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Article

Gravity Model Applied on Trade Flows Between Portugal and the OECD

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Abstract: The study analyses foreign trade between Portugal and the OECD countries in the period 1980-2020. The objective, of course, is to analyse foreign trade and understand the main factors that influence foreign trade. The analysis is estimated using a gravity model, analysed using ordinary least squares, random effects, fixed effects and the Hausman Taylor estimator. According to the results, there is a negative impact of the real GDP of the country of origin, Portugal being in the sample, and a positive impact on the economies of the destination countries, thus being relevant for explaining trade. These results are related to the fact that most OECD countries have a significantly larger economic size than Portugal. Physical distance produced results that show a negative impact on the volume of trade transacted, so when trade is made with the countries furthest away from Portugal (with Australia, for example), the volume of trade drops to -5.60 'coeteris paribus'. On the other hand, the real effective exchange rate (reer) has a positive impact of 1.6. We also used some binary variables to analyse whether trade is made with a country that belongs to an economic integration zone itself, so trade made with a country in the European Union produces negative impacts, unlike the results of the binary variable MERCOSUR, which characterises whether countries belong to this economic bloc, where there are positive impacts on trade volume when trade is made with Brazil or Argentina, for example.

Keywords: foreign trade; economic integration zones; international economy & OECD

JEL classification: F00; F1; F14;

1. Introduction

In recent years, foreign trade has grown steadily, mainly due to various factors such as the growing demand for various goods on the international market, which in turn is related to population growth on the one hand and the shortcomings of the production sector in the countries in question on the other.

The intensification of international trade is seen above all in countries with a high level of economic development, where these exchanges intensify due to various issues in the markets themselves in general and particularly the need for these countries to exchange relevant goods and services to meet the various difficulties, in other words, the needs that these countries have. Bearing in mind that not all the countries in the world produce all the goods and services and even fewer have a complete industrial matrix, this motivates the demand for services that are not offered in these countries or the demand for goods that are not produced by them either.

In the same way that many countries in the world have emerged in recent years, there have also been significant advances in trade between countries in general terms, and in particular in trade zones, where on the one hand there have also been significant advances in the economic integration of countries. Economic zones have evolved significantly in recent years. This progress has been driven by the growing increase in trade flows and the new major players in the world market, such as China and other Asian countries like Singapore, for example.

The world's major economic blocs, for the most part, are made up of countries with a high level of economic and social development, based above all on a growing industrial component. The richest

countries in the world, by nature, are the ones with the most industrial development and with the appropriate incorporation of innovation.

Economic integration zones are currently a fundamental pillar in the economic development of countries, on the one hand, and the growing increase in foreign trade, on the other, so understanding the different levels of economic integration allows us to understand intraregional trade between countries in a generic way.

Naturally, countries trade what they produce. This makes them, on the one hand, dependent on the other country in terms of their export and import matrix. Thus, factors of various kinds make countries categorically relevant in the international arena, as well as their evolution in recent years. According to the OECD (2009), international trade influences a whole range of activities, including jobs, consumption and the fight against poverty. It also affects the environment and relations between countries. Trade is itself shaped by a series of influences ranging from natural resources to fashion. Also according to the report, the world share of OECD countries fell from 73 per cent in 1992 to 64 per cent in 2008.

It is therefore essential to understand the evolution of foreign trade in recent years, which has been driven above all by various factors in general and particularly in the OECD countries, which have various particularities, many of them related to the levels of economic integration of their member states.

These are distributed heterogeneously in different regions, which on the one hand makes it possible to have a diversified analysis by economic integration zones. In this respect, economic integration zones play a major role in foreign trade between countries.

As the OECD is an organisation of countries with the world's highest development indicators, the study is worth exploring in full. Economic literature focussing on foreign trade has been literally linked to the growth of the world's main export matrices. The strong need for the main industries and their components motivates trade between member states. On the other hand, the oscillations of the main markets for goods and services in the world stand out, influenced on the one hand by exogenous factors of various kinds.

The aim is to analyse the main factors influencing foreign trade between OECD member countries, and also to understand whether countries belonging to different levels of economic integration are relevant to explaining foreign trade between member countries and whether the fact that countries have a heterogeneous geographical distribution influences trade.

Thus, the hypotheses of the study are:

H1: To analyse whether economic and physical distances influence foreign trade between member countries;

H2: To analyse whether physical distances explain foreign trade between OECD countries;

H3: To understand some of the different factors that influence foreign trade.

The study has the following structure: section 1 analyses the Introduction, section 2 analyses the literature review and the theoretical framework, section 3 analyses the methodology and the data to be used, chapter 4 analyses and discusses the results and section 5 analyses the main conclusions of the study and finally the article ends with the references and appendices.

2. Literature Review

This section focuses on analysing the literature, essentially studies that analyse foreign trade between OECD countries. In particular, a brief analysis will also be made of the theoretical basis of the subject. When analysing the literature on studies applied to foreign trade using gravity models, some particularities related to the type of analysis itself should be taken into account. Most of these studies analyse foreign trade between a country and a group of countries or between member states

of the same economic integration zone or economic community. Thus, the study of **(Melitz , 2007)**, analysing the distance between North and South and South-South, the authors apply a battery of robustness tests and distinguish between North-North, North-South and South-South latitudes and control for other measures of factor endowment, such as differences in per capita production and differences in average temperature, rainfall and seasonal temperature variation. The authors emphasise in the text that the impact of differences in the North-South impact of bilateral trade is decreasing, and that this decrease is related to the influence of distance, which has been decreasing since the Second World War. Another relevant aspect pointed out by the authors is that internal distance has a greater impact than distance in the order of 10, the authors conclude. **(Yeshine , 2016)**, use a gravity model to analyse the determinants of foreign trade in Ethiopia, where Ethiopia's foreign trade is positively determined by the size of the economies, the GDP per capita differential and the openness of the economies of the trading countries. On the other hand, the authors also emphasise the cost of transport as a relevant aspect that has a negative influence on Ethiopia's foreign trade. In addition, the study shows through specific studies that Ethiopia could trade better with COMESA member countries and the new emerging economies in Asia, with Hong Kong, Singapore and Yemen and other European countries such as Russia and Turkey. **(Martinez- Zarzoso & Nowak-Lehmann, 2003)**, study trade between MERCOSUR and the European Union, where the analysis is based on a sample of 20 countries. The results show that the fixed effects model is relevant and preferable to a random effects model. The authors also highlight some aspects such as the number of variables, namely infrastructure, income differences and exchange rates added to the equation of the standard gravity model, which according to these characteristics, are considered important determinants of bilateral trade flows. **(Filippini & Molini, 2003)**, The study analyses the determinants of trade flows in East Asia, using a gravitational model applied to foreign trade. The authors analyse trade flows between the industrialised countries of East Asia (including China) and some developed countries, where they try to show the trade performance of these countries over the last 30 years. The main innovation in this study is related to the inclusion of a variable that analyses technological distance, so the authors try to understand the relevance of the technological difference between countries in determining trade flows. The authors sought to understand the dynamics of the Asian industrialised countries over the sub-periods and to measure the impact of technological distance on trade flows, making a brief comparison with the success of Latin American countries. **(Erginbay & Irena, 2019)**, show through the gravitational model that countries trade with each other according to their proximity, the size of their GDP, while the study analyses negative influences through trade barriers and positive influences through common traditions and a common political context. According to the study, large countries like the USA and Germany trade with each other and with other countries on other continents, while small countries like the Czech Republic have a less significant impact on world trade. The results also show that the size of imports and exports is influenced by whether or not they are part of a trade bloc, such as the EU in Europe or NAFTA in America. **(Binh et al., 2014)**, They applied the gravity model to analyse bilateral trade activities between Vietnam and 60 countries, analysing the period 2000- 2010. The results show that Vitenam's economic size, the economic size of the partner countries, physical distance and culture are relevant in explaining trade flows between partner countries. Also according to the studies, the convergence speed method was applied, where the results indicate that there is evidence of trade potential with new markets such as Africa and Western Asia.

(Lohani , 2020), studies India's trade flows with the rest of the BRICS member countries, the results indicate that the traditional arguments of the gravitational model in the context of India are valid, however, as the distance increases, the export of goods is negatively affected, i.e. due to a high cost related to the transport of goods, on the other hand, the common language and the common border positively influence foreign trade. On the other hand, according to the authors, the study suggests that the Indian government should negotiate trade dialogues to resolve trade barriers and market access obstacles between BRICS member countries.

(Camacho , 2013), studies Portugal's integration into world trade. Using a gravity model, the authors show that Portugal's participation in the EU and CPLP is important for both exports and imports. However, the results do not allow us to conclude whether Portugal's participation in the EEZ has advantages for Portuguese exports to EEZ countries.

(Frede & Yetkiner, 2017), analyse the dynamics of Turkey's regional trade using a gravity model with panel data. The study is analysed in two different periods, the first from 1960-2012, with a sample of 180 countries, and in the second period, the study is estimated with a sample of 176 countries, with the time horizon extending from 1994-2010. The results show that the gravity equation model is effective in explaining trade flows between Turkey and neighbouring regions, including the European Union, and has a significant impact on Turkey's trade flows, while other results show a negative effect on Turkish exports and a positive effect on imports. The authors conclude that while some regions contribute positively in most sectors, others contribute negatively, producing mixed results.

(Sokchea, 2006), analyse Cambodia's trade flows using a gravitational model, where the authors show the relevant factors affecting Cambodia's trade flows with its 20 relevant partner countries in the period 1994- 2004, with the remaining variables in the model assumed to be constant, thus the results indicate that trade flows depend significantly on the economic dimensions of the exporting and importing countries, the studies also show that there is evidence that trade flows depend significantly on economic dimensions. There was also a significant negative impact of exchange rate volatility on trade flows, as well as on aggregate exports. On the other hand, there seems to be little evidence that the depreciation of the Cambodian currency affects exports. In conclusion, ASEAN membership, according to the authors, plays little role in boosting trade flows in the region, results for sub-period II (1999- 2004) are relevant for explaining foreign trade between countries. The authors conclude that the results for sub-period II suggest that ASEAN membership helps to improve border trade. Which has suffered from the Asian financial crisis in recent years. (Eita , 2008), In a study of the determinants of Namibia's exports, using a gravity model applied to foreign trade, the authors show that economic distances, measured by the GDP of the countries of origin and destination, have a positive impact on foreign trade between Namibia and its partner countries. On the other hand, the analysis shows that the decrease in exports is related to the decrease in exports, while Namibia's GDP per capita and real exchange rates have no impact on exports. The results also show that exports are more intense with the countries with which Namibia shares a common border, the SADC and the European Union. Also according to the results, there seems to be an untapped export potential especially for trade with Australia, Kenya, Mauritius, the Netherlands, Portugal, South Africa, Switzerland and the United Kingdom. (Lucie & Vladimír, 2014), analysing the determinants of Austrian international trade, using the gravity model, the authors analyse the impacts on decision-making, with 3396 observations of Austrian exports to 211 countries, during the period 1995-2011, according to the authors, during the period in question, exports were very dependent on the German market, Thus, the model proved to be a natural result, on the other hand, other aspects have been verified, among many smaller trading partners, whose importance has been gradually shifting eastwards, thus, to analyse the estimates, the authors use the techniques of fixed effects and random effects.

(Irshad & Anwar , 2021), the study analyses bilateral trade between Pakistan and 198 trading partners during the period 1992-2016, the results show that market size, bilateral exchange rates, income differential, common religion, border and trade agreements positively influence the volume of external trade, on the other hand while distant and landlocked countries showed a negative relationship in relation to Pakistan's bilateral trade with the rest of the world. On the other hand, the results also show that Pakistan's trade pattern depends on the Hecksher-Ohlin theory, where it can be explained by differences in factor endowments, while WTO membership is less significant in bilateral trade with Pakistan.

(Rault et. al , 2007) study modelling international trade flows between Eastern European countries and OECD countries, the results of the study provide clear evidence in favour of the

traditional trade theory based on comparative advantage, which suggests a relocation of labour-intensive industry to the European Economic Community, where complementary specialisation is generated.

(Hung, 2014), studies the determinants of trade flows in services between Vietnam and the European Union using a gravity model estimated using random effects and fixed effects over the period 2002-2011 for total trade in services, exports and imports between Vietnam and the European Union. The results show that total trade in services indicates that bilateral trade flows in services between Vietnam and its European partner countries are mainly affected by the difference in GDP per capita, the population of the partner countries, the real effective exchange rate, the colonial relationship and being former members of CMEA (The Council for Mutual Economic Assistance).

(Ddia , Nica , & Yu , 2015), study Albania's foreign trade through a gravity model, the authors show the theoretical and empirical considerations on the development of trade, above all, with an emphasis on exports-imports, on the other hand, the results of the application of the model result in stable trade flows for Albania.

(Golovko & Sahin, 2021), analyse the international integration of the Eurasian countries using a gravity model, the results show that the Eurasian countries during the period of analysis were 35% less integrated into the world trade system than the expected potential level. (Garcia , Pabsborf , & Herrera , 2013) analyse foreign trade flows between MERCOSUR using a gravity model, the results of the study show that the influence of the agreement on trade has been positive but moderate as a whole, Mercosur has had positive effects and this agreement can be strengthened with the deepening of its relations and the entry of new members. (Martinez & Inmacullada , 2003) they study the determinants of trade flows between 47 countries and particularly the effects of preferential agreements between various economic blocs and zones, from 1980 to 1999. Using a gravity model, they compare the weight of the influence of preferential agreements and also infer the relevance of other determinants of bilateral trade flows such as geographical proximity, income levels, population and cultural similarities.

Another study with significant relevance is analysed in (Sandambi , 2021), which studies foreign trade between Portugal and the PALOP through a gravity model and a panel VAR model, the results of the study show that trade policy is affected by the tariff variable in the model, where there is a negative impact, motivated by the increase in customs duties on products imported by Portugal to the PALOP, the physical distance in the model has a positive impact, being relevant to explain foreign trade flows, on the other hand the economic distance has a positive impact of 0.792% on trade volume. (Pablo Chaves Ortiz, 2015), analyse the pacific alliance using the gravitational model. The results show that estimated trade for 2013 was only 1% below actual trade, equivalent to 240.6 million U\$D. On the other hand, the analysis by country pair showed that Mexico, for example, would benefit the most from the creation of the PA, where there is a significant expansion in imports and exports.

3. Methodology and Data

The chapter analyses the gravity model, applied in particular to foreign trade between OECD countries, in order to understand its rationale and implications. Gravitational models date back to 1962 and were first applied in (Tinbergen , 1962), where the model is used to explain the main factors that influence trade in a particular way. This chapter also reviews the empirical literature on analysing the main indicators that directly influence foreign trade, as well as the different types of models applied to trade in general. As for the data, it will be obtained from indirect sources, from the main international institutions such as the IMF, the World Bank, the OECD and other multilateral institutions, as well as some databases from the National Statistical Institutes of the countries being analysed. The time horizon of the analysis is 1980-2020, taking into account the individual heterogeneity of the countries in the sample. In the case of variables where there are no observations, an arithmetic mean is taken of the observations being analysed, so that the data is significantly filled in and a complete sample is obtained. Modelos Gravitacionais

Gravitational models applied to foreign trade in general measure economic distance through the real GDP variables of the country of origin and the country of destination and physical distances through the distance in kilometres between the main capitals of the countries of origin and destination. The model was first implemented in (Tinbergen , 1962), With the implementation of microeconomic functions, several authors later developed the gravity model, introducing relevant variables in foreign trade between countries. In (Bergstrand , 1985) e (Bergstrand, 1989), use the gravity model to analyse trade in goods, particularly Cobb-

Douglas functions. (Deardorff , 1998), analyses the determinants of bilateral trade using the Heckscher-Ohlin model. (Helpman , 1987), derived intra-industry trade, where changes over time in the relative size of the country explain the increase in the relationship between trade and income. (Limao & Venables , 1999), analysed the determinants of transport costs. (Egger , 2000) studies the problems of estimating gravity models using random effects models, in (Egger, 2004) the author analyses the effects of regional trade blocs with panel data, where he suggests techniques for estimating the gravity model. Authors have tried to analyse foreign trade using different model estimation techniques, taking into account the main characteristics related mainly to the different ways of estimating the model. Thus, various forms of estimation have appeared in the econometric literature, as analysed by the authors, such as the (Baldwin & Taglioni , 2006), the authors study the gravity model using dummy variables, on the other hand (Egger & Pfafmayr, 2003), analyse trade flows with time-invariant variables.

3.1. Model Descriptive Statistics

The section analyses the main descriptive statistics of the model, taking into account the data in references.

Table 1. Descriptive statistics for the gravity model.

Variables	Obs.	Mean	Standard Deviation	Min.	Max.
Vc	1,489	6.93e+14	4.69e+14	0	1.99e+15
Yi	1,555	197824.2	95384.66	7656	372076
Yj	1,441	893819.3	2065822	2837	2.14e+07
Ypci	1,558	16742.74	3.364.994	10743.64	21617.41
Ypcj	1,408	29970.15	20261.58	3.146.616	112417.9
Popi	1,558	1.02e+07	237485.4	9766312	1.06e+07
Popj	1,558	3.16e+07	5.10e+07	228138	3.32e+08
Dij	1,23	3.915.951	3.629.384	1453.11	19594.67
Reer	1,522	9.418.532	1.754.713	9.711.638	1.862.169
Front	1,558	.0519897	.2220776	0	1
UE	1,558	.4473684	.4973818	0	1
NAFTA	1,558	.1052632	.3069907	0	1
MERCOSSUL	1,558	.3947368	.488951	0	1
APEC	1,558	.2105263	.4078134	0	1
OCE	1,558	.0789474	.2697432	0	1
LC	1,558	.0263158	.1601241	0	1

Notes: The table shows the descriptive statistics for the gravity model. **Source:** Study results **Table 2** shows the data on the sample being analysed, together with the respective economic integration zones.

Table 2. Countries in the sample.

Country	Integration Zone	Country	Integration Zone
Portugal	EU	Lithuania	UE
Australia	APEC	Luxembourg	UE

Austria	EU	Mexico	MERCOSSUL
Belgium	EU	Netherlands	UE
Canada	NAFTA	New Zeland	APEC
Chile	MERCOSSUL	Norway	UE
Colombia	MERCOSSUL	Poland	UE
Costa Rica	MERCOSSUL	Slovakia	UE
Czech Republic	EU	Slovenia	UE
Denmark	EU	Spain	UE
Estonia	EU	Sweden	UE
Finland	EU	Switzerland	UE
France	EU	Turkey	OCE
Germany	EU	UK	
		USA	
Grece	EU		NAFTA
Hungary	UE	Ireland	EU
Iceland	UE	Israel	
Korea	APEC	Italy	EU
Latvia	EU	Japan	APEC

Notes: The table shows the countries in the sample and their respective Economic Integration Zones. **Source:** Study results.

3.2. Model Specification

The specification of the gravity model follows the basis of the original model proposed by the authors as the (Tinbergen , 1962) e (Bergstrand, 1985). Thus, in line with the original models described, the following model is adapted to analyse foreign trade between Portugal and the OECD countries. The model was originally described as follows:

$$X_{ij} = G^{Mi} M_j^{Dij} \quad (3.1)$$

The model analysing foreign trade between Portugal and the OECD is estimated as follows:

$$\ln X_{ij} = \beta_0 + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 \ln PC_i + \beta_4 \ln PC_j + \beta_5 \ln POP_i + \beta_6 \ln POP_j + \beta_7 \ln REER + \beta_8 LC + \beta_9 FRONT + \beta_{10} UE + \beta_{11} NAFTA + \beta_{12} MERCOSSUL + \beta_{13} APEC + \beta_{14} OCE \quad (3.2)$$

Where:

$\ln X_{ij}$, represents the volume of foreign trade between the countries of origin and destination;

$\ln Y_i$, is the GDP of the country of origin;

$\ln Y_j$, is the GDP of the destination country;

$\ln POP_i$, is the population of the country of origin;

$\ln POP_j$, is the population of the destination country;

$\ln REER$, is the real effective exchange rate;

$\ln Dij$, represents the distance between the countries being analysed;

LC , Dummy variable, shows whether the countries in the sample share the same language when the value is equal to 1 and 0 otherwise;

UE , is a dummy that indicates whether the country belongs to the Eurozone economic integration zone;

$FRONT$, is a dummy variable indicating whether the countries share a common border;

$NAFTA$, dummy variable, indicates whether the country belongs to the NAFTA free trade area;

MERCOSSUL, dummy variable indicating whether the country belongs to the MERCOSUR free trade area;

APEC, is a dummy representing whether the country belongs to the APEC economic bloc;

OCE, is a dummy representing whether the country belongs to the OECD free trade area;

u_{ij} , represents the error term of the equation;

3.2.1. Model Estimation Techniques

This section analyses the main techniques for estimating the gravity model. It also analyses the main model specification tests, such as the BP test, the Hausman test for choosing between fixed effects and random effects models, the BP test for choosing between random effects models and the fixed effects model.

There are, however, various techniques in the economic literature for estimating gravity models, and this literature analyses the fundamental techniques and those particularly applied in this study.

3.2.2. Ordinary Least Squares Model (OLS)

The OLS model is the most basic model in econometric estimation, assuming endogeneity between the models, where the correlation between the explanatory variable and X_j and the error term u , being non-zero $cov(x_{ij}, \varepsilon_{it}) \neq 0$. (Wooldridge, 2002), where gender problems are related to measurement errors and simultaneity between variables, individual specifics and heterogeneous characteristics related to the bilateral business relationship, according to (Chin & Serlenga, 2007), on the other hand, the fact that the variables are correlated with the standard error leads to invalid statistics, according to the analysis made in (Davidová, 2015).

3.2.3. Random Effects Model

The random effects model is one of the standard models in econometric literature, in which the variation of unobserved effects between individuals over time is assumed at the outset, according to the analysis carried out. (Baltagi, 2005). However, it is appropriate in studies with a large sample size. In general terms, the random effects model allows for variation in the intercept, where the $Corr(a_i, x_{itj}) = 0 \forall t, j$, This means that the unobserved heterogeneous component must be randomly distributed with a given mean and variance among the observed countries.

3.2.4. Fixed Effects Models

Fixed effects models take into account the effect that is not observable over time, and this effect is fixed in nature, so the effect is removed by transforming the model into first differences or by least squares with dummy variables, according to the analysis carried out in (Wooldridge, 2016), Another disadvantage is that the fixed effects model cannot be estimated because it does not allow for time-invariant variables, so we naturally opted to estimate the model with random effects. Estimator do Hausman & Taylor

The model previously described as the Hausman & Taylor estimator, is a solution to the models with the intercept invariant in time, problems analysed in fixed effects models, in addition, they are models that produce consistent and efficient estimates, this type of model is designated in the literature as being a hybrid type model, the model has the advantage of correcting the problems of autocorrelation and heteroscedasticity previously analysed in the fixed effects and random effects models, proposed in (Hausman & Taylor, 1981).

The model has the following specification:

$$Y_{it} = \beta_0 + x'_{1it} \beta_1 + x'_{2it} \beta_2 + z'_{1i} \alpha_1 + z'_{2i} \alpha_2 + u_i + \varepsilon_{it}, \quad (3.3)$$

Where: x_1 & x_2 , are the variables that vary over time, z_1 e z_2 are the time-invariant variables, the x_1 e z_1 are exogenous, i.e. that is, they are not correlated with the individual effects u_i , on the other

hand, the variables x_2 e z_2 , are correlated with the individual effects, being naturally endogenous in the model.

3.2.5. Main tests used in Gravitational Models

The section analyses the main specification tests used in gravity models, which include heteroscedasticity tests, autocorrelation tests and the specification test for choosing between random effects and fixed effects models, naturally known as the Hausman test.

Breush-Pagan Model Specification Test (1980)

The specification test proposed by the authors (**Breusch & Pagan , 1980**), is an asymptotic test based on Lagrange multipliers, the null hypothesis of the test accepts random effects models, on the other hand, the alternative hypothesis accepts Ordinary Least Squares models, so the same test is used to analyse the significance of random effects.

Teste Para Análise da Heterocedasticidade Breush-Pagan (1979)

The BP test, which analyses the existence of heteroscedasticity in the models, is an asymptotic test based on Lagrange multipliers, where the null hypothesis of the test assumes homoscedasticity in the models. According to the analysis carried out in (**Breusch, 1979**), but the variances of the residuals are constant over time, $E(u^2) = \sigma^2$, $i = 1, 2, \dots, n$. On the other hand, the alternative hypothesis assumes the presence of heteroscedasticity, where there are differences in the variances of the residuals.

Teste Hausman (1978)

The Hausman test is ideal for analysing the choice between fixed and random effects models, while the alternative hypothesis accepts the presence of fixed effects models, according to the analysis seen in (**Hausman , 1978**).

Teste para Análise da Autocorrelação (Wooldridge, 2002)

Autocorrelation in the model is analysed using the test proposed in (**Wooldridge , 2002**), the null hypothesis of the test assumes the absence of autocorrelation in the model, while the alternative hypothesis assumes the presence of autocorrelation in the model. Thus, the Wald test was used to analyse the presence of time fixed effects, a test proposed in (**Wald, 1943**).

4. Analysis and discussion of results

This section analyses and discusses the main results of the study applied to the gravity model. The results of the heteroscedasticity tests, BP tests, autocorrelation tests, random effects models, fixed effects models and the Hausman and Taylor model will be analysed.

Table 2. Estimation results for the Gravitational Model.

Variables	OLS	RE	FE	HT
Yi	-3,23E+11	-4,464E+11	-6,58E+11	-5,28E+11
Yj	-2150906.3	7986096.2	20460332	12061970
Ypci	4.034e+10***	4.062e+10***	3.939e+10***	4.024e+10***
Ypcj	-29455005	4,769E+11	3,12E+12	1,32E+12
Popi	-2827420.2	-9700075.9	-15008137	-13826272
Popj	-2215405.9**	-2726060.4**	-4354927.1	-2953867.2*
Dij	-4,92E+12	-5,601E+12	(omitted)	-4,20E+12
Reer	1,11E+15	1,664E+15	2,24E+15	1,98E+15
Front	9,50E+16	4,672E+16	-7,38E+17	-7,81E+16

EU	-3,45E+16	-5,243E+16	(omitted)	-5,41E+16
NAFTA	6,19E+16	7,851E+16	(omitted)	7,00E+16
MERCOSSUL	7,62E+16	6,182E+16	(omitted)	5,61E+16
APEC	1,94E+16	2,578E+16	(omitted)	7,01E+14
OCE	2.373e+14***	2.502e+14*	(omitted)	2,40E+17
LC	1.912e+14*	2,476E+17	(omitted)	3,66E+17
_cons	3,24E+16	7,867E+16	1,87E+17	1,02E+17
N	1084	1084	1084	1084
RE	[0,000]			
Hausman Test	[0.0789]			
Test BP	0.0000			
Heterocedasticidade	[.9723]			
Autocorrelação	[0,008]			

Notes: The Table shows the results of the estimation of the gravity model and the results of the main tests used in the study, BP test, Hausman test, autocorrelation and BP test for Heteroscedasticity. **Source:** Study results.

Table 2 shows the results for the gravitational model, the equation was estimated with the 4 models using panel data, the different specification tests were also carried out, such as the BP test, which indicates the absence of heteroscedasticity in the model, thus the p-value was 0.000 and the null hypothesis was rejected.

The Hausman test, proposed in (**Hausman , 1978**) The results produced a p-value of 0.0789, and if the null hypothesis was not rejected, the random effects model was significantly accepted over the fixed effects model.

The latter have the disadvantage of not presenting the estimates of the fixed variables over time. O teste BP proposto em (**Breusch & Pagan , 1980**), for the choice between the random effects models and the ordinary least squares model, produced a p-value of 0.0000, rejecting the null hypothesis, so the best model is the random effects model.

Autocorrelation in the model is analysed using the test proposed in (**Wooldridge , 2002**), where the results produced a p-value of 0.008, failing to reject the null hypothesis, which indicates that there is no autocorrelation in the gravity model.

The sample has 1084 observations. The model's economic distance is measured through the real GDP of the country of origin and the real GDP of the country of destination, while the physical distance is analysed through the physical distances between the countries of origin and destination.

We also estimated a complementary model, the Hausman-Taylor model, which is a hybrid model that combines both the random effects model and the fixed effects model, so it is a model that considers all the variables invariant from the outset, i.e. all the variables considered in the model are constant. It is therefore a model that produces consistent and efficient estimates from the outset.

In order to analyse the results, according to the analysis of the tests of the choice of models, through the specification tests it is certainly fundamental to use the random effects model. Thus, according to the results, the economic distance in the model produced the following results; the GDP of Portugal as the country of origin has a negative effect in the model of -4.46, while the GDP of the rest of the OECD countries has a positive and non-significant effect, which from the outset cannot explain the foreign trade between Portugal and the rest of the OECD. The reason for this result could be related to the fact that the country has a relatively smaller economy and also taking into account that the OECD brings together at least 10 of the world's largest economies and the European Union economic bloc. This doesn't allow us to make a precise judgement about the explanation of trade through economic distance, a similar analysis can be seen in (**Luz , 1997**).

Despite not being very relevant in foreign trade analyses, the variables that measure income were used, so according to the results there seems to be a positive impact between income and foreign trade, where GDP per capita has a significant and relevant impact for analysing foreign trade between Portugal and the OECD countries, so increasing income levels in the Portuguese economy stimulates

trade with its OECD partner countries by 4.03%, keeping everything else constant. This result could be associated with the need for imports from OECD countries. Naturally, the GDP per capita variable, being a qualitative variable, does not allow us to plausibly understand how it measures trade levels.

On the other hand, most OECD member countries are considered by the economic literature to be upper-middle income countries. Thus, these countries are more trade-intensive and, by nature, variables that measure income levels are rarely used in gravity model studies. (**Kubrendan , 2020**), used GDP per capita to analyse foreign trade between India and other BRICS countries.

The variable measuring income among the other OECD countries has a negative impact, which from the outset does not allow us to analyse in detail its plausible explanation of foreign trade between OECD countries.

The size of the country, on the one hand, influences the levels of foreign trade between the member countries; intuitively, foreign trade flows tend to be greater between countries with a large population, i.e. taking into account the country's domestic needs.

Physical distance in gravitational models was introduced by the (**Linnemann, 1966**), as a proxy for analysing the determinants of foreign trade between countries. Theoretically, gravitational models suggest that the greater the distance between partner countries, the greater the negative impact on foreign trade flows between OECD member countries.

Thus, the results of the analysis suggest a negative impact of - 5.60, which could be related to the geographical dispersion between OECD countries. However, distance is relevant in explaining foreign trade when it is carried out with Australia, for example, in line with the results analysed in (**Sandambi , 2021**).

The real effective exchange rate is relevant for analysing the levels of trade between countries, with an impact of 1.66, keeping everything else constant. We used the variable *Front*, a binary variable equal to one if the countries share the same border and zero otherwise, to analyse whether trade is carried out with a neighbouring country, in the particular case of this study, Portugal shares a border with Spain, so, holding everything else constant, trade carried out in the presence of Spain significantly increases trade flows by 4.67. This result may also be associated with trade carried out in the presence of countries close to Portugal.

Foreign trade zones are highly relevant in analysing trade flows between member countries, so it is plausible that there is a correlation between free trade zones and trade volume, with a significant increase in countries with a high increase in trade volume between countries in the same zone. In this analysis, the EU variable was used as a binary variable that takes on the value one when trade is made with the member countries of the European Union. The results of the study seem to indicate the opposite, i.e. the results suggest a negative impact on foreign trade flows between Portugal and the OECD countries. There is evidence of negative trade flows of 4.67.

On the other hand, trade with the countries of the NAFTA economic bloc has a positive impact of 7.85 per cent. This result may be associated with the fact that trade is being carried out in the presence of countries with a large economic dimension and also with a huge volume of trade transacted. With the MERCOSUR countries, the volume of trade has an impact of 6.18, which is a positive impact and can explain the levels of trade between Portugal and the MERCOSUR member countries.

With APEC countries, foreign trade has a positive impact of 2.57, and 2.50 when foreign trade is carried out in the presence of OEC countries, so the results provide a plausible explanation for the volume of foreign trade transacted between the countries.

In general terms, the study plausibly analysed foreign trade between Portugal and the OECD countries, where the results show different impacts according to the nature of the variables being analysed, thus showing the different ways of measuring trade flows between Portugal and the OECD member countries.

5. Conclusion

The results produced in the analysis are in line with the variables under study, so according to the results, the analysis shows there is evidence of a positive impact on foreign trade between Portugal and the OECD member countries, the variable related to income levels in the economy points to the existence of a positive impact on the volume of trade transacted, that is, both in the countries of origin and for the countries of destination, the population variable shows negative impacts on foreign trade between Portugal and the OECD countries, so these results do not seem to plausibly explain foreign trade flows. On the other hand, physical distance in the model had a negative impact, proving the theory of gravitational models, where the greater the distance, the greater the negative impact on foreign trade flows.

In general terms, the results are plausible evidence of what was expected when analysing foreign trade between Portugal and the OECD countries. On the other hand, there are some limitations related to the stata software, as it is a version without an official licence, so parameter estimations end up being limited.

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