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Abstract

This paper provides an updated calculation of the price and income responsiveness of Spanish consumers of car fuels, with an explicit exploration of the effects of the recent economic crisis. We examine separate gasoline and diesel demand models using a set of estimators on a panel of 16 Spanish regions over the period 1999-2015. The paper confirms the persistence of low own-price elasticities both for diesel and gasoline in the short and long runs. It also shows that the crisis of 2008-2013 slightly increased the price elasticity of demand for car fuels, with a higher effect on diesel than on gasoline. By contrary, the crisis slightly reduced the income elasticity of car-fuel demand. Given the intensity and length of the economic recession in Spain, the results of this paper may be useful to anticipate the effects of domestic public policies that impact car-fuel prices as well as to advance some of the potential consequences of crises elsewhere.

Keywords

Diesel, gasoline, income, price, regions, panel data.

JEL codes: C23, D12, Q41

1. Introduction[*]

From the mid-1990s until the outbreak of the 2008 crisis, the demand of car fuels in Spain saw an impressive and unprecedented evolution: between 1999 and 2007, gasoline and diesel consumption grew at an average annual rate of respectively 5.1% and 6.5%, reflecting both the strong growth of the Spanish economy and a limited responsiveness of demand to price changes (which in this period respectively grew at annual average rates of 1.8% and 3.5%). Yet, six years of crisis led to a completely different picture: between 2008 and 2013 gasoline and diesel demand, respectively, fell at an average annual rate of 5% and 4.3%; while prices increased at average annual rates of 3.2% (gasoline) and 1.9% (diesel) –although with significant reductions in the years 2009 and 2013. It is obvious that such a boom-and-bust evolution, as Figure 1 later depicts, brings about remarkable socio-economic and environmental effects and it affects existing policies in the field.

It is widely known that the economy of Spain, one of the developed countries that suffered the sharpest falls in economic activity and employment after 2008, was badly shaken by the global financial crisis and its aftermath. Given the aforementioned observed changes in energy consumption over the last few years, this paper focuses on providing an updated calculation of the price and income responsiveness of car fuel demand in Spain. Yet it devotes special attention to testing whether the crisis has had an effect on price and income elasticities so its results may be useful for illustrating the consequences of other pervasive and long economic crisis on car fuel demand. This is very relevant, as the availability of reliable demand elasticities is a necessary condition for a proper economic evaluation of energy, environmental or fiscal policies and strategies that impact car fuel prices (Hughes et al., 2008).

Some authors have pointed out that economic crises are likely to have effects on the price elasticities of goods due to, for instance, the larger incentives to react to prices that are associated to less availability of income (Estelami et al., 2001); yet academic evidence has been rather scarce so far. In this sense, the literature on marketing generally considers price elasticity of demand to be countercyclical, that is, it experiments increases when the economy weakens (van Heerde et al., 2013; Lamey et al., 2007). This especially seems to be the case in products with low-price elasticity, like energy goods, and in those that account for a big share of total expenditure (Gordon et al., 2013). However, the actual empirical evidence on the variation of demand elasticities at times of economic crisis is rather limited. Some exceptions are the meta-analyses of elasticity figures for different energy goods by Espey and Espey (2004), who show that the short-run price elasticity of electricity experienced a reduction during the energy crisis of the 1970s; and by Labandeira et al. (2017), who provide evidence of reduction of short and long-run price elasticities of energy demand after the 1973 crisis and of long-run elasticities after the 1979 and 2008 crises. Finally, Altinay and Yalta (2016) find increased price elasticities of natural gas in Istanbul after the 2008 crisis while Romero-Jordán et al. (2016) also report an increase in the price elasticity of demand for domestic electricity in Spain after the recent recession.

To provide a more precise and comprehensive analysis on the effects of the economic cycle on the demand elasticities of energy goods, this paper examines separate gasoline and diesel demand models using a set of estimators, including generalized method of moments and bias-corrected dynamic fixed-effect models, on a panel of Spanish regions covering the 1999-2015 period. Dealing carefully with the main econometric problems found for the estimation of this kind of demand models, we try to reconcile some apparently contradictory evidence available for Spain.

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The remainder of the article is structured as follows. Section 2 reviews related literature. Section 3 describes the methodology used in this analysis. Section 4 presents the empirical analysis discussing the data used and reporting the core results of various estimation techniques. The last section concludes and discusses some implications from the results.

2. Literature

Both reduced-form and structural demand models have been extensively used to research on automobile fuel demand. Model estimation can adopt different forms by using either static or dynamic models in function of the type of data available, which can be purely time-series data, cross-section data or panel data. In the first category, the Partial Adjusted Model (PAM) stands as one of the preferred alternatives for analyzing fuel demand and estimating elasticities. The PAM is a dynamic model that provides short and long-run elasticities with a basic assumption: markets are imperfect because several issues (e.g. consumer habits) preclude the attainment of the proper equilibrium (Houthakker et al., 1974). That is why this approach incorporates the limited adjustment ability of agents to the long-run equilibrium when facing changes in a number of factors like price or income (Barla et al., 2014; Erdogdu, 2014; Li et al., 2010; Banaszak et al.1999; Al-faris, 1997; Sterner and Dahl, 1992). Yet other approaches, e.g. using co-integration techniques, have stressed the need to account for the potential non-stationarity of time series. Indeed, it has been pointed out that failure to reach stationarity can provoke overestimation of long-run price elasticities (Eltony and Al-Mutairi, 1995; Samimi, 1995; Ramanathan; 1999; Dahl and Kurtubi, 2001). In line with the cointegration technique, various empirical studies have employed the Autoregressive Distributed Lag (ARDL) bounds-testing approach of Pesaran et al. (2001) to determine long-run elasticities (Mensah et al., 2016; Hasanov, 2015; Boshoff, 2012; Akinboade et al., 2008; De Vita et al., 2006).

Developments of panel data econometric methods and the increasing availability of this kind of data have made it possible to estimate energy demand models with combined time-series and cross-sectional data. The growing use of panel data modeling is largely due to the ability of this technique to sort several econometric problems. For instance, panel data models can control for invariant unobserved heterogeneity, a usual issue in fitting models with cross sectional data that, if correlated to observed variables included in the model, would bias the estimates. Panel data models also allow for the introduction of dynamics in the specifications, an important matter when adjusting economic relationships (Hsiao, 2003; Baltagi, 2001; Wooldridge, 2002).

In this context, the fact that the decision on car fuel consumption is largely made at the household level means that their demographic characteristics are very relevant, even though there are also several applications that have used aggregate data to implement estimations at local or regional levels (see Table 1). Dahl and Sterner (1991), Sterner and Dahl (1992), Dahl (1995), Goodwin et al. (2004), de Jong and Gunn (2001), Graham and Glaister (2002,2004), Basso and Oum (2007) or Dahl (2012) have provided surveys of the existing literature on car-fuel demand elasticities.

Although studies on the demand for car fuels in advanced countries are abundant in the economic literature, the number of papers for the Spanish case is limited. The second part of Table 1 provides a summary of the main pieces of research that report price and income elasticities of car-fuel demand for Spain. It distinguishes between complete-demand models at household level, microdata approaches without demand system estimation, and papers that use aggregate data of Spanish regions.

Table 1. Selected economic literature on car fuel demand

Study	Country	Consumer	Model	Fuel	Price elasticity	Income elasticity
			WORLD			
Baltagi and Griffin (1997)	18 OECD countries	Total	Aggregate	Gasoline	[-0.38; 0.37] (ST) [-2.38; 0.71] (LT)	[-0.63; 0.83] (ST) [-3.15; 0.82] (LT)
Schmalensee and Stocker (1999)	USA	Residential	Micro model	Gasoline	-0.29 (ST)	0.16 (ST)
Kayser (2000)	USA	Residential	Discrete-continuous model	Gasoline	-0.23 (ST)	0.49 (ST)
Yatchew and No (2001)	Canada	Residential	Micro model	Gasoline	-0.90 (LT)	0.29 (LT)
Baltagi et al. (2003)	France	Residential	Aggregate	Gasoline	[-0.19; -0.02] (ST) [-0.72; -0.34] (LT)	[-0.03; 0.52] (ST) [-0.80; 1.91] (LT)
Liu (2004)	23 OECD countries	Total	Aggregate	Gasoline Diesel	[-0.19; -0.14] (ST) [-0.99; -0.60] (LT) -0.09 (ST) [-0.43; -0.27] (LT)	[0.05; 0.20] (ST) [0.37; 0.61] (LT) [0.34; 0.43] (ST) [1.21; 1.71] (LT)
Wadud (2010)	USA	Residential	Micro model	Gasoline	-0.47 (ST)	0.34 (ST)
Pock (2010)	14 European countries	Residential	Aggregate	Gasoline	[-0.19; -0.03] (ST) [-0.84; -0.31] (LT)	[0.04; 0.24] (ST) [0.17; 0.61] (LT)
Liddle (2012)	14 OECD countries	Total	Cointegration	Gasoline	-0.16 (ST) [-0.43; -0.19] (LT)	0.28 (ST) [0.20; 0.34] (LT)
Frondel and Vance (2014)	Germany	Residential	Micro model	Gasoline Diesel	-0.45 (ST) -0.42 (ST)	0.02 (ST) 0.02 (ST)
Scott (2015)	29 OECD countries	Total	Aggregate	Gasoline	[-0.20; -0.05] (ST) [-0.73; -0.19] (LT)	0.21 (ST) 0.76 (LT)
			SPAIN			
Labeaga and López (1997)	Spain	Residential	Micro model	Gasoline	[-0.54; -0.42] (ST)	[0.34; 0.43] (LT)
Labandeira and López (2002)	Spain	Residential	Complete demand system	Car fuels	-0.08 (ST)	0.99 (ST)
Labandeira et al. (2006)	Spain	Residential	Complete demand system	Car fuels	[-0.11;-0.06] (ST)	[1.60; 1.80] (ST)
Romero-Jordán et al. (2010)	Spain	Residential	Complete demand system	Car fuels	[-0.64; -0.33] (LT)	[0.92; 1.46] (LT)
del Río et al. (2012)	Spain	Residential	Complete demand system	Car fuels	[-0.48;-0.43] (LT)	[1.33; 1.34] (LT)
González-Marrero et al. (2012)	Spain	Total	Aggregate	Gasoline Diesel	[-0.42; -0.29] (ST) [-0.08; -0.03] (ST)	[-0.01; .29] (ST) [-0.00; 0.48] (ST)
Bakhat and Rosselló (2013)	Spain (Balearic I.)	Total	Aggregate	Gasoline Diesel	[-1.08; -0.68] (ST) [-2.66; -1.52] (LT) [-1.19; -0.49] (ST) [-2.66; -1.40] (LT)	[0.19; 1.30] (ST) [1.93; 3.97] (LT) [0.76; 1.43] (ST) [3.16; 3.96] (LT)
Romero-Jordán et al. (2014a)	Spain	Residential	Micro model	Car fuels	[-0.34;-0.31] (ST)	[0.57; 0.59] (ST)
Romero-Jordán et al. (2014b)	Spain	Residential	Complete demand system	Car fuels	-0.90 (LT)	-
Asensio et al. (2014)	Spain	Total	Aggregate	Gasoline	[-0.24; -0.20] (ST)	-
Danesin and Linares (2015)	Spain	Total	Aggregate	Gasoline Diesel	[-0.26;-0.25] (ST) [-0.82; -0.56] (LT) [-0.24;-0.23] (ST) [-1.67; -0.88] (LT)	[0.06; 0.07] (ST) [0.12; 0.23] (LT) [0.22; 0.30] (ST) [1.09; 1.56] (LT)

Note: ST: short-term; LT: long term

3. Methodology

3.1. Econometric model

The theoretical model we employ to adjust fuel demand closely follows the approach adopted by Baltagi and Griffin (1983, 1997). We assume that the desired fuel (gasoline or diesel) consumption per vehicle in period *t* (c_t^*) is related through a Cobb-Douglas function to its determinants as in (1),

$$c_t^* = \alpha p_t^{\beta} y_t^{\gamma} x_t^{\delta} \tag{1}$$

where p, y and x are fuel prices, income and other determinants of the demand for car fuels, respectively. α, β, γ and δ are coefficients (δ is a vector) that describe the responsiveness of the long-run level of demand to its determinants; β and γ are the long-run price and income elasticities; and α is a constant. We follow Houthakker et al. (1974) by introducing a function to contemplate the limited capability of immediate adjustment by agents to the long-run equilibrium level of consumption when facing changes in price, income or other variables such as,

$$\frac{c_t}{c_{t-1}} = \left(\frac{c_t^*}{c_{t-1}}\right)^{\theta} \tag{2}$$

where parameter θ indicates the year-to-year inertia (habit persistence of fuel consumers) that varies between 0 and 1 (partial adjustment). Substituting (2) in (1), operating, re-arranging and adding an individual subscript, *i*, and an error term (*u*), we may express it as,

$$logc_{it} = \theta log\alpha + (1-\theta)logc_{it-1} + \theta\beta logy_{it} + \theta\gamma logp_{it} + \theta\delta logx_{it} + u_{it} \tag{3}$$

which is the adopted PAM specification of car-fuel demand. The individual subscript refers to Spanish regions, and x contains the number of cars and the saturation level of the road network. Consumption and income are defined in real terms; and both variables, together with the number of cars, are per capita[1]. To get real variables, nominal figures are deflated with the use of an index defined in the next section. Since data have time and individual variation, it is possible to consider $u_{it} = \eta_i + \varepsilon_{it}$ when assuming that unobserved regional effects (η_i) are randomly distributed. ε_{it} is a standard mixed error term. Finally, a time trend is used to capture potential efficiency affecting car fuel consumption by cars.

Of course, it would be possible to include alternatives in specification (3) such as time dummies or specific trends by regions. However, we believe that the general trend adequately captures efficiency gains by vehicles and, conditional on the other covariates, all regions have access to the same vehicles. Therefore, we assume that the effect of efficiency on consumption is not different by region (although, it also will be a matter of empirical testing).

The short-run elasticities of car-fuel demand per car with respect to per capita income, real price, total cars per capita (or per driver) and level of saturation are respectively, $\theta\beta, \theta\gamma$ and $\theta\delta$[2]. The corresponding long-run responses are given by β, γ and δ. $(1-\theta)$ is the speed of adjustment to the long-run equilibrium. Since the stock of cars appears both in the left and right-hand sides, the short

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[1] It could be discussed whether total consumption, income and the number of cars in per capita terms should come from total drivers, instead of total population. We leave this matter, however, for further empirical testing.

[2] Note that δ is a vector.

and long-run responses of car-fuel demand, relative to changes in the saturation level of the road network, are respectively $(1 + \theta\delta)$ and $(1 + \delta)$.

An important objective of this paper is to analyze car-fuel consumer responses to price and income changes during the time span 1999-2015, which includes the crisis period. We are particularly interested in testing whether the crisis had any effect on elasticity figures. Thus we modify Equation (3) to allow for the inclusion of a variable to proxy a treatment (crisis) as follows,

$$logc_{it} = \theta log\alpha + (1-\theta)logc_{it-1} + (\theta\beta + \lambda_1 T_t)logy_{it} + \\ +(\theta\gamma + \lambda_2 T_t)logp_{it} + \theta\delta logx_{it} + u_{it} \quad (4)$$

where T_t is a dummy variable equal to 1 between 2008 and 2013 and zero otherwise, and λ_1 and λ_2 are additional parameters. The short-run income and price elasticities during the crisis period are respectively $\theta\beta + \lambda_1$ and $\theta\gamma + \lambda_2$, where λ_1 and λ_2 capture the causal effects of the crisis on short-run elasticities. Likewise, it is possible to calculate the causal effects of the crisis on long-run values and, thanks to the parameter of adjustment to the long-run equilibrium, the duration of these effects.

3.2. Estimation

To calculate the different elasticities of fuel demand we must estimate Equations (3) or (4), which are subject to two main methodological challenges: unobserved heterogeneity and the presence of a lagged dependent variable. Individual heterogeneity, if assumed random, is a problem because of its potential correlation with the covariates (it is correlated with the lagged dependent variable by construction). The presence of the lagged dependent variable could generate, in addition to the difficulty just mentioned, an endogeneity problem when u_{it} is correlated or when consumption suffers measurement error problems. Generally the control variables used to explain fuel demand are periodically published by public entities or statistical agencies, but other variables are unlikely to be easily accessed or recorded and thus researchers relying solely on observable variables need to assume unconfoundedness (Imbens and Woodridge, 2009).

Nevertheless, under the assumption that the effects of time-invariant factors can be ruled out by any transformation of the specification, we may consistently estimate the model, even in the presence of correlated effects, by using either Least Squares Dummy Variables (LSDV) estimators or instrumental variables in a first-differenced specification, or by transforming the model using orthogonal deviations (see Arellano and Bover, 1995). The estimator obtained in a within-groups regression (the LSDV) is consistent under strict exogeneity of the regressors. Obviously, there is potential for predeterminedness or endogeneity of the lagged-dependent variable. The LSDV is downward biased in these cases and the bias is particularly severe when the number of time periods, *T*, is small (Nickell, 1981; Roodman 2006). *T* should generally be larger than 50 to significantly reduce the bias. However, this is not our case. We therefore, use instrumental variables to ensure consistent estimates even in the presence of measurement error in the regressors.

The use of two-stage procedures or efficient Generalized Method of Moments (GMM) in this context has been a matter of significant discussion[3]. In any case, the instruments should be relevant for the endogenous variable and uncorrelated to the errors. When using more than one instrument for each variable to be instrumented, one can easily compute a test for the validity of the instruments (not correlated with the errors) but additional diagnostics should still ensure they are not weak. One of the main problems for the validity of the instruments, for any of the aforementioned reasons, is that we

[3] This approach was introduced by Hansen (1982). Further developments of the method are due, among others, to Arellano and Bover (1995) and Blundell and Bond (1998). See also Hansen and Singleton (1982), Holtz-Eakin et al. (1988) and Arellano and Bond (1991).

must estimate the model in a transformation of the variables to rule out unobserved heterogeneity. This transformation could worsen the measurement error problem if it was present in the original series (Griliches and Hausman, 1986).

To deal with the weak instruments problem, we may still use System-GMM (see Arellano and Bover, 1995 or Blundell and Bond, 1998), an improved version of the GMM estimator, by incorporating the equations in levels in the estimation. The approach is based on a system of equations that contains equations in levels and differences, with the first-differenced variables employed as instruments for the equations in levels. However, as suggested by Blundell and Bond (1998), this method can help when the coefficient of the lagged dependent variable is close to 1 (to be tested in the empirical section below). Yet the instrument proliferation in the System-GMM method does not come without a cost: Roodman (2009) argued that it could bias the coefficient estimates of the endogenous variables due to overfitting, reduce the power of the instrument validity tests, and result in standard errors that are downward biased. Windmeijer (2005) addressed the latter through a variance correction for the two-step Blundell and Bond (1988) estimator, which this paper also considers. In addition, Roodman (2009) suggested testing results for sensitivity to reductions in the number of instruments.

Another issue is that the instrumental variables are valid for large *N*, and less is known about their performance in small sample sizes. Under the assumption of strict exogeneity of the explanatory variables other than the lagged dependent variable, Kiviet (1995) used an asymptotic expansion technique to correct the biased LSDV estimator for samples where *N* is small. In another study based on Monte Carlo simulations and departing from the results of Kiviet (1995), Judson and Owen (1999) showed that Corrected LSDV (LSDVC) improved the GMM approach both in bias and efficiency. Bruno (2005) subsequently extended the LSDVC so that it could be applied in unbalanced panels. In a recent study, Flannery and Hankins (2013) compared the performance of various estimators on simulated datasets of short panels. They concluded that Blundell-Bond and the bias-corrected fixed effects estimators of Kiviet (1995) had the best performance. Section 4 deals with all the preceding issues.

4. Empirical application

4.1. Data description

The dataset used in this paper is a panel of 16 Spanish administrative regions (*comunidades autónomas*) that covers the 1999-2015 period (annual data, so T=17)[4]. We have information about fuel consumption, disaggregated in regional gasoline and diesel items. These variables are obtained from the annual reports of National Commission on Markets and Competition (CNMC, its acronym in Spanish); real gasoline and diesel prices are obtained from the Spanish Ministry of Energy; regional Spanish population from the National Institute for Statistics (INE, its acronym in Spanish); number of gasoline and diesel cars (a relevant determinant of the evolution of traffic in the long term) and number of drivers from the General Direction of Traffic (DGT, its acronym in Spanish); total kilometers of regional roads from the Ministry of Infrastructures (known as *Fomento* in Spanish); and household disposable income and retail price index from the INE. As already mentioned, the effect of technical progress on car-fuel consumption is taken into account by including a trend[5].

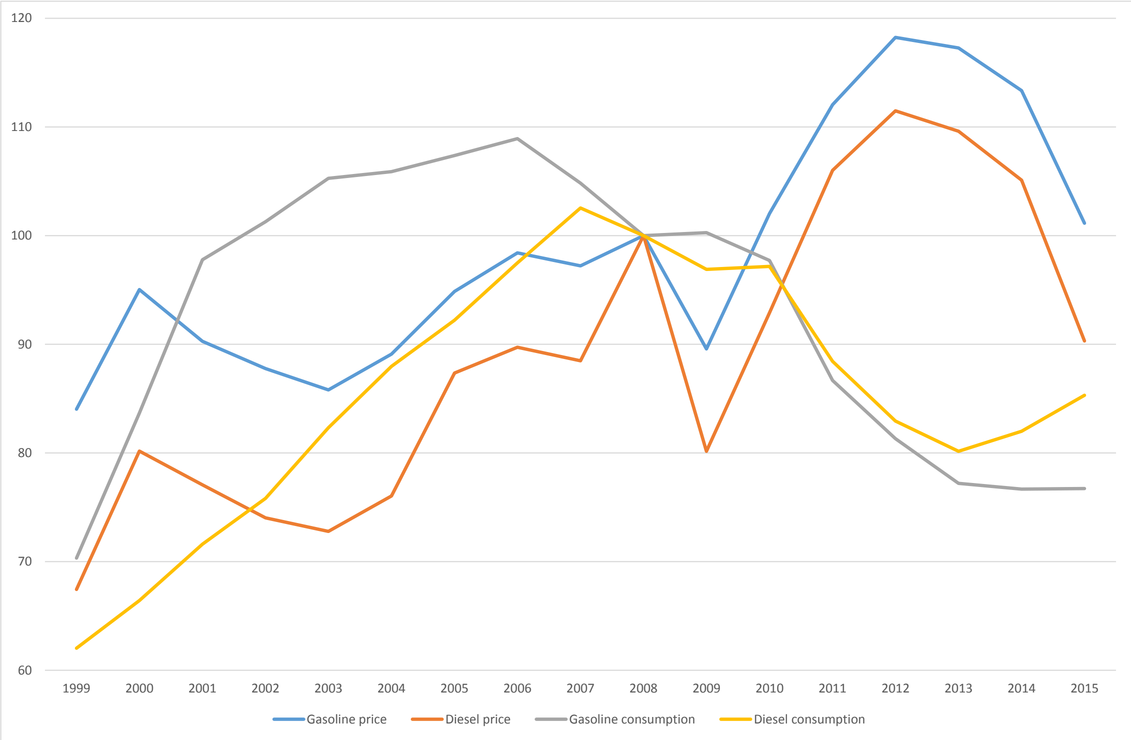
Figure 1 depicts the evolution of Spanish consumption and real prices of both gasoline and diesel between 1999 and 2015. Diesel demand has been steadily increasing since 1999, while demand for gasoline has decelerated its growth since 2001. Indeed, due to a favorable tax regime (see Table A1 in the Appendix), diesel now constitutes over 80% of Spanish demand of car fuels; thus, it is close to a saturation stage. However, the recent economic crisis strongly affected both car fuels and stopped their growth. Spain's annual diesel consumption in 2015 was around 21.6 million tons or 49.7% lower than the counterfactual following the pre-2007 trend of annual growth of 6.5%. However, the demand increase from 2013 onwards relates to the recovery the economy and the reduction of oil prices. Similarly, gasoline consumption in 2015 was about 4.3 million tons, or 38% lower than it would have been if the 2004-2006 annual growth of 1.4% had been maintained. In addition, since the start of the recession, a high level of unemployment has reduced disposable income and strongly affected car sales and, thus, the quality of the fleet and its efficiency. For instance, the annual growth rate of diesel fleet dropped from 11.1% between 2004 and 2006 to 1.9% between 2012 and 2015.

Figure 1 shows that gasoline and diesel price trends were broadly similar over the period 1999-2015. Real prices increased at a faster rate between 1999 and 2000 and, after a price-decreasing interval between 2001 and 2003, prices went up again until the sharp reduction caused by the outbreak of the crisis. The strong upwards rebound from 2009 to 2012 was followed by a substantial drop in the prices of car fuels during the last period of the sample.

[4] Ceuta, Melilla and Canary Islands were excluded from this analysis because they have a special tax regime that may distort the results.

[5] The introduction of a common trend was justified in the previous section, although we also test between a specification with a trend and a specification with annual dummies.

Figure 1. Gasoline and diesel, real prices and consumption. Spain, 1999-2015 (2008=100)



Source: The authors with data from Ministry of Energy and CNMC

This study is based on panel data, so it is important to assess the variations of the variables over time and across regions. Table A2 in the Appendix summarizes the extent of data variation, both within and between regions, for the key variables: gasoline and diesel consumption per car, gasoline and diesel prices, per capita income, cars per capita, and road saturation. Variations in diesel consumption were more pronounced within the same region than between regions across the years. By contrary, variations in gasoline price and consumption were more intense within each region than between regions; while the variation of gasoline vehicles was more remarkable in per capita terms between regions. Finally, road saturation variation was predominantly between regions, whilst the variation of real income was less pronounced within each region than between regions.

4.2. Results

Tables 2 and 3 report the coefficients of our preferred specifications estimated by GMM. We also provide baseline OLS and LSDV results for comparison. The coefficients of the lagged-dependent variable obtained from these two estimators provide the bound limits, a useful check on the results from a theoretically superior estimator (Bond, 2002). In particular, while the naïve OLS estimator overestimates the coefficient of the lagged dependent variable because regional fixed effects are unaccounted; the LSDV coefficient decreases due to the importance of regional effects. The preceding tables only report one alternative to these reference specifications: the Arellano-Bond (1991) GMM estimator (AB)[6]. The Arellano and Bover (1995) and Blundell and Bond (1998) procedures involve the use of the full instrument set available (in first differences and levels) but only apply when the autoregressive coefficient exhibits a high degree of inertia, which is not our case, once the panel structure of the data has been considered.

6 We have also obtained results using the methods proposed by Anderson and Hsiao (1982), Kiviet (1995), Arellano and Bover (1995) and Blundell and Bond (1998), which are available upon request.

Tables 2 and 3 also supply the heteroskedasticity-consistent asymptotic standard errors in parenthesis, the t-statistic for the linear restriction test under the null hypothesis of non-significance, and the Sargan test of over-identifying restrictions. The latter is asymptotically distributed as χ^2 under the null of absence of correlation between the instruments and the error term. Besides, the previous tables report two tests of first and second order serial correlation $(m_i, i = 1, 2)$, which are computed using the residuals in first differences, asymptotically distributed as *N(0, 1)* under the null of absence of serial correlation (see for details Arellano and Bond, 1991). In the equation for gasoline we only include one lag because, while m_1 detects the expected correlation of order 1 as the model is estimated in first differences, m_2 does not detect second-order serial correlation at standard significance levels. In the case of diesel, m_2 provides evidence of misspecification in a model with one lag. The value is reduced once a second lag is included. This test, together with the one on overidentifying restrictions, seems to give validity to the instrument set.

As indicated before, diesel vehicles represent a large portion of the Spanish fleet and it is reasonable to assume that many of them are employed for economic activities (the original reason for the preferential tax treatment of diesel over gasoline). This in turn explains the existence of more inertia or less capacity to adjust with respect to gasoline-fueled cars. Based on the Sargan test, the overidentification restrictions are valid at any significance level for both diesel and gasoline. *F*- and χ^2 - statistics reject the null hypothesis that estimated parameters are jointly zero. Finally, the Hausman test detects correlated effects.

Table 2. Estimates of the diesel dynamic demand model

VARIABLES	OLS	LSDV	AB
Lag 1 of diesel consumption/car	1.076***	0.906***	0.547***
	(0.063)	(0.062)	(0.111)
Lag 2 of diesel consumption/car	-0.108*	-0.095	-0.101
	(0.063)	(0.061)	(0.068)
Trend	0.005***	0.001	-0.015***
	(0.001)	(0.002)	(0.005)
Diesel real price	-0.071**	-0.049	-0.015
	(0.031)	(0.030)	(0.030)
CrisisXprice	-0.004***	-0.004***	-0.005***
	(0.001)	(0.001)	(0.001)
Real income	0.039**	0.078	0.318***
	(0.018)	(0.056)	(0.077)
Cars per driver	-0.014	-0.067	-0.132**
	(0.017)	(0.042)	(0.060)
Road saturation	-0.005	-0.185**	-0.253**
	(0.004)	(0.077)	(0.119)
Constant	0.323	0.858	-0.341
	(0.303)	(0.601)	(0.755)
m1	-	-	-2.77***
m2	-	-	-0.93
Sargan test	-	-	11.64 (0.999)
Jointly zero coefficients	F(8, 231)=3001***	F(8, 216)=1642***	χ^2 (8)=2100***
Hausman test	-	63.44 (0.000)	-
Observations	240	240	224
R-squared	0.991	0.906	-
Number of regions	16	16	16
Number of instruments	-	-	48

Notes: 1. Robust standard errors in parentheses
2. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level
3. m1 and m2 are tests for autocorrelation of order 1 and 2, respectively.
4. Hausman test compare random and fixed effects models.

Table 3. Estimates of the gasoline dynamic demand model

VARIABLES	OLS	LSDV	AB
Lag of gasoline consumption/car	0.752***	0.647***	0.652***
	(0.019)	(0.029)	(0.043)
Trend	-0.004***	0.001	-0.018***
	(0.001)	(0.003)	(0.006)
Gasoline real price	-0.067	-0.008	-0.064
	(0.044)	(0.047)	(0.055)
CrisisXprice	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)
Real income	0.015	0.257***	0.248**
	(0.017)	(0.066)	(0.112)
Cars per driver	0.004	0.103	-0.568***
	(0.015)	(0.072)	(0.162)
Road saturation	-0.022***	-0.078	-0.296
	(0.004)	(0.068)	(0.190)
Constant	0.504	-1.497*	-0.277
	(0.428)	(0.068)	(0.665)
m1			-3.31***
m2			1.86*
Sargan test			12.94
			(0.999)
Jointly zero coefficients	F(7, 248)=397***	F(7, 233)=255***	χ^2 (7)=967***
Hausman test		76.01	
		(0.000)	
Observations	256	256	240
R-squared	0.918	0.833	
Number of regions	16	16	16
Number of instruments			72

Notes: 1. Robust standard errors in parentheses
2. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level
3. m1 and m2 are tests for autocorrelation of order 1 and 2, respectively.
4. Hausman test compare random and fixed effects models.

The preceding results show relevant impacts of the crisis on the values of the price elasticity of gasoline and diesel; and they are in line with the existing evidence on their countercyclical nature (see van Heerde et al., 2013 or Romero-Jordán et al., 2016). Although the reported magnitude of the effect is very small, it is quite important because the average price elasticity without crisis is not significantly different from zero. That is to say, despite the fact that gasoline and diesel are very price inelastic, the economic crisis has led consumers to increase their reaction to price changes. Table 4 depicts the price elasticities of car fuels in Spain that, as expected, show larger values in the long-run case[7]. Moreover, consumers show a higher capacity to adjust to price changes in gasoline both in the short and long

[7] We get larger values but, in statistical terms, we cannot reject that they are statistically different from zero.

terms. As previously hinted, this may be related to the importance of (vehicle) diesel consumption in industrial and commercial sectors, which implies a lower capacity to adjust to price changes with respect to gasoline (as change of habits or leisure is less possible) and a higher linkage between consumption and the evolution of the business cycle. Yet the implicit coefficient of partial adjustment, estimated at around 0.35, is similar for diesel and gasoline; and it implies that the speed of adjustment to the long-run equilibrium lasts for around three years after a shock. That is why unsurprisingly, by the end of 2016, Spanish consumption of diesel and gasoline for transport almost completely recovered from the low amounts seen during the crisis.

Table 4. Short and long-run price elasticities of car fuels

	Diesel	Gasoline
Short-run (non-crisis period)	-0.015	-0.064
Short-run (crisis period)	-0.019	-0.067
Long-run (non-crisis period)	-0.026	-0.185
Long-run (crisis period)	-0.035	-0.193

The results reported in Table 4 also compare well with previous evidence on price elasticities of car fuels in Spain. They are in the range of those obtained by Labandeira et al. (2006) for gasoline and smaller in the case of diesel. This relates to the fact that this application considers total demand for diesel vehicles (including industrial and commercial consumers, with less capacity of adjustment) and not only residential demand, as did the aforementioned 2006 paper. This too may be the origin of the differences with the results provided by Del Río et al. (2012) and Romero-Jordán et al. (2014a, 2014b) for Spanish residential demand. Although it is not easy to compare our results with those of aggregate demand for fuel obtained by González-Marrero et al. (2012), Asensio et al. (2014) or Danesin and Linares (2015), this article reports slightly lower values. This may be due to the shorter time span and the consideration of two types of gasoline, 95 and 97 octane, by the abovementioned exercises (only 95-octane gasoline in our case).

In a recent paper Labandeira et al. (2017) conduct a comprehensive meta-analysis of price elasticities of energy products and, as in this exercise, find that the average elasticity of diesel is smaller than the average elasticity of gasoline, although they report higher values than the ones obtained here. This may be related to the concentration of most of the 1876 elasticity values considered by the meta-analysis in the period before the last, and most intense, economic crisis (2008) on the one hand and to the use of regional aggregates on the other. The results of our paper are in line with those reported by Baltagi et al. (2003) for the French regions, Baltagi and Griffin (1997) for 18 OECD countries, Sa'ad (2009) for Indonesia, Pock (2010) for the EU countries or Wadud et al. (2009) and Lin and Price (2013) for the USA; so this seems to indicate the prevalence of the second explanation.

It should also be noted that the time trend has the expected negative effect and is statistically significant for both car fuels, suggesting that technological advances in engines have reduced annual vehicle fuel consumption by respectively 1.5% and 1.8% for diesel and gasoline. This obviously reflects the continuous energy performance improvement in automobiles over the last few years[8]. Moreover, the increase in the number of cars by driver has also reduced fuel consumption per vehicle, while the level of saturation of the road network has had a significant negative impact on diesel demand. This result could be related with the use of alternative means of transport by industrial and

[8] Both, in statistical and economic terms, the specification with annual dummies is rejected against our preferred specification. Results are available upon request.

commercial firms when congestion affects their activities[9]. As expected, income has a positive effect on demand and it is more important for diesel in the short-run (again related to the importance of diesel as input for industrial and commercial activities that are closely linked to the economic cycle). Yet in the long-run there seems to be scope for adjustment in all the agents. Related to this, we have carried out a test for complementarity-substitutability of diesel and gasoline; but the effect of the cross-price is not significant in any of the two specifications[10].

To further explore the effect of the crisis on the responsiveness of car-fuel demand, we performed an estimation including interactions of income with the treatment dummy. Our objective was to evaluate whether the crisis affected the relationship between income and consumption of car fuels (see Table 5 and Table A3 in the Appendix). The results show that the coefficients of the interaction terms are negative and significant, indicating that gasoline and diesel demands have responded more to increases in income than to declines in income and thus showing imperfect income-reversibility (Gately and Huntington, 2002).

The intuition behind such imperfect income-reversibility could be related to the fact that some sectors of the economy may grow more strongly than others at times of economic expansion and vice versa, which could be exacerbated by the existence of different energy intensities across economic activities. In the case of households, this phenomenon could be explained because a substantial portion of consumption may be inelastic (with a small margin of adjustment in the short-run) and thus be largely unresponsive to moderate negative shocks. Actually, the evolution of car-fuel consumption and income during the expansion (1999-2007) and recession (2008-2013) periods indicates that the increase (decrease) in demand was higher than the increase (decrease) in income during expansion (recession), although the magnitude of the differences in growth rates of consumption and income was bigger during the expansion in the case of diesel. This implies a larger impact of income on consumption in the expansive period for diesel, which does not happen with gasoline due to other factors such as the progressive reduction of gasoline vehicles within the fleet (although our model adjusts consumption by car and hence our results are robust to these changes)[11].

Table 5. Short and long-run income elasticities of diesel and gasoline demand

	Diesel	Gasoline
Short-run (non-crisis period)	0.318***	0.248**
Short-run (crisis period)	0.311***	0.244**
Long-run (non-crisis period)	0.591***	0.706*
Long-run (crisis period)	0.578***	0.694*

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Finally, a panel data heterogeneous model (see Baltagi and Griffin, 1997) was estimated to evaluate the effects of the crisis on the price and income elasticities of car fuel demand. To do so, we incorporated regional dummies interacted with prices and income in the empirical analysis (see Table A4 in the Appendix). The results show that the price elasticity of car fuel demand has significantly increased in most regions (11 out of 16, for gasoline and diesel), while only one small Northern region (Cantabria) experienced a significant reduction in the case of gasoline. Moreover, the crisis brought about a reduction of income elasticities in most regions (see Table A5 in the Appendix), thus

[9] It must be noted that any impact assessment of road improvement on mobility and car-fuel consumption would require additional variables, such as vehicle-miles travelled, and a different approach that is beyond the capabilities and scope of this paper.

[10] We believe that the cross-price could have an effect at the extensive margin, when the agent decides to purchase a vehicle. Once taken this decision, substitution is not possible.

[11] In the expansive period diesel (gasoline) demand increased 1.56 (1.23) times over income, while in the recessive period diesel (gasoline) demand was down 1.37 (1.59) times over income.

providing robustness to the previous results of the paper. Yet Galicia, a medium-sized Northern region and the only poor area where the crisis had no effect on income and price elasticities of diesel or gasoline, illustrates the importance of geographic and demographic issues. In this region, a largely dispersed population makes agents more dependent on the use of cars and thus reduces their capacity to react at times of economic crisis.

Our empirical analysis concludes with an enquiry on the effects of the crisis on the elasticities of car-fuel demand in Spain's poor and rich regions (see Tables A6 and A7 in the Appendix)[12]. The results show that the crisis had a negative effect on elasticities; that is, it led to an increase of the price elasticity and an income elasticity reduction both for diesel and gasoline demand. Such effects have been more intense in poor regions; this is particularly the case of diesel, with higher price elasticity in poor regions (and non significant price elasticity in rich regions). This is again related to the lower capacity of industrial and commercial activities to adjust, particularly in rich areas where price increases can be more easily absorbed without adjustments in consumption. The reverse occurs in the case of gasoline, more related to residential consumption, which may offer rich regions more possibilities of adjustment through a reduction of the larger (pre-crisis) allocation to leisure activities. All these results together with the current data on demand for car fuels seem to suggest that the crisis had a very limited impact on long-run behavior and, given the estimated speed of adjustment (see above), at the moment of writing this paper car-fuel consumption in Spain is close to its pre-crisis figures.

5. Conclusions

This paper reports the results from various specifications of a dynamic demand model for gasoline and diesel (for use in transportation) estimated on Spanish regional data from 1999 to 2015. The article shows that, after the outbreak of the 2008 economic crisis, price and income changes have had an additional effect on the demand for car fuels in Spain. Put in other words, consumer response throughout the 2008-2013 recessive period was found to be more elastic (inelastic) to price (income) changes than it was throughout the rest of the sampling period. A consistent finding across the different estimators employed in the analysis is that the diesel (gasoline) price elasticity is 0.004 (0.003) larger with respect to the pre-crisis levels. Besides, estimated income elasticities for diesel and gasoline were respectively 0.007 and 0.004 lower throughout the crisis than they were throughout the non-crisis years.

Our empirical enquiry has also explored the effect of the crisis on price and income elasticity by region, showing a significant increase (in absolute terms) of the price elasticities of car fuels and a significant reduction of the income elasticities in most regions. Thus these results support the preceding conclusions for the whole of Spain. The paper also looks at the differences between the elasticities of poor and rich regions; it shows that, although the crisis had a negative and significant influence on the income and price elasticities of gasoline and diesel, this influence was larger in poor regions, particularly in the case of diesel.

Our work suggests that the significant reduction of car-fuel consumption and the concomitant fall in sales and tax revenues, seen in Spain during the crisis, were partly due to changed values of price and income elasticities. It is rather obvious that the behavior of Spanish car-fuel demand after the outbreak of the crisis responded both to soaring fuel prices and to strong economic difficulties for households (wage reductions, unemployment, etc.) and firms (a shrinking internal demand). However, our results indicate that these effects were exacerbated by a modification of price and income elasticities of demand. This indicates that the use of pre-crisis elasticities to anticipate the effects of

[12] For the purposes of our analysis, we classify poor regions as those whose average household disposable real income during the sampling period is below the average of the whole sample: Andalusia, Castile-Mancha, Valencia, Extremadura, Galicia and Murcia.

price and income changes (associated or not to public policies) provides inaccurate results, as can be easily tested for the Spanish case with the pre-crisis existing (*ex-ante*) empirical evidence and real price, income and consumption data.

The article underlines the importance of accurate panel data estimation and of a proper treatment of the predeterminedness-endogeneity problems by using adequate GMM estimation. Based on such a careful empirical approach, we believe that this paper provides up-to-date and robust price and income elasticities of car-fuel demand in Spain, fully in line with those obtained by Baltagi et al. (2003), Pock (2010) or Lin and Price (2013), among others, for the developed world. Our results also show that improvements in energy efficiency are leading to a progressive reduction in Spanish car-fuel consumption, whereas the saturation of roads has a negative influence on diesel consumption because it promotes the use of alternative means of transportation by firms.

The findings of the paper may thus be useful to anticipate the possible effects of deep and persistent economic crises in other developed or emerging countries. It may also provide a cautionary message on the procyclical effects of economic expansion on car-fuel consumption, such as the one that is currently taking place in Spain. In this sense, the paper provides evidence indicating that the Spanish demand for gasoline and diesel in the transport sector is quickly returning to pre-crisis figures. Given the relevance of car-fuel consumption in energy and environmental terms, the results of this paper may assist in defining and implementing different (corrective) public policies.

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Appendix

Table A1. Tax percentage (including VAT) in gasoline and diesel prices

	Gasoline	Diesel
1999	66.86	61.59
2000	59.22	52.66
2001	59.85	52.81
2002	62.41	56.46
2003	62.30	56.20
2004	59.38	52.72
2005	55.29	46.70
2006	52.65	44.88
2007	52.08	45.30
2008	49.55	40.53
2009	55.89	49.62
2010	52.19	46.23
2011	48.82	42.52
2012	48.03	42.42
2013	49.83	44.59
2014	50.90	45.79
2015	54.97	50.40

Source: OECD/IEA (2009, 2016)

Table A2. Variations of the Spanish regional data (n=16, T=1999-2015)

Variable		Mean	Std. Dev.	Min	Max	Observations	
Gasoline consumption per car	overall	0.478	0.077	0.248	0.687	N =	272
	between		0.044	0.391	0.557	n =	16
	within		0.064	0.259	0.609	T =	17
Diesel consumption per car	overall	2.838	1.125	1.108	6.348	N =	272
	between		0.790	1.513	4.362	n =	16
	within		0.825	1.087	5.651	T =	17
Gasoline price	overall	81.937	8.927	68.696	102.685	N =	272
	between		1.280	79.622	84.352	n =	16
	within		8.840	67.843	100.270	T =	17
Diesel price	overall	74.962	11.364	56.195	98.454	N =	272
	between		1.206	72.876	77.312	n =	16
	within		11.304	55.468	96.104	T =	17
Real income per capita	overall	10.552	1.800	6.942	15.074	N =	272
	between		1.675	8.157	13.359	n =	16
	within		0.775	8.503	12.267	T =	17
Gasoline cars per capita	overall	0.249	0.071	0.160	0.569	N =	272
	between		0.061	0.209	0.462	n =	16
	within		0.039	0.162	0.358	T =	17
Diesel cars per capita	overall	0.212	0.065	0.074	0.355	N =	272
	between		0.029	0.159	0.278	n =	16
	within		0.059	0.075	0.323	T =	17
Saturation	overall	179.120	214.889	28.517	998.421	N =	272
	between		220.687	34.993	942.098	n =	16
	within		18.701	61.650	235.443	T =	17

Source: Own calculations with data from Ministry of Energy, CNMC, DGT and INE.

Table A3. Parameter estimates for diesel and gasoline demand with interaction between income and crisis. AB GMM estimator

Variables	Diesel	Gasoline
Lag 1 of consumption/car	0.463***	0.648***
Trend	-0.015***	-0.021***
Real price	-0.034	-0.075
Real income	0.318***	0.248**
CrisisXreal income	-0.007***	-0.004***
Cars per driver	-0.094*	-0.671***
Road saturation	-0.287**	-0.308
Constant	0.011	-0.187
Joint Significance	χ^2 (7)=1874***	χ^2 (7)=873***

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table A4. Parameter estimates for diesel and gasoline demand with interaction between prices and crisis by region. AB GMM estimator

Variables	Diesel	Gasoline
Lag 1 of consumption/car	0.462***	0.652***
Lag 2 of consumption/car	-0.044	-
Trend	-0.017***	-0.028***
Real price Andalusia	0.034	0.063
Real price Aragon	0.060	-0.044
Real price Asturias	-0.013	-0.003
Real price Balearic Islands	-0.014	-0.090
Real price Cantabria	-0.189***	-0.290***
Real price Castile-Mancha	-0.011	-0.170
Real price Castile-Leon	-0.147**	-0.170***
Real price Catalonia	-0.178***	-0.058
Real price Valencia	0.039	-0.069
Real price Basque Country	0.105*	-0.271***
Real price Extremadura	-0.106	-0.078
Real price Galicia	-0.059	-0.103
Real price La Rioja	-0.127**	-0.126
Real price Madrid	0.025	-0.514***
Real price Murcia	0.105**	0.050
Real price Navarre	0.174***	0.116
CrisisXreal price Andalusia	-0.007***	-0.008***
CrisisXreal price Aragon	-0.005***	-0.005***
CrisisXreal price Asturias	-0.005**	-0.004*
CrisisXreal price Balearic Islands	-0.001	-0.005***
CrisisXreal price Cantabria	0.000	0.005**
CrisisXreal price Castile-Mancha	-0.007***	-0.001
CrisisXreal price Castile-Leon	-0.003	-0.000
CrisisXreal price Catalonia	-0.004***	-0.005**
CrisisXreal price Valencia	-0.006***	-0.004**
CrisisXreal price Basque Country	-0.006***	-0.007***
CrisisXreal price Extremadura	-0.006***	-0.005*

CrisisXreal price Galicia	-0.001	-0.003
CrisisXreal price La Rioja	-0.003**	0.001
CrisisXreal price Madrid	-0.004	-0.002*
CrisisXreal price Murcia	-0.007***	-0.008***
CrisisXreal price Navarre	-0.008***	-0.004***
Real income Andalusia	0.298**	0.260**
Real income Aragon	0.098	0.232
Real income Asturias	0.231***	0.305***
Real income Balearic Islands	0.296**	-0.249**
Real income Cantabria	0.253***	-0.008
Real income Castile-Mancha	0.580***	0.354**
Real income Castile-Leon	0.829***	0396***
Real income Catalonia	0.301**	-0.032
Real income Valencia	0.352***	0180
Real income Basque Country	0.179**	-0.245***
Real income Extremadura	0.368***	0.415***
Real income Galicia	0.203**	0.376*
Real income La Rioja	0.135	0.077
Real income Madrid	-0.299***	-0.826***
Real income Murcia	0.352	0.475
Real income Navarre	0.446**	0.313***
Cars per driver	-0.102*	-0.808***
Road saturation	-0.288**	-0.159
Constant	0.153	0.250
Joint Significance	χ^2 (15)=1081***	χ^2 (15)=212***

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table A5. Parameter estimates for diesel and gasoline demand with interaction between income and crisis by region.

Variables	Diesel	Gasoline
Lag 1 of consumption/car	0.455***	0.650***
Lag 2 of consumption/car	-0.039	-
Trend	-0.017***	-0.028***
Real price Andalusia	0.029	0.056
Real price Aragon	0.058	-0.050
Real price Asturias	-0.019	-0.006
Real price Balearic Islands	-0.019	-0.096*
Real price Cantabria	-0.193***	-0.285***
Real price Castile-Mancha	-0.009	-0.172
Real price Castile-Leon	-0.148**	-0.172**
Real price Catalonia	-0.175***	-0.061
Real price Valencia	0.036	-0.072
Real price Basque Country	0.103*	-0.280***
Real price Extremadura	-0.113	-0.080
Real price Galicia	-0.060	-0.102
Real price La Rioja	-0.127***	-0.124
Real price Madrid	0.021	-0.514***
Real price Murcia	0.103***	0.049

Real price Navarre	0.168***	0.110
Real income Andalusia	0.314**	0.275**
Real income Aragon	0.104	0.239
Real income Asturias	0.236***	0.311***
Real income Balearic Islands	0.297**	-0.244**
Real income Cantabria	0.253***	-0.007
Real income Castile-Mancha	0.611***	0.356**
Real income Castile-Leon	0.837***	0.399***
Real income Catalonia	0.325**	-0.021
Real income Valencia	0.368***	0.189
Real income Basque Country	0.191***	-0.241***
Real income Extremadura	0.385***	0.423***
Real income Galicia	0.202**	0.386**
Real income La Rioja	0.141	0.085
Real income Madrid	-0.289***	-0.820***
Real income Murcia	0.375*	0.497
Real income Navarre	0.462**	0.320***
CrisisXreal income Andalusia	-0.010***	-0.011***
CrisisXreal income Aragon	-0.007***	-0.006***
CrisisXreal income Asturias	-0.006**	-0.005*
CrisisXreal income Balearic Islands	-0.002	-0.007***
CrisisXreal income Cantabria	0.000	0.007**
CrisisXreal income Castile-Mancha	-0.010***	-0.001
CrisisXreal income Castile-Leon	-0.004	-0.000
CrisisXreal income Catalonia	-0.006***	-0.006**
CrisisXreal income Valencia	-0.008***	-0.005**
CrisisXreal income Basque Country	-0.008***	-0.008***
CrisisXreal income Extremadura	-0.008***	-0.007*
CrisisXreal income Galicia	-0.001	-0.004
CrisisXreal income La Rioja	-0.005**	0.001
CrisisXreal income Madrid	-0.005	-0.002*
CrisisXreal income Murcia	-0.010***	-0.011***
CrisisXreal income Navarre	-0.010***	-0.004***
Cars per driver	-0.108**	-0.809***
Road saturation	-0.283**	-0.162
Constant	0.066	0.230
Joint Significance	χ^2 (15)=571***	χ^2 (15)=182***

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table A6. Parameter estimates for diesel and gasoline demand with interaction between prices and crisis: poor regions vs. rich regions. AB GMM estimator

Variables	Poor regions		Rich regions	
	Diesel	Gasoline	Diesel	Gasoline
Lag 1 of consumption/car	0.733***	0.784***	0.359***	0.570***
Lag 2 of consumption/car	-0.028	-	-0.175**	-
Trend	-0.007	-0.024***	-0.020***	-0.027***
Real price	-0.036**	0.012	0.014	-0.145*
CrisisXreal price	-0.005***	-0.004***	-0.004***	-0.004***
Real income	0.161	0.380**	0.532***	0.066
Cars per driver	-0.114***	-0.800***	-0.247**	-0.769***
Road saturation	-0.036	-0.567***	-0.398**	0.050
Constant	-0.408	-0.687	-1.198	-0.066
Joint Significance	χ^2(5)=1160***	χ^2(5)=14071***	χ^2(8)=2306***	χ^2(7)=763***

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table A7. Parameter estimates for diesel and gasoline demand with interaction between income and crisis: poor regions vs. rich regions. AB GMM estimator

Variables	Poor regions		Rich regions	
	Diesel	Gasoline	Diesel	Gasoline
Lag 1 of consumption/car	0.726***	0.782***	0.354***	0.567***
Lag 2 of consumption/car	-0.024	-	-0.173**	-
Trend	-0.007	-0.024***	-0.020***	-0.027***
Real price	-0.039***	0.009	0.012	-0.148*
Real income	0.174	0.387**	0.539***	0.071
CrisisXreal income	-0.007***	-0.005***	-0.005***	-0.005***
Cars per driver	-0.118***	-0.801***	-0.249***	-0.772***
Road saturation	-0.035	-0.567***	-0.391**	0.054
Constant	-0.472	-0.717	-1.257	-0.089
Joint Significance	χ^2(5)=1038***	χ^2(5)=15737***	χ^2(8)=2324***	χ^2(7)=760***

Note: *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

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