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The "distance-varying" gravity model in international economics: is the distance an obstacle to trade?

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Abstract

In this paper, we address the problem of the role of the distance between trading partners by assuming the variability of coefficients in a standard gravity model. The distance can be interpreted as an indicator of the cost of entry in a market (a fixed cost): the greater the distance, the higher the entry cost, and the more we need to have a large market to be able to cover a high cost of entry. To explore this idea, the paper uses a method called Flexible Least Squares. By allowing the parameters of the gravity model to vary over the observations, our main result is that the more the partner's GDP is large, the less the distance is an obstacle to trade.

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1. Introduction

The gravity model is the most commonly used analytical framework for the study of bilateral flows and is inspired by the Newton's law of gravity. In the trade context, the typical form of the gravity model is given by $T_{ij} = kY_i^{\alpha}Y_j^{\beta}D_{ij}^{\epsilon}$,where T_{ij} is the bilateral trade, nominal exports, imports, or total trade, from country i to country j, Y_i ($resp.$ Y_j) is the nominal GDP in country i ($resp.$ j), and D_{ij} is the geographical distance between countries i and j. In conformity with the law of gravity, we expect trade to be positively affected by GDP (the economic mass) and negatively related to the distance. The success of the gravity model in empirical international economics[1] can be explained by the fact that it yields good results in explaining bilateral flows and more fundamentally, because it helps addressing the issue of the direction of trade which is neglected in traditional trade theories. As shown by Feenstra, Markusen, and Rose (1999), the mass variables are not difficult to justify. But the role of the distance in the gravity model is not so clear and motivates this paper. We will show that the distance determines the relationships between exports or imports and the mass variables. More precisely, for the US exporters, the partner's GDP represents the attractiveness of the market and, for US importers, the partner's GDP is an indicator of the capability to export to a large market. The distance can thus be interpreted as an indicator of the cost of entry in a market (a fixed cost): the greater the distance, the higher the entry cost, and the more we need to have a large market to be able to cover a high cost of entry. To explore this idea, the paper uses the Flexible Least Squares (FLS) developed by Kalaba and Tesfatsion (1990) for estimating a model with varying coefficients; our main result is that the more the partner's GDP is large, the less the distance is an obstacle to trade.

The paper is organized as follows. Section 2 extends the discussion about the role of the distance variable and describes the model. Section 3 presents the method of analysis. Section 4 discusses the empirical specification and results. Section 5 concludes the paper.

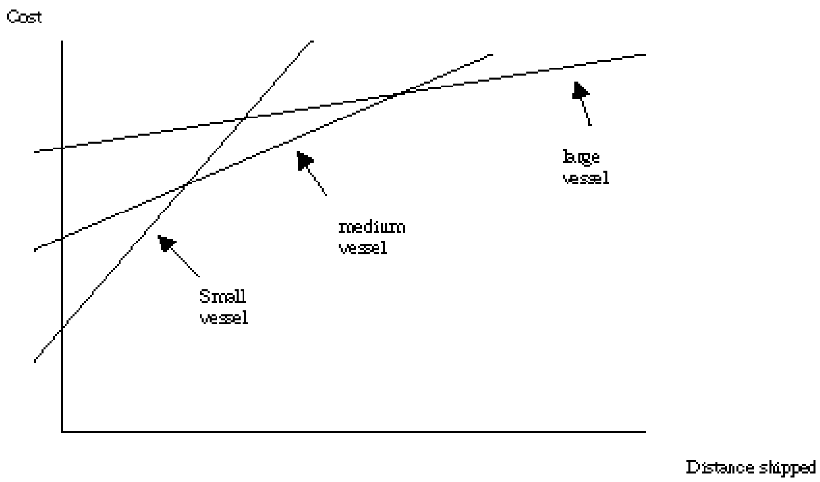
2. The role of the distance and the gravity model

In gravity models, the distance variable is usually presented as a proxy for transportation costs because trade costs (e.g., transportation and communication) are likely to increase with distance, but distances between different

[1]See, among others, Anderson (1979), Bergstrand (1985), Bergstrand (1989), Davis (1995), Deardorff (1998), Dhar and Panagariya (1994), Eaton and Kortum (1997), Evenett and Keller (1998), Feenstra, Markusen, and Rose (1999), Helpman (1987), Linneman (1966), Markusen (1986), Poyhonen (1963) and Tinbergen (1962).

countries are not homogenous (Hong, 1999, p.8). The first explanation draws on the topology of the globe: countries can be separated by mountains or by ocean or land. The second explanation concerns the problem of measurement: measuring the distance between two countries is difficult, especially when a large country is involved. A further explanation is related to the transportation mode. For short distances, it is possible to use a monomodal system of transportation. But, as the distance becomes larger, the intermodal system is often the only choice; furthermore, the size of transport equipment can change. As David Hummels (1999) shows, the cost functions are not the same for the different sizes of vessels which are used for maritime shipment, and depend on the distance. In his study, he draws three cost functions corresponding to three types of vessels (see Figure 1). As the distance increases, the size of the vessel is larger and fixed costs increase while marginal costs decrease. Broadly speaking, an exporter who wants to serve a distant market has to incur large fixed costs which can be supported only if the volume of exports (and the market) is large. For closer markets, as the fixed cost is lower, the exporter can trade a smaller volume and thus serve smaller markets; in such cases, economies of scale do not matter.

Figure 1. Relationship between cost and distance shipped (from Hummels (1999))



In regard to the above arguments, we estimate a gravity model in order to investigate the effect of distance on the US exports and imports, peculiarly by focusing our attention on the trade-off between the distance and the economies of scale associated with the importance of the different markets. Our basic gravity relationship[2], which we shall improve by introducing

[2]We could introduce a panel of dummy variables to take into account additional factors

varying coefficients, is the following:

$$y_t \approx a + b\log(GDP_t) + c\log(D_t) + dPolicy_t \quad t = 1, ..., T \tag{1}$$

where $y_t = \log(X_t)$ or $\log(M_t)$; X_t (*resp.* M_t) represents the exports (*resp. imports*) from US to partner t, GDP_t is the GDP of country t and D_t is the geographical distance between US and partner t. The variable $Policy_t$ is a discrete variable on a scale of one to five describing the level of import protection (very low, low, moderate, high, and very high)[3]. While distance can be seen as a fixed cost of entry into a foreign market, the $Policy_t$ variable serves as an indicator of the variable costs of entry. The gravity model is estimated using the FLS method[4].

3. Description of the FLS method

Following the seminal papers by Kalaba and Tesfatsion (1990 and 1996)[5], let us consider a varying coefficient model, called the measurement relationship, that is assumed to be approximately linear:

$$y_t \approx x_t'\beta_t \quad t = 1, ..., T \tag{2}$$

where $\{y_t\}$ is the process to be modelled, x_t is a $k \times 1$ vector of explanatory variables defined by $x_t = (1, x_{t2}, ..., x_{tk})'$ and β_t is a $k \times 1$ vector of parameters given by: $\beta_t = (\beta_{t1}, \beta_{t2}, ..., \beta_{tk})'$. The parameter path is determined by a dynamic relationship, assumed to take the following form between β_{t+1} and β_t:

$$\beta_{t+1} \approx \beta_t \quad t = 1, ..., T \tag{3}$$

which postulates that parameters evolve slowly from one period to the next; the degree of coefficient variation between two successive observations is thus small. The FLS method can thus be considered as an element of the varying

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as language, common borders, free zone area membership..., but this will not change significantly the results concerning the role of distance. See, for instance a recent article by Baier and Bergstrand (2009).

[3] This variable corresponds to the Factor #1 in the Index of Economic Freedom calculated every year by the Heritage Foundation. For a complete description of indicators, see Wall (1999, p. 36).

[4] Following the seminal papers by Kalaba and Tesfatsion (1990 and 1996), the FLS method has been used in a number of empirical applications (see for instance Tesfatsion and Veitch (1990), Dorfman and Foster (1991), Lütkepohl (1993), Lütkepohl and Herwartz (1996), Wood (1998),Chauveau and Maillet (1998)).

[5] The explicit procedure for estimating the FLS parameters is given in Kalaba and Tesfatsion (1990) and is not described here. The computer programs used in the application presented below use some FLS procedures developed by Roncalli (1996) in GAUSS.

parameter models literature in terms of their ability to capture unspecified and possibly unspecifiable parameter variations. Let us define $r_M^2(\beta, T)$, the cost of violating the measurement specification, and $r_D^2(\beta, T)$, the cost of violating the dynamic relationship, as:

$$r_M^2(\beta, T) = \sum_{t=1}^{T} (y_t - x_t'\beta_t)^2 \text{ and } r_D^2(\beta, T) = \sum_{t=1}^{T} (\beta_{t+1} - \beta_t)' D (\beta_{t+1} - \beta_t) \tag{4}$$

where D is a $k \times k$ suitably chosen scaling matrix[6]. The principle of FLS method relies upon finding the path of the coefficient vector which minimizes the cost function defined by:

$$C(\beta, \mu, T) = r_M^2(\beta, T) + \mu r_D^2(\beta, T) \tag{5}$$

with $\mu > 0$. This parameter μ makes explicit the trade-off between observation and dynamic errors because it evaluates the relative cost of each relation along a residual efficiency frontier traced out by minimizing $C(\beta, \mu, T)$ for different values of μ across the range from 0 to ∞.

4. Empirical results: the "distance-varying" gravity model

The data employed come from the Wall (1999) database[7], including US exports and imports with 85 partners, the distances[8] between US and its partners and the GDP[9] of all of them, for the years 1994-96. While Wall uses panel analysis to deal with time effect, we transform the data by computing the average of each series over the three years. The FLS method is employed here with cross-section data: we order the data according to increasing spatial distance, such that the first observation corresponds to the nearest neighbor of the US (Canada) and the last one to the country very far from the US (Indonesia). This ranking enables us to see the effect of

[6] Following Tesfatsion and Veitch (1990), we specify D as the diagonal matrix whose ith diagonal term D_{ii} is given by $\sum_{t=1}^{T} x_{ti}^2/T$; this choice makes the cost function invariant to the choice of units for the regressor variable: it just changes the size of the coefficient.

[7] This database is available on the FRB of St Louis Web site. http://www.stls.frb.org/docs/publications/review/99/01/9901hw.xls
along with the Wall's article:
(http://www.stls.frb.org/docs/publications/review/99/01/9901hw.pdf)

[8] The distance variable is the great-circle distance between Washington, D.C., and the capital city of the trading partner.

[9] The national income data are GDPs at market prices in U.S. dollars, taken from the World Banks World Tables. Nominal GDP and trade data are converted into constant chained 1992 dollars (see Wall (1999) for more details).

different factors, especially the spatial distance, on the export or import relationship. Consequently, the dynamic equation given in (3) relating β_t and β_{t+1} means that the economic phenomena characterized by the β_t vector are not very different between the country t and the slightly more far country $t+1$. It is for this reason that we may call this model the "distance-varying" gravity model. This method allows us to study the effect of the different factors by assuming that the combined effects of the mass variable and the distance mentioned above are not very different between countries that are geographically close.

4.1 The export equation

In order to investigate the export model by the FLS method, we use the measurement relation given by (2) with $y_t = \log(X_t)$ and $x_t = (1\ , \log(GDP_t)\,, \log(D_t),\ Policy_t)'$. The constant coefficient version of the export equation is first estimated using OLS. Table 1 summarizes the main results. The Ploberger, Krämer and Kontrus (1989)'s structural stability test, where the null hypothesis H_0 is a constant coefficients relation, rejects the null at the 99% confidence level, supporting the idea that the coefficients would be more adequately estimated using a varying coefficient method.

FLS coefficients are obtained for a range of smoothness μ. Figures 2 (a) to (c)[10] depict paths of the different coefficients obtained with $\mu = 1$. It is worth noting that the mass and distance variables have the major influences: for US. exports, the economic size of the destination country plays the leading role in determining the volume of this flow. This is confirmed by the large coefficient we find for the $\log(GDP)$ variable in the FLS results. The variability of this coefficient is shown in Figure 2 (a). As the distance increases, the coefficient becomes larger, except in a first range where it seems to decrease slightly.

Table 1. OLS results of export equation

Variable	Estimators	Std-errors	t-statistics	p-values
Constant	3.0224	0.8002	3.7769	0.00
GDP	0.9182	0.0585	15.6741	0.00
Distance	-1.0979	0.2016	-5.4459	0.00
Policy	-0.0061	0.0423	-0.1464	0.88

$R^2 = 0.804$
$R^2_A = 0.797$
$\widehat{\sigma} = 0.435$
$F(3, 81) = 110.767 \quad (0.000)$
$PKK = 51.53$

[10]The x-axis represents the 85 partners of US, as in Figures 3, 4, 5 and 7.

Note: $\widehat{\sigma}$ is the standard error of the residuals; F is the Wald test F-statistic for overall goodness of fit. PKK represents the statistic of the stability test of Ploberger, Krämer and Kontrus (1989); the 99% critical value is 1.83.

More precisely, we can approximately divide the graphs in Figure 2 into three parts:

- In the first range, less than 3500 km, we find the nearest neighbors of the US. Exports are less sensitive to the size of the partners GDP as shown by a small coefficient of the GDP logarithm.

- In the middle range, i.e. 3500-10000 km, as the distance becomes larger, the GDP coefficient increases (Figure 2 (a)). We also observe, from Figure 2 (b), that in this range the coefficient for the distance variable becomes strongly negative. Therefore, the distance acts as a handicap for exports. The size of the market becomes more important in determining the incentive for firms to incur fixed entry costs.

- In the last range, i.e. more than 10000 km, the size of the destination country becomes more important while the negative role of the distance is decreasing.

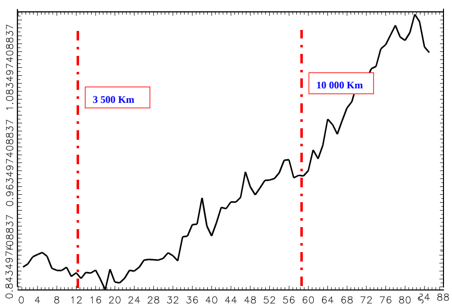
The combined effect of the mass variable and the distance supports the idea that the distance variable is an indicator of the fixed entry cost (including fixed transportation cost). This can be an explanation of the fact that this variable has influence only when combined with GDP (economies of scale)[11]. Figure 2 (c) shows the path of the coefficient of the policy variable. We similarly detect roughly the same groups of countries. In the first group, the effect is weak and slightly increasing, while in the last group, there is a decrease in the coefficient.

The residual efficiency frontier for the export equation is shown in Figure 3.

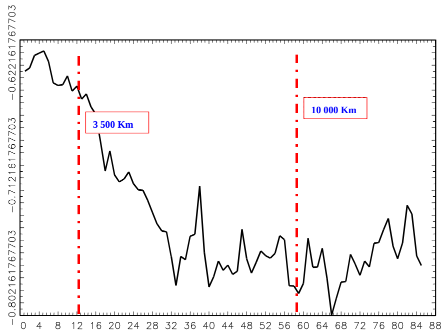
[11] As data are ordered by increasing spatial distance, the graph a in figure 3 shows that the coefficient of the variable $log(GDP_t)$ increases with the distance. Therefore, for higher distances, the market size is more explanative. However, the graph b in figure 3 confirms the results of other authors by showing that the coefficient of $log(D_t)$ is negative. Now, mixing the interpretations of these two graphs, we can remark that both GDP and distance are important, but the GDP is more and more important when the distance increases.

Figure 2. Paths of the FLS coefficients of the export equation for $\mu = 1$

(a)
coefficient of $\log(\mathrm{GDP_t})$



(b)
coefficient of $\log(\mathrm{D_t})$



(c)
coefficient of Policy

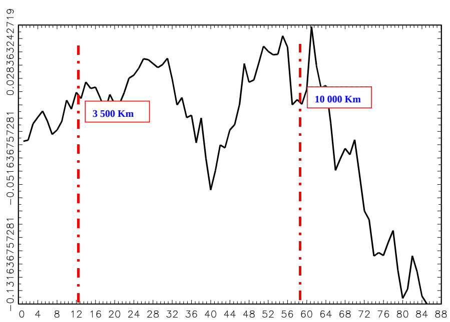
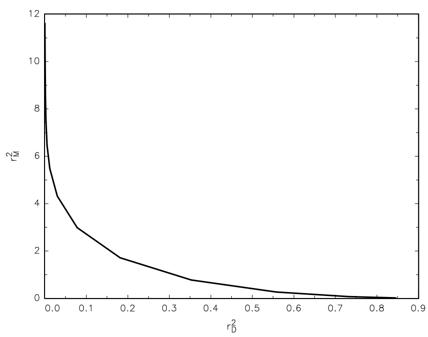


Figure 3. Residual efficiency frontier for the export equation



It is important to note the difference in scale used for the axes representing the measurement and dynamic errors: even a small decrease in the dynamic error r_D^2 results in large decrease in measurement error r_M^2. Therefore, the residual efficiency frontier is steeply sloped in the neighborhood of the OLS estimate. This suggests that the export model is unstable and may be poorly represented by the OLS estimation method (see Tesfatsion and Veitch (1990)). Summary descriptive statistics of the FLS estimates are reported in Table 2 for different values of μ or δ, the normalized smoothness weight (given by $\delta = \mu/(1+\mu)$ and $\delta \in [0,1]$), along the residual efficiency frontier; therefore, we evaluate the paths of the elements of the parameter vector for different values of δ (and μ) in order to see the stability of the different coefficients. This table gives, for each specified δ, the average values of the FLS estimates (i.e. the mean value of the FLS coefficients over the observations) with their empirical standard deviations and their variation coefficients for the full sample. The average of the FLS coefficients can be compared directly to the OLS estimates; this gives an idea of whether the constant coefficient approach provides an adequate representation of the data generation process. Moreover, the standard-deviations and the variation coefficients illustrate the magnitude of the variation of parameters. Table 2 suggests that the OLS coefficients are not a suitable representation of these relationships because the average coefficients are not very stable, changing strikingly for different values of μ, except the $\log(GDP)$ coefficient. Moreover, the standard deviations and variation coefficients are largely decreasing when $\mu \to \infty$, indicating a temporal instability for all the coefficients.

It is interesting to consider the Figures 4 (a) and (b) which show the paths of the coefficients of $\log(GDP)$ and of $Policy$ for different values of μ. Figure 4 (a) shows that the $\log(GDP)$ coefficient is variable and its nearly constant mean given in Table 2 does not imply the stability of this coefficient. On the whole, these results confirm that the OLS solution is not robust when the constant coefficients' hypothesis is relaxed.

Table 2. Summary statistics for the FLS coefficients along the residual efficiency frontier for export equation

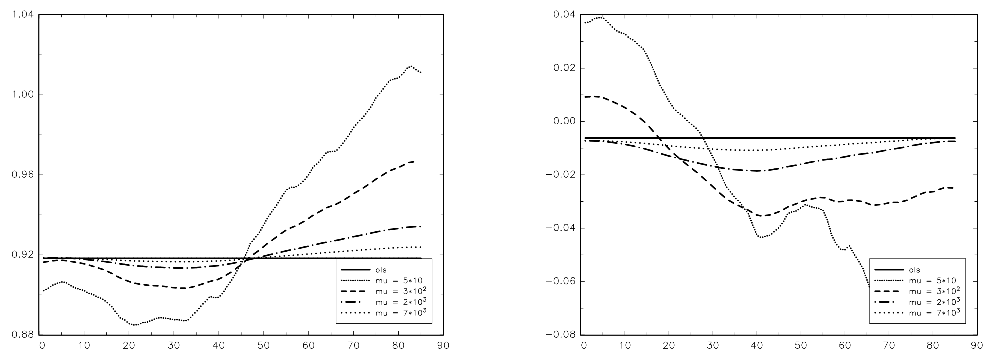
μ	δ	*Constant*	*GDP*	*Distance*	*Policy*
10^{-3}	9×10^{-4}	1.549	0.926	-0.702	-0.027
		(0.2730)	(0.1139)	(0.0692)	(0.0567)
		[0.1763]	[0.1230]	[-0.0985]	[-2.059]
1	0.5	1.720	0.930	-0.750	-0.029
		(0.2304)	(0.1047)	(0.0584)	(0.0519)
		[0.1339]	[0.1125]	[-0.0779]	[-1.770]
10^{3}	0.999	3.871	0.922	-1.313	-0.015
		(0.0342)	(0.0108)	(0.0096)	(0.0059)
		[0.0088]	[0.0117]	[-0.0073]	[-0.3778]
10^{6}	1	3.025	0.918	-1.098	-0.006
		(6.68×10^{-5})	(1.86×10^{-5})	(1.90×10^{-5})	(1.17×10^{-5})
		$[2.21\times10^{-5}]$	$[2.03\times10^{-5}]$	$[-1.73\times10^{-5}]$	[-0.0018]

Note : For each value of μ, we report the mean, the standard deviation given by (.) and the coefficient of variation given by [.] for the different FLS coefficients; $\delta = \mu/(1+\mu)$ is the normalized smoothness weight ($\delta \in [0,1]$).

Figure 4. Paths of some FLS coefficients of the export equation for $\mu \to \infty$

(a)
coefficient of $\log(\mathbf{GDP_t})$

(b)
coefficient of Policy



4.2 The import equation

Let the import process be represented by the varying coefficient model given by the dynamic relationship (3) and the measurement equation given by (2), with $y_t = \log(M_t)$ and $x_t = (1, \log(GDP_t), \log(D_t))'$[12]. A constant coefficient version of this model is estimated by the OLS estimation method. The OLS results are listed in Table 3. It is worth noting that the Ploberger, Krämer and Kontrus (1989) test provides again a clear justification for using the FLS method in order to estimate the import relation.

Table 3. OLS results of import equation

Variable	Estimates	Std-errors	t-statistics	p-values
Constant	1.7746	0.9948	1.7838	0.07
GDP	0.9300	0.0659	14.0988	0.00
Distance	-0.7802	0.2480	-3.1456	0.00

$R^2 = 0.715$
$R_A^2 = 0.708$
$\widehat{\sigma} = 0.546$
$F(3, 81) = 102.813 \quad (0.000)$
$PKK = 51.96$

Note: $\widehat{\sigma}$ is the standard error of the residuals; F is the Wald test F-statistic for overall goodness of fit. PKK represents the statistic of the stability test of Ploberger, Krämer and Kontrus (1989); the 99% critical value is 1.79.

The paths obtained by using FLS analysis are depicted in Figures 5 (a) and (b). When US. imports are considered, the attractiveness of the US. and the partner country's capacity to export play a role. The results show that this capacity to export becomes essential as the distance increases. More precisely, we can define again three ranges, characterized by different effects of the distance over import capacity:

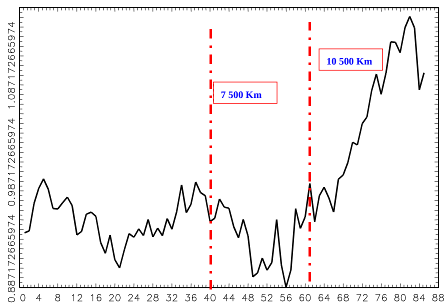
- When the distance between US and the partner countries is below 7500 km, the coefficient of the $\log(GDP_t)$ variable is nearly stable and at a low level while the coefficient of the $\log(D_t)$ is increasing in absolute value. In this range the proximity effect probably plays a role.

[12]The *Policy* variable is not taken into account because it is nearly constant over the full sample, except for two countries (Canada and Mexico).

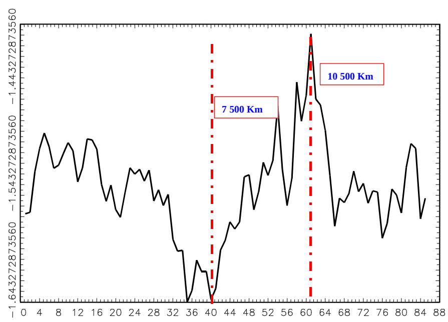
- Between 7500 km and 10500 km, the absolute value of the $\log(D_t)$ coefficient is decreasing while the GDP variable's coefficient is still low even decreasing. In this range, the distance is not really an obstacle.
- Over 10500 km, the coefficient of $\log(D_t)$ becomes stable: the distance seems less and less important in the explanation of US import from foreign countries. The main explanation of the flows becomes the size of the partner country.

Figure 5. Paths of the FLS coefficients of the import equation for $\mu = 1$

(a) coefficient of $\log(\mathrm{GDP_t})$

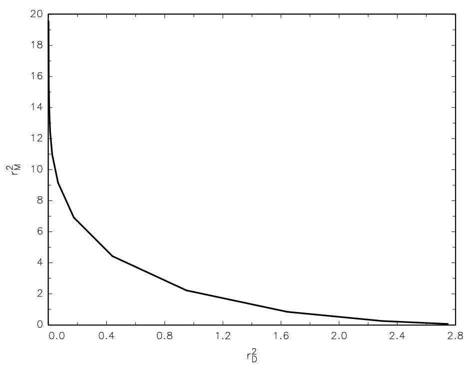


(b) coefficient of $\log(\mathrm{D_t})$



The residual efficiency frontier is shown in Figure 6. Starting from the OLS point, we observe an important decrease in the measurement error r_M^2 for small increases in dynamic errors, showing that we may again accept the hypothesis of varying coefficients for import process.

Figure 6. Residual efficiency frontier for the import equation



Summary statistics for some values of μ along the residual efficiency frontier are given in Table 4.

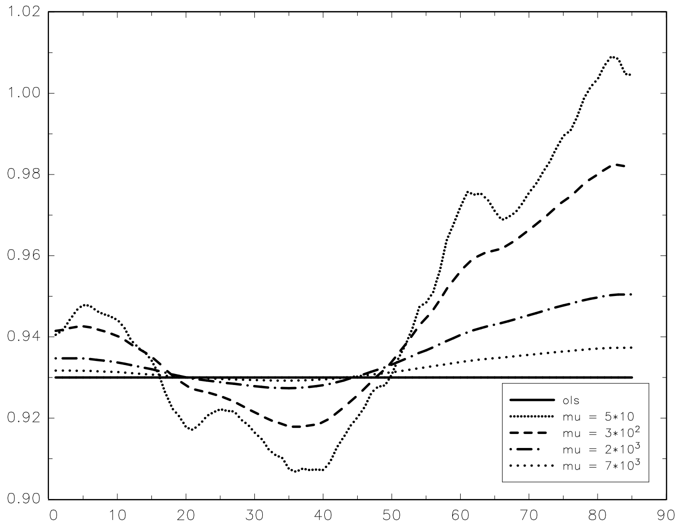
Table 4. Summary statistics for the FLS coefficients along the residual efficiency frontier for import equation

μ	δ	*Constant*	*GDP*	*Distance*
10^{-3}	9×10^{-4}	6.122	0.942	-1.917
		(0.2717)	(0.0867)	(0.0611)
		[0.0443]	[0.0920]	[-0.0318]
1	0.5	4.714	0.953	-1.566
		(0.1836)	(0.0666)	(0.0454)
		[0.0389]	[0.0698]	[-0.0290]
10^3	0.999	2.999	0.939	-1.107
		(0.0472)	(0.0119)	(0.0133)
		[0.0157]	[0.0126]	[-0.0120]
10^6	1	1.777	0.930	-0.780
		(8.50×10^{-5})	(2.08×10^{-5})	(2.41×10^{-5})
		[4.78×10^{-5}]	[2.23×10^{-5}]	[-3.09×10^{-5}]

Note : For each value of μ, we report the mean, the standard deviation given by (.) and the coefficient of variation given by [.] for the different FLS coefficients; $\delta = \mu/(1+\mu)$ is the normalized smoothness weight ($\delta \in [0,1]$).

This table confirms the idea that the constant coefficient hypothesis can be relaxed. Apart from the $\log(GDP)$ variable, all the other coefficients show important variations depending on μ; all the β_t have decreasing standard deviations and variation coefficients when μ increases. Moreover, the average values are strikingly different from the OLS estimates. Concerning the $\log(GDP)$ variable, Figure 7 illustrates the convergence of the coefficient towards the OLS estimator for different values of μ, showing that even this coefficient is varying over the full sample. On the whole, these results indicate that all the coefficients are varying through the sample.

Figure 7. Paths of the FLS coefficient of the import equation for log(GDP) for $\mu \rightarrow \infty$



Conclusion

In this paper, we have addressed the issue of the role of the distance between trade partners by assuming the variability of coefficients in a standard gravity model. By applying the FLS analysis developed by Kalaba and Tesfatsion (1990), we have been able to show that the distance can have a varying role in the relation between the size of bilateral trade flows and the economic size of the partners. The larger the partner's GDP, the less will be the distance effect on trade. If we compare our results to previous studies using gravity equation, - aside the "proximity effect" emphasized by those studies to explain bilateral trade flows -, there exists a possibility for a large country to be a prime partner even if the distance is large. Even if the influence of the distance is negative, as shown in the literature (see Leamer (1993)), this influence can be thus counterbalanced by the market size.

This FLS method introduces a large flexibility, in the sense that the parameters are free to vary, and can be considered as a first step in the modeling process to see if a method with varying parameters has to be used. Therefore, our results showing the varying role of the distance show that a possible extension of this paper could be the use of more standard nonlinear methods (such as threshold or smooth transition methods for instance), introducing a smaller flexibility than the FLS analysis.

References

[1] Anderson, J. E. (1979) "A theoretical foundation of the gravity model" *American Economic Review* **69**, 1, 106-16.

[2] Baier, S.L. and J.H. Bergstrand (2009) "Bonus vetus OLS: A simple method for approximating international trade-cost effects using the gravity equation" *Journal of International Economics* **77**, 1, 77-85.

[3] Bergstrand, J. (1985) "The gravity equation in international trade: some microeconomic foundations and empirical evidence" *The Review of Economics and Statistics* **20**, 474-81.

[4] Bergstrand, J. (1989) "The Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade" *The Review of Economics and Statistics* **71**, 143-53.

[5] Chauveau, T. and B. Maillet (1998) "Flexible least squares betas: the French market case" Working Paper, Caisse des Dépôts et Consignations, Service de la Recherche, Paris.

[6] Davies, A. (1995) "Local economies and globalization" *Note Book N° 20, OECD.*

[7] Deardorff, A. V. (1998) "Determinants of bilateral trade: Does gravity work in a neoclassical world?" in *The Regionalization of the World Economy* by J. A. Frankel, Ed., University of Chicago Press.

[8] Dhar, S. and A.Panagariya (1994) "Predictions of bilateral trade and the gravity equation" Working Paper, International Trade Division, World Bank, Washington, D.C.

[9] Dorfman, J.H. and K.A. Foster (1991) "Estimating productivity changes with flexible coefficients" *Western Journal of Agricultural Economics* 16, 2, 280-290.

[10] Eaton, J. and S. Kortum (1997) "Technology and bilateral trade" *NBER Working Paper No. W6253*, National Bureau of Economic Research, Inc.

[11] Evenett, S.J. and W. Keller (1998) "On theories explaining the success of the gravity equation" *NBER Working Papers 6529*, National Bureau of Economic Research, Inc.

[12] Feenstra, R.C., J.A. Markusen and A.K. Rose (1999) "Understanding the Home Market Effect and the Gravity Equation: The Role of Differentiating Goods" *NBER Working Papers 6804*, National Bureau of Economic Research, Inc.

[13] Helpman, E. (1987) "Imperfect competition and international trade: evidence from fourteen industrial countries" *Journal of the Japanese and International Economies* **1**, 62-81.

[14] Hong, P. (1999) "Import elasticities revisited" *DESA Discussion paper* $N°10$, United Nations.

[15] Hummels, D. (1999) "Toward a Geography of Trade Costs" GTAP Working Papers 1162, Purdue University.

[16] Kalaba, R. and L. Tesfatsion (1990) "Flexible least squares for approximately linear systems" *IEEE Transactions on Systems, Man and Cybernetics* **20**, 5, 978-989.

[17] Kalaba, R. and L. Tesfatsion (1996) "A multicriteria approach to model specification and estimation" *Computational Statistics and Data Analysis* **21**, 193-214.

[18] Leamer, E.E. (1993) "U.S. manufacturing and an emerging Mexico" *North American Journal of Economics and Finance* **4**, 51-89.

[19] Linneman, H. (1966) *An Econometric Study of International Trade Flows*, Amsterdam: North Holland.

[20] Lütkepohl, H. (1993) "The sources of the U.S. money demand instability" *Empirical Economics* **18**, 729-743.

[21] Lütkepohl, H. and H. Herwartz (1996) "Specification of varying coefficient time series models via generalized flexible least squares" *Journal of Econometrics* **70**, 261-290.

[22] Markusen, J.A. (1986) "Explaining the volume of trade: an eclectic approach" *American Economic Review* **76**, 3, 1002-1011.

[23] Ploberger, W., W. Krämer and K. Kontrus (1989) "A new test for structural stability in the linear regression model" *Journal of Econometrics* **40**, 307-318.

[24] Poyhonen, P. (1963) "A tentative model for the volume of trade between countries" *Weltwirschaltliches Archiv.* **90**, 93-100.

[25] Roncalli, T. (1996) *TSM - Advanced Time Series Estimation*, Global Design, France.

[26] Tesfatsion, L. and J.M. Veitch (1990) "U.S. money demand instability - A flexible least squares approach" *Journal of Economic Dynamics and Control* **14**, 151-173.

[27] Tinbergen, J. (1962) *Shaping the World Economy: Suggestions for an International Economic Policy*, New York, The Twentieth Century Fund.

[28] Wall, H.J. (1999) "Using gravity model to estimate the costs of protection" *Review of the Federal Reserve Bank of St. Louis*: January/February, 33-40.

[29] Wood, B.D. (1998) "Estimating time-varying parameters with flexible least squares" Working Paper, Department of Political Science, Texas A&M University.