The Empirical Economics Letters, 18(11): (November 2019) ISSN 1681 8997

Spatial Three-Dimensional Panel Gravity Model for International Trade in Eurozone

Ferda Yerdelen Tatoglu

Department of Econometrics, Faculty of Economics
Istanbul University, Beyazit, Turkey

Email: yerdelen@istanbul.edu.tr

Abstract: This study examined the presence of spatial effects on international trade within the Eurozone through the use of the three-dimensional (3D) panel gravity model. A spatial weight matrix was incorporated within this model to simulate neighboring relations between countries of origin and destination. An analysis was conducted for the 14 countries within the Euro region, and the resulting findings confirmed that inter-country distance and neighboring borders are important factors influencing international trade between countries.

Keywords: Panel gravity, Three-dimensional panel, Spatial panel

JEL Classification Number: C1, C5, F1

1. Introduction

After being introduced by Tinbergen (1962), the gravity model has gained theoretical and practical importance in international trade literature through the use of various trade models by Begstrand (1989), Deardorff (1995), and Evenett and Keller (2002). A number of previous studies are documented, and, although these have mostly considered a single destination, research has been carried out since 2000 which includes estimation using a three-dimensional (3D) panel gravity models. Work has, in particular, discussed the estimation methods of the 3D panel data model using fixed and random effects for the inclusion of two unit effects by various means. The following authors are credited with analysis in this field: Egger and Pfaffermayr (2003); Baldwin and Taglioni (2006); Baier and Bergstrand (2007); Balazsi, Matyas, and Wansbeek (2015); Matyas, Hornok, and Pus (2013); Balazsi, Baltagi, Matyas, and Pus (2017); and Baltagi and Bresson (2017).

Regardless of whether gravity models are two or three dimensional, inter country distance is a significant explanatory variable affecting trade relations between countries. Neighboring relations between countries are also an important factor, and initial studies introducing the concept of spatial dependence in trade were conducted by LeSage and Pace (2009) and included within the gravity equation by LeSage and Polasek (2008), LeSage and Llano (2013), and LeSage and Thomas-Agnan (2015). Of the work that has been documented, only a small number of studies have considered two dimensional estimates using the spatial panel gravity model. In recent times, research combining spatial

models and multidimensional panel data models has been carried out by: Baltagi, Fingleton, and Pirotte (2014); He and Lin (2015); Fingleton, Gallo, and Pirotte (2018); and Galle and Pirotte (2017). These studies performed estimations using spatial nested panel data models through the use of fixed and random effects.

This study discusses estimation with a three dimensional (3D) panel gravity models with non-nested two unit dimensions employing spatial econometric techniques. A total of 14 countries, each using the single European currency (euro) between 1997 and 2016, were included in this analysis. This paper has the following structure: section 2 discusses the models used and method of estimation; section 3 contains the estimations and test results for the selection of the most appropriate model. The final part is conclusion.

2. Model and Method

The basic gravity model is based on Newton's laws of motion and was adapted for international trade flows by Tinbergen (1962). It is logarithmically, three dimensional, and with two unit (exporter and importer) effects defined as:

$$\ln X_{ijt} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln D_{ij} + \mu_i + \gamma_j + \ln u_{ijt} \qquad (1)$$
$$i=1,....N;\ j=1,...,N-1;\ t=1,..,.T$$

Here, *i* denotes the country of origin and *j* denotes the country of destination. X_{ij} represents the exports from country *i* to country *j* in time *t*; and Y_i and Y_j constitute the gross domestic product (GDP) per capita for country i and country j, respectively. D_{ij} is the geographical distance between the countries in question and is a significant explanatory variable of the model. μ_i and γ_j are exporter and importer effects respectively. In addition, the effects of the neighboring relations of country *i* and country *j* are included, giving rise to the following 3D spatial panel gravity models:

$$\ln X_{ijt} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln D_{ij} + \rho W_{ij} X_{ijt} + \mu_i + \gamma_j + u_{ijt} \quad u_{ijt} = \lambda W_{ij} u_{ijt} + \varepsilon_{ijt} \qquad (2)$$

$$\ln X_{ijt} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln D_{ij} + \rho W_{ij} X_{ijt} + \mu_i + \gamma_j + u_{ijt} \qquad (3)$$

$$\ln X_{ijt} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln D_{ij} + \mu_i + \gamma_j + u_{ijt} \qquad u_{ijt} = \lambda W_{ij} u_{ijt} + \varepsilon_{ijt} \qquad (4)$$

In all cases, *W* is the spatial weight matrix indicating the neighboring relations between countries *i* and *j*. The elements of this matrix are either 0 or 1; 1 signifies that the two countries border each other, while 0 indicates that this is not the case. Model 3 is a spatial autoregressive (SAR) model which dictates that exports from country *i* depend on exports from country *j*. Model 4 is a spatial error model (SEM) which asserts that the residuals from the export models of neighboring countries are spatially auto-correlated. Model 2, a spatial autoregressive combined (SAC) model, include the influence of the SAR and SEM and indicates that both dependent variables and residuals in the neighboring countries are related.

Multidimensional spatial panel data models differ from spatial panel data models by incorporating a spatial weight matrix. Here, in addition to the neighbors of country *i*, the neighbors of countries *j* are also incorporated, and a (N*N-1)*(N*N-1) dimensional matrix is produced. The estimation also includes the effects of country *j*, in addition to those of *i*, as a unit effect. Moreover, it is possible to combine different estimation methods proposed for multidimensional panel data models and spatial econometric techniques.

3. Empirical Analysis

3.1. Data

This study examined the international trade of 14 bordering European countries[1], which used the euro between 1997 and 2016, within the framework of gravity models which included spatial effects. A total of 3640 observations were made with *i*, *j*, and *t* set to values of 14, 13, and 20, respectively. The spatial weight matrix was row-standardized and generated by skew neighboring, having dimensions of 182 by 182. In these models, X_{ijt} denotes exports (in 2010 US$), Y_{it} and Y_{jt} represent GDP per capita for the origin and destination countries (in 2010 US$), and D_{ij} is the distance between two countries.

Figure 1: Bordering Eurozone Countries



[1] Austria, Belgium, Estonia, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Slovak Republic, Slovenia, Spain.

In Figure 1, the red areas indicate countries that were included in this study. These countries are 14 bordering European countries, which used the euro.

3.2. Test and Estimation Results

First, the presence of the unit effects was tested and then tested whether these effects were correlated with the independent variables. One-way and two-way Lagrange Multiplier (LM) and adjusted LM (ALM) tests were carried out to test the basic hypotheses $H_0:\sigma_\mu^2=0$ and $H_0:\sigma_\gamma^2=0$; these were both rejected, and it was concluded that the model was influenced by origin and destination country effects (Table 1).

Table 1: Test Results for Unit Effects

$H_0:\sigma_\mu^2=0$				$H_0:\sigma_\gamma^2=0$			
$H_1:\sigma_\mu^2\neq 0$		$H_1:\sigma_\mu^2>0$		$H_1:\sigma_\gamma^2\neq 0$		$H_1:\sigma_\gamma^2>0$	
LM	**ALM**	**LM**	**ALM**	**LM**	**ALM**	**LM**	**ALM**
1.01e+04*	7304.59*	100.44*	85.46*	5550.97*	3453.54*	74.50*	58.77*

Note: * denote statistical significance at 1 percent.

A Hausman test was used to determine whether both unit effects were correlated with the independent variables; this was found to be the case, and it was therefore concluded that the fixed effects estimator was consistent (Table 2).

Table 2: Hausman Tests

$H_0:\mathrm{E}(X_{it}\mu_i)=0$	$H_0:\mathrm{E}(X_{it}\gamma_j)=0$
-386.83*	985.15*

Note: * denote statistical significance at 1 percent.

The SAC, SAR, and SEM estimations with fixed effect assumptions are presented in Table 3. In accordance with the results obtained for Global Moran's I, Global Getis-Ord, and Moran's I error test, the basic assumption that there was no spatial effect was rejected, and the presence of spatial effects was accepted. Since the value of Moran's I is positive, high values and low values were clustered. In addition, the findings from the LM SAC test conducted using the SAC model with the null hypothesis of H_0: $\rho=\lambda=0$, to test the significance of combined spatial error and spatial lag, enabled the H_0 hypothesis to be rejected, and it was concluded that either the spatial error or spatial lag was significant. The LM error test, conducted to test the hypothesis of H_0: $\lambda=0$, indicated that the spatial error was significant. The LM lag test showed that the hypothesis of H_0: $\rho=0$ is valid and

that the spatial lag is not significant. The model is the fixed effect SEM model with no spatial lag but with a spatial error.

Table 3: Estimation Results

	SAC		SAR		SEM	
$\mathbf{Y_{it}}$	1.848*	1.864*	2.033*	2.039*	2.440*	2.440*
$\mathbf{Y_{it}}$	0.969*	1.014*	0.969*	1.015*	0.970*	1.018*
$\mathbf{D_{ij}}$	-1.419*	-1.453*	-1.419*	-1.452*	-1.419*	-1.452*
λ	-0.338*	-0.307*	-	-	0.313*	0.314*
ρ	0.325*	0.313*	0.232*	0.227*	-	-
$\mathbf{R^2}$	0.251	0.308	0.567	0.587	0.859	0.869
Wald	1215.11*	1604.53*	47390.10*	5136.79*	22104.11*	23926.23*
F	75.98*	57.30*	269.19*	183.457*	1381.51*	854.51*
n	3640	3640	3640	3640	3640	3640
Dummy	μ_i	μ_i, γ_j	μ_i	μ_i, γ_j	μ_i	μ_i, γ_j
Global Moran's I	0.023*	0.025*	**LM error(robust)**		42.832*	49.2773*
Global Geary GC	0.997	0.990	**LM lag(Anselin)**		0.155	0.165
Global Getis-Ord GO	-0.023*	-0.025*	**LM lag(robust)**		0.064	0.067
Moran MI error test	6.671*	7.150*	**LM SAC**		42.988*	49.438*
LM error (Burridge)	42.923*	49.371*				

Note: * denote statistical significance at 1 percent.

The last two columns of Table 3 present the estimations from the fixed effects SEM model. The first column indicates the estimations for the origin country only, and the second column provides the estimations for both the origin and destination countries. Although the parameter estimates are close to each other, and the test results presented in Table 1 illustrate the significance of both effects, the use of the model estimate in the last column is considered to be the correct choice. According to the results, the F and Wald tests indicate the model's general significance and the R^2 value is almost 87%. A 1% increases in the origin country's GDP increases the exports of the destination country by 2.44%; a 1% increases in the destination country's GDP increases its exports by 1.02%. A 1% increase in inter-country distance decreases exports by around 1.5%.

4. Conclusion

This study used a multidimensional spatial panel gravity model to estimate the bilateral trade relations in the Eurozone. The results showed that the spatial relation between origin and destination countries is a significant and positive component of the gravity model.

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