Universidad de La Laguna
Cátedra de Economía y Finanzas Internacionales

INSTITUTO UNIVERSITARIO DE DESARROLLO REGIONAL

Documento de Trabajo/Working Paper
Serie Economía

The effect of dieselization in road transport emissions: the case of Spanish regions between 1998 and 2006

by

Rosa M. González
Rosa M. Lorenzo-Alegría
Gustavo A. Marrero
and
Arnaldo Esquivel

March 2011

DT-E-2011-06

ISSN: 1989-9440

Instituto Universitario de Desarrollo Regional, Facultad de Ciencias Económicas y Empresariales, Universidad de La Laguna, Camino de la Hornera s/n - 38071 La Laguna, Santa Cruz de Tenerife, Spain

THE EFFECT OF DIESELIZATION IN ROAD TRANSPORT EMISSIONS: THE CASE OF SPANISH REGIONS BETWEEN 1998 AND 2006

Rosa Marina González
Departamento de Análisis Económico, IUDR. Universidad de La Laguna (ULL)
Rosa M. Lorenzo-Alegría
Departamento de Análisis Económico, IUDR. ULL
Gustavo A. Marrero
Departamento de Análisis Económico (ULL) and FEDEA
Programa de Investigación de Energía y Cambio Climático (FEDEA-ABENGOA)
Arnaldo Esquivel
Proyecto Estructurante de Transporte (ULL)

ABSTRACT:

The purpose of this paper is to examine the overall effect on CO_2 emissions in the road transport sector of the recent dieselization process taken place in Spain. To this end, we use a panel data set for 16 Spanish regions between 1998 and 2006 and estimate a dynamic panel data (DPD) model that relates CO_2 emissions with alternative measures of the dieselization process. The main conclusion of the paper is that the global impact of dieselization on emissions is statistically different from zero and positive, though small, but it is never negative. Thus, we conclude that for the Spanish road sector from 1998 to 2006, the 'rebound' effect on CO_2 emissions caused by dieselization has been more important than its direct, technology-efficiency impact. This result is highly robust to the alternative econometric methods used and to alternative measures of the dieselization process considered. This result highlights the need to combine energy efficiency policies with strategies for managing transport demand so as to mitigate the impact of the rebound effect that occurs when the efficiency of fuel and vehicles is improved.

JEL: R41, O13, O56

KEY WORDS: CO_2 emissions, dieselization, Dynamic Panel Data model, GMM estimates, road transport.

INTRODUCTION

The Spanish economy experienced one of its largest expansive economic cycles between 1995 and 2006, resulting in, among other things, a large increase in transport demand.[1] As a consequence, the road transport energy consumption and emissions involving this sector almost doubled during this period. It is worth noting that CO_2 emissions from the transport sector increased by about 70% in Spain between 1995 and 2006, while the growth average in the EU-27 was about 25% (CE, 2009). Currently, the Spanish transport sector is one of the highest in Europe in terms of its contribution to total emissions: it represents about 30% of total CO_2 emissions, with more than 70% coming from road transport (MITYC, 2009). The Spanish government has been concerned about this for a long time, recognizing that the trend in this sector over the last decade has been one of the main obstacles to improving the country's environmental criteria.[2]

Between 1998 and 2006, the Spanish Government – at the urging of European officials (IEA, 2000; Clerides and Zachariadis, 2006; Fontana and Zamora, 2007) – engaged in a more active policy called the dieselization process: the replacement of gasoline vehicles by diesel vehicles. The success of its implementation in Spain is evident: the ratio of diesel to gasoline private vehicles was 45% in 1998, a ratio that had increased to 105% by 2006. The dieselization process is also reflected in the trend in the diesel to gasoline consumption ratio, which went from 1.7 in 1998 to 3.6 in 2006. Several factors are behind this rapid dieselization process (Monaham and Friedman, 2004): diesel engines are more fuel efficient than gasoline engines; there are fiscal advantages to acquiring and fueling diesel vehicles;[3] and important technical improvements have been made to diesel vehicles, resulting in better driving performance

In order to measure the overall success of the dieselization policy, the analysis must consider its full impact on CO_2 emissions. In this regard, most of the literature on the relationship between dieselization and emissions focuses only on the direct and efficiency advantages of diesel with respect to gasoline. Thus, they conclude that the dieselization process would reduce CO_2 emissions in the transport sector.[4] But, in order to understand the overall impact on emissions, we must consider the existence of important induced indirect channels involving the reaction of economic agents to such changes in efficiency. For example, since the cost per kilometer for diesel automobiles is lower, the dieselization process might also incentivize mobility; moreover, the positive income effect gained from tax advantages in the acquisition and use of diesel vehicles could encourage the purchase of more powerful and larger vehicles, with the ensuing higher energy consumption and emissions. The latter outcome is called the rebound effect for the purchase of diesel vehicles, which is added to the rebound effect caused by the rising disposable income of consumers and fuel energy efficiency.[5] Thus, these indirect rebound effects are related to the mobility generated by the dieselization policy. Hence, the overall effect of dieselization on emissions would depend on whether the direct (efficiency) effect prevails over these indirect (rebound) impacts.[6]

The purpose of this paper is to examine the overall effect on CO_2 emissions in the road transport sector of the recent dieselization process taken place in Spain. To this end, we use a panel data set for 16 Spanish regions between 1998 and 2006. We estimate a dynamic panel data (DPD) model that relates CO_2 emissions in road transport with alternative measures of the dieselization process: the diesel to gasoline private vehicle ratio (our benchmark measure), the diesel to gasoline consumption ratio, the overall diesel to gasoline car fleet ratio and the diesel to gasoline car registrations ratio. As is standard in the literature, we also include a global activity measure (i.e., real GDP per capita) and total fuel consumption per capita as additional control variables in the model. Using aggregate data, this type of model has been widely used to study the determinants of energy consumption[7]. In addition, these models allow for simultaneous estimates of the short- and long-term effects of alternative control variables on emissions (i.e., the dieselization process in our case). To the best of our knowledge, this paper is the first to consider and estimate a DPD emissions model applied to road transport emissions.[8]

An important aspect discussed in this article concerns the process of estimating these emissions DPD models. Using these models, Marrero (2010), González et al (2009), Pock (2010), Huang et al (2008) and Baltagi et al (2003) among others, have shown that the results can change significantly depending on the econometric method used. Along these lines, Section 3 will discuss the convenience of using the one-step system GMM estimator of Arellano and Bover (1995) and Blundell and Bond (1998).[9] Nevertheless, for the sake of robustness, we consider a battery of panel estimation procedures (pooled-OLS, fixed and random effects panel estimates and two different GMM-based methods).

The main conclusion of the paper is that the global impact of dieselization on emissions is statistically different from zero and positive, though small. But we found that it is never negative. Short-term estimates of the elasticities of CO_2 emissions with respect to the dieselization measure are between 1.8% and 3.5%, while long-term elasticities are between 5.7% and 10.1%. We can thus conclude that for the Spanish road sector from 1998 to 2006, the ‘rebound’ effect on CO_2 emissions caused by dieselization was more important than its direct, technology-efficiency impact. We show also that this result is highly robust to the alternative econometric methods used and to alternative measures of the dieselization process considered.

This paper is structured as follows. In Section 2 we analyze CO_2 emissions in Spain, along with energy consumption indicators and different dieselization measures for the 1998-2006 period. Section 3 presents the DPD model and discusses alternative econometric methods. Section 4 shows the results and discusses several important policy implications. Finally, the conclusions are given in Section 5.

2. Road transport emissions, fuel consumption and dieselization in Spanish regions

Road transport is the sector that contributes the most to CO_2 emissions in Spain, after the energy industry. In 2006 this contribution was about 25% in Spain, while it was about 22% in the EU-15. An important measure adopted in Spain to control CO_2 emissions from road transport was the promotion of diesel use with respect to gasoline consumption, a process commonly known as ‘dieselization’. The period studied in this paper is 1998-2006. We consider this period because it coincides with the most intensive part of the dieselization process in Spain. The year 1998 was the first in which diesel passenger car registrations in Spain achieved figures similar to those for gasoline cars, before eventually surpassing them every year since then.[10] In 2006, there was a change in the trend in diesel car registrations, causing them to become almost constant by 2007. Since then, largely motivated by the financial crisis, registrations have decreased significantly.

The variables considered in this paper as the determinants of road transport emissions are: i) per capita fuel consumption; ii) real Gross Domestic Product (GDP); iii) alternative measures to dieselization, such as the ratios of diesel to gasoline passenger cars, of diesel to gasoline fuel consumption, of diesel to gasoline car registrations and of diesel to gasoline total vehicle stock. Among these dieselization measures, we consider the first as the most interesting, since most measures for boosting diesel consumption have involved the promotion of private diesel vehicles. Tables I and II summarize these data for every Spanish region (excluding the Canaries, Ceuta and Melilla).[11] The last row shows data for Spain. We show 1998 data (start of the period), 2006 data (end of the period) and the annual growth rate between these years. Except for the dieselization measures, all other variables (CO2 emissions, total fuel consumption and real GDP) are expressed in per capita terms. [12]

(INSERT TABLE I)

Between 1998 and 2006, per capita road traffic CO_2 emissions increased in every Spanish region (2.8% for Spain as a whole), although we observe some important differences (see Table 1). With the exception of Catalonia, Madrid, Valencia and the Balearic Islands, which are among the richest regions in Spain in terms of per capita GDP, per capita road emissions increased above 2.1% per year during this period in every region. Of particular note are the cases of Castilla La Mancha, Andalusia and Extremadura, which are among the poorest regions, and whose emissions increased more than 3.6% per year. These facts suggest that the recent trend in per capita CO_2 emissions in the road sector has, if anything, an inverse relationship with its per capita GDP or regional degree of development. [13] We will test this relationship in the analysis carried out in Section 4.

The comparison between total fuel consumption and emissions data is noteworthy. From Table 1, Navarre, Castilla La Mancha and Castilla-Leon were the regions with the highest per capita fuel consumption between 1998 and 2006, while Madrid, Asturias and Andalusia had the lowest. This ranking basically coincides with the per capita CO_2

emission levels in the road transport sector. As concerns growth rates, we find that regions such as Castilla La Mancha, Andalusia and Aragon, with high rates of growth of per capita fuel consumption (around 3.3% per year), also experienced very significant growth in their emissions (up 3.7% .) By contrast, the Balearic Islands and Catalonia show low levels of emissions growth (below 1.3%), which also correspond to low levels of fuel consumption growth (below 1.2%).

(INSERTE TABLE II)

Table II shows data for the alternative dieselization measures considered in this paper. The overriding trend between 1998 and 2006 in every Spanish region was the significant increase in the amount of diesel versus gasoline vehicles. For example, between 1998 and 2006, the ratio of privately-owned diesel to gasoline cars almost tripled, going from 0.31 to 0.90, with variations of 7 percentage points per year.

To emphasize how widespread this process was among the various Spanish regions, Graph 1 shows the progression of this ratio for every Spanish region between 1998 and 2006. This ratio tripled in nearly every Spanish region, almost quadrupling in some, as was the case in Andalusia and Madrid.

A similar trend is observed if instead of looking at the ratio of private vehicles, we consider all vehicles. In this case, the ratio more than doubled for Spain as a whole. These profiles are very similar for the other two considered dieselization measures. For example, total diesel consumption went from being almost twice that of gasoline consumption in 1998 to almost quadruple in 2006. Similarly, the number of diesel cars registered doubled compared to gasoline vehicles registered in the period considered. If we compare these indicators among all Spanish regions, we must highlight the case of

Madrid as being most exemplary of the dieselization process, while said process was least significant in Galicia.

(INSERT GRAPH 1)

3 A Dynamic Panel Data Model for Road Transport Emissions

A common practice in the literature on modeling and forecasting CO_2 emissions is to apply an index decomposition technique in order to characterize the driving forces behind such emissions. This approach is based on an identity that relates emissions to economic structural factors. The IPAT identity is the most popular and is referred to as the Kaya decomposition[14]. Similar methods have been employed to disentangle the determinants of change in energy consumption or CO_2 emissions in the transport sector. For example, the ASIF equation extends the IPAT identity (Schipper et al, 2000) to the transport sector.[15]

When using aggregate data (as in our case), at least, these models show an important shortcoming: their reduced-form representation is static, which prevents taking into account the dynamic nature of variables such as aggregate emissions or fuel consumption. Using aggregate data, the dynamic nature of energy and emission variables has been shown to be an important aspect to be considered in empirical applications. Since the seminal paper by Houthaker et al. (1974), the partial adjustment (dynamic) model has been widely used in many fuel demand applications. Papers such as Baltagi et al (2003), Pock (2010), Sterner (2007) and Basso and Oum (2007), have motivated the use of these dynamic models to estimate the determinants of energy consumption or emissions. Auffhammer and Carson (2008) used a dynamic model to forecast the trend of China's CO_2 emissions. Moreover, these dynamic empirical models can be seen as the reduced form of neoclassical growth models extended with emissions, as shown in Brock and Taylor (2005, 2010), Álvarez et al (2005) and Marrero (2010). These authors estimate a DPD model for aggregate CO_2 emissions. Applied to the road sector, the recent work by Ryan et al (2009) uses a dynamic model to determine which variables are the most important causes of car CO_2 emissions in the EU over the 1995-2004 period.

Taking these references as our starting point, we estimate the following DPD model for CO_2 emissions in the Spanish road transport sector, which is similar to that estimated in Marrero (2010) for aggregate emissions in Europe. Specifically, aggregate road transport emissions in region i at time t, E_{it}, can be assumed to be a linear logarithmic function of real per capita income, Y_{it}, per capita fuel consumption, e_{it}, a dieselization measure, d_{it} and an error term, ε_{it}, which is assumed to be identically and independently distributed with zero mean and constant variance:

$$\ln(E_{it}) = \alpha + \beta \ln(E_{i,t-1}) + \lambda_1 \ln(Y_{it}) + \lambda_2 \ln(e_{it}) + \lambda_3 \ln(d_{it}) + \varepsilon_{it} \qquad (1)$$
$$t = 1998,...,2006 \qquad i = 1,2,...,16$$

The time period spans from 1998 to 2006 and we consider a total of 16 regions.[16] As commented in the previous section, we consider alternative ratios to measure the dieselization process in Spain.[17] The regional-specific terms α_i capture all the fixed factors (time-invariant) related to these emissions inherent to each region, which are either not considered in the model, such as geographical, social and local policy regional aspects, or not directly observed, such as the initial emission technology for vehicles in each region. The ε_{it} includes effects of a random nature that are not considered in the model and which are assumed to have a standard error component structure (Arellano and Bond, 1991; Arellano and Bover, 1995), A1) $E(\varepsilon_{it}) = 0;\ E(\alpha_i \varepsilon_{it}) = 0; E(\varepsilon_{it}\varepsilon_{is}) = 0,\ i = 1,..., N; t = 1,..., N; s \neq t$

A2) $E(y_{i1}\varepsilon_{it}) = 0,\ i = 1,..., N; t = 2,..., T$

With the remaining factors conditioned, the coefficient λ_3 in (1) reflects the short-term elasticity between the dieselization variable and CO_2 emissions in the road sector. As for the accumulated, or long-term, elasticity, this can be easily obtained by dividing the short-term elasticity by $1-\beta$, i.e., $\lambda_3/(1-\beta)$ in the case of the dieselization impact, which is an additional advantage of working with these kinds of dynamic models.

4. Empirical Results

Marrero (2010) and González et al. (2009) have emphasized the importance of considering an appropriate quantitative approach when estimating a dynamic model such as (1). First, we discuss the differences that might exist in estimating a DPD model like (1) using alternative econometric methods. Second, we show the estimation results, considering alternative measures of the dieselization process.

4.1. Estimation procedure

This section is based on Marrero (2010) and González et al (2009). See these and other related references in the bibliography for more details on this issue. Since the lagged, endogenous term in (1) is not independent of the error term, traditional methods for estimating a panel data model (i.e., pooled-OLS, fixed or random effects) are not suited to a dynamic model like (1) (Hsiao, 1986). To solve this endogeneity problem, Holtz-Eakin et al (1988) and Arellano and Bond (1991) transform the dynamic model into a first-difference model. This transformation allows them to characterize certain orthogonality conditions between the endogenous lagged variable and the residual, which can be used to identify a set of valid instruments, enabling them to build a generalized method of moments (GMM) estimator, which they denote GMM-DIF.

The GMM-DIF approach, however, poses a serious bias problem when the series used in the model exhibit significant persistence, as is the case with the variables considered in (1). This persistence results in weak instruments in the GMM-DIF approach, meaning that the correlation between the instruments and the variable to be instrumentalized is small, leading to the bias problems noted above. Arellano and Bover (1995) and Blundell and Bond (1998) emphasize this result and offer an alternative procedure. Specifically, they propose estimating a system of equations (GMM-SYS) by combining the conditions of the first-difference estimator with those of a level estimator. This procedure estimates a system of equations in both first-differences and levels, where the instruments in the level equations are lagged first differences of the variables. Although we will show results for alternative methods, we will focus on GMM-SYS estimates. We will also consider the following tests to validate the assumptions underlying GMM methods: the *m1*, *m2* and the Sargan tests (Arellano and Bond, 1991).[18]

4.2. Estimation results

Table III shows the estimation results of equation (1) when using the diesel to gasoline private vehicle stock as a proxy of the dieselization process. We consider alternative estimation procedures: pooled-OLS, fixed effects, random effects, GMM-DIF and GMM-SYS. We also show standard specification tests for each model. First, notice that the Haussman test rejects the null hypothesis of random effects at any standard level of significance. For any GMM-based estimates, we show the m_1 and the m_2 tests and conclude that the moment conditions underlying GMM estimates seem to be robustly supported.

(INSERT TABLE III)

Following the practical rule proposed by Blundell et al (2000), which is consistent with the theory, we compare the estimates of the β-coefficient in (1) and discuss the bias problems of the alternative method. Comparing this coefficient among all of the methods, pooled-OLS and random effects seems to give an upward-biased estimate of the β-coefficient (0.8748 and 0.9628, respectively), while the fixed effects appear to give a downward-biased estimate (0.1364). Using GMM-DIF, the β-coefficient is barely lower than the fixed effect estimates, suggesting the existence of significant finite sample bias due to the weak instruments problem (Blundell and Bond, 1998). Finally, the GMM-SYS estimate of β is between those of the fixed effects and the pooled-OLS, suggesting that GMM-SYS is a convenient way to overcome the weak instruments problem of GMM-DIF and the endogeneity problem of the other methods.

The estimated coefficients of the other regressors (*Y, e* and *d* in our case) might also differ among the alternative procedures (Marrero, 2010; González et al., 2009). In this case, we note the following. First, the relationship between emissions and overall fuel consumption is always positive, regardless of the estimated model and the method used. In this regard, however, we note that the coefficients are not significant for the fixed effect and GMM-DIF. Most notable is the comparison of different estimates for the coefficient associated with GDP (*Y*). As in Marrero (2010) and González et al. (2009), the coefficient is positive when estimating the model with fixed effects and GMM-DIF, while it is negative in all other cases. Specifically, in the case of GMM-SYS, the elasticity is negative (-0.1206 in the short-term and -0.3537 in the long-term) and significant. This result is consistent with the findings of many authors in the related literature.[19]

While significant differences are effectively found for the GDP (*Y)* and fuel consumption (*e*) coefficients, the estimated coefficients for the dieselization variable are quite robust to the econometric method used: elasticities are always positive and statistically significant for the fixed effect, GMM-DIF and GMM-SYS methods. This result shows that irrespective of the estimation method used, the dieselization process led to increased CO_2 emissions in the road transport sector in Spain between 1998 and 2006.

From now on, we will focus our attention on the one-step GMM-SYS estimates. Table IV shows the estimation results when using alternative dieselization measures (recall from Section 2). We show that results are also quite robust to the alternative dieselization measure considered.

(INSERT TABLE IV)

Finally, Table 5 shows the short- and long-term elasticities when using the alternative dieselization measures. Short-term elasticities are between 0.0182 and 0.0353, while long-term elasticities are between 0.0571 and 0.1013. Connecting these results with the discussion presented in the Introduction, we conclude that the rebound (indirect) effects of dieselization on CO2 emissions in the road sector are more important than their efficiency and direct impacts. This result has important implications to the design of transport policies.

(INSERT TABLE V)

4.3 Policy implications

From the results obtained in the previous section, we can conclude that the dieselization process that took place in Spain between 1998 and 2006 did not achieve the desired goal of reducing CO_2 emissions in the road transport sector. The tax advantages that were applied to diesel compared to gasoline and the greater efficiency of diesel vehicles generated a significant rebound effect that fostered the growth of mobility, energy consumption and emissions in the Spanish road transport sector.

This result is not to say that we should abandon policies that promote fuel efficiency, but it does highlight the need to simultaneously introduce measures that mitigate the resultant rebound impact. This policy message is in line with Schipper and Fulton (2008), who conclude that the lower taxation of diesel fuel does not seem justified, given that it has led to a greater travel rebound effect and has offset some of the CO_2 and other benefits of its higher fuel efficiency. Therefore, the dieselization process should have been accompanied by a package of measures to mitigate the resulting rebound effect, instead of the applied tax policy which has served to deepen the impact on mobility. So, such as mention Van den Bergh (2011), the policies need integrate incentives for energy conservation and limitation of rebound effect.

Some authors suggest that one way to reduce this rebound effect is by applying strong infrastructure, spatial and pricing policies (Markowskta et al, 2009). Therefore, the mobility management of vehicles must be included in any policy package that has the objective of reducing fuel consumption and emissions. So, what is important is to analyze how much, how and where vehicles are moving, rather than the type of fuel being used. .One way to study the real contribution of alternative fuel vehicles to public welfare is to tax the use of cars and other modes of transport as a function of their respective external costs.

Thus, alongside energy efficiency policies, we highlight the need to consider policies that simultaneously manage transport demand. For example, these policies should support (in travel time and money) public transport as opposed to the use of private vehicles, regardless of the type of fuel used. It is necessary to improve the modal distribution of demand, reducing the length and number of motorized trips, and the progressive introduction of mobility plans in cities (Ministry of the Environment, 2007)

5. Final Remarks

Improving energy efficiency in the transport sector has been considered by most governments as a way to support growth while providing environmental benefits. However, there is an extensive debate about whether the reduction in energy consumption or emissions as a result of improved energy efficiency can be more than offset by the existence of an induced rebound effect leading to a sharp increase in mobility.

For the case of Spanish regions between 1998 and 2006, we have seen that replacing gasoline vehicles by more fuel efficient diesel vehicles (*dieselization* process) has not contributed to reducing per capita CO_2 emissions in the road sector, serving instead to increase overall emissions. More specifically, we have found that alternative measures of dieselization are significant in explaining the trend in road transport CO_2 emissions in Spanish regions. Our estimates confirm that the dieselization elasticity of road transport emissions is positive and significant in the short- and long-term. In the long-term, this elasticity can reach 10%. Additionally, we have emphasized the relevance of considering a dynamic model and a suitable econometric approach (the one-step system GMM) to estimate the explanatory factors of such emissions.

These results highlight the existence of an important rebound effect in road transport in Spain during the dieselization period. Clearly, the conjunction of several factors led to this important rebound effect; namely, the lower cost per kilometer for diesel automobiles (an efficiency effect) and the existence of tax reductions on diesel consumption and tax incentives on the purchase of diesel vehicles (an income effect).

These incentives, in turn, have led to a greater market share for diesel vehicles, which has prompted producers to improve vehicle performances (i.e., turbo-diesel, etc.), which may be considered as a quality effect.

Therefore, it is clear that a partial analysis of technical efficiency is insufficient for predicting total energy and emissions reductions in the transport sector (Schipper et al, 2000). A complete analysis should also consider the response of consumers and producers to such efficiency improvements. Thus, analyses that consider only the efficiency impact could lead to misleading predictions regarding the impact of the dieselization process on emissions. As a final remark, our results highlight the need to combine energy efficiency policies with strategies for managing transport demand so as to mitigate the impact of the rebound effect that occurs when the efficiency of fuel and vehicles is improved.

[1] For example, between 1995 and 2007, the number of passenger-kilometers in Spain grew by 60% (4% per year), and freight transport increased by 136% (more than 7% annually). In both cases, the increases were well above those of real GDP and population, whose annual growth rates were 3.7% and 1.1%, respectively.

[2] At the European level, concerns over the pollution generated by transportation have resulted in relevant policies being drafted, as set out in the White Paper on Transportation, the Green Paper on the Security of Energy Supply and the Green Paper on Energy Efficiency. At the Spanish level, since 1970 several EU Directives (70/220/CEE, 88/77/CEE, 70/157/CEE, 1999/94/CE, etc.) have been adopted (i.e., fiscal incentives to adopt less polluting vehicles), for the purpose of reducing emissions in the road sector. More recently, we highlight the Spanish Strategy of Climate Change and Clean Energies (2007–2012–2020 horizon) and the E4 strategy for 2004-2012, which sets a series of energy savings and efficiency goals for the road transport sector. These plans are integrated into the Action Plan for Energy Efficiency Community required by the 2006/32/EC European Directive, and the National Programs to allocate emissions rights (PNA 2005-2007 and PNA 2008-2012). In addition, the *Plan Estratégico de Infraestructuras del Transporte* (PEIT) 2005-2020 is aimed at improving the road network, energy efficiency and the competitiveness of the sector.

[3] Reitveld and Van Woudenberg (2005) emphasizes that differences in taxes is the main reason for the price heterogeneity between gasoline and diesel fuels in the EU.

[4] See, among others, Sullivan et al. (2004), Zervas and Bikas (2005), Zervas (2006), Zervas et al. (2006), Zachariadis (2006), Zervas and Lazarou (2007) and Fontaras and Samaras (2007).

[5] There exists an extensive literature on the rebound effect estimate resulting from technological improvements and their positive impact on energy efficiency. For example, see Herring (1999), Birol and Keppler (2000), Greening et al (2000), Berkhout et al (2000), Saunders (2000), Dimitropoulos (2007) and Sorrell et al (2009), among many others. Applied to the transport sector, see, for example, Small and Van Dender (2007), Sprei et al (2008) and Barla et al. (2009).

[6] So Schipper et al. (2002) has shown that increasing sales of diesel vehicles over gasoline vehicles does not always translate into a reduction in vehicle fleet CO_2 emissions. Other authors argue that continuously increasing the share of diesel passenger cars is a controversial practice for reducing fuel consumption (Jensen, 2003; Hugrel and Joumard, 2001).

[7] See, among other, Baltagi and Griffin (1983, 1997), Schipper et al. (1992) and Johansson and Schipper (1997) for OECD countries, Baltagi and Griffin (1984) for the U.S., Mazzarino (2000) for Italy, Kwon (2005a) for the United Kingdom, Polemis (2006) for Greece, Tapio et al. (2007) for the EU-15 and Huang et al (2008) for 82 countries.

[8] There exists an extensive literature that has studied the determinants of CO_2 emissions for the road sector in Spain. For example, Pérez Martínez and Monzón de Cáceres (2006) developed a regional model that explains the relationship between greenhouse gas emissions from transportation and per capita growth in the GDP; Burón et al. (2005) forecast emissions from road transport in Spain for 2000-2010; Lumbreras et al (2008) advanced projections for energy consumption and emissions for the region of Madrid until 2012, Gutierrez et al (2008) modeling and analysis the emissions of greenhouse gases attributable to the activities of the land transport for the case of Spain, Perez-Martínez (2009) reviews some of the key indicators that are measuring the efficiency and the operational performance of the freight road transport. However, all of these papers focus mainly on the relationship between emissions and activity or fuel consumption, while leaving aside the specific effect of *dieselization*.

[9] The one-step system GMM estimator was recently used in DPD models to study the relationship between total CO_2 emissions and energy (Marrero, 2010), the determinants of gasoline consumption (Pock, 2010; and González et al, 2009, the relationship between energy and growth (Huang et al., 2008), the labour supply in Norway (Baltagi et al., 2005) etc.

[10] According to data published by the Spanish DGT, prior to 1998, gasoline passenger car registrations reached figures higher than those for diesel. In 1998 passenger car registrations totaled 662,798 gasoline and 620,172 diesel vehicles.

[11] We removed Ceuta, Melilla and the Canary Islands from the sample because of the difficulty of some series, their geographical peculiarities and the special tax regime in the Canary Islands.

[12]Data on CO_2 emissions were obtained from the Ministry of the Environment and are measured in kilotons of CO_2 equivalent. Fuel consumption data (the sum of gasoline and diesel consumption) come from CORES (Ministry for Industry, Tourism and Commerce) and are measured in kilotons. Regional population and real GDP were taken from the National Statistics Institute (INE in Spanish) and are measured in number of persons and in real terms, respectively. Gasoline and diesel fleet car registrations were taken from the National Traffic Office (DGT)

[13] Applied to the road transport sector, a negative relationship between per capita GDP and emissions is consistent with the downward part of the inverted U-shaped relationship between these two variables, as postulated by the literature on the Environmental Kuznets Curve (EKC) (Shafik and Bandyopadyay (1992), Selden and Song (1994), Grossman and Krueger (1995)).

[14] The IPAT breaks down the determinants of changes in environmental impacts (I) into population (P), affluence (A) and technology (T). The IPAT equation can be seen as a static reduced-form model that is used as a starting point to decompose total emissions into the components included in the identity (e.g. Harrison, 1993, Bongaarts, 1992, Martínez-Zarzoso et al, 2007). Other authors, such as Dietz and Rosa (1997) and Shi (2003), use the IPAT identity to motivate a regression based analysis, this approach is known as Stochastic Impact by Regression on Population, Affluence and Technology (STIRPAT) Dietz and Rosa, 1994).

[15] The ASIF equation states that the emissions from transport are equal to $A*S_i*I_i*F_{ij}$, where A represents transport activity, S the transport structure, I is the modal energy intensity of each mode and F the carbon effect associated with a mix of fuels j for modes i.

[16] Ceuta, Melilla and the Canary Islands were omitted from the sample due to the numerous anomalies present in the traffic volume series.

[17] The lagged term controls for short-term dynamics and conditional convergence. A significant β coefficient between 0 and 1 would be indicative of conditional convergence of CO_2 emissions in road traffic among Spanish regions. The larger the coefficient, the greater the effect of the inertia as an explanatory factor of its own progression, as well as the slower the convergence speed.

[18] If the disturbance ε_{it} in (1)' is not serially correlated, there should be evidence of negative first order serial correlation and no evidence of second order serial correlation in first difference residuals, $\varepsilon_{it}-\varepsilon_{it-1}$. The *m1* and *m2* tests are based on the standardized average residual autocovariance, which is asymptotically N(0,1) distributed under the null hypothesis of no autocorrelation. The Sargan test, in contrast, is distributed chi-squared with degrees of freedom equal to the number of moment restrictions minus the number of parameters, estimated under the null hypothesis that moment conditions are valid. However, the Sargan test is less meaningful since it requires that the error terms be

independently and identically distributed, which is not expected in our case. Hence, we will focus on the *m1* and *m2* tests.

[19] For the case of diesel demand, Burguillo et al (2009) finds the same result: the coefficient associated with real income is negative, but non-significant. There are other papers in the literature which estimate a model for aggregate energy consumption or CO_2 emissions whose income-elasticity estimate is very low, and even negative in some cases (Schmalensee et al, 1998; Judson et al, 1999; Holtz-Eakin and Selden, 1995; Marrero, 2010; González et al, 2009). Baltagi and Griffin (1997) obtain that the income elasticities are frequently insignificant in the long run.

REFERENCES

Álvarez F, Marrero G.A, Puch L.A (2005). Air pollution and the macroeconomy across European countries, *Working Papers-10 (FEDEA)*.

Arellano M, Bond S (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 58: 277-297.

Arellano, M. and O. Bover. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, 68: 29-52.

Auffhammer M, Carson R (2008) Forecasting the path of Cihina´s Co2 emissions using province-level information. Journal of Environmental Economics and Management 55: 229-247.

Baltagi, B (2001). Econometric Analysis of Panel Data, second edition, Chichester: John Wiley&Sons, Ltd.

Baltagi B., Bresson G., Griffin J. and Pirotte A (2003). Homogeneous, Heterogeneous or Shrinkage Estimators? Some Empirical Evidence from French Regional Gasoline Consumption. Empirical Economics 28: 795-811.

Baltagi, B. and Griffin J. (1997) Pooled estimators vs. heterogenous counterparts in the context of dynamic demand for gasoline.Journal of Econometrics 77: 303-327.

Baltagi B, Griffin J (1983). Gasoline demand in the OECD: An application of pooling and testing procedures. European Economic Review, 22: 117:137.

Baltagi B, Bratberg E, Holmas T (2005). A panel data study of physicians labor supply: the case of Norway. Health Economics 14: 1035-1045.

Barla P, Lamnde B, Miranda-Morento L, Boucher N. (2009). Traveled distance, stock and fuel efficiency of prívate vehicles in Canada: Price elasticities and rebound effect. Transportation 36:389-402.

Basso, L and Oum T. (2007) Automobile fuel demand: A Critical Assessment of Empirical Methodologies. Transport Review 4: 449-484.

Berkhout P, Muskens J, Velthuijsen J (2000). Defining the rebound effect. Energy Policy 28:425-432.

Birol F, Keppler J (2000) Price, technology development an the reboun effect. Energy Policy 28: 457-479.

Blundell, R. and S. Bond. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1): 115-143.

Blundell, R. and S. Bond. (2000). GMM estimation with persistent panel data: an application to production functions. Econometric Reviews, 19(3), 321-340

Bongaart J (1992). Population growth and global warming. Population and Development Revoew 18 (2): 299-319.

Brock and Taylor (2005). W.A. Brock and M.S. Taylor, Economic growth and the environment: a review of theory and empirics. In: P. Aghion and S. Durlauf, Editors (edition 1), *Handbook of Economic Growth* **vol. 1**, Elsevier: 1749–1821.

Burguillo-Cuesta M., Jorge-Garía I. and Romero D. (2009) Dieselization of passenger cars in the EU-15 in the nineties: environmental implications for transport policy . 8th International Conference of the European society for Ecological Economics , Slovenia.

Burón , J. M., F. Aparicio, O. Izquierdo, A. Gómez y L. López (2005) Estimation of the input data for prediction of road transportation emissions in Spain from 2000 to 2010 considering several scenarios, *Atmospheric Environment* 39, 5585-5596.

Clerides S. and Zachariadis T. (2008). The effect of standards and fuel prices on automobile fuel economy: an international analysis. Energy Economics 30 : 2657-2672.

COMISIÓN EUROPEA (2009): EU energy and transport in figures. Statistical pocket-book, Bruselas.

Dietz T., Rosa E.A. (1994). Rethinkingthe environmental impacts of population, affluence and technology. Human Ecology Review 1 (2): 277-300.

Dietz T., Rosa E.A. (1997). Environmental impacts of population and consumption. In; Stern, P.C., National Research Council (U.S.), Diets (eds.), Environmentally Significant Consumption: Research Directions. National Academy Press, Washington.S.C

Dimitropoulus J (2007). Energy productivity improvements and the rebound effect: An overview of the state of knowledge. Energy Policy 35 (12): 6354-6363.

EC(2009). Energy and Transport in figures. Statistical Pocketbook.

Fontaras, G. and Samaras, Z. (2007). A quantitative analysisi of the European Automakers´ voluntary commitment to reduce CO2 emissions from new passenger cars based on independent experimental data. Energy Policy 35: 2239-2248.

González , Lorenzo, Marrero (2009). Gasoline and diesel consumption for road transport in Spain: a dynamic panel data approach, WP del IUDR (ULL) (DT-E-2009-06).

Greening L, Greene D, Difiglio C (2000): Energy efficiency and consumption- the rebound effect: a survey. Energy Policy 28(6-7):389-401.

Grossman G, Krueger A (1995). Economic growth and the environment. Quarterly Journal of Economics 112: 353-377.

Harrison P (1993). The third revolution: environment, population and a sustainable world. Penguin, London.

Herring, H. (1999) Does energy efficiency save energy? The debate and its consequences. Applied Energy 63: 209-226.

Holtz-Eakin D, Selden T. (1995). Stoking the fires? CO2 emissions and economic growth. *Journal of Public Economics* 1995; 57, 85-101.

Holtz-Eakin, D.,W. Newey and H. Rosen. (1988). “Estimating vector autoregressions with panel data.” *Econometrica*, 56, 1371-1395.

Houtthakker H., Verleger P. and Sheekan D. (1974) Dynamic demand for gasoline and residential electricity. American Journal of Agricultural Ecnomics, 56, 412-418.

Hsiao, C. (1986). *Analysis of panel data*. Cambridge: Cambridge University Press.

Huang, B., Hwang, M. and Yang, C. (2008). Causal relationship between energy consumption and GDP growth revisite: A dynamic panel data approach. Ecological Economics, 67, 41-54.

IEA 2000. *The Road from Kyoto*. Paris: International Energy Agency

Johansson, O and L. Schipper (1997): 'Measuring long-run automobile fuel demand: separate estimations of Vehicle stock, mean fuel intensity, and mean annual driving distance', *Journal of Transport Economic and Policy*, 31(3), 277-292.

Judson R., Schmalensee R. and Stoker M. (1999). Economic Development and the Structure of the Demand for commercial energy. Energy Journal 20 (2): 29-57.

Kiang, N., Schipper, L: (1996). Energy trends in the Japanese transportations sector. Transport Policy, 3, (1/2), 21-35.

Kwon, T-H. (2005a): 'The determinants of the changes in car fuel efficiency in Great Britain (1978-2000)', *Energy Policy*, 2, 261-275.

Kwon T-H. (2005b) Decomposition of factors determining the trend of CO2 emissions from car travel in Great Britain (1970-2000). Ecological Economics 53: 261-275.

Lumbreras, J., M. Valdés, R. Borge and M. E. Rodríguez (2008): 'Assessment of vehicle emissions projections in Madrid (Spain) from 2004 to 2012 considering several control strategies', *Transportation Research Part A*, 42: 646-658.

Markowska a, Van Essen H, Kampman B(2009). Transport Chapter on RECIPE project. The Economic of Decarbonisation. Potsdam Institute for Climate (,PIK). Potsdam, Germany.

Marrero G (2010). Greenhouse gases emissions, growth and the energy mix in Europe. Energy Economics 32 (6): 1356-1363.

Mazzarino, M. (2000): 'The economics of the greenhouse effect: evaluating the climate change impact due to the transport sector in Italy', *Energy Policy*, 28: 957-966.

Martínez-Zarzoso I, Bengochea-Morandho A, Morales_Lage R (2007). The impact of population on co2 emissions:evidence from European countries. Environmental Resource Economics 38: 497-512.

Ministry of Environment (2007). *Estrategia Española de Cambio Climático y energia limpia, horizonte 2007-2012-2020,* Madrid.

MITYC (2009).Ministerio de Industria, Turismo y Comercio. La Energía en España.

Monaham, P., Friedman, D., 2004. The dilemma diesel, *Union of Concerned Scientists, Citizens and Scientists for Environmental Solutions*, Cambridge.

Papagiannaki, K., Diakoulaki, D. (2009). Descomposition anlysis of CO2 emissions from passenger cars: The case of Greece and Denmark. Energy Policy, 37: 3259-3267.

Pérez-Martínez, P (2009). The vehicle approach for freight road transport energy and environmental analysis in Spain. European Transport Research Review 1: 75-85.

Pérez- Martínez, P. and A. Monzón de Cáceres (2006): Relación entre la emisión de gases de efecto invernadero por el transporte y la renta por habitante, Prospección 1990-2025 por Comunidades Autónomas. *Actas del XIV Congreso Panamericano. Ingeniería, tránsito y transporte.* Las Palmas de Gran Canaria.

Pérez-Martínez, P. y Monzón de Cáceres (2008). A. Consumo de energía por el transporte en España y tendencias de emisión. Observatorio Meidoambiental, 11: 127-147.

Pock, M. (2010) Gasoline demand in Europe: New insights. Energy Economics 32 (1): 54-62.

Polemis, M. L. (2006): ‘Empirical assessment of the determinants of road energy demand in Greece’, *Energy Economics*, 28, 385-403.

Rietveld P, Van Woudenber S. (2005) Why fuel prices differ. Energy Economics 27: 79-92.

Ryan L., Ferreira S., Convery F. (2009). The impact of ofiscal and other measures on new passenger car sales and CO2 emissions intensity: Evidence from Europe. Energy Economics 31: 365-374.

Saunders H (2000) A view from the macro side: rebound, backfire, and khazzoom-Brookes. Energy Policy 28 (6-7): 439-449.

Schmalensee R., Stoker M. Judson R !998). Worl Carbon dioxide emissions:1950-2050. Review of Economics and Statistics 80(1): 15-27.

Schipper, L. (1995). Determinants of automobile use and energy consumption in OECD countries. Annual Review of Energy and Envirnment 20: 325-386.

Schipper L (2011) Automobile use, fuel economy and CO2 emissions in industrialized countries: Encouraging trends through 2008? Transport Policy 18: 358-372.

Schipper, L., Steiner R, Duerr P, Strom S(1992) Energy Use in Passenger Transport in OCDE Countries: Changes since 1970”, *Transportation* 19: 25-42.

Schipper, L., Scholl, L. Price, L.(1996). Energy use and carbon emissions from freight in 10 industrialized countries: an analysis of trends from 1973 to 1992. Transportation Research part D Transport and Environment 2 (1): 57-76.

Schipper, L., Marie-Lilliu, C., Fulton, L. (2000). Diesel in Europe: Analysis of Characteristics, usage patterns, energy savings and CO2 emissions implications. Energy Efficiency Techology Office. International Energy Agency

Schipper, L.,Unander, F., Murtishaw, S., Ting, M. (2001) Indicators of energy use and carbon emissions: explaining the energy economy link. Annual Review of Energy and Environment, 26:

Schipper, L., C. Marie-Lilliu y L.Fulton (2002) Diesels in Europe. Analysis of Characteristics, usage patterns, energy savings and CO2 emission implications, *Journal of Transport Economics and Policy*, 36(2): 305-340.

Schipper L, Fulton L. (2008). Disappointed by diesel? The impact of the shift to diesels in Wurope through 2006. Transportation Research Record, 2215, Dec 2009.

Scholl L., Schipper L., Kiang N. (1995). CO2 emissions from passenger transport. A comparison of international trends from 1973 to 1992. Energy Policy 24: 17-30.

Selden T, Song D (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions. Journal of Environmental Economics and Management 27: 147-162.

Shi A (2003) The impact of population pressure on global carbon dioxide emissions, 1975-1996: evidence from pooled cross-country data. Ecological Economics 44: 29-42.

Shafik N, Bandyopadyay S (1992). Economic growth and environmental quality. Background Paper for the 1992 World Development Report, The World Bank, Washington, D.C.

Small, K., Van Dender, K. (2007) Fuel efficiency and motor Vehicle travel: the declining rebound effect. The Energy Journal, 28(1): 25-51.

Schmalensee R, Stoker T.M., Judson R.A. (1998). World carbon dioxide emissions: 1950-2050. *The Review of Economics and Statistics*; 80: 15-27.

Selden T.M., Song, D. (1994). Environmental quality and development: Is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and Management*; 27: 147-162.

Sorrel S, Dimitropoulos J, Sommerville M. (2009). Empirical estimates of the direct rebound effect: A review. Energy Policy 37: 1356-1371.

Sprei, F, S. Karlsson and J. Holmberg (2008): 'Better performance or lower fuel consumption: Technological development in the Swedish new car fleet 1975-2002', *Transportation Research Part D*, 13: 75-85.

Sterner T. (2007) Fuel taxes: An important instrument for climate policy. Energy Policy, 35: 3194-3202.

Sullivan J.L., Baker R. E. , Boyer B. A., Hammerle R.H., Kenney T.E., Muniz L. and Wallington T.J. (2004). CO2 emission benefit of diesel (versus gasoline) powered vehicles. Environmental science & technology 38: 3217-3223.

Tapio, P., D. Banister, J. Luukkanen, J. Vehmas and R. Willamo (2007): 'Energy and transport in comparison: Immaterialisation, dematerialisation and decarbonisation in the EU15 between 1970 and 2000', *Energy Policy* 35: 433-451.

Van den Bergh J (2011). Energy conservation more effective with rebound policy Environmental Resource Economics, 48: 43-58.

Zachariadis T. (2006). On the baseline evolution of automobile fuel economy in Europe. Energy Policy 34: 1773-1785.

Zervas E. (2006). CO_2 benefit from the increasing percentage of diesel passenger cars. Case of Ireland. Energy Policy 34: 2848-2857.

Zervas E, Bikas G, (2005). CO_2 emissions change from the increasing percentage of diesel passenger cars in Norway. Energy and Fuels 19:1919-1926.

Zervas E., Poulopoulos S., Philippopoulos C. (2006). CO2 emissions change from the introduction of diesel passenger cars: Case of Greece. Energy, 31, 2915-2925.

Zervas E. and Lazarou C. (2007). CO2 benefit from the increasing percentage of diesel passenger cars in Sweden. International journal of energy research, 31: 192-203.

Graph 1: Diesel to gasoline private cars in Spanish regions between 1998 and 2006

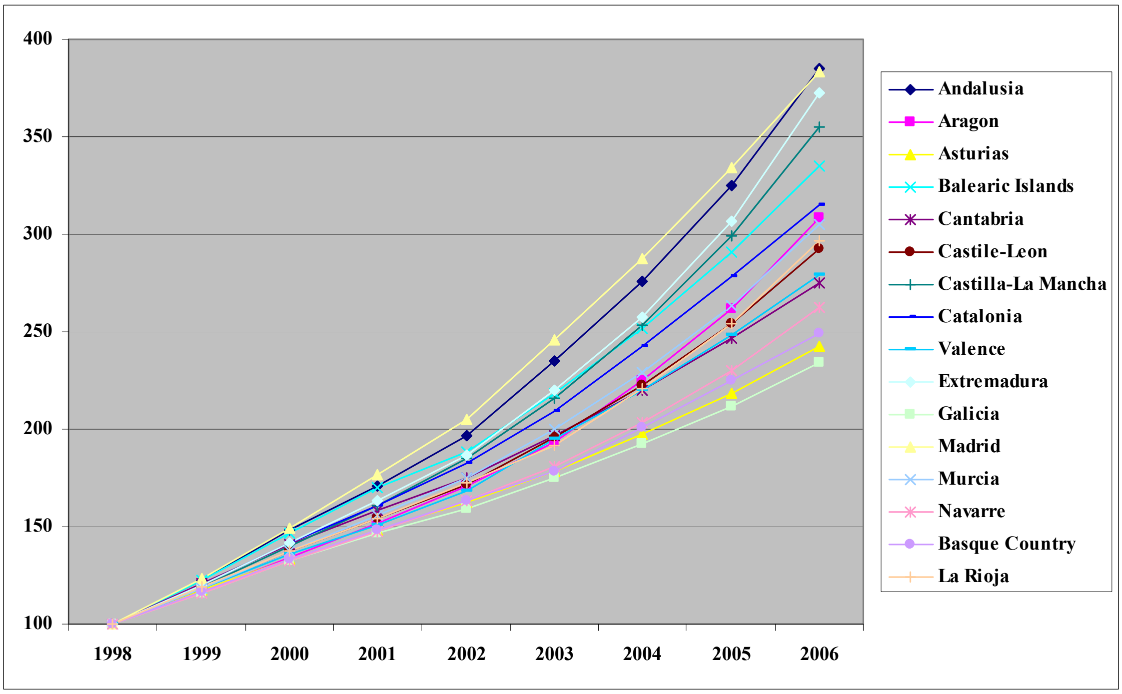

TABLE I: LISTS THE VARIABLES FOR THE PERIOD 1998-2006

	road traffic CO_2 emission pc			real GDP pc			fuel consumption pc		
REGION	**1998**	**2006**	**1998-2006***	**1998**	**2006**	**1998-2006***	**1998**	**2006**	**1998-2006***
Andalusia	1.39	1.87	3.80	10.53	13.30	2.97	0.49	0.63	3.21
Aragon	2.26	2.86	3.72	15.12	18.83	2.79	0.67	0.88	3.58
Asturias	1.66	2.05	2.73	12.26	15.51	2.99	0.47	0.60	2.99
Balearic Islands	2.07	2.10	1.29	18.52	18.49	-0.01	0.64	0.66	0.36
Cantabria	1.97	2.61	3.61	13.37	17.03	3.07	0.59	0.78	3.63
Castilla-Leon	2.43	3.19	3.53	13.08	16.91	3.26	0.75	1.00	3.62
Castilla La Mancha	2.70	3.66	4.01	11.59	13.72	2.14	0.77	0.99	3.28
Catalonia	1.85	1.98	0.89	17.57	20.62	2.03	0.64	0.70	1.15
Valencia	1.93	2.17	1.53	13.94	15.86	1.64	0.60	0.71	2.18
Extremadura	1.64	2.17	3.68	9.02	12.10	3.75	0.50	0.68	3.97
Galicia	1.84	2.33	3.06	11.40	14.43	2.99	0.53	0.61	1.77
Madrid	1.46	1.70	2.01	19.39	22.93	2.13	0.46	0.52	1.43
Murcia	1.96	2.38	2.44	12.17	14.23	1.98	0.65	0.88	3.84
Navarre	1.95	2.55	3.57	18.13	22.33	2.65	0.88	1.22	4.19
Basque Country	1.62	1.94	2.32	17.46	22.55	3.26	0.58	0.78	3.77
La Rioja	2.11	2.49	2.11	16.49	18.89	1.72	0.65	0.75	1.95
SPAIN	**1.93**	**2.38**	**2.77**	**14.38**	**17.36**	**2.46**	**0.62**	**0.77**	**2.81**

***Average annual variation rate**

TABLE II: LISTS THE ALTERNATIVE DIESELIZATION MESSURES

REGION	diesel cars/ gasoline cars			diesel fleet/ gasoline fleet			diesel consump./gasoline consump.			diesel car registrat./gasoline car registrat.		
	1998	2006	1998-2006*	1998	2006	1998-2006*	1998	2006	1998-2006*	1998	2006	1998-2006*
Andalusia	0.24	0.93	0.09	0.41	1.09	0.09	1.62	3.47	0.23	1.08	2.56	0.19
Aragon	0.24	0.74	0.06	0.42	1.01	0.07	2.01	4.50	0.31	0.85	2.78	0.24
Asturias	0.43	1.05	0.08	0.58	1.21	0.08	1.90	3.88	0.25	1.99	2.26	0.03
Balearic Islands	0.11	0.36	0.03	0.19	0.47	0.03	0.72	1.54	0.10	0.25	1.08	0.10
Cantabria	0.39	1.07	0.09	0.54	1.23	0.09	1.74	3.97	0.28	1.64	2.25	0.08
Castilla-Leon	0.29	0.83	0.07	0.46	1.06	0.08	2.24	4.65	0.30	1.34	2.58	0.15
Castilla La Mancha	0.30	1.07	0.10	0.54	1.36	0.10	2.20	5.11	0.36	1.68	4.01	0.29
Catalonia	0.22	0.69	0.06	0.34	0.79	0.06	1.56	3.29	0.22	0.79	2.21	0.18
Valencia	0.30	0.83	0.07	0.44	0.98	0.07	1.61	3.43	0.23	0.98	1.55	0.07
Extremadura	0.23	0.86	0.08	0.42	1.11	0.09	1.66	3.60	0.24	1.27	3.49	0.28
Galicia	0.55	1.29	0.09	0.69	1.42	0.09	2.06	3.59	0.19	2.67	2.75	0.01
Madrid	0.24	0.92	0.08	0.34	1.07	0.09	1.06	3.04	0.25	0.87	3.22	0.29
Murcia	0.37	1.13	0.10	0.54	1.31	0.10	2.14	5.19	0.38	1.63	3.21	0.20
Navarre	0.36	0.94	0.07	0.55	1.21	0.08	2.99	6.28	0.41	1.39	2.74	0.17
Basque Country	0.36	0.91	0.07	0.51	1.08	0.07	2.21	4.97	0.35	1.28	2.36	0.14
La Rioja	0.29	0.85	0.07	0.51	1.17	0.08	2.20	4.30	0.26	1.08	2.49	0.18
SPAIN	**0.31**	**0.90**	**0.07**	**0.47**	**1.10**	**0.08**	**1.87**	**4.05**	**0.27**	**1.30**	**2.60**	**0.16**

*Annualized variation between 1998-2006

TABLE III: DPD MODEL FOR ROAD TRANSPORT EMISSIONS: ALTERNATIVE METHODS

	OLS-Pool	WD fixed	WD random	GMM-dif (1)	GMM-sys (1)
Emissions (-1)	0.8748*** (0.0412)	0.1364 (0.0894)	0.9628*** (0.0223)	0.0672 (0.1354)	0.6590*** (0.0900)
GDP	-0.063** (0.0264)	0.6318* (0.2068)	-0.0380* (0.0140)	0.5447** (0.3500)	-0.1206*** (0.0782)
Fuel consumption	0.1144*** (0.0422)	0.0644 (0.1237)	0.0463** (0.0221)	0.1546 (0.1980)	0.2384*** (0.0747)
Diesel/gasoline private vehicles	0.0024 (0.0120)	0.0533** (0.0261)	0.0076 (0.0076)	0.0648*** (0.0453)	0.0247*** (0.0229)
R2	0.924	0.6588	0.9799	--	--
Haussman (random)	--	99.0442 (0.0000)	--	--	--
Sargan	--	--	--	44.8624 (0.9907)	39.3816 (1.00)
m1-test	--	--	--	-2.2683 (0.0233)	-5.2576 (0.000)
m2-test	--	--	--	-1.1145 (0.2651)	-0.8747 (0.3818)

*: significant at 10%; **: significant at 5%; ***: significant at 1%

TABLE IV: GMM-SYS ESTIMATES OF DPD ROAD TRANSPORT EMISSIONS MODEL: ALTERNATIVE DIESELIZATION MEASSURES

	diesel/gasoline car fleet	diesel/gasoline car registrations	diesel/gasoline consumption
Emissions (-1)	0.6515*** (0.0906)	0.6810*** (0.0915)	0.6634*** (0.0903)
GDP	-0.1180*** (0.0755)	-0.1209*** (0.0689)	-0.1260*** (0.0740)
Fuel consumption	0.2463*** (0.0751)	0.2231*** (0.0748)	0.2389*** (0.0758)
Dieselization	0.0353*** (0.0282)	0.0182** (0.0223)	0.0296** (0.0274)
Sargan	38.7479 (1.0000)	41.2427 (1.000)	39.4873 (1.000)
m1-test	-5.1772 (0.0000)	-6.4036 (0.000)	-6.0949 (0.000)
m2-test	-0.8726 (0.3829)	-0.8823 (0.3776)	-0.8708 (0.3839)

*: significant at 10%; **: significant at 5%; ***: significant at 1%

TABLE V: SHORT- AND LONG-RUN ELASTICITIES: GMM-SYS ESTIMATES

	diesel/gasoline private vehicles[(1)]	diesel/gasoline car fleet	diesel/gasoline car registrations	diesel/gasoline consumption	Fuel consumption[(1)]	Real per capita GDP[(1)]
Short-run elasticity	0.0247	0.0353	0.0182	0.0296	0.2384	-0.1206
Long-run elasticity	0.0724	0.1013	0.0571	0.0879	0.6991	-0.3537

(1): Results correspond to the last column in Table III