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Prices, taxes and automotive fuel cross-border shopping☆

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ABSTRACT

The aim of the present paper is to determine whether differences in automotive fuel prices among neighboring Autonomous Communities (i.e. Spanish political-administrative regions) affect the decisions taken by individuals regarding the region in which to purchase fuel. In particular, the intention is to discover if price increases in certain Autonomous Communities, as a result of the application of the regional tranche of the Hydrocarbon Retail Sales Tax (HRST) has affected fuel purchases in neighboring Communities.
In order to achieve the above-mentioned objectives, the monthly purchases of automotive diesel in Aragon between January 2001 and March 2007 is estimated from the fuel price in Aragon, the relation between prices in each of the bordering Communities and Aragon, weighted by density of traffic, the number of vehicles registered in that Community, and three dummy variables representative of the implementation of the regional tranche of the HRST in Madrid, Catalonia, and Valencia. The paper finds empirical evidence to demonstrate a positive effect of the relative prices in the neighboring Communities and vehicle registrations, and also a negative effect of prices in Aragon, upon the acquisition of diesel in this region. In the case of Catalonia, some evidence suggests that the price effect may have been strengthened following the introduction of the regional tranche of the HRST in August 2004.

1. Introduction

The process of regional decentralization in Spain has made possible, since a decade ago, variations in certain taxes applied in the different Autonomous Communities, such as the Personal Income Tax, Inheritance and Gift Tax or Property Transfer Tax and Stamp Duty.

Since 2002, this possibility of fiscal diversification has included a newly created tax, the Hydrocarbon Retail Sales Tax (HRST), for which the Autonomous Communities may establish, as several have done, different tax rates (the so-called "health cent"). Consequently, from 2002 onwards, it has been possible for the price of automotive fuels to vary significantly among Communities. Such differences may cause residents of a particular Community to decide to acquire fuel for their vehicles in Communities with lower prices, especially if the latter share borders with or are close to that in which they reside.

The aim of the present paper is to estimate the impact of price differences in automotive fuels between neighboring Autonomous Communities upon individual decisions of where to purchase fuel. In particular, the intention is to verify whether price increases in certain Communities, due to the regional tranche of the HRST, has affected the acquisition of fuel in bordering or nearby Communities. As far as we are aware, this is the first study undertaken in Spain with this objective in mind. Although the literature has previously dealt with the HRST, the approach adopted has been different, analyzing, for example, the effects of the implementation of the tax upon revenue collection, income distribution and welfare.[1]

In order to achieve the stated objective, the paper is divided into five sections. The second of these reviews the literature concerning the cross-border phenomenon, from both a theoretical and applied perspective. Fuel taxation in Spain is briefly described in the third section. The fourth section describes the empirical exercise, in which the monthly purchases of automotive diesel in Aragon between January 2001 and March 2007 are estimated from the fuel price in Aragon, the relation between prices in each of the bordering Communities (plus the Community of Madrid) and the Community of Aragon, weighted by density of traffic, the number of vehicles registered in that Community, and three dummy variables representative of the implementation of the

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[1] See, for example, Labandeira and López Nicolás (2002), Romero and Sanz (2003), Cansino, Cardenete and Román (2004), De Miguel, Cardenete and Pérez Mayo (2005), and Romero, Álvarez and Jorge (2007).

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regional tranche of the HRST in Madrid, Catalonia, and Valencia. The fifth section of the paper presents various final considerations.

In the long term, the paper finds empirical evidence to demonstrate a positive effect of the relative prices in Catalonia and Madrid and vehicle registrations, and also a negative effect of prices in Aragon, upon the acquisition of diesel in this region. In the short term, the paper suggests that changes in prices in the neighboring Communities have had a rapid impact upon the purchase figures for Aragon. In the case of Catalonia, that effect may have been strengthened following the introduction of the regional tranche of the HRST in August 2004.

2. Revision of the literature

The current section reviews the literature which has analyzed the impact upon cross-border shopping produced by the different tax structures of neighboring regions or countries. On the theoretical plane, the work of Kanbur and Keen (1993) is the reference point regarding the increasing pressure placed upon national tax structures by the various processes of economic integration.

The partial equilibrium model proposed by Kanbur and Keen (1993) considers an open economy, with a single good, constituted by two neighboring countries (national and foreign) with different population sizes. The objective of the governments is to maximize revenue. Consumers will purchase the good if its cost to them is lower or equal to their reservation price: this is v for national residents and V for foreigners. The price for the producers of the commodity is constant and the same in both countries, and thus the price to consumers may be identified with the tax paid in each territory: t in the country of residence, T abroad. Each store must charge the tax rate of the country in which it is located. In this model, "national" consumers must choose between purchasing that commodity in their own country or crossing the border and acquiring it in the neighboring country, incurring a cost of $\delta>0$ per distance unit (s). There exist two necessary and sufficient conditions for cross-border shopping to occur: that the surplus the consumer enjoys by buying abroad exceeds that of doing so in the national market (in other words, that $v-T-\delta{\cdot}s>-t$) and that this surplus be non-negative ($v-T-\delta\cdot s>0$).

In a closed economy, cooperative and non-cooperative solutions coincide, cross-border shopping does not exist and each government establishes its taxation at the level which coincides with the reservation price of its residents. When moving from a closed economy to an open economy, in a non-cooperative model, the smaller country will reduce its tax rates, which will produce a reduction in the revenue collection of the larger country (as a result of cross-border shopping), an increase in that of the smaller country, if the difference of size between the two is sufficiently great, and a reduction in joint revenue. In Nash equilibrium, the tax rate of the smaller country is lower and the per capita (but not absolute) revenue collection greater than in the larger country.

Kanbur and Keen (1993) identify two strategies to achieve increases in welfare: an increase in transport costs and the imposition of a minimum common tax rate, in which the best strategic response of the larger country is to ensure a sufficient level of cross-border trade, from which the smaller country will also benefit.

Following the study by Kanbur and Keen (1993), the literature has branched out in many directions. While some research has maintained the emphasis upon the difference in country size (Trandel, 1994; Wang, 1999), others have argued that inter-country asymmetry results principally from their geographical extension (Ohsawa, 1999; Nielsen, 2001, 2002). Other authors have analyzed the effects upon cross-border shopping of market structure (Christiansen, 1994), the different preferences regarding public goods (Haufler, 1996), transaction costs (Scharf, 1999; Nielsen, 2001) or the degree of political and fiscal decentralization (Lucas, 2003), and the implications of cross-border shopping for the tax structure (Christiansen, 2003).

Empirical analyses have been performed, since at least the 1950s, of the effect which differing sales tax rates among neighboring countries have upon consumer purchasing decisions. In this regard, recurrent references are made to the studies by Maliet (1955), McAllister (1961), Hamovitch (1966), Levin (1966) or Mikesell (1970, 1971), in each case for the USA, which confirm the existence of tax-induced cross-border shopping.

From among the initial research, special mention should be made of that by Fisher (1980), which has been a reference point for subsequent studies. This author estimates the effect of sales tax rates differences between the District of Columbia and the adjacent suburbs in the states of Maryland and Virginia. To this end, he specifies a model based upon the standard microeconomic consumer theory, in which the consumption of the taxed commodity i in the District, C_{ic} is a multiplicative function of income and price, expressed as follows:

$$C_{ic} = A \cdot I^{\alpha_1} \cdot \left[\frac{P_{ic}(1+t_{ic})}{P_{jc}}\right]^{\alpha_2} \left[\frac{P_{ic}(1+t_{ic})}{P_{is}(1+t_{is})}\right]^{\alpha_3} \tag{2.1}$$

where I is income, P_{ic} is the domestic price of the commodity i, t_{ic} is the tax rate borne by that commodity, P_{jc} is the domestic price of the commodity j, P_{is} is the foreign price of the commodity i and t_{is} is the tax rate applied to that commodity.

The revenue obtained from the commodity i in the District of Columbia is:

$$R_{ic} = t_{ic} \cdot C_{ic} \tag{2.2}$$

Fisher estimates, in a logarithmic form, Eq. (2.2) for commodities subject to the general tax rate, for food consumed at home and for apparel, in the period 1962–1976.

The results of the estimation show that the coefficients of the variables which display the fiscal variations between territories for products taxed at the general rate and for apparel are negative but not significant. By contrast, the same coefficient is negative and significant for food: every rise of one percentage point in the tax rate differential variable (the tax rate for food in the District of Columbia being maintained as constant), revenue from food in the sales tax of the District decreases by approximately 7%.

The existence of the cross-border effect — and its impact upon revenue — has been tested for various goods, geographical areas and time periods. The majority of the results confirm that tax differentials among bordering territories affect consumer decisions regarding where to purchase. Research into sales taxes in the USA includes the studies by Fox (1986), Mikesell and Zorn (1986), Walsh and Jones (1988) and Tosun and Skidmore (2007). Boisvert and Thirsk (1994) and Ferris (2000) have empirically demonstrated the influence which differential tax treatment exerts upon the decision of Canadian consumers to cross the US border in order to purchase. Numerous studies have estimated the cross-border

Table 1
Community directives regarding the harmonisation of excise duties on mineral oils

Directive	Objectives
92/12 EEC[a]	Establishes dispositions regarding the general system of products subject to excise duties
92/81 EEC[b]	Establishes common norms to authorise the creation of new exemptions or reduced tax rates in the member states
92/82 EEC[c]	Incorporates minimum tax rates
03/96 EEC[d]	Fixes the minimum tax levels applicable to fuels and electricity

Source: Romero and Sanz (2006).

[a] Council Directive 92/12 EEC, of 25 February 1992, on the general arrangements for products subject to excise duties and on the holding, movement and monitoring of such products.

[b] Council Directive 92/81 EEC, of 19 October 1992, on the harmonisation of the structures of excise duties on mineral oils.

[c] Council Directive 92/82 EEC, of 19 October 1992, on the approximation of the rates of excise duties on mineral oils.

[d] Council Directive 03/96 EEC, of 27 October 2003, reestructuring the Community framework for the taxation of energy products and electricity.

Table 2
Fuel prices and taxes (in euros)

	USA	Germany	UK	France	Italy	Spain
Petrol[a]						
Price/liter before taxes	0.41	0.46	0.43	0.42	0.48	0.48
Excise duty[b]	0.08	0.65	0.68	0.59	0.56	0.40
VAT (%)[c]	4.00	16.00	17.50	19.60	20.00	16.00
VAT [c]	0.02	0.18	0.19	0.20	0.21	0.14
Total taxes	0.10	0.83	0.87	0.79	0.77	0.54
Gas station price/liter	0.51	1.29	1.30	1.21	1.25	1.02
% taxes	19.51	64.72	66.98	65.13	61.92	52.73
Automotive diesel						
Price/liter before taxes	0.40	0.49	0.47	0.46	0.53	0.51
Excise duty[b]	0.09	0.47	0.68	0.42	0.41	0.29
VAT (%)[c]	4.00	16.00	17.50	19.60	20.00	16.00
VAT [c]	0.02	0.15	0.20	0.17	0.19	0.13
Total taxes	0.11	0.62	0.88	0.59	0.60	0.42
Gas station price/liter	0.51	1.11	1.35	1.05	1.13	0.93
% taxes	22.05	56.04	64.78	56.19	53.12	45.42

Source: Servicio de Estudios de la Caja de Ahorros y Pensiones de Barcelona (2005), and author's elaboration.
[a] Regular grade in the USA and Eurosuper 95 in the EU.
[b] In Spain, it includes the national tranche of the HRST.
[c] New York sales tax for the USA.

effect upon alcohol and tobacco trade: Smith (1976), Warner (1982), Thursby, Jensen and Thursby (1991), Coats (1995), Crawford and Tanner (1995), Saba et al. (1995), Beard, Gant and Saba (1997), Fleenor (1998, 1999), Asplund, Friberg and Wilander (2007), Chiou and Muehlegger (2008), Lovenheim (2008). Garrett and Marsh (2002), Tosun and Skidmore (2004) and Skidmore and Tosun (2008) have estimated the impact upon lottery revenues of cross-border lottery shopping between neighboring regions.

Concerning cross-border fueling, Rietveld, Bruinsma and Van Vuuren (2001) estimate a logit model for the decision on the location of fuelling by Dutch residents in 1997: in The Netherlands or abroad (Germany or Belgium). Their analysis reveals that with a price difference of about 5 Euro-cents per liter, approximately 30% of the Dutch car owners living at the border decide to fuel in Germany. Rietveld, Bruinsma and Van Vuuren (2001) also analyze the potential consequences of the introduction of a spatial differentiation of fuel taxes: low near the border and higher farther away.

Banfi, Filippini and Hunt (2005) estimate, using a panel data model, and for the period 1985–1997, the impact of price differentials on cross-border fuelling behavior for the three regions of Switzerland that border Italy, France and Germany. Their results show a significant cross-border effect, since the price elasticities estimated suggest that a reduction of 10% in the Swiss gasoline price would contribute to an increase in the border areas demand of approximately 17.5%. Furthermore, their analysis demonstrates that, in case a proposed Swiss CO_2-tax could manage to be passed, the present fuel tourism would reduce significantly.

Doyle and Samphantharak (2008) analyze the effects of a moratorium for the gasoline sales tax in Illinois and Indiana, as a result of a fuel price hike in the spring of 2000. Applying the technique of difference in differences to a dataset of daily prices at the gas-station level, they conclude that approximately 70% of the tax suspension is passed on to consumers in the form of lower prices, while between 80 and 100% of the tax reinstatements are passed on to consumers. Their estimations suggest, moreover, a lesser impact upon prices in the counties close to state borders.[2]

Manuszak and Moul (2008) examine consumers' trade-off between travel and gasoline (and cigarette) prices, in four neighboring tax regions in the surroundings of Chicago and northern Indiana. Using data from 2001, the authors find that the willingness of a consumer to travel one additional mile to buy gasoline corresponds to a saving of between 6.5 and 8.4 cents per gallon.

The dramatic development of e-commerce has meant that the analysis of the impact of taxation upon new purchasing habits is both interesting and necessary. As Ballard and Lee (2007) state, consumers can now purchase goods in any of several ways. First, they can buy goods in their own country, second, they can travel across a border and purchase products in a different country; and third, consumers can buy over the Internet. For the USA, Goolsbee (2000), Alm and Melnik (2005), and Goolsbee, Lovenheim and Slemrod (2007) find a positive and significant relationship between residence in a locality with high sales taxes and the probability of purchasing over the Internet. Ballard and Lee (2007) confirm these results and show, moreover, that consumers who reside in jurisdictions adjacent to others with a lower sales-tax rate (or base) are less likely, *ceteris paribus*, to shop online, which the authors interpret as a reflection of cross-border shopping.

3. Fuel taxation in Spain

Currently, fuel in Spain is subject to a general tax on consumption, VAT, at a rate of 16%, and two excise duties on mineral oils: the Special Hydrocarbons Tax (SHT) and the Hydrocarbons Retail Sales Tax (HRST).

The SHT taxes the production and importation of fuels. Its taxable base is the volume of products subject to the tax, expressed in thousands of liters, which are taxed at a specific rate: for example, for diesel fuels usable as automotive fuels, 278.00 euros per 1000 l; for unleaded petrol, 402.92 euros per 1000 l.

The SHT is a tax established and regulated entirely at the central level. 40% of its revenue is distributed among the Autonomous Communities, on the basis of the regional consumption of the products subject to the tax. Analogously, the Communities receive 35% of VAT revenue, distributed among them according to regional household consumption.[3]

At the European level, there exists a relatively limited harmonization of excise duties on mineral oils (Table 1), due to the non-taxation of a considerable number of energy products and to the lack of updating. Directive 92/82 EEC establishes the minimum levels of the energy excise duties applied by the member states.

The proportion of fuel prices accounted for by taxes varies greatly between countries (Table 2). Thus, in the USA, total taxes on fuels represent approximately 20% of the retail price, while in the UK this figure rises to nearly 65%. Taxes generally account for over 60% of the final price in most EU countries, although Spain is one of the European countries with the lowest taxation of automotive fuels, almost 25% below average EU levels.

The HRST was introduced in 2002 to increase the tax resources of the Autonomous Communities. This tax is levied on retail sales of automotive fuels (petrol, diesel, fuel oil and kerosene), certain additives applicable to such products, and liquid fuels generally used for heating (special-use diesel, diesel and kerosene for heating and fuel oil). The taxable base of the HRST is the volume of products subject to the tax, expressed in thousands of liters. The tax rate is the sum of the national and Community rates. The latter (the so-called "health cent") is established, within certain limits (Table 3), by each Autonomous Community, which also can exercise tax administration competencies. The remaining regulatory competencies belong to the central level.

The revenue from the HRST is ceded entirely (the national and regional tranches) to the Autonomous Community in whose territory

[2] Using monthly panels of gasoline price at state level, Chouinard and Perloff (2004) and Alm, Sennoga and Skidmore (2006) obtain similar results of tax shifting to those of Doyle and Samphantharak (2008). Chouinard and Perloff (2004) find, furthermore, that consumer incidence of state taxes is greater in those states which have a lower participation in total gasoline consumption in the USA. Alm, Sennoga and Skidmore (2006) find that gasoline markets in urban states exhibit full shifting, but those in rural states show somewhat less than full shifting; this is consistent with the greater degree of competition in the retail gasoline markets which exist in the former.

[3] The Communities of Navarre and the Basque Country, which enjoy a special ("foral") system of financing, receive 100% of both the SHT and the VAT.

Table 3
Tax rates of the HRST

Tax rate	Petrol, general-use diesel and kerosene (per 1000 l)	Special-use diesel, diesel and heating kerosene (per 1000 l)	Fuel oil (per Tm.)
National	24 euros	6 euros	1 euro
Regional in 2002	0 to 10 euros	0 to 2.5 euros	0 to 0.40 euros
Regional in 2003	0 to 17 euros	0 to 4.25 euros	0 to 0.70 euros
Regional in 2004	0 to 24 euros	0 to 6 euros	0 to 1 euro
Regional in 2006	0 to 48 euros	0 to 12 euros	0 to 2 euros

Source: Authors' elaboration.

the taxable products are sold, and must be assigned in its totality to the financing of expenditure on health and the environment.

Table 4 offers information regarding those Communities which have implanted the regional tranche to date.

The creation of the HRST revived the debate regarding the adequacy and effects of the taxation of these products (Labandeira and López Nicolás, 2002). Rising oil prices, which have increased 300% since 1999 and by over 30% in the last two years,[4] have had two immediate consequences for oil-importing countries: a reduction of income and an increase in inflation.

The first impact of oil price variations is upon fuels. Increases in the price of crude are rapidly transmitted to petrol station pump prices; these rises are affected by the excise duties on fuels. Since such duties are a fixed quantity per liter, the percentual increase in the price of the liter of fuel is lower than that experienced by oil and fuel before taxes. Borenstein, Cameron y Gilbert (1997) indicate the existence of an asymmetry in the absorption of the variations of crude prices with regard to final price, i.e. increases in world oil prices are transferred to the final price more rapidly than decreases in the price of crude.

In summary, the sales price formation process for fuels is the following:

$$P_V = (P_0 + T_{SHT} + T_{HRSTN} + T_{HRSTR})(1 + t_{VAT}) \tag{3.1}$$

where P_V is the final price paid; P_0 is the price of the fuel before taxes; T_{SHT} is the SHT quota; T_{HRSTN} is the national tranche of the HRST; T_{HRSTR} is the regional tranche of the HRST; and t_{VAT} is the rate of VAT.

Table 5 details the weight of taxes in the price formation of automotive diesel in each Autonomous Community. As the table shows, differences in prices before taxes between Autonomous Communities (as measured by standard deviation) are very small, and can be explained by logistic and trade fixed costs, depreciation, and wholesalers and retailers profit margins. Differences in taxes applied in each Community are very significant, and are due to the regional tranche of the HRST, since the remaining taxes are equal throughout Spanish territory. As a consequence, differences between regions in diesel sales prices are also considerable, as Table 5 reflects.[5]

Figs. 1 and 2 show, respectively, the changes in the sales and prices of diesel for three regions with special importance for our study: Aragon, Catalonia, and Madrid. As reflected in Table 4, Madrid introduced the regional tranche of the HRST in August 2002, and increased it in January 2003, and Catalonia implanted its regional tranche in August 2004. Fig. 2 clearly shows that the introduction of the regional HRST have lead to permanent diesel price differences between these Autonomous Communities. These differences offer an incentive for individuals to purchase fuel in the Communities with the lowest prices, especially if these are adjacent or close to those in which they reside. In the following section we shall attempt to verify whether drivers take advantage of this incentive in practice.

[4] However, measured in real terms, the prices of crude continue to be at levels equivalent to half of those registered in the crises of the 1970s and 1980s.

[5] As Table 2 shows, similar conclusions can be reached in an international comparison. See also Rietveld, Bruinsma and Van Vuuren (2001: 435–436).

4. An application to diesel purchases in Aragon

In this section we perform a specific analysis of the influence of price differences upon cross-border purchases of automotive fuels, estimating econometrically the determinants of monthly diesel purchases in Aragon between January 2001 and March 2007. Aragon is a region located at the centre of the most developed Spanish regions: Madrid, Catalonia, La Rioja, the Basque Country and Navarre (Fig. 3).

Following Kanbur and Keen (1993) and Manuszak and Moul (2008), we assume that consumer *i*'s utility from purchasing fuel at region *r* is expressed by:

$$u_{ir} = A_i - \beta_i (q_i^G p_r^G) - \delta_i d_{ir} \tag{4.1}$$

where A_i is consumer *i*'s base utility of a purchase, q_i^G is the size of consumer *i*'s fuel purchases, P_r^G is the price of fuel at location *r*, d_{ir} is the round-trip distance from consumer *i* to region *r*, and β_i and δ_i are consumer *i*'s disutility of price and distance respectively.

In contrast to Kanbur and Keen (1993), Manuszak and Moul (2008) and other authors, we excluded from the model consumer *i*'s disutility of distance to region *r*, since we assume that cross-border fueling will affect, fundamentally, those individuals who are going to make the trip in any case (for pleasure or, more likely, on business), and that they only need to decide in which region they are going to refuel.

Each consumer purchases fuel from the region that yields the highest utility. We can aggregate the decisions of all consumers to derive the fuel demanded at some region:

$$Q_r = Q_r\left(P_r^G, P_{\bar{r}}^G, \chi_r\right) \tag{4.2}$$

where $P_{\bar{r}}^G$ is the price of fuel in other regions, and χ_r reflects additional factors, such as income, that may affect the demand for fuel in region *r*. On the basis of this demand function we obtain the specifications which are usual in the literature, as given above in Eq. (2.1).

In principle, we assume that diesel acquisition in Aragon depends basically on its price and on relative prices in this region compared to its bordering regions. This specification permits us to identify the internal effect of the substitution of diesel consumption by other goods, when the price of the former rises in Aragon and, secondly, of the substitution of diesel purchases in bordering regions by purchases in Aragon, when relative prices between regions increase. We utilize automotive diesel, as we believe it to be the product which may be most sensitive to price differences between Autonomous Communities, since diesel is the most consumed fuel, especially when a long distance has to be covered.[6]

Consequently, we propose the following demand function for automotive diesel in Aragon:

$$Q_{AR} = f(P_{AR}, P{*}_{CLE}/P_{AR}, P{*}_{CAT}/P_{AR}, P{*}_{MAD}/P_{AR}, P{*}_{RIONAV}/P_{AR}, P{*}_{VAL}/P_{AR}, REG_{AR}) \tag{4.3}$$

where Q_{AR} are the monthly quantities of automotive diesel (in kilotons) purchased in Aragon, P_{AR} is the average official monthly price of that fuel in Aragon, $P{*}_{CLE}$, $P{*}_{CAT}$, $P{*}_{MAD}$, $P{*}_{RIONAV}$ and $P{*}_{VAL}$ are the respective average prices in Castile and León, Catalonia, Madrid, the area comprising the Autonomous Communities of La Rioja and Navarre, and finally Valencia, weighted as explained immediately below and, lastly, REG_{AR} is the monthly number of vehicle registrations in Aragon.

In order to reflect the greater or lesser importance of these relative prices, each has been weighted by the density of traffic, measured as the quotient between the volume of commodities transport starting from or passing through Aragon and with destination in the region

[6] Diesel vehicles account for more than 50% of total vehicles and the consumption of diesel represents, approximately, 70% of total fuel consumption.

Table 4
Autonomous Communities applying the regional tranche of the HRST

	National tranche	Madrid	Asturias	Galicia	Catalonia	Valencian Community	Castile–La Mancha
Entry into force	01/01/2002	(01/08/2002) 01/01/2003	01/01/2004	01/01/2004	01/08/2004	01/01/2006	01/01/2006
Petrols (euros per 1000 l)	24	(10) 17	24	24	24	24	24
General-use diesel (euros per 1000 l)	24	(10) 17	20	12	24	12	24
Special-use and heating diesel (euros per 1000 l)	6	(2.50) 4.25	6	0	6	0	2
Fuel oil (euros per Tm.)	1	(0.4) 0.7	1	1	1	1	1
General-use kerosene (euros per 1000 l)	24	(10) 17	24	24	24	24	24

Source: Authors' elaboration.

Table 5
Price per liter of automotive diesel (in euro cents) in August 2005, 2006, and 2007

	Prices before taxes				All taxes				Sales price		
	2005	2006	2007		2005	2006	2007		2005	2006	2007
Navarre	50.8	55.9	52.3	Navarre	42.2	43.0	43.4	Navarre	93.0	98.9	95.7
Aragon	51.1	56.1	52.7	Aragon	42.3	43.0	43.3	Aragon	93.4	99.1	96.0
La Rioja	50.9	55.9	52.6	La Rioja	42.2	43.1	43.5	La Rioja	93.1	99.0	96.1
Cantabria	50.9	55.9	52.9	Cantabria	42.2	43.1	43.5	Cantabria	93.1	99.0	96.4
Murcia	50.9	56.1	52.9	Murcia	42.2	43.1	43.5	Murcia	93.1	99.2	96.4
Castile and León	51.0	56.1	53.1	Castile and León	42.3	43.1	43.4	Castile and León	93.3	99.2	96.5
Andalusia	51.1	56.3	53.2	Andalusia	42.3	43.1	43.4	Andalusia	93.4	99.4	96.6
Basque Country	50.8	56.0	53.1	Basque Country	42.2	43.1	43.5	Basque Country	93.0	99.1	96.6
Extremadura	51.1	56.2	53.2	Extremadura	42.2	43.1	43.5	Extremadura	93.3	99.3	96.7
Balearic Islands	51.7	56.7	53.9	Balearic Islands	42.4	43.2	43.6	Balearic Islands	94.1	99.9	97.5
Galicia	**51.0**	**56.2**	**53.0**	Galicia	**43.6**	**44.4**	**44.9**	Galicia	**94.6**	**100.6**	**97.9**
Valencian Comm.	51.2	**56.3**	**53.1**	Valencian Comm.	42.3	**44.4**	**44.9**	Valencian Comm.	93.5	**100.7**	**98.0**
Asturias	**50.6**	**55.7**	**52.4**	Asturias	**44.6**	**45.3**	**45.7**	Asturias	**95.2**	**101.0**	**98.1**
Catalonia	**50.9**	**56.1**	**52.8**	Catalonia	**45.0**	**45.8**	**46.2**	Catalonia	**95.9**	**101.9**	**99.0**
Castile–La Mancha	51.1	**56.1**	**52.9**	Castile–La Mancha	42.3	**45.8**	**46.2**	Castile–La Mancha	93.4	**101.9**	**99.1**
Madrid	**51.2**	**56.5**	**53.5**	Madrid	**44.3**	**45.1**	**45.6**	Madrid	**95.5**	**101.6**	**99.1**
Average	51.0	56.1	53.0		42.8	43.9	44.3		93.8	100.0	97.2
Standard deviation	0.24	0.24	0.39		0.98	1.09	1.12		0.96	1.11	1.16

In bold, the Autonomous Communities which have introduced the regional tranche of the HRST.
Source: Authors' elaboration, using data from the Ministry of Industry, Tourism and Trade.

concerned and the total volume of goods transported through Aragon and with destination in any of the regions considered in this study:[7] $D_{\mathrm{R}} = \frac{CT_{\mathrm{AR}}}{\sum_{K} CT_{\mathrm{AK}}}$.

As can be observed in expression (4.3), in addition to the Communities bordering Aragon, the Autonomous Community of Madrid has been incorporated into the analysis, given its importance as the origin and destination of traffic passing through the Autonomous Community of Aragon. As the subject of the study is the consumption of automotive fuel, we believe that the analysis is not impaired by the extension of the concept of cross border purchases to those made in a region which is neighboring rather than strictly bordering.

However, we chose not to take into consideration the relative price in the Autonomous Community of Castile–La Mancha, which does indeed share a border with Aragon, due to the extremely high correlation which, in the econometric exercise described below, is displayed by the series of relative prices in Castile–La Mancha and that of Madrid (correlation coefficient = −0.98). The insignificant flow of overland goods movements between this Community and Aragon (barely 3% of the total volume explained in the text) is a further argument in favor of the chosen option. For the same reason, we have not included the French regions which share borders with Aragon in the specification.[8]

A combined average price[9] was constructed for the regions of La Rioja and Navarre, given the peculiarities of the routing of the principal roads between these two Communities and Aragon[10].

The variable REG, which reflects monthly vehicle registrations in Aragon, is introduced as a control variable. The exclusion, as an explanatory variable, of per capita income is due to the non-availability of a monthly series of this magnitude or a related one, although the REG variable itself may be interpreted as a proxy of income. The descriptive statistics of the variables considered are presented in Table 6.

The analysis performed shows that the variables are first-order integrated series.[11] We therefore employ the two-stage estimation procedure described by Engle and Granger (1987). Firstly, we use ordinary least squares to estimate the cointegrating relationship between the variables, as reflected in the following equation:

$$\begin{aligned}\ln Q_{\mathrm{AR}_t} = {} & \alpha_0 + \alpha_1 \mathrm{TIME} + \alpha_2 \ln P_{\mathrm{AR}_t} \\ & + \alpha_3 \ln\left(P^*_{\mathrm{CLE}}/P_{\mathrm{AR}}\right)_t + \alpha_4 \ln\left(P^*_{\mathrm{CAT}}/P_{\mathrm{AR}}\right)_t + \\ & + \alpha_5 \ln\left(P^*_{\mathrm{MAD}}/P_{\mathrm{AR}}\right)_t + \alpha_6 \ln\left(P^*_{\mathrm{RIONAV}}/P_{\mathrm{AR}}\right)_t + \alpha_7 \ln\left(P^*_{\mathrm{VAL}}/P_{\mathrm{AR}}\right)_t + \\ & + \alpha_8 \ln \mathrm{REG}_{\mathrm{AR}_t} + \varepsilon_t\end{aligned} \tag{4.4}$$

The variable TIME represents a time trend. The logarithmic specification permits an interpretation of the coefficients which accompany the

[7] Average data for the period 2000–2005 (source: Ministry of Public Works), traffic densities are as follows: Castile and León, 8%, Castile–La Mancha, 3%, Catalonia, 48%, La Rioja–Navarre, 11%, Madrid, 14% and Valencia, 16%.

[8] Data from the Ministry of Public Works show that in 2004 the average daily intensity of lorries crossing the border between Aragon and France represented less than 1% of total lorry traffic using Pyrenees border crossings. Average daily intensity of light vehicles constituted 2.5% of the total vehicles crossing the Pyrenees, while coaches accounted for 4%.

[9] This combined average price was calculated using the number of service stations existing in each Community as weights.

[10] In fact, the principal roads linking Aragon with La Rioja follow this route after passing through Navarre for a relatively long stretch.

[11] The establishment of the order of integration of the different series was performed by analysing the Augmented Dickey-Fuller (1979) ADF test, taking into additional account the possible presence of constants or deterministic trends and including the lags necessary to guarantee the absence of autocorrelation.

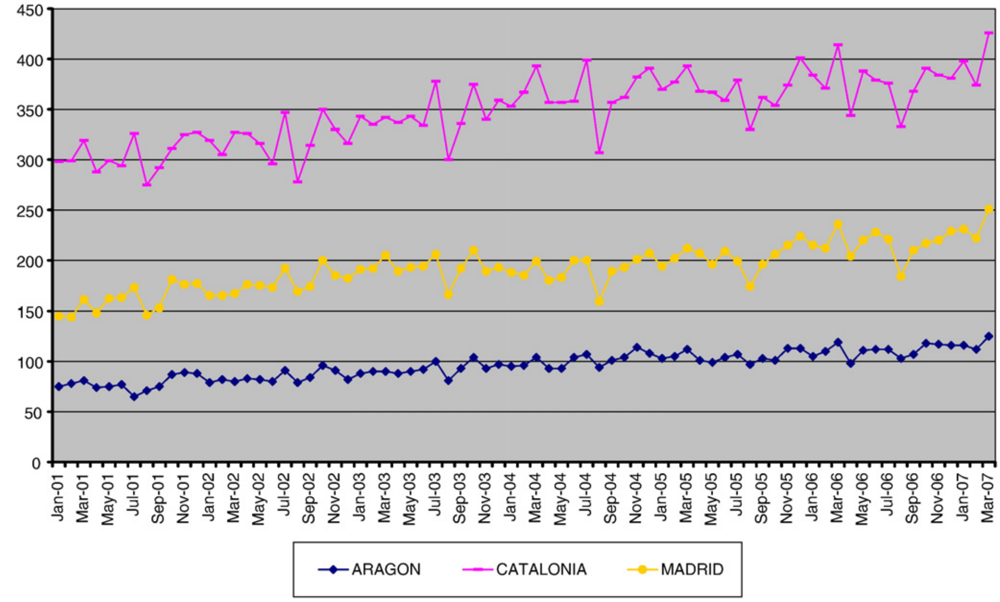

Fig. 1. Monthly quantities of automotive diesel purchased (in kilotons).

relative prices in terms of elasticities. The ADF test of the cointegration residuals indicates that they are stationary, given the calculated value of the *t*-ratio (=−7.04), which is lower than the critical value of 5% provided by MacKinnon (1991), thereby rejecting the null hypothesis and indicating that the variables considered are cointegrated. Consequently, we estimate the following error correction model (ECM):

$$\begin{aligned}\Delta_{12}\ln Q_{AR_t} = {} & \beta_0+\beta_1\mathrm{TIME}+\beta_2\Delta_{12}\ln P_{AR_t}+\beta_3\Delta_{12}\ln\left(P^*_{CLE}/P_{AR}\right)_t+\\ & +\beta_4\Delta_{12}\ln\left(P^*_{CAT}/P_{AR}\right)_t+\beta_5\Delta_{12}\ln\left(P^*_{MAD}/P_{AR}\right)_t+\\ & +\beta_6\Delta_{12}\ln\left(P^*_{RIONAV}/P_{AR}\right)_t+\beta_7\Delta_{12}\ln\left(P^*_{VAL}/P_{AR}\right)_t+\\ & +\beta_8\Delta_{12}\ln\mathrm{REG}_{AR_t}+\beta_9\mathrm{RESID}_{t-12}+\varepsilon_t\end{aligned} \tag{4.5}$$

In this expression, RESID_{t-12} represents the lagged cointegration residuals. Given the monthly frequency of the series, the seasonal difference of each of them — i.e. application of the differencing filter, Δ_{12} — converts them into stationary series.[12]

Column (1) of Table 7 displays the results of the estimation of the long-term relationships between the endogenous and exogenous variables (i.e. the value of the static regression coefficients). In turn, column (1.1) reflects the results of the estimation of these same relationships in the short term (i.e. the value of the coefficients of the differenced series in the modeling when using the ECM).

Leaving aside deterministic terms, these results show that in the long term the effect of the price of automotive diesel in Aragon upon the purchase of that good in the region is significant and shows the negative sign expected. Particularly, each 1% drop in the price increases sales by 2.45%. The significance and the positive sign of the coefficients corresponding to relative prices in Catalonia and Madrid with regard to Aragon indicate the positive effect upon demand for this fuel in Aragon of the evolution of prices in these neighboring regions. A one percentage rise in prices in Catalonia or Madrid implies, respectively, a 1.60 or 0.59 increase in diesel sales in Aragon. As expected, the pace of registrations also has a positive significant effect upon the purchase of diesel in the region.

The short-term effects, in general, coincide, except for the price of fuel in the region (which shows the negative sign expected, but at the limit of the 10% significance level) and for the relative price in Castile and León, which proves to have a positive and significant effect upon demand in Aragon. The coefficient corresponding to the cointegration residuals indicates the speed of adjustment of the model to the equilibrium values.

Furthermore, in the econometric exercise we tested alternative specifications for the ECM, based on the grounds we now explain. As stated in Section 3, some Autonomous Communities have exercised their regulatory capacity to implement, respecting the prescribed limits, the so-called regional tranche of the HRST. Concretely, within the geographical and time field of our estimations, the Autonomous Community of Madrid, at two successive points in time (1 August 2002 and 1 January 2003), Catalonia (1 August 2004) and, finally, Valencia (1 January 2006) have established this tax.

Thus, for the exercise we propose, it is interesting to determine whether this fiscal measure has affected diesel purchase figures in Aragon. Such an analysis requires the incorporation of dummy variables to represent the differential taxation in these regions. These dummy variables may be incorporated into the specification of the ECM utilizing either an additive or a multiplicative scheme[13] i.e. assuming that regional surcharges may affect either the independent term of the model or the coefficients corresponding to the relative prices of these three regions.[14]

Column (1.2) of Table 7 displays the results of an estimation which includes as a dummy variable the application of regional taxation to diesel in Catalonia, *CAT*. It is interesting to interpret the coefficient of this

[12] The application of the Granger test (1969) provides certain empirical evidence that the direction of causality is that displayed in the function described in Eq. (4.3), since this test indicates that the differentiated variables which represent average prices in Catalonia and Valencia and registrations contribute to the explanation of the quantities of diesel consumed in Aragon. However, this latter variable cannot explain the behavior of any of those presented in the right-hand side of the equation. Nevertheless, the application of the same test to the level series does not provide conclusive evidence regarding the direction of this causality.

[13] Tests were made including these dummy variables in the static regression, but the results were not satisfactory.

[14] The abovementioned dummy variables take a value of 1 for the 12 months following the establishment of the regional tranche (it must be remembered that we are working with seasonally differentiated variables) and 0 in the remaining observations. Thus, we are characterising possible permanent effects upon the demand for diesel caused by these public interventions. In the case of Madrid, two different dummy variables were constructed to reflect both the initial establishment of the regional tranche in this Autonomous Community (1 August 2002) and its subsequent raising (1 January 2003). In turn, different starting periods of the abovementioned effects have been considered, in order to test the possibility of deferment in agents' behavior, but this possibility was not confirmed.

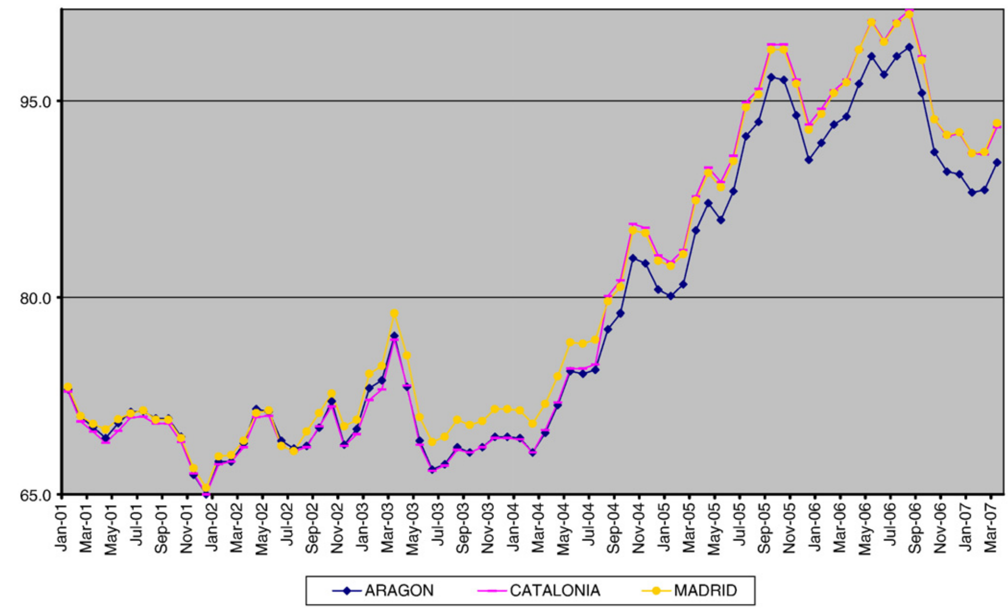

Fig. 2. Average official monthly prices (in Euro cents per liter of automotive diesel).

variable, introduced in a multiplicative fashion to modify, following the introduction of the surcharge, the slope of the regressor corresponding to the relative price in Catalonia. The result presented indicates the positive repercussion which the implementation of the Catalonian regional surcharge has had upon diesel acquisition in Aragon i.e. a considerable increase in the short-term effect of this relative price from August 2004 onward, although it is only significant at the 10% level: A one percentage increase in the year-to-year variation of prices in Catalonia raises the year-to-year variation in the purchase of automotive diesel in Aragon by 1.08% up to August 2004, and by 3.09 from this date. This alternative specification of the ECM shows, in addition, how (in this short-term context) the evolution of the relative price in the Valencian Community has also positively affected the figures for Aragon, while that of the price in the later region displays the negative expected effect.

The additional inclusion of dummy variables to represent the possible effects of the regional surcharges of Madrid and Valencia, and taking into account a set of alternative scenarios, produced either non-significant estimations of their coefficients or results which make no economic sense whatsoever.

Columns (2), (2.1) and (2.2) of Table 7 present estimations in which the variable representing relative prices in the Navarre–La Rioja area has been eliminated. This decision was taken upon observing the non-

Fig. 3. Map of Aragon and its neighbouring Communities.

Table 6
Average prices (in euro cents per liter of automotive diesel) by Autonomous Community, quantities consumed (in kilotons of automotive diesel) and registrations of diesel vehicles in Aragon: basic descriptive statistics

	P_{AR}	P_{CLE}	P_{CLM}	P_{CAT}	P_{MAD}	P_{RIONAV}	P_{VAL}	Q_{AR}	REG
Average	78.58	78.62	79.07	79.61	80.22	78.27	78.96	96.03	4.058.33
Median	73.20	73.40	73.10	73.00	74.80	73.23	73.50	96	3.884
Maximum value	99.10	99.20	101.90	101.90	101.60	98.93	100.70	125	6.308
Minimum value	65.00	65.20	65.40	65.00	65.50	64.16	65.20	65	2.473
Standard deviation	10.71	10.72	11.57	12.03	11.39	10.80	11.17	13.63	882.41
Skewness coefficient	0.58	0.58	0.63	0.53	0.54	0.58	0.60	−0.09	0.49
Kurtosis coefficient	1.77	1.77	1.83	1.65	1.71	1.78	1.79	2.16	2.67
Jarque–Bera statistic	8.86	8.95	9.30	9.17	8.83	8.76	9.05	2.32	3.31

Source: Authors' elaboration, using data from the Ministry of Industry, Tourism and Trade (prices and quantities) and from the Ministry of the Interior (registrations).

Table 7
Results of the estimations performed

Long term		(1)		(2)
α_0		8.33 (3.23)***		8.39 (3.33)***
TIME		0.006 (6.49)***		0.006 (9.25)***
$\ln P_{ARt}$		−0.26 (−1.83)* [−2.45]		−0.27(−2.25)** [−2.50]
$\ln(P^*_{CLE}/P_{AR})_t$		0.26 (1.48)		0.25 (1.50)
$\ln(P^*_{CAT}/P_{AR})_t$		1.60 (1.72)*		1.66 (1.98)*
$\ln(P^*_{MAD}/P_{AR})_t$		0.59 (1.73)*		0.57 (1.85)*
$\ln(P^*_{RIONAV}/P_{AR})_t$		−0.07 (−0.14)		
$\ln(P^*_{VAL}/P_{AR})_t$		0.89 (1.19)		0.82 (1.51)
$\ln REG_t$		0.19(4.67)***		0.19 (4.73)***
$\bar{R}^2$		0.88		0.88
Short term	**(1.1)**	**(1.2)**	**(2.1)**	**(2.2)**
β_0	0.07 (8.79)***	0.14 (3.42)***	0.07 (10.23)***	0.07 (10.39)***
TIME		−0.001 (−1.78)*		
$\Delta_{12}\ln P_{ARt}$	−0.13 (−1.64) [−1.84]	−0.16 (−2.02)** [−4.24/−6.25[+]]	−0.16 (−2.15)** [−2.01]	−0.17 (−2.29)** [−2.85]
$\Delta_{12}\ln(P^*_{CLE}/P_{AR})_t$	0.21 (2.20)**	0.37 (2.66)**	0.19 (2.08)**	0.17 (1.92)*
$\Delta_{12}\ln(P^*_{CAT}/P_{AR})_t$	1.11 (2.24)**	1.08 (2.09)** [1.08/3.09[+]]	1.25 (2.73)***	1.38 (2.99)***
$\Delta_{12}\ln(P^*_{MAD}/P_{AR})_t$	0.52 (2.35)**	0.55 (2.54)**	0.41(2.49)**	0.48 (2.80)***
$\Delta_{12}\ln(P^*_{RIONAV}/P_{AR})_t$	−0.23 (−0.74)	−0.73 (−1.59)		
$\Delta_{12}\ln(P^*_{VAL}/P_{AR})_t$	0.78 (1.59)	2.08 (2.41)**	0.50 (1.61)	0.65 (1.98)*
$\Delta_{12}\ln REGt$	0.21 (3.00)***	0.24 (4.05)***	0.19 (3.69)***	0.22 (3.97)***
CAT $^*\Delta_{12}\ln(P^*_{CAT}/P_{AR})_t$		2.01 (1.68)*		1.58 (1.40)
$RESID_{t-12}$	−0.56 (−4.67)***	−0.52 (−4.42)***	−0.55 (−4.68)***	−0.54 (−4.64)***
$\bar{R}^2$	0.51	0.51	0.49	0.50
White (1980)	8.44 (0.94)	14.55 (0.80)	8.59 (0.86)	10.89 (0.82)
Ljung–Box (1978)	r=1: 0.90 (0.34)	r=1: 2.20 (0.14)	r=1: 0.88 (0.35)	r=1: 1.39 (0.24)
	r=2: 2.42 (0.30)	r=2: 3.34 (0.19)	r=2: 2.51 (0.28)	r=2: 3.20 (0.24)
	r=3: 2.75 (0.43)	r=3: 3.48 (0.32)	r=3: 2.95 (0.40)	r=3: 3.41 (0.33)
	r=4: 3.94 (0.41)	r=4: 3.77 (0.44)	r=4: 3.73 (0.44)	r=4: 3.78 (0.44)
	r=12: 12.12 (0.44)	r=12: 11.11 (0.52)	r=12: 11.89 (0.45)	r=12: 11.87 (0.46)

In the case of the coefficients of the variables the Student t-values are given in parentheses *** significant at 1%, ** significant at 5%, * significant at 10%. Additionally, the values of the t-ratio given for the coefficient of the lagged cointegration residuals indicate, following Ericsson and MacKinnon (2002), that in the specifications presented in Columns (1.1), (2.1) and (2.2), a cointegration relationship can be detected among the variables, at a significance level of 10%: for the test of the null hypothesis of non-cointegration, the critical values obtained by these authors for this significance level, taking into account the sample size, the number of variables and the deterministic regressors of the different estimations, are −4.49 in the case of the first two ECMs presented in the table, and −4.35 for the two remaining ones. For the estimations of the different ECMs, we present both the values of the adjusted R^2 and the White (1980) and Ljung–Box (1978) statistics. These statistics indicate, respectively, in any of the estimations, that there exist no problems of either heteroskedasticity or serial autocorrelation for the specified order: r=1, 2, 3, 4, 12. P-values are given in parentheses.
Elasticities are in square brackets, when those differ from the estimated coefficients. [+] means figures from August 2004 onwards. Elasticities are given by differentiating Eqs. (4.4) and (4.5).

significant effects of the relative price in this area in earlier estimations and the strong correlation existing between this variable and that associated to the Valencian Community (specifically, 0.90 for the level series and 0.89 for the differenced series), which could lead to a problem of imperfect multicollinearity in the estimations.[15]

The robustness of the results previously attained is ratified by demonstrating that both the long-term and short-term elasticities of the different variables scarcely vary when using the new approach. Nevertheless, using these new estimations we cannot validate the significance of the effect associated to the introduction of the regional tranche in Catalonia.

Furthermore, and as an alternative way of measuring the possible short-term impact of regional tax measures, we have introduced another conventional method for evaluating exogenous events, i.e. the estimation of differences-in-differences. The treatment group comprises those regions which have decided to introduce the regional tranche of the HRST and the control group consists of the remaining regions. In order to increase the number of observations of the estimations we have extended the geographical area of analysis to the set of the 15 mainland Autonomous Communities (that is to say, the Balearic and Canary Islands are excluded). We have performed a series of estimations concentrated on detecting the

[15] For the remaining variables such high values were not observed, since it must be underlined that although the original series of average prices do maintain very high correlations, when performing the estimations we are applying successive transformations of the initial values, such as the relativisation of prices and seasonal difference of the data.

possible impact of the introduction of the regional tranche in Madrid and Catalonia, since the most significant interventions have taken place in these regions.

In short, estimations do not find that the introduction by a region of the regional tranche of the HRST has been an important factor in the explanation of fuel sales behavior in that region, although the various regressions performed do seem to confirm the important role played in the above-mentioned behavior by the prices observed in other regions and by registrations.[16]

5. Concluding remarks

The present paper has demonstrated that the raising of the average prices of automotive diesel in Catalonia and Madrid in relation to prices in Aragon has a positive and significant long-term effect upon sales of this fuel in Aragon. Bearing in mind that the volume of commodities transport passing through Aragon and having its final destination in these Communities accounts for (on average for the period 2000–2005), approximately 62% of goods transport through Aragon with destination in the regions analyzed in this study, the results simply confirm the particular sensitivity of the purchases of diesel in Aragon with respect to the behavior of prices in these two Communities. As expected, the long-term elasticities estimated also indicate the negative effect which the price of diesel in Aragon has upon purchases in this region and, by contrast, the positive effect which can be associated to the behavior of vehicle registrations.

Furthermore, the econometric analysis of the short-term reactions of demand in Aragon for automotive diesel shows that the evolution of relative prices in neighboring Communities has rapidly affected purchase figures in Aragon.

With regard to the impact upon the purchase of diesel of the introduction of the regional tax, in the case of Catalonia, some empirical evidence indicates that the abovementioned relative price effect may have been significantly strengthened, in the short term, following the introduction of the regional tranche of the HRST in this Autonomous Community in August 2004. However, it was not possible to demonstrate the same type of impact for other regions, although for the estimations which include the surcharge in Valencia this may be due to its relatively recent implementation (January 2006). Neither has the application of the difference in differences technique allowed us to identify any specific effect of the regional tranches of the HRST.

The results attained by the present study may be useful for the design of regional tax policy, insofar as they suggest that Autonomous Communities should exercise great caution when deciding whether to implement the regional tranche of the HRST and its tax rate. Regional authorities should bear in mind that their decision may negatively affect the tax revenue obtained from the taxes explained in the third section of the paper, if fuel purchase is diverted to other regions. Firstly, part of the revenue expected from the regional tranche of the HRST may be lost. Secondly, the reduction in regional fuel purchases will reduce the tax revenue obtained by the Autonomous Community from the Special Hydrocarbons Tax (SHT) and the national tranche of the HRST and will affect the region's VAT revenue. The importance of these effects must not be underestimated. Recently, in the case of the United States, Manuszak and Moul (2008) have estimated that the area of Chicago, the territory with the highest gasoline taxes, is losing approximately 40% of the tax-raising capacity that would exist if taxes were equal throughout the region.

In addition to the direct effects upon revenue collection from fuel taxes, Fisher (2007) notes that the reduction in fuel purchases may affect retail sales activity, employment and house prices in the region and, consequently, tax revenue from real estate, income and sales.

[16] Results of the differences-in-differences estimations are available from the authors upon request.

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