columns (1)-(2) and (5)-(6) is replaced by the accessibility measure variable,  $a_{vj}$ , to test the competition-agglomeration hypothesis. In a robustness check, columns (2)-(4) and (6)-(8) show the results for the estimation of the gravity equation when the bilateral distance in kilometers between the two capitals used in columns (1)-(3) and (5)-(7) is replaced by distance weighted by the share of the city in the country's overall population. In Table 1, for every Poisson model, according to the Wald test the overall significance of the regressors is not rejected at the 1% significance level. Following Santos-Silva and Tenreyro (2006), we added the square of fitted values into the auxiliary regression for the RESET test. The rejection of the significance of the additional variable confirms that the model is well specified.

The coefficient estimates all have the correct signs and are significant as seen in columns (1) to (8). The estimates of the gravity model under both geographical patterns' characterizations suggest, as expected, a positive and significant coefficient for country  $i$ 's demand



**Table 1: PPML Fixed Effects Estimates**

Label	Benchmark Model				Extended Model			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<b>Push Factors</b>								
Log $D_i$	0.403*** (0.000)	0.419*** (0.000)	0.403*** (0.000)	0.420*** (0.000)	0.425*** (0.000)	0.430*** (0.002)	0.426*** (0.000)	0.430*** (0.001)
<b>Pull Factors</b>								
Competitiveness ( $\alpha n_j/w_{vj}$ )	0.362*** (0.000)	0.434*** (0.000)	0.362*** (0.000)	0.433*** (0.000)	—	—	—	—
Population Density ( $w_{vj}$ )	—	—	—	—	-0.082*** (0.002)	-0.314*** (0.002)	-0.082*** (0.000)	-0.313*** (0.001)
Technological Level ( $n_j$ )	—	—	—	—	1.311*** (0.001)	0.412*** (0.001)	1.312*** (0.001)	0.412*** (0.001)
<b>Spatial Factors</b>								
Distance ( $\tau_{ij}$ )	-2.428*** (0.000)	—	-2.427*** (0.001)	—	-2.471*** (0.000)	—	-2.472*** (0.001)	—
Distance Weighted ( $\tau^{w_{ij}}$ )	—	-2.570*** (0.000)	—	-2.571*** (0.001)	—	-2.596*** (0.002)	—	-2.595*** (0.002)
<b>Geographical Pattern</b>								
Competition Factor ( $c_{ij}$ )	-0.288*** (0.000)	-0.270*** (0.004)	—	—	-0.287*** (0.000)	-0.269*** (0.000)	—	—
Accessibility Measure ( $a_{ij}$ )	—	—	-0.287*** (0.000)	-0.269*** (0.004)	—	—	-0.287*** (0.000)	-0.268*** (0.004)
Nr. Observations	2156	2156	2156	2156	2156	2156	2156	2156
Nr. Countries	7	7	7	7	7	7	7	7
Nr. Industries	7	7	7	7	7	7	7	7
Wald Test	379000***	373000***	379000***	373000***	396000***	384000***	396000***	384000***
Degrees of Freedom	4	4	4	4	5	5	5	5
RESET Test p-Value	0.509	0.487	0.509	0.487	0.489	0.490	0.489	0.490

Robust Standard errors in parentheses.

\*\*\* Rejects the null at the 1% level.

for inputs,  $D_i$ , a positive and significant coefficient for country  $j$ 's technological level, and a negative and significant coefficient for the country  $j$ 's labor density, which suggests that comparative advantages play an important role in trade in intermediate goods. With regard to the variables that make up the spatial factors in the model, namely distance in kilometers between the two capitals used in columns (1)-(3) and (5)-(7) and distance weighted by the share of the city in the country's overall population used in columns (2)-(4) and (6)-(8), the results show the importance of distance in trade in intermediate goods. With respect to the variables that characterize the geographical pattern in the model, competition factor, and accessibility measure, the estimated negative and significant effect of the competition factor on intermediate goods' imports reflects the fact that the lower the cost and the better localized the concurrent countries, the less trade in intermediate goods one expects to occur to a particular country. The result by which the accessibility measure negatively affects trade in intermediate goods is explained by the fact that the more accessible a country is to its competitors raises the competition between countries and the less trade in intermediate goods we observe. This result validates the presence of competition or congestion forces when analyzing trade in intermediate goods. The relevance of such a result in the present context is that by highlighting the importance of the gravity of alternative countries on input flows, it supports the analytical framework proposed in this paper.

## 5 Conclusion

Final goods increasingly include a large proportion of intermediate goods that have been imported into the country, and it is therefore critical to analyze trade in intermediate goods. In that regard, this paper sets up a competing-destinations gravity model to characterize trade in intermediate goods. The competing-destinations formulation of the gravity model ensues from the fact that unlike the classic version, this approach explicitly acknowledges the interdependence of the flows between a set of alternative countries. The analytical model reveals that imports of intermediate goods is increasing in the importing country's demand for inputs, in the competitiveness of the exporting country, and decreasing in distance and competition posed by alternative countries. The results of the model were then tested empirically with an international input-output dataset using the PPML estimator. The empirical results support the findings of the analytical model.

We also test the competition-agglomeration hypothesis, and determine that the existence of competition forces in the trade in intermediate goods is supported by our finding that the accessibility measure has a negative effect on the trade in inputs. The importance of such a result in the present context is that by highlighting the influence of the gravity of alternative countries on input flows, it supports the competing-destinations gravity equation proposed in this paper, which recognizes interdependencies in spatial choice.

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