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AUGMENTED GRAVITY MODEL: AN EMPIRICAL APPLICATION TO MERCOSUR-EUROPEAN UNION TRADE FLOWS

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This paper applies the gravity trade model to assess Mercosur-European Union trade, and trade potential following the agreements reached recently between both trade blocs. The model is tested for a sample of 20 countries, the four formal members of Mercosur plus Chile and the fifteen members of the European Union. A panel data analysis is used to disentangle the time invariant country-specific effects and to capture the relationships between the relevant variables over time. We find that the fixed effect model is to be preferred to the random effects gravity model. Furthermore, a number of variables, namely, infrastructure, income differences and exchange rates added to the standard gravity equation, are found to be important determinants of bilateral trade flows.

JEL classification codes: F14, F15

Key words: gravity equation, panel data, infrastructure, integration

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I. Introduction

This paper explores the determinants of bilateral trade flows between European Union (EU) and Mercosur countries in the recent past. A gravity model of international trade is empirically tested to investigate the relationship between the volume and direction of international trade and the formation of regional trade blocs where members are in different stages of development. Furthermore, the standard gravity model is augmented with a number of variables to test whether they are relevant in explaining trade. These variables are infrastructure endowments, squared differences in per capita incomes and real exchange rates. Finally, we analyze to what extent potentials for trade between these two economic areas are important.

Hence, the specific aim of this paper is to apply a gravity model to annual bilateral exports between 20 countries: Mercosur + Chile and the 15 current members of the EU and to study the determinants of Mercosur-European Union trade flows and the trade potentials between the two blocs.

There are two novelties in our approach. First, to our knowledge this is the first attempt to investigate the role that infrastructure variables, per capita income differences and exchanged rates play as explaining bilateral trade flows in a panel data framework.

Only a few recent papers added infrastructure to the gravity equation but they used more limited methodologies. For example, Limao and Venables (1999) used cross-section analysis over one year, Garman, Petersen and Gilliard (1998) used cross-section analysis over various years and Bougheas *et al*. (1999) averaged the data over time and then applied seemingly unrelated regression analysis estimation. Squared differences in per capita income are the variable introduced to identify a possible Linder effect (Arnon, Spivak and Weinblatt, 1996). Since we are analyzing a North-South integration process, this variable might be of significant importance. Berstrand (1985, 1989) first introduced real exchange rates in the gravity model. However, as Soloaga and Winters (1999) pointed out, the incorporation of price effects in a cross-section analysis does not give any information of whether a currency is over or under-valued. Only when the time dimension is considered in the analysis, exchange rate movements become relevant. Soloaga and Winters (1999) also incorporated real exchange rate variables into the gravity equation. They averaged their variables over several three-year periods and obtained

Tobit estimates on single regressions. The use of panel data methodology in the empirical application cast some doubts on the usual interpretation of integration dummies when pooling time series or cross-section analysis is the methodology applied. A two step estimation procedure is employed here in order to exploit the richness of the data and to estimate time invariant parameters and dummy coefficients in a fixed effect model.

The second novelty is the application of the gravity model to estimate trade flows between two economic blocs, EU and Mercosur, which are of special interest in world trade.

Section II presents a brief overview of Mercosur-EU trade relations. In Section III, we review the literature on gravity models of international trade. In Section IV, the empirical analysis and results are shown. Section V evaluates results and prediction performance of our model. Finally, Section VI concludes.

II. Regional Integration: The Mercosur-EU FTA

The first regional movements in the 1950s and 1960s consisted on regional arrangements whose members were all either developed countries or developing countries. Two clear examples of North-North regional agreements were the European Community and the European Free Trade Area, whereas the Andean Pact or the Central American Common Market were both South-South arrangements. In the 1980s and 1990s a new movement towards regionalism started to flourish with the Canada-USA free trade agreement (FTA). A new feature can characterize this new regionalism: several agreements were signed between developed and developing countries. Mexico joined Canada and US to form the North American Free Trade Area (NAFTA) and the European Union (EU) signed several agreements with Central and East European countries.

A very recent example of North-South integration is the EU-Mercosur trade agreement. The first negotiations started in 1995 with the signing of an Interregional Framework Agreement aimed to foster economic co-operation and closer trade relations between the two regional blocs. A further objective is the creation of a FTA in the year 2005. Until June 2001, the exchanges developed in the agreement framework consisted on gathering information and laying the grounds for future negotiations. Mercosur and EU had the third meeting of negotiations in Brasilia from the 7th to the 10th of November

2000. However, in practice concrete negotiations only started in the year 2001, when questions relative to tariffs and services started to be discussed.

On the side of the EU, incentives to engage in substantive negotiations with Mercosur will depend closely on the consolidation and progress recorded by the Mercosur as a customs union. On the side of Mercosur, trade, international bargaining and credibility considerations are incentives playing a major role to engage into FTA negotiations with the EU.

Mercosur has surely a shorter history than the EU and therefore a more uncertain future. Argentina, Brazil, Paraguay and Uruguay signed the Mercosur agreement in 1991 and it went into effect in 1995 becoming a Customs Union. Following the entry into force of the Common External Tariff on January 1, 1995, the Mercosur countries will maintain a common commercial policy. Mercosur also signed a free-trade agreement with Chile in 1991.

There is a shared consensus that since its inception Mercosur outperformed expectations. This is revealed in part by rapidly growing trade and investment flows. In fact, between 1991 and 1997, intra-Mercosur exports rose at a rate that trebled the growth of exports to the rest of the world. Nevertheless, if imports are taken as the indicator, the gap between the growth rates of intra and extra-regional trade flows is remarkably lower. This indicates no evidence of significant trade diversion. There have been several attempts to measure the effects on trade flows of the formation of Mercosur (Yeats, 1998; Diao and Somwaru, 2000), most of them refer to aggregated trade flows and predict small net welfare gains for the country members.

Since its creation Mercosur has faced an extremely demanding agenda of extra-regional trade negotiations. It is considered as an emerging market offering good investment opportunities, with a population over two hundred millions of inhabitants (it represents half of the population of Latin America and Caribbean altogether). Mercosur has probably more to gain by joining the EU in a FTA rather than negotiating with North America, since Mercosur member countries already have free access to the North American market. An FTA with the EU will improve access to that market (Panagariya, 1996).

III. The Gravity Equation

Tinbergen (1962) and Pöyhönen (1963) were the first authors applying the gravity equation to analyze international trade flows. Since then, the gravity model has become a popular instrument in empirical foreign trade analysis. The model has been successfully applied to flows of varying types such migration, foreign direct investment and more specifically to international trade flows. According to this model, exports from country *i* to country *j* are explained by their economic sizes (GDP or GNP), their populations, direct geographical distances and a set of dummies incorporating some kind of institutional characteristics common to specific flows.

Theoretical support of the research in this field was originally very poor, but since the second half of the 1970s several theoretical developments have appeared in support of the gravity model. Anderson (1979) made the first formal attempt to derive the gravity equation from a model that assumed product differentiation. Bergstrand (1985, 1989) also explored the theoretical determination of bilateral trade in a series of papers in which gravity equations were associated with simple monopolistic competition models. Helpman and Krugman (1985) used a differentiated product framework with increasing returns to scale to justify the gravity model. More recently Deardorff (1995) has proven that the gravity equation characterizes many models and can be justified from standard trade theories. Finally, Anderson and Wincoop (2001) derived an operational gravity model based on the manipulation of the CES expenditure system that can be easily estimated and helps to solve the so-called border puzzle. The differences in these theories help to explain the various specifications and some diversity in the results of the empirical applications.

There is a huge number of empirical applications in the literature of international trade, which have contributed to the improvement of performance of the gravity equation. Some of them are closer related to our work. First, in recent papers, Mátyás (1997) and (1998), Chen and Wall (1999), Breuss and Egger (1999) and Egger (2000) improved the econometric specification of the gravity equation. Second, Berstrand (1985), Helpman (1987), Wei, (1996), Soloaga and Winters (1999), Limao and Venables (1999), and Bougheas *et al*, (1999) among others, contributed to the refinement of the explanatory variables considered in the analysis and to the addition of new variables.

According to the generalized gravity model of trade, the volume of exports between pairs of countries, X_{ij}, is a function of their incomes (GDPs), their populations, their geographical distance and a set of dummies,

$$X_{ij} = \beta_0 \; Y_i^{\beta_1} Y_j^{\beta_2} N_i^{\beta_3} N_j^{\beta_4} D_{ij}^{\beta_5} A_{ij}^{\beta_6} \; u_{ij} \tag{1}$$

where $Y_i\,(Y_j)$ indicates GDPs of the exporter (importer), $N_i\,(N_j)$ are populations of the exporter (importer), D_{ij} measures the distance between the two countries' capitals (or economic centers), A_{ij} represents any other factors aiding or preventing trade between pairs of countries, and u_{ij} is the error term. An alternative formulation of equation (1) uses per capita income instead of population,

$$X_{ij} = \gamma_0 \; Y_i^{\gamma_1} Y_j^{\gamma_2} YH_i^{\gamma_3} YH_j^{\gamma_4} D_{ij}^{\gamma_5} A_{ij}^{\gamma_6} \; u_{ij} \tag{2}$$

where $YH_i\,(YH_j)$ are the exporter (importer) GDP per capita. The two models above are equivalent and the coefficients are expressed as: $\beta_3 = -\gamma_3$; $\beta_4 = -\gamma_4$; $\beta_1 = \gamma_1 + \gamma_3$; $\beta_2 = \gamma_2 + \gamma_4$.

The second specification is usually chosen when the gravity model is applied to estimate bilateral exports for specific products (Berstrand, 1989), whereas the specification given by equation (1) is often used to estimate aggregated exports (Endoh, 2000). For estimation purposes, model (1) in log-linear form for a single year, is expressed as,

$$lX_{ij} = \beta_0 + \beta_1 lY_i + \beta_2 lY_j + \beta_3 lN_i + \beta_4 lN_j + \beta_5 lD_{ij} + \sum_h \delta_h P_{ijh} + u_{ij} \tag{3}$$

where l denotes variables in natural logs, $\sum_h \delta_h P_{ijh}$ is a sum of preferential trade dummy variables, and P_{ijh} takes the value one when a certain condition is satisfied (e.g. belonging to a trade bloc), zero otherwise. Our model includes dummy variables for trading partners sharing a common language and common border as well as trading blocs dummy variables evaluating the effects of preferential trading agreements. The coefficients of all these trade variables (δ_h) are expected to be positive.

A high level of income in the exporting country indicates a high level of production, which increases the availability of goods for exports. Therefore we expect β_1 to be positive. The coefficient of Y_j, β_2, is also expected to be positive since a high level of income in the importing country suggests higher imports. The coefficient estimate for population of the exporters, β_3, may be negative or positive signed, depending on whether the country exports less when it is big (absorption effect) or whether a big country exports more than a small country (economies of scale). The coefficient of the importer population, β_4, has also an ambiguous sign, for similar reasons. The distance coefficient is expected to be negative since it is a proxy of all possible trade cost sources.

Traditionally, the gravity model uses distance to model transport costs. However, recently Bougheas *et al.* (1999) showed that transport costs are a function not only of distance but also of public infrastructure. They augmented the gravity model by introducing additional infrastructure variables (stock of public capital and length of motorway network). Their model predicts a positive relationship between the level of infrastructure and the volume of trade, which is supported using data from European countries. We took a further step in this direction by introducing a new infrastructure index[1] (taking information on roads, paved roads, railroads and telephones) and differentiating between exporter and importer infrastructure as explanatory variables of bilateral trade flows. Our index is similar to Limao and Venables (1999) index.

We also incorporated differences in incomes between exporters using a variable similar to that in Arnon, Spivak and Weinbllat, (1996). Our variable $ydif_{ij}$ is constructed as the square of the difference in per capita incomes. Finally, a real exchange rate variable is added to our specification, once the time dimension is incorporated in the analysis, as shown in next section.

For a single period, the augmented gravity model is specified as follows,

$$lX_{ij} = \beta_0 + \beta_1 lY_i + \beta_2 lY_j + \beta_3 lN_i + \beta_4 lN_j + \beta_5 lD_{ij} + \beta_6 l\,I_i + \beta_7 l\,I_j \qquad (4)$$
$$+ \beta_8\, ydif_{ij} + \sum_h \gamma_h P_{ijh} + u_{ij}$$

where I_i, I_j denote respectively exporter and importer infrastructure, and $ydif_{ij}$ denotes the square of the difference in per capita incomes between countries i and j.

[1] Infrastructure in each country is measured by an index constructed taking the mean over four variables; km of road, km of paved road, km of rail (each one divided per population density) and telephone main lines per person. Since these measures are highly correlated among themselves is not possible to identify each of their influences on transport cost separately.

IV. Empirical Evidence

In constructing our empirical model we consider a sample of 20 countries, 15 EU countries (Belgium and Luxembourg data are added together) and five Mercosur countries (the four formal members and Chile as associated country). The time period under study goes from 1988 to 1996. Our data consists therefore, of an unbalanced panel data of 342 trading pairs, with 3,028 observations. Data sources are detailed in Appendix.

We estimated the gravity model of trade described in Section III, in a panel data framework. The use of panel data methodology has several advantages over cross-section analysis. First, panels make possible to capture the relevant relationships among variables over time. Second, a major advantage of using panel data is the ability to monitor the possible unobservable trading-partner-pairs individual effects. When individual effects are omitted, OLS estimates will be biased if individual effects are correlated with the regressors.

The estimated gravity models with individual effects for each trading pair are given by,

$$lX_{ijt} = \alpha_{ij} + \beta_1 lY_{it} + \beta_2 lY_{jt} + \beta_3 lN_{it} + \beta_4 lN_{jt} + \beta_5 lD_{ij} + \sum_h \gamma_h P_{ijh} + u_{ijt} \qquad (5.1)$$

$$lX_{ijt} = \alpha_{ij} + \beta_1 lY_{it} + \beta_2 lY_{jt} + \beta_3 lN_{it} + \beta_4 lN_{jt} + \beta_5 lD_{ij} + \beta_6 lI_i + \beta_7 lI_j + \sum_h \gamma_h P_{ijh} + u_{ijt} \qquad (5.2)$$

$$lX_{ijt} = \alpha_{ij} + \beta_1 lY_{it} + \beta_2 lY_{jt} + \beta_3 lN_{it} + \beta_4 lN_{jt} + \beta_5 lD_{ij} + \beta_6 lI_i + \beta_7 lI_j + \beta_8 ydif_{ij} + \beta_9 lRER_{ij} + \sum_h \gamma_h P_{ijh} + u_{ijt} \qquad (5.3)$$

where, α_{ij} stands for the individual effects, with (5.1) corresponding to the basic gravity model and (5.2, 5.3) to the augmented gravity models. $lRER_{ij}$ denotes the natural log of country *i* real exchange rate defined as the local currency value of 1 unit of country *j* currency, multiplied by country *j* GDP deflator and divided by country's *i* GDP deflator, where *i* is the exporter country and *j* is the importer.

Since individual effects (α_{ij}) are included in the regressions, we have to decide whether they are treated as fixed or as random. From an a priori point of view, the random effects model (REM) would be more appropriate when estimating typical trade flows between a randomly drawn sample of trading partners from a larger population. On the other hand, the fixed effects model (FEM) would be a better choice than REM when one is interested in estimating typical trade flows between an ex ante predetermined selection of nations (Egger, 2000). Since our sample includes trade flows among all the country members of the Mercosur and EU regional blocs, our intuition leads us to think that this view is consistent with a fixed effect specification. However, we also use the Hausman test to check whether the REM is more efficient that the FEM model. This will be the case under the null hypothesis of no correlation between the individual effects (α_{ij}) and the regressors.

A problem we faced with FEM is that we cannot directly estimate variables that do not change over time because the inherent transformation wipes out such variables. However, these variables can be easily estimated in a second step, running another regression with the individual effects as the dependent variable and distance and dummies as explanatory variables,

$$IE_{ij} = \alpha_0 + \alpha_1 D_{ij} + \alpha_2 Adj + \alpha_3 Lang + \mu_i \tag{6}$$

where IE_{ij} denotes the individual effects, D_{ij} denotes distance in natural logs, *Adj* is a dummy taking the value one when two countries share border and zero otherwise and *Lang* is a second dummy variable taking the value one when a pair of countries share the same language, zero otherwise.

A. Ordinary Least Squares and Cross-Section Means

We estimated equations (5.1, 5.2, and 5.3) for aggregate trade flows using several methodologies. Firstly, for comparison purposes, we used OLS $(\alpha_{ij} = \alpha)$. The results are shown in Table 1.

Secondly, we applied the regression to cross-section means (between estimation) obtaining similar results, shown in Table 2. In both cases all the coefficients present the expected sign, apart from infrastructure variables, and their magnitude is similar to that found in other studies cited above.

We performed an F-test to check for the poolability of the data. The

Table 1. OLS Results for the Basic and Augmented Generalized Gravity Equations

Independent variables	Model 1: Standard gravity (eqn. 5.1)	Model 2: Augmented gravity (eqn. 5.2)	Model 3: Augmented gravity (eqn. 5.3)
Constant	0.30 (0.53)	0.71 (1.32) *	-2.85 (-3.27) *
Exporter income	1.30 (24.54) *	1.28 (23.91) *	1.23 (23.65) *
Importer income	1.20 (24.18) *	1.39 (26.65) *	1.26 (21.33) *
Exporter population	-0.41 (-7.91) *	-0.38 (-7.78) *	-0.33 (-7.13) *
Importer population	-0.25 (-4.42) *	-0.35 (-6.47) *	-0.23 (-3.65) *
Distance	-0.91 (-38.20) *	-0.93 (-39.50) *	-0.85 (-32.46) *
Exporter infrastructure	---	-0.003 (-0.40)	-0.0005 (-0.06)
Importer infrastructure	---	-0.08 (-8.59) *	-0.08 (-8.94) *
Per capita income differential	---	---	-0.23 (-5.28) *
Real exchange rate	---	---	0.54 (4.60) *
EU dummy	0.11 (1.94) **	0.10 (1.73) **	0.12 (2.13) **
Mercosur dummy	0.65 (4.29) *	0.48 (2.90) *	0.41 (3.10) *
Adjusted R^2	0.830	0.834	0.837
F test	58.36 **	57.77 **	56.62 **
SSR	3,509	3,431	3,358
Log Amemiya prob. cr.	0.153	0.132	0.120
Akaike info. crt.	2.990	2.970	2.958
Log-likelihood	- 4,519	- 4,486	- 4,466

Notes: Time dummies are not reported. All variables except dummies are expressed in natural logarithms. Estimations use White's heteroskedasticity-consistent covariance matrix estimator. t-statistics are in parentheses. *, **, *** denote significance at the 1%, 5% and 10% level, respectively. F (n-1, nT-n-K) degrees of freedom in brackets. Where K is the number of variables in the regression, n is the number of trading pairs and T is the number of time periods. The number of observations equals (n x T) = 3,028.

Table 2. Between (OLS on Means) Results for the Basic and Augmented Generalized Gravity Equation

Independent Variables	Model 1: Standard gravity (eqn. 5.1)	Model 2: Augmented gravity (eqn. 5.2)	Model 3: Augmented gravity (eqn. 5.3)
Exporter income	1.31 (11.21)	1.32 (9.87) *	1.31 (8.58) *
Importer income	1.21 (10.37) *	1.42 (10.59) **	1.39 (9.88) *
Exporter population	-0.39 (-3.43) *	-0.37 (-3.14) **	-0.40 (-2.69) *
Importer population	-0.24 (-2.12) *	-0.34 (-2.90)	-0.35 (-2.68) *
Distance	-0.93 (-16.07) *	-0.94 (-16.40) *	-0.89 (-14.20) *
Exporter infrastructure	---	-0.02 (-0.57)	-0.02 (-0.64)
Importer infrastructure	---	-0.08 (-3.11) *	-0.08 (-3.23) *
Per capita income differential	---	---	-0.19 (-1.93) **
Real exchange rate	---	---	0.17 (0.65)
Adjusted R^2	0.844	0.85	0.852
SSR	351.80	341.70	336
Log Amemiya prob. cr.	0.032	0.012	0.013
Akaike info. crt.	2.87	2.85	2.85
Log-likelihood	-484.7	-479.2	-477

Notes: Time dummies are not reported. All variables except dummies are expressed in natural logarithms. Estimations use White's heteroskedasticity-consistent covariance matrix estimator. t-statistics are in parentheses. *, **, *** denote significance at the 1%, 5% and 10% level, respectively. The number of observations equals n = 342.

restricted model is the pooled model given by equations (5), with the restrictive assumption of a single intercept ($\alpha_{ij} = \alpha$) the same parameters over time and across trading partners, as shown in Table 1. The unrestricted model, however, is the same behavioral equation but allows the intercept to vary across trading partners. Results from the test, reported in Table 1, show that we cannot accept the null hypothesis of equality of individual effects. This indicates that the

OLS results are biased and we have to select a model with individual effects. The between estimates exploit the between dimension of the data (differences between individuals), but ignore any information within individuals. It is usually presented as an alternative to estimate long-run coefficients. As we can observe in Table 2, the coefficient estimates for the standard gravity model are very similar to those obtained by pooling the data (first column of Table 1). The same appears to be true looking at the augmented gravity model (second column of table 2). Nevertheless, we notice that the coefficients on exporter and importer infrastructure variables present the wrong sign, the former is not statistically significant but the latter is.

B. Fixed Effects and Random Effects Models

Tables 3 and 4 report respectively estimation results for the basic and augmented versions of the FEM and REM. The estimates of the country-pair individual effects are omitted for space considerations. In order to discriminate between the two models we test for the null hypothesis that the explanatory variables and the individual effects are uncorrelated using a Hausman test. The fixed effects estimates are consistent under both the null and alternative hypothesis whereas the random effects estimates are only consistent and efficient under the null hypothesis. Therefore REM will be preferred if the null hypothesis hold, otherwise FEM will be preferred.

Table 3 shows results for the test. The rejection of the null leads us to select fixed effects estimates since random effects estimates are inconsistent. Comparing our results of the pooled and fixed effects models, allowing for country-pair effects, as in FEM, slightly lowers the estimated income elasticities of trade, greatly rises the absolute value of population coefficients and more important, for the infrastructure variables, own infrastructure becomes statistically significant and has the correct sign, foreign infrastructure has the wrong sign.[2]

The variable *ydif* (squared per capita income differential) presents a positive signed coefficient, which is also significant. However, there might be a problem

[2] We will see later that when the model is estimated with time effects the coefficient of importer infrastructure becomes statistically non-significant.

Table 3. Regression Results for the Fixed Effect Model

Independent variables	Model 1: Standard gravity (eqn. 5.1)	Model 2: Augmented gravity (eqn. 5.2)	Model 3: Augmented gravity (eqn. 5.3)
Exporter income	0.77 (6.11)*	0.82 (6.63)*	1.18 (9.95)*
Importer income	1.19 (9.98)*	1.16 (9.69)*	1.05 (7.55)*
Exporter population	-7.24 (-7.54)*	-7.47 (-7.85)*	-8.01 (-8.21)*
Importer population	5.57 (9.30)*	5.73 (9.69)*	4.67 (8.17)*
Distance	---	---	---
Exporter infrastructure	---	0.11 (3.98)*	0.10 (3.79)*
Importer infrastructure	---	-0.07 (-3.28)*	-0.08 (-3.56)*
Per capita income differential	---	---	0.34 (3.58)*
Real exchange rate	---	---	0.39 (6.38)*
EU dummy	0.07(5.95)*	0.16(5.97)*	0.15 (5.88)*
Mercosur dummy	0.16(4.73)*	0.38 (4.91)*	0.38 (4.90)*
Adjusted R^2	0.97	0.977	0.978
SSR	416.23	410.73	400.82
Hausman test	864.14*	409.15*	679.05*
Log Amemiya prob. cr.	-1.75	-1.765	-1.781
Akaike info. crt.	1.084	1.072	1.056
Log-likelihood	-1,292	-1,272	-1,247

Notes: Time dummies are not reported. All variables except dummies are expressed in natural logarithms. Estimations use White's heteroskedasticity-consistent covariance matrix estimator. t-statistics are in parentheses. *, **, *** denote significance at the 1%, 5% and 10% level, respectively. The number of observations equals (n x T) = 3,028. The Hausman test follows a χ^2 with 6, 8 and 10 degrees of freedom in models 1, 2 and 3 respectively.

of multicollinearity. Another possible explanation for the positive sign is that higher differences in per capita income, a proxy for differences in factor endowments, have a positive effect on exports. Finally, the integration dummy for EU countries increases in magnitude whereas the one for Mercosur membership decreases. Both present the expected positive sign.

Table 4. Regression Results for the Random Effects Model (Generalized Least Squares Estimation)

Independent variables	Model 1: Standard gravity (eqn. 5.1)	Model 2: Augmented gravity (eqn. 5.2)	Model 3: Augmented gravity (eqn. 5.3)
Constant	-1.53 (-1.11)	-1.53 (-1.11)	-4.34 (-3.08) *
Exporter income	0.98 (13.13) *	0.89 (11.44) *	1.06 (13.49) *
Importer income	0.84 (11.24) *	0.94 (12.07) *	0.77 (9.77) *
Exporter population	-0.17 (-1.84) **	-0.15 (-1.56)	-0.31 (-3.19) *
Importer population	0.17 (1.78) **	0.13 (1.41) *	0.29 (3.06) *
Distance	-1.01 (-19.48) *	-1.00 (-18.81) *	-1.01 (-17.64) *
Exporter infrastructure	---	0.03 (3.48) *	0.05 (3.04) *
Importer infrastructure	---	-0.02 (-2.93) *	-0.05 (-2.59) *
Per capita income differential	---	---	0.02 (0.30)
Real exchange rate	---	---	0.61 (10.41) *
EU dummy	0.16 (3.85) *	0.16 (3.89) *	0.16 (3.91) *
Mercosur dummy	0.30 (3.93) *	0.305 (3.96) *	0.30 (3.97) *
LM Test	7,896 *	7,782 *	7,835 *
Adjusted R^2	0.976	0.976	0.977
SSR	488.01	484.26	465.07

Notes: Time dummies are not reported. All variables except dummies are expressed in natural logarithms. Estimations use White's heteroskedasticity-consistent covariance matrix estimator. t-statistics are in parentheses. *, **, *** denote significance at the 1%, 5% and 10% level, respectively. The number of observations equals (n x T) = 3,028.

C. Two Ways Fixed Effects Model Adding Cross-Section Weights

A further refinement in our model consists in adding time dummies to the former explanatory variables. We might offer several interpretations for these time-specific parameters. They could be interpreted as a proxy for EU-

Mercosur integration (globalization), but they also could be showing the effects of business cycle phenomena. Since additional interpretations could be convincing, we would like to emphasize that these time-dummies will pick up the effects of any variables affecting bilateral exports that vary over time, are constant across trading-pairs and have not been included in the list of explanatory variables. Results are shown in the first column of Table 5. We conducted a Wald test to check for the significance of time effects. We could not accept the null of insignificant time dummies.

Since we suspect that cross-section heteroskedasticity may be present, given the importance of the cross-section dimension of our data (n = 342), we estimate the same specification, but each pool equation is now downweighted by an estimate of the cross-section residual standard deviation. The second column of Table 5 reports the estimates of the two ways fixed effects model with cross-section weights. We obtain similar results, apart from the coefficient of the importer infrastructure variable, which is now positive signed, as the theory predicts, but non-significant.

In column 3 the income difference variable (*ydif*) is added to test for the existence of a Linder effect. Since we have problems of multicollinearity between the income variables and *ydif*, we estimated the model without exporter and importer income. The estimated coefficient on the variable *ydif* has now the expected negative sign and it is statistically significant. According to Linder's trade model, bilateral trade will be greater when the per capita GDPs of the trading countries are more similar. The rest of explanatory variables present very similar estimated coefficients.

Column 4 of Table 5 reports our results when movements in the real exchange rate are considered. The estimated coefficient for real exchange rate is positive and significant, indicating that price competitiveness is important. A 10% depreciation (devaluation) of the exporter currency rises exports by 2.8% according to our estimations. Main results concerning the rest of explanatory variables remain unchanged.

The interpretation of the coefficients on the integration dummy variables is also relevant for our analysis. Since our model is estimated in natural logs, all dummy variables are given a value of one in natural logs when the correspondent condition is satisfied and a value of zero otherwise. Thus a value of 0.40 (the Mercosur dummy in column 1 of Table 5) indicates that

Table 5. Regression Results for the Two Ways Fixed Effects Model

Independent variables	Model 4: No weights (eqn. 5.2)	Model 5: Cross-section weights (eqn. 5.2)	Model 6: Gravity model with Linder effect[a]	Model 7: Gravity model with real exchange rate[a]
Exporter income	0.87 (6.11)*	0.69 (28.94)	---	0.92 (35.51)*
Importer income	1.21 (7.35)*	1.09 (43.30)*	---	0.97 (41.88)*
Exporter population	-7.56 (-7.93)*	-5.92 (-34.86)*	-5.23 (-32.76)*	-5.62 (-32.15)*
Importer population	5.65 (9.82)*	4.08 (25.53)*	4.24 (29.97)*	3.98 (25.98)*
Exporter infrastructure	0.12 (4.47)*	0.07 (12.38)*	0.07 (15.99)*	0.07 (13.49)*
Importer infrastructure	-0.06 (-2.55)	0.001 (0.23)	-0.003 (-0.56)	-0.01 (-1.97)
Per capita income diff.	---	---	-0.1 (-26.19)*	---
Real exchange rate	---	---	0.26 (24.41)*	0.28 (28.32)*
EU dummy	0.17 (5.31)*	0.06 (18.79)*	0.04 (10.68)*	0.07 (19.15)*
Mercosur dummy	0.39 (4.88)*	0.39 (14.40)*	0.41 (14.22)*	0.33 (11.99)*
Wald t. H_0=no time dumies	64.11*	7,064*	15,450*	6,675*
Log Amemiya prob. cr.	-1.783	-1.780	-1.768	-1.8

Table 5. (Continued) Regression Results for the Two Ways Fixed Effects Model

Independent variables	Model 4: No weights (eqn. 5.2)	Model 5: Cross-section weights (eqn. 5.2)	Model 6: Gravity model with Linder effect[a]	Model 7: Gravity model with real exchange rate[a]
Akaike info. crt.	1.054	1.040	1.069	1.037
Log-likelihood	-1,236	-1,220	-1,259	-1,210
Adjusted R^2	0.98	0.99	0.99	0.99
SSR	401.37	411.04	416.87	403.83

Notes: Time dummies are not reported (but there are significant except for Model 7 in 1994 and Model 4 in 1989 and from 1993 to 1996). All variables except dummies are expressed in natural logarithms. Estimation uses White's heteroskedasticity-consistent covariance matrix estimator. t-statistics are in parentheses. [a] estimated based on equation (5.3). *, **, *** denote significance at the 1%, 5% and 10% level respectively. The number of observations equals (n x T) = 3,028.

intra-Mercosur trade is about 49% {[exp (0.40) -1] * 100} above what could be expected from the gravity model. Similarly, intra-UE trade is about 18% {[exp (0.17) - 1] * 100} higher than expected levels.

An alternative specification to the FE model consists in estimating the gravity equation in first differences (with 2,686 observations). This method has the advantage of eliminating the effects of possible autocorrelated disturbances, controlling at the same time for heterogeneity. Results[3] for the model in first differences and model 7 are very similar in order of magnitude and sign of the coefficients.

Table 6 reports the results obtained when the fixed effects from models 4, 5 y 7 are regressed on the distance variable and dummies which are fixed over time (common language and adjacency). According to our findings, only distance is statistically significant, whereas language and adjacency dummies present the correct sign but they are not significant. We obtain a very low R^2 coefficient, which means that there are other determinants of the trading-pair effects, different from the ones traditionally included in the analysis, which

Table 6. Cross-section Regression Results: Individual Effects Regressed over Distance and Dummies

Independent variables	FE from model 4 (eqn. 6)	FE from model 5 (eqn. 6)	FE from model 7 (eqn. 6)
Constant	26.04 (6.23) *	28.04 (8.67) *	22.23 (7.29) *
Distance	-1.04 (-1.98) **	-1.03 (-2.59) *	-0.96 (-2.53) *
Language dummy	1.21 (0.45)	0.80 (0.38)	0.86 (0.44)
Adjacency dummy	0.03 (0.01)	0.58 (0.33)	0.61 (0.38)
Adjusted R^2	0.011	0.02	0.02
SSR	42,271	25,840	22,255

Notes: Time dummies are not reported. All variables except dummies are expressed in natural logarithms. Estimation uses White's heteroskedasticity-consistent covariance matrix estimator. t-statistics are in parentheses). *, **, *** denote significance at the 1%, 5% and 10% level respectively. n = 342.

[3] These results are not reported here (available upon requests).

should be investigated. Our results are similar to those obtained by Chen and Wall (1999). The coefficient estimate for the distance variable is around 1%, slightly higher than the one obtained in the pooled and between regressions (Tables 1 and 2) and very similar to the one obtained in the REM (Table 4).

D. Dynamic Panel

Finally, considering that, trade relations once established might last for a long time, we estimated equation (5) in dynamic form. Results are shown in Table 7.

Lagged exports and lagged exchanged rates were added to the list of explanatory variables. The estimated parameter for lagged exports is statistically significant and with the expected positive sign. Additionally, we confirm that exchanged rates affect exports with one lag, since the correspondent estimated parameter is also significant. The short run coefficients of the variables are lower than the long run coefficients and the latter are similar to those obtained before with the signs remaining unchanged. We confirm that a 1% change in domestic/foreign income rises exports by 1% and a 10% change in the real exchange rate fosters exports by 2.6%.

V. Results' Evaluation: Estimates of Potential Trade

We use the coefficients obtained from the gravity equations to calculate potential exports. Estimated coefficients from model 7 presented in Table 5 (two ways fixed effects model with cross-section weights) served as the basis for the calculation.[4] According to our approach estimated exports equal potential exports. Table 8 reports our estimates for potential exports of each of the Mercosur countries to the EU for every year in our sample.

The potential for Mercosur exports exceeds the actual export value in 1996 for each single country. This means that the actual level of exports is below those that normal trade relations would support. However if we look at previous years, Uruguay and Paraguay results show a common picture, for these countries export potentials are higher than actual exports since 1994

[4] Very similar results were obtained with model 6.

Table 7. Regression Results for the Dynamic Fixed Effects Model (Eqn. 5.3)

Independent variables	Dynamic panel: Short-run coefficients:	Dynamic panel: Long-run coefficients
Lagged exports	0.50 (28.83) *	---
Exporter income	0.49 (15.66) *	0.98
Importer income	0.45 (17.04) *	0.90
Exporter population	-3.06 (-16.22) *	-6.12
Importer population	2.40 (13.45) *	4.8
Exporter infrastructure	0.04 (7.24) *	0.08
Importer infrastructure	0.01 (1.18) ***	0.01
Per capita income differential	-0.01 (-3.13) *	-0.03
Real exchange rate	0.11 (9.46) *	0.22
Lagged real exchange rate	0.02 (1.90) **	0.04
EU dummy	0.05 (16.89) *	0.1
Mercosur dummy	0.12 (4.52) *	0.24
Wald test (H_0 = no time dummies)	64.11 *	---
Log Amemiya prob. cr.	-2.123	---
Akaike info. crt.	0.714	---
Log-likelihood	-604	---
Adjusted R^2	0.98	---
SSR	246	---

Notes: Time dummies are not reported. All variables except dummies are expressed in natural logarithms. Estimations use White's heteroskedasticity-consistent covariance matrix estimator. t-statistics are in parentheses. *, **, *** denote significance at the 1% , 5% and 10% level, respectively. The number of observations equals (n x T) = 2,686.

and the difference has increased over time to a wide extent. The same seems to apply for Chile since 1992, apart from the results for 1995, where actual exports exceeded potential exports. As far as Argentina and Brazil are concerned, the evolution through time presents a mixed picture. Export potentials only exceeded actual exports in 1988-89, 1992-1993 and 1996.

Table 8. Mercosur Potential Exports* to the European Union: Estimates from Gravity Equation Augmented with Linder Effect and Real Exchange Rate (Equation 5.3)

Forecasted exports from:	Argentina	Brazil	Chile	Paraguay	Uruguay	Mercosur + Chile
1988	3,772,866	12,884,104	2,614,865	320,880	428,689	20,021,404
1989	4,021,197	12,060,940	2,811,569	357,014	451,760	19,702,480
1990	4,139,057	14,095,231	3,385,708	396,599	549,220	22,565,814
1991	3,992,203	10,166,112	3,269,409	320,363	534,759	18,282,846
1992	4,345,984	13,221,531	3,556,979	321,461	542,639	21,988,594
1993	3,900,643	11,162,124	3,150,351	268,193	472,845	18,954,156
1994	4,380,546	11,792,375	3,328,236	250,645	540,666	20,292,467
1995	4,758,004	12,984,401	3,982,954	268,189	600,341	22,593,889
1996	4,624,666	12,783,038	3,980,907	231,026	648,257	22,267,893
% Change	**Argentina**	**Brazil**	**Chile**	**Paraguay**	**Uruguay**	**Mercosur + Chile**
1988	16%	16%	-7%	-27%	-60%	7%
1989	28%	4%	-12%	-25%	-40%	3%
1990	-11%	14%	-4%	-32%	-28%	3%
1991	-17%	-16%	-4%	-15%	9%	-14%
1992	-2%	6%	1%	25%	9%	4%
1993	1%	1%	12%	-7%	10%	3%
1994	-4%	-12%	5%	3%	16%	-7%
1995	-5%	-8%	-6%	11%	26%	-6%
1996	7%	9%	6%	40%	39%	9%

Note: * Potential exports are expressed in current dollars.

Explanations about increasing and decreasing potentials should be based on time specific factors, such as for example, climate phenomena affecting the agriculture sector.

We also calculate intra-Mercosur trade potential in base on our estimates. Results are shown in Table 9.

Table 9. Mercosur Potential Exports* to the whole Mercosur: Estimates from Gravity Equation Augmented with Linder Effect and Real Exchange Rate (Equation 5.3)

Forecasted exports from:	Argentina	Brazil	Chile	Paraguay	Uruguay	Mercosur + Chile
1988	2,329,340	3,082,267	582,301	305,948	409,795	6,709,651
1989	2,786,503	2,715,159	642,314	370,454	461,101	6,975,532
1990	2,721,728	3,304,730	774,472	409,099	564,133	7,774,161
1991	2,662,404	2,811,783	785,196	332,621	568,886	7,160,890
1992	3,014,255	4,081,918	890,680	342,262	597,589	8,926,703
1993	3,012,120	3,873,043	873,236	316,701	575,058	8,650,157
1994	3,677,318	4,391,066	1,003,240	323,215	713,583	10,108,423
1995	6,107,491	6,947,828	1,736,052	514,956	1,176,161	16,482,488
1996	6,588,842	7,332,956	1,894,616	486,225	1,384,449	17,687,089

% Change	Argentina	Brazil	Chile	Paraguay	Uruguay	Mercosur + Chile
1988	105%	42%	4%	97%	18%	75%
1989	57%	32%	18%	-12%	-15%	45%
1990	19%	83%	18%	0%	-8%	51%
1991	8%	-6%	-1%	8%	-2%	13%
1992	4%	-19%	-9%	16%	1%	1%
1993	-30%	-40%	-21%	-4%	-19%	-27%
1994	-37%	-37%	-26%	-29%	-24%	-29%
1995	-26%	-6%	-2%	-8%	14%	-5%
1996	-32%	-12%	7%	-29%	16%	-12%

Note: * Potential exports are expressed in current dollars.

We observe that for all five countries (Mercosur current members plus Chile) export potentials seem to have been fully exploited before 1993. Total intra-Mercosur exports are bigger than our estimates since 1993 onwards.

VI. Conclusions

The objective of this paper was to analyze which are the determinants of Mercosur-European Union trade flows and to forecast trade potentials between the two blocs. With this aim we apply a gravity model to annual bilateral exports between 20 countries: Mercosur + Chile and the 15 current members of the EU.

Our results show that exporter and importer incomes, as expected, have a positive influence on bilateral trade flows. Income elasticities are close to unity as predicted by the theory. Exporter population has a large and negative effect in exports showing a positive absorption effect, whereas importer population has a large and positive effect on exports, indicating that bigger countries import more than small countries.

We investigated the role that infrastructure variables, income differences and exchange rates play as explaining bilateral trade flows in a panel data framework. This framework, which allowed for trading-pair heterogeneity, was shown to be statistically superior to the standard model. Our findings support the hypothesis of the importance of these variables since they are all statistically significant and present the expected sign, apart from the importer infrastructure variable that is not significant. Our results concerning infrastructure might have some important implications for economic policy. Viewing infrastructure as a international public good rises the question of how the cost of infrastructure should be shared between trading partners. For Mercosur-EU trade it seems that only exporter infrastructure fosters trade, therefore investing to improve the trading-partner infrastructure appears not to have spill-over benefits for the investor.

When testing intra-bloc trade effects, both preferential dummy variables present a positive sign and are statistically significant, suggesting that belonging to one of the two preferential arrangements fosters trade. However, since in our study we are not considering the difference between trade creation and trade diversion (Endoh, 2000), these results have to be taken with caution.

With reference to potential trade estimates, our results show that the potential for Mercosur exports exceeds the actual export value in 1996 for each single country, but in previous years we observed a mixed picture. This could be interpreted as a positive starting point for the future trade liberalization arrangements between both blocs on the side of Mercosur. Further research is needed to confirm this interpretation.

Appendix. Data Sources

CEPAL, Statistical Year Book for Latin America and the Caribbean, various years, United Nation Publication:
- Bilateral trade Mercosur + Chile.
- Infrastructure Mercosur + Chile.

OEA, America en Ciphers 1965, 1970:
- Bilateral trade Mercosur + Chile.

Wilke, James, Statistical Abstract of Latin America, Vol. XVII, University of California, Los Angeles (1976):
- Bilateral trade Mercosur + Chile.

BID, Intra-ALALC Exports (grouped according to Standard International Trade Classification), various years (1965 - 1969):
- Bilateral trade Mercosur + Chile.

OCDE, International Trade by Commodities Statistics (ITCS), CD ROM 1960-1996:
- Bilateral trade for MERC countries.

World Bank, World Development Indicators, CD ROM 2000:
- GDP.
- GDP deflator.
- Total exports and imports.
- Exchange rates against dollar.
- Population.
- Infrastructure for MERC countries.

World Bank, World Data, 1995 CD ROM:
- Germany data before 1990.

World B., Railways Database, http://www.worldbank.org /html/fpd/transport/rail/rdb.htm:

- Railways data.

FAO, Faostat Agriculture Data, http://apps.fao.org/page/collections:
- Population (forecast).

John Haveman's web site and http://www.indo.com/distance:
- Distance, expressed in kilometres, is the distance between capital cities.

References

Amjadi, A, and L.A. Winters (1997), "Transport Costs and Natural Integration in Mercosur," Policy Research Working Paper 1742: 1-33.

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

Anderson J.E. and E. van Wincoop (2001), "Gravity with Gravitas: A Solution to the Border Puzzle," NBER Working Paper 8079.

Arnon, A., Spivak, A., and J. Weinblatt (1996), "The Potential for Trade between Israel, the Palestinians and Jordan," *World Economy* **19**: 113-134.

Bergstrand, J.H. (1985), "The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence," *The Review of Economics and Statistics* **71**: 143-153.

Bergstrand, J.H. (1989), "The Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade," *The Review of Economics and Statistics* **67**: 474-481.

Bougheas S. *et al.* (1999), "Infrastructure, Transport Costs and Trade," *Journal of International Economics* **47**: 169-189.

Breuss, F., and Egger, P. (1999), "How Reliable Are Estimations of East-West Trade Potentials Based on Cross-Section Gravity Analyses?" *Empirica* **26** (2): 81-95.

Chen, I-H., and H.J. Wall (1999), "Controlling for Heterogeneity in Gravity Models of Trade," Federal Reserve Bank of St. Louis Working Paper 99-010A.

Deardorff, A.V. (1995), "Determinants of Bilateral Trade: Does Gravity Work in a Neo-Classic World?" NBER Working Paper 5377.

Diao, X., and A.S. Somwaru (2000), "An Inquiry on General Equilibrium Effects of MERCOSUR: An Intertemporal World Model," *Journal of Policy Modeling* **22** (5): 557-588.

Egger, P. (2000), "A Note on the Proper Econometric Specification of the Gravity Equation," *Economics Letters* **66**: 25-31.

Endoh, M. (2000), "The Transition of Post-War Asia-Pacific Trade Relations," *Journal of Asian Economics* **10** (4): 571-589.

Garman, G., J. Petersen, and D. Gilliard (1998), "Economic Integration in the Americas: 1975-1992," *Journal of Applied Business Research*, Laramie, Summer.

Helpman, E. (1987), "Imperfect Competition and International Trade: Evidence from Fourteen Industrial Countries," *Journal of the Japanese and International Economies* **1** (1): 62-81.

Helpman, E. and P. Krugman (1985), *Market Structure and Foreign Trade. Increasing Returns, Imperfect Competition, and the International Economy*, The MIT Press, Cambridge, MA/London.

Limao, N., and A.J. Venables, (1999), "Infrastructure, Geographical Disadvantage and Transport Costs," Policy Research Working Paper 2257, World Bank.

Mátyás, L. (1997), "Proper Econometric Specification of the Gravity Model," *The World Economy* **20** (3): 363-368.

Oguledo, V.I., and C.R. Macphee (1994), "Gravity Models: A Reformulation and an Application to Discriminatory Trade Arrangements," *Applied Economics* **26**: 107-120.

Panagariya, A. (1996), "The Free Trade Area of the Americas: Good for Latin America?" *World Economy* **19**: 485-515.

Poyhonen, P. (1963), "A Tentative Model for the Volume of Trade between Countries," *Weltwirtschaftliches Archiv* **90**: 93-99.

Soloaga, I., and Winters, A. (1999) "Regionalism in the Nineties: What Effects on Trade?" Development Economic Group of the World Bank, mimeo.

Tinbergen, J. (1962), "Shaping the World Economy. Suggestions for an International Economic Policy," New York.

Wei, S.-J. (1996), "Intra-national versus International Trade: How Stubborn Are Nations in Global Integration?," NBER Working Paper 5531.

Yeats, A. (1998), **"**Does Mercosur's Trade Performance Raise Concerns About the Effects of Regional Trade Arrangements?" The Word Bank Economic Review **12** (1): 1-28.