Economic Discussion Papers

Efficiency Series Paper 5/2013

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A Dynamic Approach to Road Freight Flows Modeling in Spain

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Abstract

This paper presents an innovative approach where a dynamic time specification derived from a gravity model is used for the first time to analyse the transport of goods by road. This dynamic approach, which has recently been implemented in international goods trade models instead of the traditional static specification, is applied to the case of Spain using panel data comprising the 15 NUTS-3 regions of the Peninsula between 1999 and 2009. Relying on the System General Methods of Moments methodology, we have found significant evidence that the flow of goods by road has a strong persistence effect. We have also found that the quality of road transport infrastructure has a significant impact on the flows of goods. The estimated equation is used to make predictions of traffic flows among regions and to calculate total emissions associated with these trades. According to our findings, we suggest to keep subsidizing the replacement of old vehicles by more energy-efficient ones.

Keywords: Freight flows, Interaction data, Gravity model, Dynamic Panel, CO2 Emissions

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1. Introduction

Freight transport plays a key role in economic activity and enables the exchange of goods between economic agents while boosting regional development. However, the social impact in terms of negative external effects on both security and the environment is not negligible. In recent decades, population growth and greater economic activity have caused a steady increase in goods traffic worldwide.

However, as statistics indicate, these new transport operations are not carried out uniformly by the different modes of transport. In the case of Europe, road transport is the most frequently used medium for the movement of goods. For example, in 2009, 79% of the volume of goods deployed within the borders of the EU-15 was transported by road compared to 14% by rail, with inland waterways accounting for the remaining 7%. In Spain, the pattern is very similar: according to the National Statistics Institute, road transport accounts for 77 of every 100 tons transported. The prevalence of road transport was consolidated over the period 1999-2009, when its use increased by 107% with a growth rate of 11%. To put this into context it should be noted that 80% of the products manufactured in Spain are destined for domestic trade (Llano et al., 2010).

This enormous volume of road traffic is distributed differently across the transport network of the origin and destination regions. This research aims to estimate elasticities associated with the variables that determine the different patterns of flows between regions using a gravity model. Additionally, once we have estimated the parameters of the model, we make predictions of national transport operations and compute the carbon emissions levels associated with these transport movements.

Despite the apparent simplicity of the gravity model from a theoretical point of view, in empirical applications the model is usually misspecified because unobserved heterogeneity is not controlled for and the dynamic nature of road transport flows are ignored (Egger and Pfaffermayr, 2003). In order to control for bias due to the unobserved heterogeneity of the regions, panel models are used since they are able to capture the individual effects of the territories under study. In recent years, panel models have replaced cross-section settings in the empirical trade and transport demand studies. However, the dynamic role of the internal transport of goods is usually completely ignored. Once established, trade relations between regions can last for long periods of time (Eichengreen and Irwin, 1998). Thus, current trade flows are likely to be dependent on past trade flows, with that the underlying freight movements also depend on variations in traffic flows in previous periods.

Different methodologies have been used to analyze the factors that govern the flow of goods among regions. An early classification of the models used to analyze the traffic of goods between cities (Harker, 1985) distinguished among econometric models, spatial equilibrium models, pricing models, and freight network equilibrium models. In this study, the analysis of freight flows is carried out by applying an econometric model. This methodology is based on using econometric techniques to obtain structural relations between system variables. These ignore formal aspects of the transport network such as, for example, specific nodes, and the spatial dimension of the process is included only by the distance between the regions of origin and destination (Harker, 1987).

These models, also known as microeconomic models, can be classified into aggregated and disaggregated models according to the level of data aggregation (Winston, 1983). The basic unit of observation in the aggregated data model is the total share or the total volume corresponding to a mode of transport for a given geographic level. From a theoretical point of view they are often the solution to a cost-minimization problem, though in empirical applications this is not explicitly recognized. In disaggregated models, the basic unit of observation is the decision-makers choice for a specific mode of freight. These models are more focused on behavioral aspects of decision-making and have a firmer theoretical grounding, but have the disadvantage that they require extensive data.

Broadly speaking, the data used to calibrate a model will depend on the purpose of the study and the availability of the data, as recognized by Oum (1989). Thus, if the main purpose of the analysis is to predict aggregate traffic, the use of aggregate data would be preferable because otherwise an aggregation method would need to be applied. If the main goal of the paper is simulate how decisionmakers respond to changes in regulation, on the other hand, disaggregated data would be more appropriate. In terms of cost, disaggregated models require an extensive database and these are usually difficult to obtain because of the confidentiality of private information.

Thus, the empirical approach depends on the objectives of the study and the availability of suitable data. This paper uses an aggregate database composed of a balanced panel of the 15 Spanish peninsular regions for the period 1999-2009. Our study has several aims. First, we try to determine whether the correct specification of the gravity model applied to road transport should include a dynamic component. In addition, we attempt to measure the importance of infrastructure quality and also to compute the evolution and prediction of CO2 emissions caused by road transportation. Moreover, thus is the first study, as far as we are aware, to use a time-varying variable for the distance between regions as a proxy for transportation costs.

The paper is organized as follows. Section 2 summarizes the methodology of the gravity equation applied to road freight flows modeling and its empirical specification. Section 3 describes the database used. Section 4 details the estimation process and the results are presented. Section 5 presents the application of the estimated models to the computation of carbon emissions. Finally, Section 6 contains the main conclusions of our study and possible future lines of research.

2. Freight flow models based on gravity

Gravity models have been widely used in the literature of international trade[2].In line with Newtons law of universal gravitation, they are based on the idea that bilateral trade flows are directly related to the size of regions and inversely to the distance that separates them. In general, the variables included in the models to represent the size of the regions are the GDP or population, while among the friction factors, distance is often used as a proxy for transport costs. The augmented gravity model specification can include other variables to test whether they have a significant effect on trade flows. In the international trade literature, dummy variables usually appear to capture the effect of shared language, adjacency or belonging to a monetary union. In our case, we include a proxy for the quality of road infrastructure. By including this variable we try to capture the effect of the heavy investments made by the European Union in Spain through the Structural Funds[3].

Although the theoretical support for the gravity model was originally very poor, since the second half of the 1970s, several theoretical developments have filled this gap. Anderson (1979) made the first formal attempt to derive the gravity equation from a model that assumed product differentiation.

[2]See Anderson (1979), Helpman and Krugman (1987) and Anderson and Wincoop (2003)

[3]See, among others, Cantos et al. (2005)

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 In a recent study Anderson and Wincoop (2003) applied gravity model to bilateral trade including transport costs and other specific trade factors as explanatory variables. Fidrmuc (2009) appoints other popular applications such as the study of the effects of the currency unions on international trade Rose (2000), intra-firm trade (see Egger and Pfaffermayr (2005)) and Foreign Direct Investment analysis (Egger and Pfaffermayr, 2004). Gravity models have also been widely applied in the trip distribution step of complex national and international freight transport models ((**?**).

Initially, the gravity model was developed for cross-sectional analysis of countries at a particular time. However, to avoid a poor specification of the models, the relative heterogeneity of patterns of trade flows across countries has to be considered (Glick and Rose, 2002).The panel approach has several advantages over cross-sectional analysis: apart from increasing the degrees of freedom, it also captures the relationships between variables over a long period of time and identifies the role of the business cycle on these relationships. On the other hand, the use of panel data allows taking into account the time-invariant specific effects of the different regions. The cross-section setting is likely to suffer from omitted variable bias as is does not include the unobserved effects of regions and ignores the temporal effects of trade (Harris and Mátyás). The comparisons of panel estimators Egger and Pfaffermayr (2003) show, however, that instead of using one dummy variable per country, individual country pair dummies (fixed effects) should be included to get efficient estimators. While these authors recommend panel data models, another caveat may be related to the possible non-stationarity of analyzed data (Fidrmuc, 2009).

Furthermore, studies using the gravity model with panel data typically ignore the possibility that trade has a dynamic dimension. The importance of past trade values has been stressed already by Eichengreen and Irwin (1998), who included lagged trade in repeated cross-sections for selected years. Lagged values of trade are usually a highly important determinant of current trade ows. De Benedictis and Vicarelli (2005) highlight that, despite the importance of taking into account unobserved heterogeneity and the probable persistence effect, few studies have used a dynamic specification of a panel model when estimating the gravity equation:Bun and Klaassen (2006) De Nardis and Vicarelli, De Benedictis and Vicarelli (2005) and Martínez-

Zarzoso and Nowak-Lehmann (2003); Martínez-Zarzoso et al. (2009a). To our knowledge, so far no studies in the field of freight flows have exploited this type of model. [4]

According to these authors sunk costs incurred by the companies to open distribution channels and service networks in new markets can generate inertia in bilateral trade. Bun and Klaassen (2007), in a study that examines the impact of the European Monetary Union on trade, add that consumers in a country get used to products of another nation, creating a long-term relationship. On the other hand, De Benedictis and Vicarelli (2005) justify this idea by emphasizing the importance of the accumulation of invisible political, cultural and geographical assets that have some influence on the trade between regions. Martínez-Zarzoso et al. (2009b) evaluate the link between German development aid and trade with the recipient country.

The literature on road freight flows modeling makes no reference to dynamics. However, in this study we empirically test for the existence of such effects. These could take the form of a partial adjustment process in which the current level of (observed) transport flows would be adjusted as a proportion of the difference between the desired level in a period and the levels achieved in recent periods. Thus, a coefficient of persistence in the flows variable is considered and identified in the estimation by including the lagged dependent variable as an additional regressor. According to the results, it appears that a second-order setting for a dynamic model is appropriate in line with the work of Bun and Klaassen (2007) [5].

$$\begin{aligned} Y_{ijt} &= Y_{ijt-1}^{\beta_1} Y_{ijt-2}^{\beta_2} Dist_{ijt}^{\beta_3} GDP_{it}^{\beta_4} GDP_{jt}^{\beta_5} KHCNpc_{ijt}^{\beta_6} e^{border^{\beta_6}} e^{intra^{\beta_7}} e^{u_{ijt}} \\ u_{ijt} &= \mu_{ij} + \lambda_t + \nu_{it} \end{aligned} \quad (1)$$

where

Y_{ijt} represents the flows of goods transported from the region of origin i to the region of destination j, measured by thousands of tons transported (flow variable) and transport operations. In the case of intraregional trade flows, i will be equal to j.

[4] See **?** and **?** for recent surveys of freight transport models.

[5] Introducing more than two lags of the dependent variable produces non-significant estimates. A specification with one lag was also tested but an econometric test failed to accept it.

Y_{ijt-1} and Y_{ijt-2} represent the flow of goods transported from the region of origin i to the region of destination j lagged one and two time periods respectively. As with the dependent variable, these are measured alternatively by thousands of tons carried and transport operations.

$Dist_{ijt}$ is the distance between origin and destination. It is calculated by averaging the real distances traveled by all vehicles transporting goods from an origin i to a destination j.

GDP_{it} is the real GDP of Autonomous Communities of origin i in the year t.

GDP_{jt} is the real GDP of Autonomous Communities of destination j in the year t.

$KHCNpc_{ijt}$ are the kilometers per capita of high capacity network of the regions where the traffic of goods runs.

Border is a dummy variable with value 1 in the case of adjacent Autonomous Communities and 0 otherwise.

Intra is a dummy variable with value 1 when the Autonomous Communities of origin and destination are the same, and 0 otherwise.

u_{ijt} It will pick up the individual effects defined as pairs of regions by origin and destination, μ_t stands for the unobservable time effect and ν_{ijt} is the random disturbance term.

The econometric representation of the gravity model is equation (1) in log-linear functional form and is used as highlighted in Oum (1989). This specification presents a number of advantages. The estimated coefficients are directly interpreted as elasticities. In addition, the log-linear function is able to model non-linear.

The β_1 coefficient indicates the degree of response of current flows to the flows of the previous year, whereas β_2 is associated with the flows of two years before. If the domestic trade of a country experiences inertia over time, the expected sign of these coefficients will be positive. On the other hand, the expected sign of the estimated β_3 coefficients in each model will be negative because, in accordance with theory, the distance variable acts as an impediment to the flow of goods. Finally, the remaining coefficients are expected to have positive signs: the amount of goods carried within the region itself should be higher, ceteris paribus, than flows to other regions; flows between adjacent regions are also expected to be greater than between distant communities; the GDP variable includes the size of communities in economic terms, so larger flows are expected among Autonomous Communities with greater economic activity; the number of kilometers of high capacity network per capita, which is a measure of density of high capacity roads, and can be understood in turn as a proxy of the road quality of the Autonomous Communities, is expected to have a positive influence on the flows among communities. This variable is constructed from the addition of the kilometers of high-capacity network corresponding to the region of origin, of destination and the regions with the shortest route between the capitals of the regions of origin and destination. This sum was then weighted by the total population of the regions involved in order to obtain a measure of density.

3. Database

The database used represents a balanced panel for the 15 peninsular Autonomous Communities[6] between 1999 and 2009. This study does not include the Balearic Islands, the Canary Islands and the Autonomous Cities of Ceuta and Melilla due to their geographical locations. Hence, we have a balanced panel with dimension N = 225 (all possible bilateral combinations of Autonomous Communities) and T= 11. Thus, the total number of observations is NT =2,475.

The flows of road transport of goods - the dependent variable - is measured by two alternative variables available in the Permanent Survey of Road Transport of Goods (PSRTG), issued by the Spanish Ministry of Development: these variables are flows and transport operations. Their main objective is to measure the level of activity in road freight transport. The PSRTG is aimed at Spanish transport companies and does not include international shipments entering Spain. Since 1999, this survey uses a homogeneous methodology in accordance to the European Union Regulation 1172/98. Since that date, the survey has been regularly updated on a yearly basis. These are the basis for the sample period of the current study. As may be observed in Table 1, the rest of the explanatory variables are provided by different statistical sources.

Usually, this kind of model considers distance as an indicator of the kilometers between the capital cities of the regions or between their centroids. However, this has the clear disadvantage that it is necessary to select the points of origin and destination of the regions in a discretionary way.

[6]Andalusía, Aragón, Asturias, Basque Country, Castile and León, Castile-La Mancha, Cantabria, Catalonia, Extremadura, Galicia, La Rioja, Madrid, Murcia, Navarre and Valencian Community

Table 1: Definition of variables

Variable	Description	Source
Flows	Transported tons (thousands)	Ministry of Development
Transport Operations	Number of trips	
Distance	Average Kilometers traveled	
Population	Standing population in the Autonomous Communities	National Statistics Institute
High Capacity Network	Km. High Capacity Roads	
Gross Domestic Product	Gross Domestic Product (thousands of constant Euros)	

Since the Permanent Survey of Road Transport of Goods also includes the ton-kilometer variable, it is possible to retrieve the mean travel distance of the goods by dividing the total ton-kilometers by the transported tons for each origin-destination pair. The distance variable measured in this way reports information on the routes chosen by the transport companies. The resulting variability, in contrast to the fixed character of the previously mentioned approach, will capture the cost-minimizing behavior of the companies. We firmly believe that measuring distance in this fashion is a better approximation to the cost of freight and provides a more accurate estimation of the intraregional flows included in the model.

Table 2 shows the descriptive statistics of the quantitative variables used in the estimated models. The dependent variables (transport flows and operations) contain few values equal to 0 throughout the whole sample (13 and 8 respectively). In order to avoid problems when taking logarithms in these variables, 0 values have been replaced by the value 1 since this is the minimum non-zero value among those taken by the independent variable. This is usually the most suitable statistical manner to deal with this sort of problems, aside from adding the provincial data with the aim of getting positive values per Autonomous Community ((Bergkvist and Westin, 1998)[7]

Table 2: Descriptive statistics of the variables

Variable	Mean	Std. Dev.	Minimum	Maximum
Flows	7,248.48	30,584.93	1	358.245
Transport operations	993,657.90	4,498,450	1	50,973,200
Distance	481.9282	293.91	11.47	4,834.07
Population	2,677,281	2,299.15	264,178	8,059,460
KHCN	815.5515	594.36	130	2,631
GDP	43,229,025	40,864,631	3,949,932	151,444,000

*Number of observations: 2,475 ** Dummy variables Border and Intra not included

4. Estimation and results

The inclusion of the dynamic component of trade through the lagged dependent variable leads to endogeneity problems that complicate the estimation of panel models (Baltagi, 2008). As an example, we consider a basic dynamic panel model to illustrate these issues:

$$y_{it} = y_{it-1}^{\beta_0} x_{it}^{\beta} + (\alpha_i + \epsilon_{it}) \quad (2)$$

where

y_{it} is the dependent variable, x_{it} is a vector of current and past values of independent variables, α_i represents an unobservable time-invariant specific effect and $\epsilon_{it} \sim IID(0, \sigma^2)$ is a serially uncorrelated error term[8] The econometric problem arises from the correlation between y_{it} and α_i. One possible solution is to apply a within transformation of the fixed effects estimator to eliminate the individual effect i. However, the correlation between the errors and the transformed regressors still exists, yielding an inconsistent estimator unless there is a long time period available (Nickell, 1981). This has been explored in a research paper on trade among European Monetary

[7]If the proportion of observations with 0 values was significant, alternative estimation methods should be considered. The Poisson fixed effects estimator, proposed by (Westerlund and Wilhelmsson, 2009), could be applied here.

[8]We do not consider spatial dependency in transport between regions, so the spatial correlation is ignored if it exists.

Union countries by Bun and Klaassen (2007). The database has a time horizon of 36 years, and the authors find that the Least Squares Dummy Variable (LSDV) estimator performs better than the GMM method in this case.

In order to overcome these difficulties, Anderson and Hsiao (1981) propose the two-stage least squares estimator (2SLS). In the first stage, differences are taken to eliminate the origin-destination fixed effect, α_i. However, by taking differences, Δy_{it} and $\Delta\epsilon_{it-1}$ are now correlated. This problem can be overcome by using the second lag of the dependent variable, y_{it-2} given the assumption that there is no serial autocorrelation. This instrument fulfills the requirements that it be correlated with Δy_{it-1} and not correlated $\Delta\epsilon_{it-1}$ Nevertheless, this estimator is inconsistent when the number of periods T is finite and the number of cross-section observations, N, is large (Baltagi, 2008). This is usually a common feature in gravity models estimated with panel data, so it tends to be a common problem.

As an alternative approach, GMM estimators can deal with the endogeneity of the explanatory variables. Arellano (1989) states that efficiency can be increased by GMM difference estimation using all available instruments yit-k with k¿ 1. The GMM method is based on the idea that given a set of instrumental variables correlated with the regressors but orthogonal to the errors, some moment conditions can be defined and solved using the true value of the estimated parameters. Fixed effects are eliminated by taking first differences and endogenous variables in levels lagged two or more periods are used as instruments to solve simultaneity issues (Arellano and Bond, 1991). However, the use of data in differences also involves removing all time-invariant variables which may be of interest.

The GMM model is one of the methodologies most used to estimate dynamic gravity models (Jung, 2009). However, as argued in Blundell and Bond (1998), when the data are highly persistent - as in the case of bilateral trade flows - this procedure can be improved through the estimation by System GMM (De Benedictis and Vicarelli, 2005). It has been shown that when the lagged values of the series approach a unit root, these instruments contain little information about the endogenous variables in differences. When applying the system-GMM equations in first levels, instead of transforming the regressors to eliminate the fixed effects, differences are taken of the instruments to make them orthogonal to the individual effects. Lagged first differences are used for equations in levels while lagged instrumental variables are used for equations in first differences (Roodman, 2011). The consistency of this estimator depends on no first-order autocorrelation in the errors and an array of truly exogenous instruments. System GMM is the chosen methodology. In Table 3, results and estimation tests are displayed.

The estimated coefficients have the expected signs according to the theory of the gravity model. In addition, the coefficients of the principal variables of the model (GDP and distance) are significant at the 1% level. The positive and significant coefficients associated with the proxy of the quality of infrastructure, KGCIpc, indicates that the availability of high capacity roads directly affects the transport of goods. Of particular note is that the lagged transport variables positively affect the present flows and transport operations, as indicated by the estimated coefficients of y_{it-1} and y_{it-2}. The size of these coefficients - around 0.30 in the case of the flows and 0.15 for transport operations - indicate that inertia is not very important in domestic road transport in Spain is not very large. However, the statistical significance of the estimated coefficients indicates that not taking the dynamic component into account would cause a model misspecification. In this case, the Hansen test for detecting over-identification does not reject the null hypothesis of the validity of the instruments. Autoregressive tests for AR (1) and AR (2) show the consistency of the GMM estimator and the inconsistency of estimators based on OLS[9].

Including lagged variables in the equation yields short term estimated elasticities. To recover the long-run elasticities it is necessary to divide each of the estimated values by (1-β_0-β_1). The result of this transformation is shown in Table 4.

Among the results, we highlight the magnitude of the long-run elasticities associated with the distance variable. In accordance with the model - where it acts as a proxy for transport costs - and noting also the elasticities associated with high-capacity network, we emphasize the importance of quality infrastructure in order to stimulate the road transport of goods. The coefficients that accompany the GDP variables are inelastic but close to unity.

[9] Arellano and Bond (1991) propose the hypothesis test of no second-order serial correlation in perturbations of the equation in first differences: E[$\Delta\epsilon_{it}$,$\Delta\epsilon_{it-2}$]This is a necessary condition for the validity of the instruments. The rejection of the null hypothesis in the AR (1) test indicates the inconsistency of the OLS estimator.

5. Application of the Model: Forecast and Estimation of CO2 Emissions

The calculation of greenhouse gas emissions is one of the most interesting applications of the estimated models. In this section, we present calculations and predictions of CO2 emissions resulting from domestic road transport of goods in Spain for the period 2001-2009. The calculation procedure relies on the exploitation of the data provided by the Permanent Survey on Road Transport of Goods and the high explanatory capacity of the estimated models. The analysis does not include other greenhouse gases because CO2 emissions are proportional to fuel consumption whereas the contamination by other gases such as CH4 and N2O depends largely on the emissions control systems (States., 2006) of vehicles and such information is not available.

The different modes of transport in Spain dedicated to both passenger and goods transport consume 32.5% of total energy demand. Road transport accounts for just over 70% of the total gases emitted to the atmosphere. To our knowledge, no studies as yet have computed disaggregated data for internal traffic of goods and we strongly believe it is important to know this information for policy decision-making. The following equation has been used to obtain the total amount of CO2 emissions in the year t:

$$E_{CO2}^{t} = \sum_{i=1}^{n}\sum_{j=1}^{n}(D_t \cdot Q \cdot Dist_{ijt} \cdot O_{ijt}) \tag{3}$$

where

D_t are the liters of diesel per kilometer.

Q are the kilograms of CO2 emitted to the atmosphere per liter of diesel.

$Dist_{ijt}$ are the kilometers separating the region of origin i from the region of destination j for each year t.

O_{ijt} are the transport operations between the region of origin i and the region of destination j for each year t.

In order to calculate the fuel consumption (in liters), we relied on the information provided by the Transport Costs Observatory, derived from the Permanent Survey of Road Transport of Goods. According to this report, the average consumption of an articulated freight vehicle in 2001 amounted to 0.385 liters per kilometer. Due to the long timeline of this study, the technological improvements applied to the vehicles have to be taken into account. The mean gain of energy efficiency of new vehicles in the last

40 years accounts for 0.8-1% per year (McKinnon, 2008). In addition, the Permanent Survey provides the average age of the fleet of heavy vehicles for each year. On the basis of these data, a fuel consumption efficiency index was generated for heavy vehicles in Spain.

Figure 1: Average age of road transport vehicles

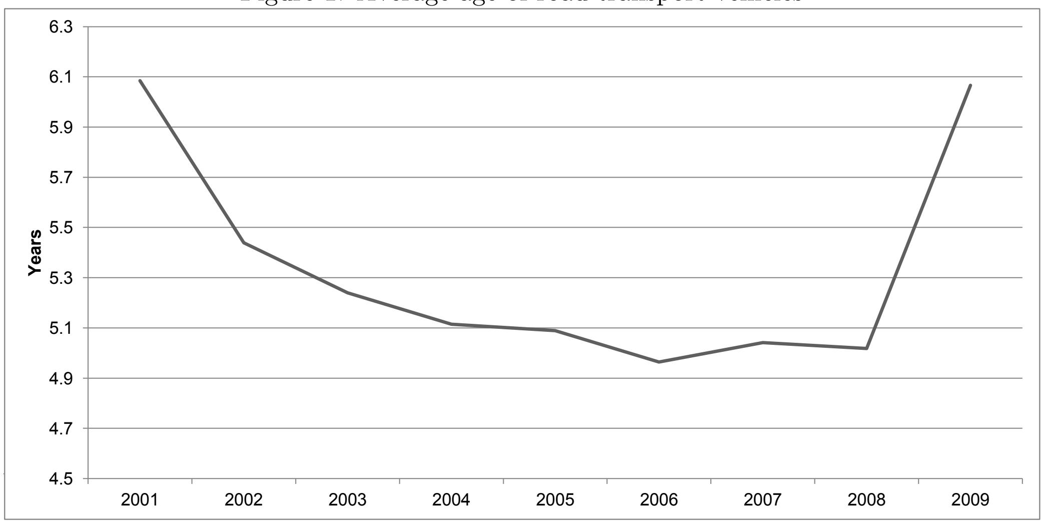


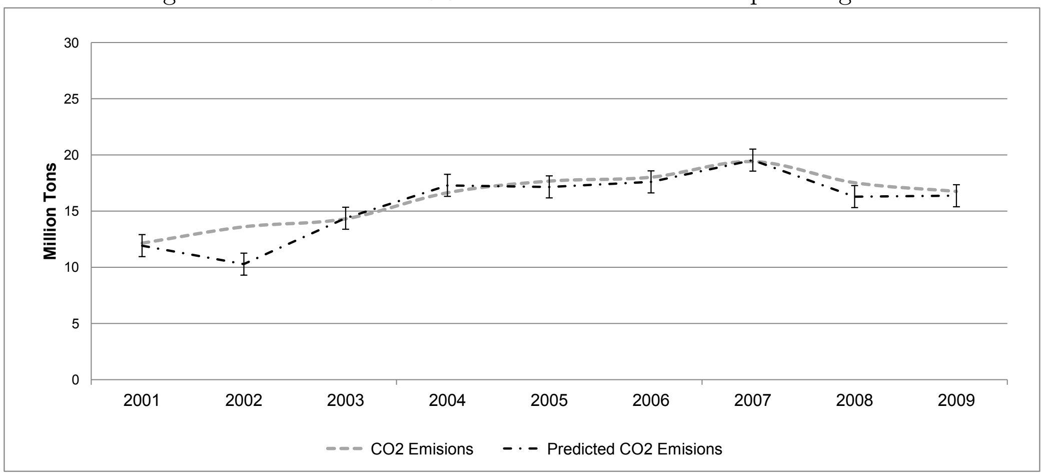
Figure 1 shows the evolution of the average age of heavy goods vehicles in Spain. The average age of vehicles declined to 5 years in 2006. After that, due to a slower pace in the renovation of older vehicles the average age began to rise back to 2001 levels.

Regarding the amount of CO2 kilograms emitted to the atmosphere per liter of diesel, it accounted for 2.71 CO2 Kg. / liter; this figure is included in the inventory of Greenhouse gas emissions in Spain (Spain, 2009).

The total amount of CO2 gas emissions obtained using this methodology is illustrated in Figure 2. Calculations are performed ex-post from 2001 to 2009 using the observed values of the transport operations coming from the survey and predictions are computed using the forecasted values of transport operations from the model estimated in Section 4.

The increasing trend in total CO2 emissions from domestic freight traffic by road reaches its peak in 2007 with nearly 20 million tons emitted into the atmosphere. From that moment there was a reduction in the amount of CO2 due to the fall in the number of transport operations in recent years because of the economic slowdown. However, in 2009 and 2010 there seems

Figure 2: Estimation of CO2 emissions of road transport of goods



to be a slight upward trend in emissions, partially caused by the lower rate of renewal of the fleet.

6. Conclusions

In this paper a dynamic panel model has been estimated to explain the flow of goods by road among the different Spanish autonomous regions and within each of them. Transport flows are measured by both the tons carried and the number of transport operations. The study period chosen is from 1999 to 2010 due to the availability of different explanatory variables.

The results obtained in the model estimated by system-GMM, show that the theory of the gravity model is verified and that there is inertia in the internal traffic of goods in Spain. While it is true that the values that accompany the lagged variables are not large in magnitude, it seems that this is the most appropriate specification for this model. The persistence of freight can be justified by the sunk costs incurred by the companies to settle in different regions.

Other empirical results to note are the statistical significance of two variables which are measured in a way that have not been used so far. On the one hand, the distance variable is not a fixed measure between two points in the regions and is instead constructed by dividing the variable ton-kilometers by the total tons transported. Thus, the distance between two regions varies from year to year and the variable captures the route choice decisions made by transport operators. On the other hand, as this study attempts to estimate structural relationships that direct the flow of goods transport, the model includes a measure of the quality of infrastructure. Therefore, a variable that reflects the density of high-capacity road network in the route of the goods is introduced. According to our specification, the quality of infrastructure measured in this fashion has a positive and significant effect on the flows of goods by road transport.

The appropriateness of the model specification and goodness of fit to the data analyzed allows worthwhile predictions to be made. Specifically, we calculate and predict the tons of CO2 emitted in that period by domestic transport of goods by road in Spain. In the case of polluting emissions, there is a reduction of the gases after 2007 provoked by the economic slowdown. However, predictions of CO2 emitted into the atmosphere show a slight upward trend in 2009 and 2010, partly explained by a lower rate of renewal of older vehicles (which are the most polluting ones). Among the policy actions that might be taken we suggest an intensification of policy incentives to replace older vehicles by new ones that are more energy-efficient and allow for a stronger control of GHG emissions.

Some of the main future research lines that could be followed are the use of the estimated demand for other modes of transport and the construction of a system of equations to study the interaction between different modes and estimate cross-elasticities between them. We also expect to be able to obtain a measure of the price of transport for each route, in which case we would be able to run simulations with different fiscal policy actions, such as taxes that internalize the environmental cost of transport, to measure the impact on road freight transport.

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Table 3: System GMM estimations

	Flows	**Transport Operations**
y_{it-1}	0.296***	0.179**
	(-5.29)	(-2.00)
y_{it-2}	0.292***	0.135***
	(-6.41)	(-3.21)
$Dist_{ijt}$	-0.741***	-1.074***
	(-4.53)	(-5,51)
GDP_{it}	0.337***	0.542***
	(-4.25)	(-4.78)
GDP_{jt}	0.392***	0.523***
	(-4.06)	(-4.67)
$KHCNpc_{ijt}$	0.660***	0.551***
	(-3.19)	(-2.62)
Intra	-0,046	0.844**
	(-0.20)	(-2.56)
Border	-0.656	0.307**
	(-0.77)	-2.46
Yr2002	-0.093	-0.206**
	(-1.41)	(-2.21)
Yr2003	0.011	0.2
	(-0.32)	(-0.661)
Yr2004	0.009	0.110***
	(-0.31)	(-2.69)
Yr2005	-0.06	0.262
	(-1.56)	-0.55
Yr2006	-0.120**	-0.029
	(-2.27)	(-0.59)
Yr2007	-0.082	0.001
	(-1.35)	(-0.002)
Yr2008	-0.273***	-0.233***
	(-4.23)	(-3.35)
Yr2009	0.335***	-0.187***
	(-7.3)	(-3.81)
Number observations	2025	2025
Number of instruments	178	178
AR(1) in first diff. p	0.001	0.01
AR(2) in first diff. p	0.018	0.282
Hansen p	0.107	0.247
F statistic (16,225)	8448.88	

** Significant at 5%. *** Significant at 1%.

Table 4: Short term and Long run elasticities

	Short Term		Long Term	
Variables	**Flows**	**Transport Operations**	**Flows**	**Transport Operations**
GDP_{it}	0.337	0.542	0.818	0.789
GDP_{jt}	0.392	0.523	0.952	0.762
$Dist_{ijt}$	-0.715	-1.075	-1.736	-1.567
$KHCNpc_{ijt}$	0.661	0.551	1.605	0.803