*Abstract

The dynamics pattern of price dispersion in retail fuel markets

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Abstract

This paper empirically investigates the dynamics of price dispersion in retail fuel markets as a response to the corresponding wholesale price changes. For this purpose we take advantage of a daily dataset of prices fixed by gas stations in two Spanish regions. It is consistently found that retail price dispersion is temporarily enlarged as a consequence of wholesale price increases, while it is reduced due to decreases. The presence of asymmetries in the short-run dynamics is also revealed. The impact of positive changes in the wholesale price is, in the first days of adjustment, clearly greater. The dynamics pattern could be explained, at least in part, by the faster response of prices in the stations associated with the two vertically integrated companies that have the largest market share (i.e. Repsol and Cepsa).

Keywords: Retail price dispersion; wholesale price variations; fuel oil markets.

JEL classification: D43; L71; Q40.

1. Introduction

It is broadly recognized that geographical markets for liquid fuels display significant dispersion of retail prices in spite of the similarity of the traded goods, and even controlling for heterogeneity characteristics across sellers (e.g. Barron et al., 2004; Lewis, 2008). Consequently, a relevant number of empirical papers have been interested in knowing what aspects underlie this type of market inefficiency in the fuel industry. Indeed, different authors have explored the importance of aspects such as the information and search costs of consumers (Marvel, 1976; Adams, 1997; Lewis and Marvel, 2011), plant size (Roberts and Supina, 1996), seller density (Clemenz and Gugler, 2006; Lewis, 2008), and even regional borders (Balaguer and Ripollés, 2017). However, nowadays there is still a considerable lack of knowledge about how the common changes in marginal production costs, derived from regular variations of wholesale fuel prices in corresponding raw material markets, affect the dispersion of retail fuel prices.[1]

The aim of this paper is to explore the pattern of time-varying price dispersion in fuel retailing exhibited after the common changes in costs. It is quite obvious that these changes could have an impact on the dispersion of retail prices, at least, in the short run unless sellers behave in a synchronized way. This can be straightforwardly illustrated from a simple Taylor-style staggered price mechanism (Taylor, 1980), where, after common costs variations, each kind of seller would adjust their prices at a given time. Then, dispersion of retail prices would firstly be increased as a consequence of positive (negative) costs changes if most sellers that adjust early have prices above (below) the price average in the market. Dispersion of retail prices could also temporally decrease to some extent. This last possibility could happen if, after a positive (negative) costs change, most of the sellers that move first have prices below (over) the price average in the market. Under this unsynchronized reaction, the dynamics of price dispersion will continue to the extent that the rest of the sellers have adjusted their prices in later stages. When all operating sellers have fully adjusted their prices, price deviation will have returned to its long-run steady state or it will have reached a new equilibrium level.

[1] This situation contrasts with the existence of a related abundant literature about the relationship between price dispersion and inflation in different retail markets (e.g. Lach and Tsiddon, 1992; Baharad and Eden, 2004; Caglayan et al., 2008).

Literature provides two reference papers on the long-run relationship between costs and price dispersion in retail fuel markets,[2] suggesting that a new equilibrium level could be reached according to different levels of costs. Only one of them, specifically the paper by Chandra and Tappata (2011), provides direct estimates about the long-run effect of common costs on fuel price dispersion. In particular, by using daily data from the period January 2006 to May 2007 related to gas stations in four U.S. states,[3] it is suggested that higher (lower) wholesale prices in the spot fuel markets involves less (more) retail price dispersion. So, a new equilibrium for price dispersion would be obtained after a variation in costs. This result is not surprising from the point of view of search behavior.[4] That is, when retail prices fall, fewer consumers decide to search because potential gains are lower and retail price dispersion increases.

The above finding is also in line with Lewis (2011), who uses weekly data for many of the gas stations operating in San Diego state between January 2000 and December 2001. However, in this last case, how fuel price dispersion is affected by costs is only indirectly analyzed by alternatively linking the profit margins of gas stations with prices (in both retail and wholesale markets). Specifically, it is shown that in those sub-periods where fuel prices are relatively lower, profit margins are higher (and vice versa). Retail price dispersion is later regressed by OLS against the corresponding (lagged) profit margins. Results suggested that higher profit margins significantly imply more dispersion.

To our knowledge, to date there are no empirical outcomes that, following common costs changes, formally provide the short-run dynamics of retail fuel price dispersion until reaching equilibrium. Moreover, as we have seen, with respect to long-term equilibrium, we have some early outcomes suggesting an inverse relationship between common costs and fuel price dispersion. They are very useful to illustrate the interesting

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[2] At this point it is also worth drawing attention to the paper by Lewis and Marvel (2011). Although the relationship between costs and price dispersion is not directly studied, the authors found an asymmetric relationship between retail prices changes and dispersion in gasoline markets. Specifically, results suggest that when retail prices are falling, the level of price dispersion (measured as price range for a city) is higher than when retail prices are rising or stable.

[3] The empirical analysis in this previous work further exploits the cross-sectional dimension of data to estimate the effect of the number of firms on price dispersion across local markets.

[4] But it is incompatible with other price-setting possibilities, such as that derived from the influential model of Carlson and McAfee (1983). In that model, common unit changes in costs are completely passed by all sellers, and price dispersion in retail markets would be unchanged.

theoretical predictions of specific search models in the two papers commented on above. However, the empirical relationship between costs and price dispersion that was obtained should be taken with caution in view of a lack of desirable unit root test analyses on the time series involved in regressions that led to this conclusion. That is to say, the empirical strategy used in previous papers, consisting in the simple application of the OLS procedure to estimate a regression model where time series are introduced in levels, would only be appropriate if they were stationary. Nevertheless, at least with regard to the wholesale prices in fuel markets directly used in Chandra and Tappata (2011), there is a lot of useful evidence that indicates that this might not be the case (e.g. Amano and Van Norden, 1998; Serletis and Herbert, 1999; Cologni and Manera, 2008; He et al., 2010; Zavaleta et al., 2015).

The rest of this paper is organized as follows. Section 2 describes the framework from which we extract the data. We also describe the specific data employed and their sources. In Section 3 we analyze the stationary properties of the variables with the aim of specifying a suitable econometric model. In Section 4 we provide the results for two different Spanish regions in order to explore their robustness, and we perform some sensitivity analyses. Section 5 we attempt to shed some further light on the evidence about the dynamic pattern of retail price dispersion. Finally, concluding remarks will be given in Section 6.

2. Framework description and data

The retail distribution sector of transportation fuels in Spain is the context from which we obtain our data. Since the abolition of the CAMPSA monopoly in 1992, this sector has undergone a long process of liberalization. Among the large number of measures implemented since then (e.g. removing the minimum distance between gas stations, facilities for establishing stations in shopping centers and industrial areas), of particular note is the abolition in 1998 of the ceiling price regulation through the implementation of the Hydrocarbon Sector Act (34/1998). From that date onwards, each gas station operating in Spanish territory was no longer subject to administrative restrictions to set their retail prices on fuel products or to transmit production cost changes. Despite this administrative freedom, the presence of vertically integrated oil companies (Repsol, Cepsa, and British Petroleum (BP)) and their supply contracts with associated gas stations have allowed those companies to decide prices for a wide network of stations facilitating collusive agreements (Garcia, 2010). That is, on the one hand, price decisions are directly taken by wholesalers in the gas stations in which they operate (i.e. company owned-company operated (COCO) and dealer owned-company operated (DOCO)). On the other hand, there are other stations that are not managed by wholesalers but also sell under their brand and have exclusive supply contracts with them (i.e. company owned-dealer operated (CODO) and dealer owned-dealer operated (DODO)). It is known that, by using these contracts, they have been indirectly forced to fix prices according to the strategies of the corresponding wholesaler. This practice was explicitly forbidden on 22 February 2013 (Royal Decree-Law 4/2013) in response to the fact that it constituted a widespread practice which was not consistent with the purpose of price liberalization.

Two years later the complete liberalization of pricing, it became compulsory for all fuel retailers to inform the Government about their current prices (Royal Decree-Law 6/2000). The aim was to provide the possibility for the public administration to disseminate information to consumers. This data can be found on the website of the Spanish Ministry of Energy, Tourism and the Digital Agenda (http://geoportalgasolineras.es/). We exploited the information provided by this website by collecting an important part of the data to be used for our empirical work.

Data obtained from the above-mentioned website refers to daily diesel prices, location, and brand of each gas station operating in the Spanish autonomous communities of Madrid and Catalonia for just over four years (1 May 2010 to 26 August 2014). It is interesting to note that both geographical areas include an important number of gas stations, which is quite stable during the period under consideration. Specifically, as can be seen in Table 1, the number of stations in Madrid ranges from about 537 to 595, and in Catalonia from about 1,181 to 1,280. Many of those stations operate under brands belonging to the companies Repsol and Cepsa. In broad terms, during the period considered, about 45% and 32% of gas stations installed in Madrid and Catalonia, respectively, were associated with Repsol.[5] Moreover, approximately 17% and 12% of

[5] The company Repsol operates under the Repsol brand and two other brands (i.e. Campsa and Petronor), which represent a less important share of the sellers of the company in the two regions. According to data from the Spanish *Ministry of Finance and Public Administration*, on 28 August 2014 Campsa represented 8.81% and 9.52% of the total number of Repsol stations in Madrid and Catalonia, respectively, while

the stations in Madrid and Catalonia, respectively, belonged to Cepsa. These firms not only enjoy a large share of the retail market and systemically set higher prices, but they are also vertically integrated.[6] Finally, it is worth mentioning that BP is another vertically integrated company operating in Spain. However, the number of gas stations under its brand is much lower. Concretely, in the period considered, only an average proportion of about 10% and 4% of gas stations were associated with BP in Madrid and Catalonia, respectively.

[Please insert Table 1 about here]

In order to use retail price data in our empirical analysis, they are expressed net of tax according to the information obtained from the Spanish *Ministry of Finance and Public Administration* (see Appendix A for more details). We then calculate a measure of retail price dispersion from these prices. Specifically, the (absolute value of) deviation of prices in gas station i at time t with respect to the cross-sectional mean of prices for all the stations operating in the region at time t (Drp_{it}). As a result, we have obtained 801 and 1,651 time series for the said variable in the case of Madrid and Catalonia, respectively. We focus on all the resulting uninterrupted daily series during the complete sample period. That is, a part of the time series cannot be used since they correspond to gas stations that close on Sundays (89 in Madrid and 117 in Catalonia), while another part cannot be used because they started operating after the first day of our sample period (181 in Madrid and 386 in Catalonia) or closed before the last sampled day (106 in Madrid and 251 in Catalonia). Finally, the remaining gas stations (94 in Madrid and 531 in Catalonia) were subject to closures of short periods within the sample, which could have been caused by diverse factors such as renovation and repair works or holidays. Therefore, we use daily observations on retail price dispersion for a total of 331 and 366 gas stations of Madrid and Catalonia, respectively.

Lastly, we also consider daily data on wholesale diesel prices in the international raw material market for the period mentioned above. This information is supplied by the

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Petronor represented 0.38% and 7.67% of the total number of Repsol stations in Madrid and Catalonia, respectively.

[6] The companies Repsol and Cepsa cover 92% of the refining capacity in the country (according to the Spanish Competition Authority, 2014), and control 19.15% of the CLH group, the hydrocarbon logistics company dedicated to the storage and wholesale distribution of fuels in Spain (CLH, 2014).

agency S&P Global Platts, and specifically refers to quotations for refined diesel fuel in Amsterdam-Rotterdam-Antwerp, which is the reference spot market for North-West Europe.

3. Time series analysis and specification

We analyze the stationary properties of the variables underlying the study in order to specify an appropriate econometric model. For the set of time series corresponding to retail price dispersion, we conduct the heterogeneous panel unit root test proposed by Breitung and Das (2005), while for wholesale price series, we apply the well-known augmented unit-root test of Dickey and Fuller (1979) and the Phillips and Perron (1988) test. Table 2 reports the corresponding results for a model with and without trend. As can be seen, regardless of whether a trend is considered or not, they suggest that dispersions of retail prices are stationary. This contrasts with the results for the wholesale price, which appears to be non-stationary in levels although stationary in first differences. We cannot therefore assume a long-term relationship between dispersion of retail prices and level of wholesale prices. In fact, as is widely recognized (e.g. Stewart, 2011), any significant association that might arise between I(0) and I(1) time series should be simply interpreted as spurious. However, we can consider that retail price dispersion may be affected by earlier changes in wholesale prices (i.e. first differences of wholesale prices).

[Please insert Table 2 about here]

In view of the stationary properties of the variables, and taking into account that each gas station will be able to freely pass wholesale price changes to retail prices, let us consider a simple heterogeneous Autoregressive Distributed Lag (ARDL) specification model such as the following:

$$Drp_{it} = \alpha_i + \sum_{j=1}^{p} \gamma_{ij} Drp_{it-j} + \sum_{j=0}^{q} \beta_{ij}^{+} \Delta wp_{t-j}^{+} + \sum_{j=0}^{q} \beta_{ij}^{-} \Delta wp_{t-j}^{-} + u_{it} \qquad (1)$$

where Drp_{it} is a measure of the dispersion obtained as the deviation of retail prices fixed by seller i with respect to the mean of prices in a geographical market at time t. The coefficient α_i represents the average deviation of prices fixed by a specific-station i

which might arise from divergence in individual characteristics. Through this coefficient, we will then attempt to control for the existence of persistent price dispersion within a market, a phenomenon which is well established in the empirical literature (e.g. Lach, 2002; Lewis, 2008; Pennerstorfer et al., 2015).[7] Moreover, γ_{ij} measures the effect of lagged price dispersion on current price dispersion. Variable Δwp_{t-j} represents the first differences of wholesale prices at time $t-j$ (i.e. $wp_{t-j} - wp_{t-j-1}$). Specifically, this last variable has been split according to whether changes are positive (Δwp_{t-j}^{+}) or negative (Δwp_{t-j}^{-}). β_{ij}^{+} and β_{ij}^{-} capture, respectively, the short-run impact of positive and negative changes of wholesale prices on dispersion, which is what we are especially interested in. Lastly, u_{it} represents a random error term.

4. Results

4.1. Benchmark

The ARDL model represented in Eq. (1) is estimated for each geographical region by adopting two approaches. First, for simplicity, the random error is assumed *iid* and the Mean Group (MG) estimator of Pesaran and Smith (1995) is applied. Second, we complementarily adopt the Mean Group Common Correlated Effects (MG-CCE) estimator of Pesaran (2006) which, assuming a cross-sectional dependency form in the random error term, allows to control for (unobserved) factors that commonly affect individuals sharing concrete attributes. This extension could be particularly useful in our case where prices of each station could be influenced by the strategy of their own brand within the local market. In line with Eberhardt and Teal (2013), henceforth, the MG-CCE is carried out in practical terms by including as regressors the cross-sectional average within both brand and city of dependent and explanatory variables.

Mean group-type estimators, which consists in performing the cross-sectional mean of the individual OLS coefficients, are especially well suited for panels with relatively large numbers of time observations (T). Further, as Pesaran and Smith (1995)

[7] Interestingly, we could find price dispersion even within very competitive markets. Although more competition lowers dispersion by reducing markups on the more price-inelastic consumers, it also can have the opposite effect. As we can see in Borenstein (1985) and Holmes (1989), more competition also reduces the prices offered to non-loyal customers leaving the prices for loyal customers practically unchanged.

demonstrated, they provide consistent estimates in dynamic models with a high degree of behavioral heterogeneity among individuals, which seems quite appropriate in our case. In fact, a Hausman-type statistical test has been applied to compare the results of the mean group-type with those obtained by pooled OLS. For both geographical regions, we rejected the null hypothesis of behavioral homogeneity across individuals (with p-values virtually equal to zero).

Table 3 shows the corresponding results obtained by both MG and MG-CCE, where the optimal lag length in the model has been selected by minimizing the Akaike Information Criterion (AIC). As can be seen, the number of optimal autoregressive coefficients is the same for both Madrid and Catalonia, and the number of coefficients associated with wholesale prices is similar.

[Please insert Table 3 about here]

[Please insert Figure 1 about here]

The effect of positive and negative changes in wholesale prices can be straightforwardly interpreted by calculating the cumulative dynamic multipliers from the estimated mean group coefficients. That is, $\sum_{j=0}^{h} \frac{\partial \widehat{Drp}_{t+j}}{\partial {wp_t}^{+}}$ and $\sum_{j=0}^{h} \frac{\partial \widehat{Drp}_{t+j}}{\partial {wp_t}^{-}}$, where $h = 0, 1, 2, \ldots$ and $\widehat{Drp}_{t+j}$ is the estimation of price dispersion at time $t+j$. Figure 1 shows the cumulative responses of price dispersion over time, as well as the corresponding 95% confidence intervals.[8] Although after controlling for unobserved common factors in MG-CCE the range of changes in dispersion is narrower than in MG, we can see that in general the dynamic pattern is quite similar for both varieties of estimates. Thus, regardless of the estimator employed, we can infer some interesting outcomes. Firstly, the cumulative responses have a similar shape for gas stations in both regions. That is, the results consistently show that positive variations temporally increase retail price dispersion, while negative changes temporally decrease it. Secondly, retail price dispersion varies quickly for about a week after wholesale price changes in both cases. Later, although with some irregularities, cumulative effects converge to zero, which implies that the dispersion of prices gradually returns to its stationary state. Thirdly,

[8] Appendix B also displays a representation of the price dispersion responses according to the fixed effects estimates of Eq. (1) with clustered standard errors by both city and brand. The results are consistent with those presented in the main text of this section.

how important the effects are seems to depend somewhat on the sign of the change. That is, there is some evidence that the impact of downward changes is more moderate. Indeed, in the results from both estimators, the null hypothesis of symmetric effects can be rejected at the 95% level of confidence during three first days and on the eleventh day in Madrid, and through the first three days in Catalonia.

4.2. Robustness checks

In this section we conduct several sensitivity analyses on the empirical results presented above. On the one hand, we wonder whether the dynamic response in price dispersion might be considerably affected when price dispersion is evaluated within a more narrow geographical scope. Specifically, in order to build the (absolute value of) deviation of prices, we use two alternative definitions of geographical markets: citywide and ZIP-code areas. In the first case, the Madrid region is divided into 80 areas, and the Catalonia region is divided into 174 areas corresponding to the respective municipalities where the gas stations included in our sample are located. In the second case, the use of ZIP-code areas implies an even narrower geographic market definition. Namely, the sample for the Madrid region is divided in 158 ZIP-code areas, while the sample for Catalonia includes 227 ZIP-code areas. Unlike considering the previous definition of dispersion for the whole region (i.e. Madrid and Catalonia), both alternatives are more in line with the definition of local markets adopted by other papers on price dispersion determinants in the retail fuel sector (e.g. Hastings, 2004; Barron, 2004; Lewis, 2008; Chandra and Tappata, 2011).

For the sake of a simplified presentation, we will focus our robustness checks on the MG-CCE procedure in accordance to the previous Subsection 4.1. Represented at the top and center of Figure 2 are the estimations on the dynamics of price dispersion, using both alternative definitions of local markets (while stationary properties for the dependent variable and the detailed results of estimations are in Appendix C and D, respectively). As can be seen, the pattern displayed is fairly consistent with that obtained from the benchmark results presented above. That is, positive variations temporally increase retail price dispersion, while negative changes temporally reduce it although more moderately. However, as expected, the changes in dispersion that have been evaluated within these smaller geographical areas are lower than those evaluated within each region as a whole.

[Please insert Figure 2 about here]

In addition, we also consider another measure of daily price dispersion as an alternative to the (absolute) deviation from the mean presented above. Specifically, we consider the standard deviation of retail prices for each region. This alternative measure sacrifices the valuable information provided by the variability of behavior across gas stations. However, it allows us to take into consideration all the gas stations included in the dataset, without eliminating those retailers that do not report prices for certain time periods. Representations of estimations by applying the OLS procedure are provided at the bottom of Figure 2 (and stationary properties for the standard deviation and the full estimation results can be seen in Appendix C and D, respectively). Once again, the pattern of dynamic behavior is quite similar to what we have found so far. Regarding the magnitudes of the estimated changes in price dispersion for each region, they are more congruent with those obtained from the MG estimator (Figure 1).

5. Further analysis of the results

5.1. Benchmark analysis

The pattern identified for the dynamics of price dispersion responses is only consistent with the predominance of retailers that move fast within the group of expensive gas stations. That is, a positive (negative) wholesale price change would imply more (lower) temporal price dispersion to the extent that stations with higher retail prices react quickly. In this subsection, we check the consistency by exploring the individual retail price responses to wholesale prices in the different categories of gas stations.

We begin by exploring the stationarity properties of our panel data. According to the unit root test (presented in Appendix E), the panels of retail prices of both regions are non-stationary in their levels but become stationary after taking first differences. In view of the fact that both individual retail prices and wholesale prices are I(1), we choose to specify a heterogeneous extension of the non-linear ARDL model developed by Pesaran et al., (2001) and Shin et al., (2014):

$$\Delta rp_{it} = \delta_i + \rho_i(rp_{it-1} - \theta_i^+ WP_{t-1}^+ - \theta_i^- WP_{t-1}^-) + \sum_{j=1}^{p} \lambda_{ij}\, \Delta rp_{it-j} + \sum_{j=0}^{q} \pi_{ij}^+\, \Delta wp_{t-j}^+$$

$$+ \sum_{j=0}^{q} \pi_{ij}^-\, \Delta wp_{t-j}^- + \epsilon_{it} \qquad (2)$$

where Δ is the first difference operator, rp_{it} represents individual retail prices during time t, δ_i is constant over time but can differ across each individual i, and, as in Eq. (1), Δwp_{t-j}^+ and Δwp_{t-j}^- denote, respectively, positive and negative wholesale price changes. Moreover, $\mathrm{WP}_{t-1}^+ = \sum_{\mathrm{j}=1}^{\mathrm{t}-1} \Delta wp_j^+$ and $\mathrm{WP}_{t-1}^- = \sum_{\mathrm{j}=1}^{\mathrm{t}-1} \Delta wp_j^-$ represent, respectively, positive and negative partial sum decompositions of wholesale price changes. In turn, ρ_i indicates the speed of adjustment of each individual i towards long-run equilibriums. It is interesting to note that this baseline approach admits asymmetries not only in the short-run price transmission process of wholesale prices ($\sum_{j=0}^{q} \pi_{ij}^+$ vs. $\sum_{j=0}^{q} \pi_{ij}^-$), but also in the long-run cost pass-through (θ_i^+ vs. θ_i^-).[9] Lastly, ϵ_{it} is a random error term.

We first proceed in estimating the retail price responses by distinguishing between two groups of retailers, depending on whether their daily prices are above or below the daily cross-sectional mean of the region where they operate for 90% or more of the sample period. Table 4 shows the MG and MG-CCE estimates of Eq. (2) for Madrid and Catalonia, and for the corresponding categories of gas stations. The optimal lag length has been selected by employing the AIC, while the coefficients and standard errors of the long-run cost pass-through (θ_i^+ and θ_i^-) have been calculated by using the conventional Delta method. As can be seen, regardless of the region and group of retailers considered, the absolute values of the computed F_{PPS} statistics in the null hypothesis of no cointegration notably exceed their corresponding upper critical value bounds at the standard levels of significance. This suggests that there is a significant long-run equilibrium between retail and wholesale prices. Estimates indicate that wholesale prices have positive long-run effects on the equilibrium retail prices.

[9] A great deal of research on fuel price responses only considers asymmetries in the short-run, disregarding the possibility of long-run nonlinearity. Some recent papers argue that possible pervasive long-run asymmetries should be tested rather than assumed (e.g. Shin et al., 2014; Greenwood-Nimmo and Yongcheol, 2013). In economic terms, long-run asymmetries would imply that the equilibrium of markup levels could depend on the direction of changes in wholesale prices. Interestingly, a relevant number of studies for fuel markets provide evidence in favor of this fact (e.g. Balke et al., 1998; Bagnai and Ospina, 2015; Pal and Mitra, 2016; Apergis and Vouzavalis, 2018).

Moreover, although the coefficients of the upward and downward pass-through seem quite similar in magnitude terms, the null hypothesis of symmetry ($\theta_i^+ = \theta_i^-$) can be rejected in all cases at the 5% level of significance.

Finally, since price dispersion changes take place mainly along the first two weeks after variation in wholesale prices, in Figure 3 we present the overall responses of retail prices in Madrid and Catalonia throughout these first days. The corresponding confidence intervals at 95% are also represented. As we can see, there are remarkable differences in the dynamic responses of expensive and cheap gas stations. The cumulative responses of retail prices for expensive gas stations are higher during the period before reaching the long-run equilibrium. This means that, in average terms, the group of expensive gas stations changes their retail prices quickly, as expected.[10]

[Please insert Table 4 about here]

[Please insert Figure 3 about here]

In order to further understand the dynamics of price dispersion, we can now attempt to find out which type of gas stations are the price leaders in the market. As was first proposed by Scherer (1970) and has been widely adopted in the literature since then (e.g. Ono, 1982; Eckard, 1982; Scherer and Ross, 1990; Revoredo-Giha and Renwick, 2012), price leadership models can be classified into three types: dominant, collusive, and barometric. On the one hand, the dominant type corresponds to those companies that, possessing the largest market share in a given industry, have de capacity of taking up the price leadership position, while the minor firms act as followers, meeting the residual demand. Similarly, it is also possible that there are some principal companies, with higher market shares, which adopt collusive price leadership. In both cases (dominant and collusive leadership types), the price level is rather more monopolistic than competitive. On the other hand, the barometric type is considered as a benign form of price leadership, where the leader's advantage is derived from its larger efficiency in obtaining appropriate information for pricing the products. In this last line, it has been highlighted that the firms' ability to react quickly to new information obtained also increases the probability of becoming price leader (Pastine and Pastine, 2004). Finally,

[10] In Appendix F we also show the retail price responses according to the MG-CCE estimations by alternatively distinguishing between expensive and cheap gas stations at city and ZIP-code level, in line with the local market definitions considered in Subsection 4.2. As can be observed, the main conclusions remain unchanged.

it is worth noting that it is also possible to conciliate the high market power of a dominant firm or some colluding firms with the presence of barometric type leadership. Indeed, as Eckard (1982) indicated, those firms with larger market shares will be relatively better informed about demand conditions and are therefore more likely to practice a barometric type leadership.

As seen in Section 2, Repsol and Cepsa, which are among the group of the most expensive gas stations, clearly have the largest share of sellers in the Spanish regional markets. In this sense, it would not be surprising if the Spanish fuel market was characterized by a leadership derived from Repsol's dominant position, or even a collusive situation between Repsol and Cepsa. Furthermore, both companies are vertically integrated as in the case of BP. It is also reasonable to think that these vertically integrated companies could exploit their first-hand information advantage on fuel prices in wholesale international markets, and this information could be quickly transmitted from their corresponding decision centers to their associated stations. However, unlike Repsol and Cepsa, BP is excluded from the pipeline network that supplies fuel in both regions, and the number of gas stations operating under its brand is much lower. In this sense, BP is expected to have less information on the conditions of demand.

Taking the above-mentioned into account, we then estimate the retail price responses by distinguishing between five groups of retailers. Firstly, we consider Repsol, Cepsa, and BP stations separately. Secondly, following the previous analysis, we divide the rest of the remaining stations operating in each region into expensive and cheaper retailers. Table 5 shows the MG and MG-CCE estimates of Eq. (2) for Madrid and Catalonia, respectively, according to this alternative division.[11] Moreover, the resulting responses of retail prices to wholesale price changes with the confidence intervals at 95% are shown in Figure 4. As we can see, for both Madrid and Catalonia and regardless of the estimator, stations associated with Repsol and Cepsa react to wholesale prices in a very similar way. In fact, at the 95% confidence level, we cannot reject the same cumulative response displayed on many days until reaching the practical completion of the costs pass-though. The speed at which stations respond clearly contrasts with that exhibited

[11] Again, the long-run equilibrium between retail and wholesale prices is significantly evidenced regardless of the region and group of retailers considered. Moreover, we can reject the null hypothesis $\theta_i^+ = \theta_i^-$ at the 5% level of significance in almost all cases.

by the rest of the gas stations. Indeed, under a decrease in wholesale prices, Repsol and Cepsa gas stations have completed about 50% of the pass-through between the fifth and sixth days in both regions. The same amount of pass-through would be completed about one day later in the case of BP stations, and about two to three days later in the remaining stations regardless of whether they are expensive or cheap.

[Please insert Table 5 about here]

[Please insert Figure 4 about here]

Thus, our results suggest that the ability to set prices above the average is not enough in itself to become a price leader. The vertically integrated company BP does not seem to act as a leader either. Therefore, its facility to access information on wholesale prices and the ease in which it quickly transfers this information to final prices in its stations also does not seem to be enough to reach this position. The results consistently suggest that Repsol and Cepsa are the companies which act as leaders in both markets. This could simply be a result of the high market share they hold (i.e. collusive leadership), or it could derive from better information on costs and on demand (i.e. barometric leadership). The information on costs could be facilitated by the vertical integration of these companies, while the information on demand could come from their extensive presence in the markets. Although we cannot specifically say what the causes are, for the purpose of our paper we can indicate that the leadership position held by both companies is favorable to the dynamics of price dispersion found.

5.2. Robustness check

We check the robustness of the further analysis by extending the Eq. (2) to allow for possible asymmetries in the speed at which retail prices return to the long-run equilibrium. Concretely, in line with other papers (e.g. Bachmeier and Griffin, 2003; Balaguer and Ripollés, 2012; Chua, et al., 2017), the speed of adjustment towards the long-run, ρ_i, is now decomposed into ${\rho_i}^+$ and ${\rho_i}^-$ according to whether wholesale price changes are positive or negative respectively.

A representation of the retail price responses according to the MG-CCE estimations is shown in Figure 5 (and detailed estimations in Appendix G). At the top of the figure we present the cumulative responses of expensive and cheap gas stations, while at the bottom of the figure we compare the responses for Repsol, Cepsa, BP, and the remaining brands which are subdivided into expensive and cheaper gas stations (according to the definitions in Subsection 5.1.). As we can see, the pattern of responses is fairly consistent with the benchmark results presented above. That is, on the one hand, expensive gas stations adjust retail prices significantly faster than cheaper stations. On the other hand, the stations belonging to Repsol and Cepsa respond quicker than the other stations, suggesting that both act as price leaders.

[Please insert Figure 5 about here]

6. Conclusions

This paper has examined the pattern of time-varying price dispersion in fuel retailing caused by the changes in common costs derived from the corresponding wholesale prices. To this end we have exploited a daily dataset from gas stations operating in two regions in Spain (Madrid and Catalonia). Empirical results are quite robust to the application of the analysis to both different regions. For both cases, it is found that retail price dispersion is a stationary variable. It contrasts with the statistical properties of the raw material price variable in level terms, where the usual tests clearly indicated that it has a unit root. Thus, given the order of integration for each of the time series in question, it was not reasonable to assume the existence of a long-run relationship between both variables. We have then explored to what extent changes in wholesale prices affect retail price dispersion in the short run. More particularly, we have attempted to identify the dynamic pattern of dispersion until returning to their steady equilibrium state.

To this end, we applied the standard Mean Group (MG) and the Mean Group Common Correlated effects (MG-CCE) estimators to an asymmetric ARDL model. It has been consistently found that the frequent changes in wholesale fuel prices cause significant variations in retail price dispersion. Namely, wholesale price increases entail more dispersion, while dispersion is temporally reduced when they decrease. We have also found that, in general, changes in dispersion derived from wholesale price increases are markedly greater. These results are robust to the consideration of citywide and ZIP-code areas as narrower definitions of geographical markets within each region. That is, although the levels of change of price dispersion within the most local areas is lower than in the whole of each region, which is quite reasonable, the dynamic pattern of changes in dispersion is similar. In addition, the dynamic pattern found is also robust to OLS application to the asymmetric ARDL model, where the standard deviation was taken as an alternative measure for price dispersion.

From the dynamic pattern revealed we can infer that, in average terms, the sellers in the group of expensive gas stations move early or adjust progressively faster. This phenomenon has been empirically corroborated by comparing the average speed of price responses between the groups of more expensive and cheaper gas stations. We also examined which firms, within the group of expensive gas stations, exhibited the highest adjustment speed. A descriptive analysis on the data showed that among the most expensive stations are systematically found those associated with Repsol and Cepsa, which are vertically integrated companies and represent the first and second largest market share, respectively. We consistently found that sellers operating under both brand names adjust their prices far more quickly and practically at the same time, which is compatible with a certain degree of collusion between the two companies. Therefore, it is suggested that the price leadership position of both companies is behind the dynamic pattern of price dispersion revealed.

In summary, this paper has provided empirical evidence on the short-run dynamics of retail price dispersion in fuel markets. In addition, we question the existence of a long-run relationship between the level of common costs (measured by wholesale prices in raw markets) and retail price dispersion obtained by previous empirical work on fuel markets. We hope that, as more high frequency microdata on gas stations become available, our empirical work encourages more research with the aim of gaining a better understanding of the determinants of the dynamics in price dispersion.

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Table(s)

Table 1. Descriptive statistics by time period and type of gas stations

		Average number of gas stations					Average price, expressed in €/liter (percentage deviation from the cross-sectional mean)			
		Total	Repsol	Cepsa	BP	Other sellers	Repsol	Cepsa	BP	Other sellers
Madrid	1st May 2010 – 31 December 2010	537	245	94	49	149	0.601 (0.167%)	0.602 (0.333%)	0.602 (0.333%)	0.597 (-0.500%)
	1st January 2011 – 31 December 2011	554	251	98	50	155	0.739 (0.271%)	0.738 (0.136%)	0.737 (0.001%)	0.733 (-0.543%)
	1st January 2012 – 31 December 2012	575	258	99	54	164	0.797 (0.378%)	0.798 (0.378%)	0.796 (0.252%)	0.789 (-0.630%)
	1st January 2013 – 31 December 2013	585	258	99	59	169	0.776 (0.518%)	0.776 (0.389%)	0.769 (-0.389%)	0.764 (-1.036%)
	1st January 2014 – 26 August 2014	595	261	99	59	176	0.752 (1.075%)	0.748 (0.538%)	0.737 (-0.941%)	0.731 (-1.747%)
Catalonia	1st May 2010 – 31 December 2010	1181	383	149	47	602	0.597 (1.015%)	0.598 (0.635%)	0.600 (1.523%)	0.585 (-1.015%)
	1st January 2011 – 31 December 2011	1217	395	151	51	620	0.734 (0.963%)	0.734 (0.663%)	0.735 (1.100%)	0.720 (-0.963%)
	1st January 2012 – 31 December 2012	1237	396	150	53	638	0.794 (1.146%)	0.793 (0.725%)	0.795 (1.274%)	0.777 (-1.019%)
	1st January 2013 – 31 December 2013	1259	396	144	53	666	0.756 (1.750%)	0.757 (1.390%)	0.751 (1.077%)	0.743 (-1.615%)
	1st January 2014 – 26 August 2014	1280	392	142	53	693	0.733 (2.661%)	0.731 (1.541%)	0.722 (1.120%)	0.714 (-1.961%)

Source: Authors' own elaboration from data of the Spanish *Ministry of Energy, Tourism and Digital Agenda*.

Table 2. Unit root tests

	Breitung-Das	Phillips-Perron		Augmented Dickey-Fuller	
Model with constant					
Drp_{it} in Madrid	-40.036***				
Drp_{it} in Catalonia	-37.203***				
wp_t		-2.122	(7)	-2.213	(1)
ΔDrp_{it} in Madrid	-130.000***				
ΔDrp_{it} in Catalonia	-95.010***				
Δwp_t		-35.320***	(7)	-26.529***	(1)
Model with constant and trend					
Drp_{it} in Madrid	-58.796***				
Drp_{it} in Catalonia	-46.261***				
wp_t		-1.931	(7)	-1.937	(3)
ΔDrp_{it} in Madrid	-160.000***				
ΔDrp_{it} in Catalonia	-110.000***				
Δwp_t		-35.323***	(7)	-20.869***	(1)

We denote ***, **, * to indicate the rejection of the null hypothesis of non-stationarity at 1%, 5% and 10% levels of significance, respectively. The optimal lag length (in parenthesis) is based on the Newey-West Criterion for the Phillips-Perron test, and the Schwarz Information Criterion for the Augmented Dickey-Fuller test. The critical values are obtained from MacKinnon (1991).

Table 3. Estimation results from Eq. (1)

	Madrid				Catalonia			
	MG		MG-CCE		MG		MG-CCE	
γ_1	0.542***	(0.005)	0.535***	(0.008)	0.630***	(0.005)	0.644***	(0.009)
γ_2	0.105***	(0.003)	0.098***	(0.004)	0.100***	(0.003)	0.061***	(0.007)
γ_3	0.014***	(0.002)	0.008**	(0.003)	-0.005**	(0.002)	0.004	(0.006)
γ_4	0.038***	(0.002)	0.034***	(0.002)	0.032***	(0.002)	0.008	(0.006)
γ_5	0.007***	(0.002)	0.001	(0.004)	0.011***	(0.002)	0.018***	(0.005)
γ_6	0.016***	(0.002)	0.002	(0.004)	0.010***	(0.002)	-0.003	(0.004)
γ_7	0.179***	(0.004)	0.155***	(0.005)	0.175***	(0.004)	0.134***	(0.006)
γ_8	-0.084***	(0.004)	-0.071***	(0.004)	-0.091***	(0.003)	-0.076***	(0.004)
γ_9	-0.014***	(0.002)	-0.011***	(0.002)	-0.02***	(0.002)	-0.007*	(0.004)
γ_{10}	-0.011***	(0.002)	-0.008***	(0.002)	-0.018***	(0.002)	-0.011***	(0.003)
γ_{11}	0.010***	(0.002)	0.010***	(0.002)	0.017***	(0.002)	0.012***	(0.003)
γ_{12}	0.002	(0.002)	0.003	(0.003)	-0.007***	(0.002)	-0.011***	(0.003)
γ_{13}	0.007***	(0.002)	0.010***	(0.002)	0.001	(0.002)	0.005*	(0.003)
γ_{14}	0.121***	(0.004)	0.106***	(0.004)	0.124***	(0.003)	0.085***	(0.004)
γ_{15}	-0.049***	(0.003)	-0.042***	(0.003)	-0.058***	(0.002)	-0.039***	(0.003)
β_0^+	0.016***	(0.002)	0.009***	(0.002)	0.024***	(0.002)	0.013***	(0.002)
β_1^+	-0.005**	(0.003)	-0.001	(0.002)	0.009***	(0.003)	0.003	(0.003)
β_2^+	0.092***	(0.005)	0.051***	(0.005)	0.092***	(0.007)	0.041***	(0.005)
β_3^+	-0.016***	(0.003)	-0.007**	(0.003)	0.022***	(0.003)	0.016***	(0.003)
β_4^+	0.025***	(0.003)	0.015***	(0.003)	0.045***	(0.003)	0.019***	(0.003)
β_5^+	0.033***	(0.003)	0.017***	(0.002)	0.031***	(0.002)	0.015***	(0.003)
β_6^+	0.014***	(0.002)	0.008***	(0.003)	0.027***	(0.003)	0.019***	(0.003)
β_7^+	-0.005***	(0.002)	0.001	(0.002)	0.016***	(0.003)	0.012***	(0.002)
β_8^-	0.006**	(0.003)	0.008***	(0.003)	0.016***	(0.003)	0.007**	(0.003)
β_9^+	-0.028***	(0.003)	-0.018***	(0.003)	-0.002	(0.004)	0.001	(0.003)
β_{10}^+	-0.011***	(0.003)	-0.007***	(0.003)	-0.015***	(0.003)	-0.004*	(0.003)
β_{11}^+	0.003	(0.002)	-0.001	(0.003)	-0.008***	(0.002)	-0.001	(0.002)
β_{12}^+	-0.004***	(0.002)	-0.002	(0.002)	-0.011***	(0.002)	-0.005***	(0.002)
β_{13}^+	0.015***	(0.002)	0.007***	(0.002)	-0.002	(0.002)	0.002	(0.002)
β_{14}^+	0.004*	(0.002)	0.002	(0.002)				
β_0^-	-0.027***	(0.003)	-0.015***	(0.002)	-0.018***	(0.003)	-0.008***	(0.003)
β_1^-	0.003	(0.002)	0.002	(0.002)	0.001***	(0.003)	-0.002	(0.002)
β_2^-	-0.004***	(0.004)	0.004	(0.004)	0.001***	(0.004)	-0.005	(0.003)
β_3^-	0.017***	(0.004)	0.010***	(0.003)	0.036***	(0.005)	0.013***	(0.004)
β_4^-	0.014***	(0.003)	0.008***	(0.003)	0.038***	(0.004)	0.018***	(0.003)
β_5^-	0.026***	(0.002)	0.012***	(0.002)	0.057***	(0.004)	0.029***	(0.003)
β_6^-	0.005***	(0.002)	0.002	(0.002)	0.032***	(0.003)	0.016***	(0.002)
β_7^-	0.017***	(0.002)	0.005**	(0.002)	0.03***	(0.002)	0.018***	(0.002)
β_8^-	0.008***	(0.003)	-0.002	(0.002)	0.015***	(0.003)	0.013***	(0.003)
β_9^-	0.014***	(0.002)	0.007***	(0.002)	0.017***	(0.002)	0.011***	(0.002)
β_{10}^-	0.019***	(0.003)	0.011***	(0.002)	0.019***	(0.003)	0.008***	(0.003)
β_{11}^-	-0.006***	(0.002)	-0.004**	(0.002)	0.007***	(0.002)	0.006***	(0.002)
β_{12}^-	0.003	(0.002)	0.001	(0.002)	0.007***	(0.002)	0.009***	(0.002)
β_{13}^-	-0.012***	(0.002)	-0.006***	(0.002)	-0.014***	(0.002)	-0.003*	(0.002)
β_{14}^-	-0.005***	(0.002)	-0.002	(0.002)				
α	0.000***	(0.000)	0.000***	(0.000)	0.001***	(0.000)	0.001***	(0.000)
Obs.	522,649		522,649		577,914		577,914	
(N x T)	(331 x 1,579)		(331 x 1,579)		(366 x 1,579)		(366 x 1,579)	

Standard errors are in parenthesis. The optimal lag length has been selected by minimizing the AIC. We denote ***, **, * to indicate statistical significance at the 1%, 5% and 10% levels, respectively. Regressions include step dummy variables to control for changes in the Spanish VAT rate on fuels (1st June 2010 and 1st September 2012), and the hydrocarbon special tax in Catalonia (1st April 2012). N and T refer, respectively, to the cross-sectional and temporal observations of the panel data.

Table 4. Estimation results from Eq. (2) for expensive and cheap gas stations

	Madrid								Catalonia							
	MG				MG-CCE				MG				MG-CCE			
	Expensive		Cheap		Expensive		Cheap		Expensive		Cheap		Expensive		Cheap	
λ_1	-0.292***	(0.005)	-0.243***	(0.014)	-0.280***	(0.008)	-0.241***	(0.013)	-0.253***	(0.005)	-0.096***	(0.017)	-0.248***	(0.006)	-0.096***	(0.017)
λ_2	-0.189***	(0.005)	-0.121***	(0.008)	-0.179***	(0.007)	-0.119***	(0.008)	-0.146***	(0.004)	-0.026**	(0.012)	-0.143***	(0.005)	-0.025**	(0.012)
λ_3	-0.194***	(0.004)	-0.149***	(0.008)	-0.185***	(0.005)	-0.147***	(0.008)	-0.161***	(0.004)	-0.058***	(0.009)	-0.159***	(0.005)	-0.058***	(0.009)
λ_4	-0.182***	(0.005)	-0.135***	(0.006)	-0.174***	(0.006)	-0.134***	(0.007)	-0.145***	(0.004)	-0.055***	(0.011)	-0.143***	(0.004)	-0.055***	(0.011)
λ_5	-0.177***	(0.005)	-0.110***	(0.009)	-0.170***	(0.007)	-0.108***	(0.009)	-0.143***	(0.004)	-0.044***	(0.008)	-0.141***	(0.004)	-0.043***	(0.008)
λ_6	-0.157***	(0.004)	-0.076***	(0.008)	-0.151***	(0.005)	-0.074***	(0.008)	-0.118***	(0.003)	-0.027***	(0.007)	-0.117***	(0.003)	-0.026***	(0.007)
λ_7	0.122***	(0.008)	0.108***	(0.009)	0.123***	(0.007)	0.110***	(0.010)	0.110***	(0.005)	0.037***	(0.012)	0.109***	(0.005)	0.036***	(0.012)
λ_8	-0.052***	(0.004)	-0.022***	(0.007)	-0.049***	(0.005)	-0.022***	(0.007)	-0.022***	(0.003)	-0.001	(0.006)	-0.022***	(0.003)	-0.001	(0.006)
λ_9	-0.086***	(0.004)	-0.037***	(0.007)	-0.083***	(0.004)	-0.037***	(0.006)	-0.065***	(0.003)	0.001	(0.004)	-0.064***	(0.003)	0.001	(0.004)
λ_{10}	-0.110***	(0.005)	-0.042***	(0.006)	-0.107***	(0.006)	-0.043***	(0.006)	-0.085***	(0.003)	-0.001	(0.007)	-0.083***	(0.003)	-0.001	(0.007)
λ_{11}	-0.067***	(0.004)	-0.034***	(0.004)	-0.065***	(0.004)	-0.034***	(0.004)	-0.056***	(0.003)	0.001	(0.007)	-0.056***	(0.003)	0.001	(0.007)
λ_{12}	-0.073***	(0.005)	-0.034***	(0.007)	-0.070***	(0.005)	-0.035***	(0.007)	-0.056***	(0.003)	0.009	(0.007)	-0.057***	(0.003)	0.009	(0.007)
λ_{13}	-0.046***	(0.004)	-0.014***	(0.005)	-0.044***	(0.004)	-0.014***	(0.005)	-0.032***	(0.003)	0.004	(0.004)	-0.032***	(0.003)	0.004	(0.004)
λ_{14}	0.141***	(0.006)	0.114***	(0.008)	0.139***	(0.006)	0.113***	(0.008)	0.119***	(0.004)	0.042***	(0.009)	0.117***	(0.004)	0.042***	(0.009)
λ_{15}	0.039***	(0.004)	0.022***	(0.006)	0.039***	(0.004)	0.020***	(0.005)	0.039***	(0.002)			0.040***	(0.002)		
π^+_0	0.039***	(0.005)	-0.019	(0.015)	0.039***	(0.005)	-0.020	(0.015)	0.046***	(0.004)	-0.005	(0.005)	0.046***	(0.004)	-0.004	(0.005)
π^+_1	0.018*	(0.010)	-0.032**	(0.014)	0.019*	(0.010)	-0.024	(0.016)	-0.002	(0.005)	-0.009	(0.010)	-0.007	(0.006)	-0.008	(0.010)
π^+_2	0.299***	(0.020)	0.079***	(0.022)	0.299***	(0.018)	0.081***	(0.022)	0.216***	(0.013)	0.044**	(0.018)	0.212***	(0.013)	0.043**	(0.018)
π^+_3	0.116***	(0.010)	0.172***	(0.017)	0.112***	(0.008)	0.178***	(0.018)	0.108***	(0.006)	0.055***	(0.017)	0.105***	(0.006)	0.054***	(0.017)
π^+_4	0.225***	(0.010)	0.076***	(0.014)	0.219***	(0.009)	0.078***	(0.015)	0.164***	(0.008)	0.030***	(0.011)	0.159***	(0.009)	0.030***	(0.011)
π^+_5	0.217***	(0.010)	0.092***	(0.014)	0.213***	(0.01)	0.093***	(0.015)	0.163***	(0.007)	0.061***	(0.014)	0.161***	(0.007)	0.060***	(0.014)
π^+_6	0.261***	(0.007)	0.216***	(0.016)	0.256***	(0.007)	0.219***	(0.017)	0.241***	(0.006)	0.088***	(0.018)	0.239***	(0.006)	0.088***	(0.018)
π^+_7	0.191***	(0.006)	0.173***	(0.012)	0.184***	(0.006)	0.174***	(0.012)	0.154***	(0.005)	0.086***	(0.019)	0.15***	(0.006)	0.086***	(0.019)
π^+_8	0.260***	(0.010)	0.117***	(0.011)	0.253***	(0.012)	0.117***	(0.010)	0.190***	(0.006)	0.049**	(0.021)	0.187***	(0.007)	0.049**	(0.021)
π^+_9	0.122***	(0.017)	0.187***	(0.009)	0.114***	(0.016)	0.187***	(0.008)	0.131***	(0.010)	0.078***	(0.018)	0.13***	(0.01)	0.077***	(0.018)
π^+_{10}	0.065***	(0.010)	0.071***	(0.014)	0.057***	(0.009)	0.070***	(0.014)	0.026***	(0.006)	0.036***	(0.010)	0.023***	(0.006)	0.035***	(0.010)
π^+_{11}	0.104***	(0.005)	0.041***	(0.009)	0.100***	(0.006)	0.040***	(0.009)	0.068***	(0.004)	0.013	(0.010)	0.064***	(0.005)	0.013	(0.010)
π^+_{12}	0.081***	(0.005)	0.050***	(0.007)	0.077***	(0.005)	0.052***	(0.008)	0.048***	(0.003)	0.040***	(0.012)	0.046***	(0.003)	0.039***	(0.012)
π^+_{13}	0.070***	(0.005)	0.058***	(0.007)	0.067***	(0.005)	0.060***	(0.007)	0.028***	(0.004)	0.022***	(0.008)	0.027***	(0.004)	0.021***	(0.008)
π^+_{14}	0.098***	(0.004)	0.064***	(0.009)	0.097***	(0.004)	0.063***	(0.009)	0.078***	(0.004)	0.056***	(0.009)	0.078***	(0.004)	0.056***	(0.009)
π^+_{15}	0.084***	(0.007)			0.082***	(0.008)			0.074***	(0.004)	0.015	(0.013)	0.070***	(0.005)	0.015	(0.013)

Table 4 (continued)

π_0^-	-0.058***	(0.010)	0.049***	(0.013)	-0.058***	(0.010)	0.047***	(0.013)	-0.037***	(0.006)	0.036**	(0.015)	-0.036***	(0.006)	0.036**	(0.015)
π_1^-	-0.093***	(0.008)	-0.100***	(0.009)	-0.092***	(0.009)	-0.092***	(0.009)	-0.111***	(0.006)	-0.089***	(0.010)	-0.117***	(0.008)	-0.089***	(0.010)
π_2^-	0.136***	(0.021)	-0.033**	(0.013)	0.139***	(0.018)	-0.026*	(0.015)	0.069***	(0.010)	-0.012	(0.015)	0.066***	(0.010)	-0.012	(0.015)
π_3^-	0.220***	(0.014)	0.064***	(0.019)	0.22***	(0.012)	0.072***	(0.019)	0.175***	(0.009)	0.021	(0.016)	0.172***	(0.009)	0.020	(0.016)
π_4^-	0.226***	(0.009)	0.142***	(0.014)	0.222***	(0.008)	0.151***	(0.015)	0.179***	(0.007)	0.034***	(0.012)	0.175***	(0.007)	0.033***	(0.012)
π_5^-	0.298***	(0.007)	0.216***	(0.017)	0.291***	(0.007)	0.22***	(0.018)	0.249***	(0.006)	0.092***	(0.019)	0.246***	(0.006)	0.092***	(0.019)
π_6^-	0.241***	(0.005)	0.176***	(0.010)	0.232***	(0.006)	0.175***	(0.011)	0.202***	(0.005)	0.071***	(0.013)	0.199***	(0.006)	0.071***	(0.013)
π_7^-	0.196***	(0.005)	0.172***	(0.008)	0.187***	(0.006)	0.173***	(0.008)	0.174***	(0.005)	0.106***	(0.010)	0.172***	(0.005)	0.106***	(0.010)
π_8^-	0.148***	(0.008)	0.189***	(0.013)	0.14***	(0.007)	0.189***	(0.013)	0.136***	(0.005)	0.129***	(0.014)	0.135***	(0.006)	0.129***	(0.014)
π_9^-	0.121***	(0.005)	0.074***	(0.007)	0.115***	(0.005)	0.076***	(0.008)	0.093***	(0.004)	0.070***	(0.010)	0.092***	(0.004)	0.070***	(0.010)
π_{10}^-	0.167***	(0.009)	0.072***	(0.011)	0.163***	(0.01)	0.07***	(0.012)	0.139***	(0.006)	0.046***	(0.008)	0.137***	(0.006)	0.046***	(0.008)
π_{11}^-	0.113***	(0.006)	0.128***	(0.011)	0.108***	(0.007)	0.126***	(0.011)	0.119***	(0.005)	0.083***	(0.012)	0.117***	(0.006)	0.082***	(0.012)
π_{12}^-	0.089***	(0.008)	0.106***	(0.008)	0.082***	(0.007)	0.103***	(0.009)	0.087***	(0.004)	0.071***	(0.011)	0.085***	(0.004)	0.071***	(0.011)
π_{13}^-	0.081***	(0.006)	0.026***	(0.008)	0.075***	(0.006)	0.025***	(0.008)	0.067***	(0.003)	0.041***	(0.008)	0.064***	(0.004)	0.040***	(0.008)
π_{14}^-	0.154***	(0.011)	0.063***	(0.008)	0.15***	(0.011)	0.062***	(0.008)	0.113***	(0.006)	0.039***	(0.008)	0.112***	(0.006)	0.039***	(0.008)
π_{15}^-	0.001	(0.012)			-0.005	(0.011)			0.005	(0.007)	0.036***	(0.012)	0.004	(0.007)	0.035***	(0.012)
ρ	-0.062***	(0.003)	-0.066***	(0.004)	-0.096***	(0.016)	-0.094***	(0.016)	-0.092***	(0.002)	-0.061***	(0.003)	-0.104***	(0.032)	-0.060***	(0.003)
θ^+	0.910***	(0.007)	0.951***	(0.011)	0.578***	(0.128)	0.583***	(0.129)	0.952***	(0.003)	1.002***	(0.013)	0.894***	(0.276)	1.002***	(0.014)
θ^-	0.884***	(0.008)	0.940***	(0.012)	0.562***	(0.124)	0.577***	(0.127)	0.927***	(0.004)	0.996***	(0.016)	0.869***	(0.268)	0.995***	(0.015)
δ	0.038***	(0.002)	0.040***	(0.003)	0.037***	(0.003)	0.035***	(0.005)	0.057***	(0.001)	0.034***	(0.001)	0.058***	(0.001)	0.034***	(0.002)
Obs.	60,002		47,370		60,002		47,370		214,744		33,159		214,744		33,159	
(N x T)	(38 x 1,579)		(30 x 1,579)		(38 x 1,579)		(30 x 1,579)		(136 x 1,579)		(21 x 1579)		(136 x 1,579)		(21 x 1579)	
F_{PPS}	646.02		376.78		571.25		101.27		2829.06		339.47		1020.82		339.34	
H_0: $\theta^+ = \theta^-$	616.88	[0.000]	30.71	[0.000]	15.01	[0.000]	5.90	[0.015]	905.37	[0.000]	4.94	[0.026]	10.04	[0.002]	4.91	[0.027]

Standard errors are in parenthesis and p-values are reported in brackets. The optimal lag length has been selected by minimizing the AIC. We denote ***, **, * to indicate statistical significance at the 1%, 5% and 10% levels, respectively. Regressions include step dummy variables to control for changes in the Spanish VAT rate on fuels (1st June 2010 and 1st September 2012), and the hydrocarbon special tax in Catalonia (1st April 2012). N and T refer to the cross-sectional and temporal observations of the panel data, respectively.

Table 5. Estimation results from Eq. (2) for Repsol, Cepsa, BP, and other expensive and cheap brands

	Madrid																			
	MG										MG-CCE									
	Repsol		Cepsa		BP		Other brands, expensive		Other brands, cheap		Repsol		Cepsa		BP		Other brands, expensive		Other brands, cheap	
λ_1	-0.279***	(0.004)	-0.304***	(0.006)	-0.292***	(0.012)	-0.275***	(0.010)	-0.224***	(0.013)	-0.270***	(0.005)	-0.301***	(0.006)	-0.283***	(0.012)	-0.246***	(0.020)	-0.224***	(0.013)
λ_2	-0.193***	(0.004)	-0.171***	(0.004)	-0.173***	(0.008)	-0.164***	(0.015)	-0.122***	(0.009)	-0.186***	(0.004)	-0.168***	(0.004)	-0.168***	(0.008)	-0.152***	(0.020)	-0.121***	(0.009)
λ_3	-0.187***	(0.003)	-0.195***	(0.004)	-0.156***	(0.007)	-0.191***	(0.012)	-0.156***	(0.010)	-0.181***	(0.004)	-0.192***	(0.005)	-0.150***	(0.007)	-0.180***	(0.010)	-0.154***	(0.010)
λ_4	-0.170***	(0.003)	-0.178***	(0.004)	-0.199***	(0.007)	-0.175***	(0.012)	-0.137***	(0.008)	-0.162***	(0.004)	-0.175***	(0.004)	-0.194***	(0.008)	-0.167***	(0.007)	-0.138***	(0.008)
λ_5	-0.175***	(0.003)	-0.168***	(0.004)	-0.133***	(0.006)	-0.136***	(0.014)	-0.110***	(0.010)	-0.169***	(0.004)	-0.166***	(0.004)	-0.129***	(0.005)	-0.127***	(0.016)	-0.111***	(0.010)
λ_6	-0.151***	(0.003)	-0.131***	(0.004)	-0.095***	(0.006)	-0.137***	(0.010)	-0.076***	(0.009)	-0.143***	(0.005)	-0.130***	(0.004)	-0.091***	(0.006)	-0.126***	(0.013)	-0.075***	(0.009)
λ_7	0.136***	(0.003)	0.059***	(0.004)	0.101***	(0.009)	0.132***	(0.012)	0.098***	(0.011)	0.139***	(0.004)	0.059***	(0.004)	0.101***	(0.008)	0.128***	(0.010)	0.100***	(0.011)
λ_8	-0.054***	(0.003)	-0.021***	(0.003)	-0.064***	(0.006)	-0.043***	(0.010)	-0.033***	(0.007)	-0.049***	(0.003)	-0.02***	(0.003)	-0.065***	(0.006)	-0.044***	(0.009)	-0.032***	(0.008)
λ_9	-0.076***	(0.002)	-0.089***	(0.003)	-0.047***	(0.004)	-0.080***	(0.013)	-0.041***	(0.006)	-0.073***	(0.002)	-0.088***	(0.003)	-0.047***	(0.004)	-0.084***	(0.014)	-0.041***	(0.006)
λ_{10}	-0.119***	(0.002)	-0.092***	(0.003)	-0.047***	(0.005)	-0.068***	(0.012)	-0.047***	(0.006)	-0.114***	(0.003)	-0.091***	(0.003)	-0.048***	(0.005)	-0.069***	(0.012)	-0.048***	(0.006)
λ_{11}	-0.067***	(0.002)	-0.067***	(0.003)	-0.065***	(0.004)	-0.026***	(0.006)	-0.037***	(0.005)	-0.065***	(0.002)	-0.067***	(0.003)	-0.065***	(0.004)	-0.028***	(0.005)	-0.037***	(0.005)
λ_{12}	-0.066***	(0.001)	-0.083***	(0.002)	-0.050***	(0.005)	-0.034	(0.022)	-0.033***	(0.007)	-0.066***	(0.002)	-0.082***	(0.002)	-0.049***	(0.005)	-0.033	(0.021)	-0.033***	(0.007)
λ_{13}	-0.052***	(0.002)	-0.008***	(0.002)	-0.002	(0.007)	-0.046***	(0.013)	-0.019***	(0.005)	-0.053***	(0.003)	-0.008***	(0.002)	-0.002	(0.007)	-0.044***	(0.012)	-0.019***	(0.005)
λ_{14}	0.156***	(0.002)	0.107***	(0.002)	0.090***	(0.006)	0.107***	(0.023)	0.115***	(0.010)	0.151***	(0.004)	0.106***	(0.002)	0.088***	(0.006)	0.102***	(0.021)	0.115***	(0.010)
λ_{15}	0.041***	(0.002)	0.023***	(0.002)	0.036***	(0.007)	0.018	(0.021)	0.014**	(0.006)	0.039***	(0.002)	0.023***	(0.002)	0.033***	(0.007)	0.017	(0.020)	0.013**	(0.005)
π_0^+	0.041***	(0.003)	0.030***	(0.004)	0.061***	(0.013)	0.012	(0.011)	-0.026	(0.016)	0.039***	(0.004)	0.030***	(0.004)	0.060***	(0.013)	0.009	(0.011)	-0.026	(0.016)
π_1^+	-0.012***	(0.003)	0.100***	(0.005)	-0.027***	(0.009)	-0.022	(0.022)	-0.046***	(0.013)	-0.020**	(0.008)	0.100***	(0.005)	-0.010	(0.012)	0.010	(0.019)	-0.046***	(0.014)
π_2^+	0.319**	(0.010)	0.273***	(0.006)	0.200***	(0.019)	0.080	(0.058)	0.062***	(0.021)	0.310***	(0.012)	0.273***	(0.006)	0.216***	(0.014)	0.107*	(0.059)	0.055***	(0.021)
π_3^+	0.122***	(0.006)	0.125***	(0.005)	0.140***	(0.010)	0.079	(0.063)	0.179***	(0.021)	0.106***	(0.008)	0.124***	(0.005)	0.147***	(0.011)	0.102*	(0.054)	0.182***	(0.022)
π_4^+	0.229***	(0.005)	0.220***	(0.005)	0.137***	(0.008)	0.128***	(0.041)	0.048***	(0.011)	0.222***	(0.006)	0.219***	(0.005)	0.143***	(0.009)	0.124***	(0.037)	0.047***	(0.011)
π_5^+	0.225***	(0.004)	0.240***	(0.005)	0.203***	(0.012)	0.112***	(0.039)	0.068***	(0.012)	0.216***	(0.007)	0.239***	(0.006)	0.208***	(0.011)	0.117***	(0.037)	0.065***	(0.012)
π_6^+	0.258***	(0.004)	0.243***	(0.005)	0.250***	(0.009)	0.250***	(0.021)	0.205***	(0.019)	0.251***	(0.005)	0.242***	(0.005)	0.25***	(0.01)	0.255***	(0.02)	0.209***	(0.020)
π_7^+	0.185***	(0.004)	0.161***	(0.005)	0.175***	(0.009)	0.188***	(0.032)	0.183***	(0.014)	0.177***	(0.004)	0.159***	(0.005)	0.173***	(0.009)	0.179***	(0.029)	0.185***	(0.014)
π_8^+	0.275***	(0.005)	0.197***	(0.004)	0.200***	(0.011)	0.207***	(0.031)	0.117***	(0.012)	0.267***	(0.006)	0.196***	(0.004)	0.198***	(0.011)	0.196***	(0.030)	0.118***	(0.012)
π_9^+	0.068***	(0.008)	0.211***	(0.004)	0.196***	(0.010)	0.239***	(0.019)	0.190***	(0.010)	0.058***	(0.007)	0.208***	(0.004)	0.192***	(0.009)	0.23***	(0.021)	0.191***	(0.010)
π_{10}^+	0.033***	(0.003)	0.037***	(0.005)	0.041***	(0.015)	0.183***	(0.027)	0.091***	(0.016)	0.027***	(0.004)	0.035***	(0.004)	0.035***	(0.013)	0.164***	(0.021)	0.092***	(0.015)
π_{11}^+	0.097***	(0.003)	0.097***	(0.003)	0.048***	(0.008)	0.078***	(0.027)	0.051***	(0.011)	0.091***	(0.006)	0.095***	(0.004)	0.047***	(0.008)	0.065***	(0.023)	0.051***	(0.010)
π_{12}^+	0.069***	(0.003)	0.057***	(0.004)	0.061***	(0.006)	0.100***	(0.021)	0.065***	(0.009)	0.062***	(0.005)	0.055***	(0.004)	0.060***	(0.005)	0.096***	(0.022)	0.068***	(0.009)
π_{13}^+	0.069***	(0.002)	0.018***	(0.004)	0.032***	(0.010)	0.058***	(0.016)	0.074***	(0.007)	0.060***	(0.007)	0.017***	(0.004)	0.031***	(0.009)	0.056***	(0.014)	0.077***	(0.007)
π_{14}^+	0.101***	(0.003)	0.093***	(0.004)	0.073***	(0.008)	0.087***	(0.015)	0.061***	(0.011)	0.094***	(0.006)	0.092***	(0.004)	0.074***	(0.007)	0.083***	(0.012)	0.060***	(0.011)
π_{15}^+	0.078***	(0.003)	0.125***	(0.004)	0.033***	(0.011)	0.033**	(0.015)	0.013***	(0.011)	0.071***	(0.005)	0.124***	(0.004)	0.032***	(0.011)	0.028	(0.018)	0.013	(0.012)

Table 5 (continued)

π_0^-	-0.082***	(0.004)	-0.032***	(0.003)	-0.088***	(0.019)	0.046**	(0.019)	0.066***	(0.011)	-0.077***	(0.007)	-0.032***	(0.003)	-0.090***	(0.019)	0.049***	(0.018)	0.065***	(0.011)
π_1^-	-0.127***	(0.003)	-0.026***	(0.003)	-0.064***	(0.011)	-0.120***	(0.027)	-0.106***	(0.009)	-0.132***	(0.006)	-0.024***	(0.003)	-0.043***	(0.008)	-0.097***	(0.032)	-0.108**	(0.010)
π_2^-	0.164***	(0.009)	0.113***	(0.006)	-0.012**	(0.006)	-0.130***	(0.029)	-0.061***	(0.009)	0.163***	(0.008)	0.114***	(0.005)	0.007	(0.010)	-0.099***	(0.026)	-0.064**	(0.010)
π_3^-	0.216***	(0.004)	0.257***	(0.007)	0.174***	(0.016)	0.033	(0.044)	0.039**	(0.016)	0.207***	(0.007)	0.259***	(0.006)	0.190***	(0.012)	0.061	(0.044)	0.039**	(0.016)
π_4^-	0.218***	(0.004)	0.254***	(0.004)	0.221***	(0.010)	0.100***	(0.011)	0.129***	(0.014)	0.207***	(0.007)	0.254***	(0.004)	0.230***	(0.008)	0.120***	(0.010)	0.133***	(0.017)
π_5^-	0.302***	(0.004)	0.257***	(0.005)	0.258***	(0.009)	0.229***	(0.024)	0.199***	(0.021)	0.288***	(0.009)	0.256***	(0.005)	0.260***	(0.010)	0.236***	(0.025)	0.202***	(0.021)
π_6^-	0.246***	(0.004)	0.216***	(0.005)	0.265***	(0.009)	0.244***	(0.023)	0.174***	(0.011)	0.229***	(0.009)	0.214***	(0.005)	0.265***	(0.009)	0.233***	(0.026)	0.171***	(0.011)
π_7^-	0.188***	(0.003)	0.196***	(0.005)	0.198***	(0.008)	0.234***	(0.016)	0.177***	(0.010)	0.174***	(0.006)	0.193***	(0.005)	0.194***	(0.008)	0.223***	(0.016)	0.177***	(0.010)
π_8^-	0.143***	(0.005)	0.148***	(0.004)	0.154***	(0.011)	0.208***	(0.025)	0.196***	(0.014)	0.133***	(0.006)	0.145***	(0.004)	0.152***	(0.010)	0.192***	(0.019)	0.196***	(0.014)
π_9^-	0.119***	(0.003)	0.104***	(0.003)	0.090***	(0.008)	0.150***	(0.031)	0.085***	(0.008)	0.116***	(0.004)	0.102***	(0.003)	0.087***	(0.008)	0.128***	(0.023)	0.088***	(0.008)
π_{10}^-	0.186***	(0.004)	0.160***	(0.005)	0.149***	(0.012)	0.096**	(0.042)	0.062***	(0.011)	0.18***	(0.005)	0.159***	(0.005)	0.149***	(0.012)	0.083**	(0.042)	0.060***	(0.012)
π_{11}^-	0.114***	(0.005)	0.109***	(0.004)	0.106***	(0.009)	0.147***	(0.031)	0.142***	(0.011)	0.108***	(0.004)	0.107***	(0.004)	0.103***	(0.009)	0.141***	(0.036)	0.142***	(0.011)
π_{12}^-	0.078***	(0.003)	0.078***	(0.003)	0.120***	(0.006)	0.179***	(0.025)	0.126***	(0.010)	0.074***	(0.003)	0.076***	(0.003)	0.116***	(0.006)	0.163***	(0.015)	0.123***	(0.011)
π_{13}^-	0.070***	(0.003)	0.112***	(0.003)	0.088***	(0.008)	0.071***	(0.017)	0.023***	(0.007)	0.068***	(0.004)	0.111***	(0.003)	0.083***	(0.008)	0.057***	(0.014)	0.023***	(0.007)
π_{14}^-	0.169***	(0.004)	0.095***	(0.003)	0.108***	(0.006)	0.053***	(0.014)	0.060***	(0.010)	0.168***	(0.005)	0.094***	(0.003)	0.104***	(0.007)	0.046***	(0.017)	0.061***	(0.010)
π_{15}^-	-0.022***	(0.005)	-0.032***	(0.005)	0.028***	(0.009)	0.153***	(0.007)	0.108***	(0.012)	-0.024***	(0.004)	-0.034***	(0.005)	0.024***	(0.008)	0.146***	(0.009)	0.107***	(0.011)
ρ	-0.068***	(0.002)	-0.059***	(0.002)	-0.071***	(0.003)	-0.058***	(0.008)	-0.064***	(0.005)	-0.082***	(0.008)	-0.077***	(0.008)	-0.103***	(0.016)	-0.188***	(0.046)	-0.09***	(0.019)
θ^+	0.922***	(0.004)	0.915***	(0.004)	0.947***	(0.011)	0.990***	(0.026)	0.963***	(0.012)	0.852***	(0.108)	0.684***	(0.080)	0.466***	(0.138)	0.145***	(0.119)	0.683***	(0.145)
θ^-	0.898***	(0.004)	0.892***	(0.005)	0.931***	(0.012)	0.974***	(0.029)	0.954***	(0.013)	0.843***	(0.113)	0.667***	(0.078)	0.458***	(0.135)	0.143***	(0.118)	0.677***	(0.143)
δ	0.041***	(0.001)	0.036***	(0.001)	0.044***	(0.002)	0.036***	(0.005)	0.039***	(0.003)	0.045***	(0.003)	0.035***	(0.001)	0.031***	(0.006)	0.015***	(0.011)	0.038***	(0.003)
Obs.	233,692		108,951		39,475		7,895		36,317		233,692		108,951		39,475		7,895		36,317	
(N x T)	(148 x 1,579)		(69 x 1,579)		(25 x 1,579)		(5 x 1,579)		(23 x 1,579)		(148 x 1,579)		(69 x 1,579)		(25 x 1,579)		(5 x 1,579)		(23 x 1,579)	
F_{PPS}	3025.31		1622.60		853.55		74.74		265.16		1069.23		819.80		140.54		439.07		156.47	
H_0: $\theta^+ = \theta^-$	1215.62	[0.000]	974.07	[0.000]	78.64	[0.000]	32.04	[0.000]	13.46	[0.000]	0.67	[0.414]	52.09	[0.000]	6.06	[0.014]	0.72	[0.397]	6.81	[0.009]

Table 5 (continued)

Catalonia — MG

	Repsol		Cepsa		BP		Other brands, expensive		Other brands, cheap	
λ_1	-0.244***	(0.004)	-0.276***	(0.005)	-0.148***	(0.022)	-0.079***	(0.008)	-0.033***	(0.011)
λ_2	-0.148***	(0.004)	-0.150***	(0.004)	-0.029*	(0.017)	0.011**	(0.005)	0.033***	(0.010)
λ_3	-0.147***	(0.004)	-0.170***	(0.003)	-0.042***	(0.010)	-0.024***	(0.007)	-0.002	(0.008)
λ_4	-0.128***	(0.003)	-0.155***	(0.004)	-0.038**	(0.016)	-0.010*	(0.005)	-0.004	(0.012)
λ_5	-0.139***	(0.003)	-0.160***	(0.004)	-0.032***	(0.008)	-0.008*	(0.004)	0.004	(0.005)
λ_6	-0.113***	(0.003)	-0.122***	(0.003)	0.005	(0.007)	-0.011***	(0.003)	0.014***	(0.004)
λ_7	0.160***	(0.004)	0.081***	(0.003)	0.192***	(0.025)	0.169***	(0.014)	0.06***	(0.012)
λ_8	-0.032***	(0.003)	-0.012***	(0.003)	0.026***	(0.009)	0.027***	(0.005)	0.017***	(0.005)
λ_9	-0.059***	(0.003)	-0.079***	(0.002)	-0.002	(0.013)	-0.007***	(0.002)	0.013***	(0.004)
λ_{10}	-0.106***	(0.003)	-0.076***	(0.003)	-0.005	(0.006)	-0.022***	(0.005)	0.009*	(0.006)
λ_{11}	-0.057***	(0.003)	-0.060***	(0.003)	-0.029***	(0.006)	-0.025***	(0.004)	0.008	(0.006)
λ_{12}	-0.057***	(0.002)	-0.072***	(0.002)	0.001	(0.005)	-0.015***	(0.004)	0.012**	(0.006)
λ_{13}	-0.057***	(0.002)	-0.007***	(0.002)	-0.033	(0.022)	-0.014***	(0.005)	0.003	(0.003)
λ_{14}	0.153***	(0.002)	0.098***	(0.002)	0.106***	(0.021)	0.115***	(0.010)	0.034***	(0.011)
λ_{15}	0.038***	(0.002)	0.031***	(0.002)	0.032***	(0.011)	0.035***	(0.004)	0.003	(0.004)
λ_{16}					-0.002	(0.011)	-0.003	(0.004)	-0.003	(0.002)
λ_{17}					-0.025**	(0.012)	0.001	(0.004)	0.001	(0.005)
λ_{18}					-0.017***	(0.005)			0.001	(0.006)
π_0^+	0.054***	(0.003)	0.061***	(0.003)	-0.011	(0.029)	0.017*	(0.009)	-0.010**	(0.005)
π_1^+	-0.019***	(0.003)	0.062***	(0.005)	-0.042	(0.026)	-0.129***	(0.010)	-0.056***	(0.011)
π_2^+	0.337***	(0.007)	0.254***	(0.007)	-0.001	(0.061)	-0.063***	(0.017)	-0.009	(0.011)
π_3^+	0.080***	(0.005)	0.093***	(0.005)	0.127***	(0.025)	0.054***	(0.015)	0.013	(0.018)
π_4^+	0.210***	(0.004)	0.199***	(0.005)	-0.012	(0.033)	-0.076***	(0.012)	-0.03***	(0.009)
π_5^+	0.196***	(0.005)	0.202***	(0.004)	0.015	(0.058)	-0.022**	(0.010)	0.008	(0.013)
π_6^+	0.238***	(0.004)	0.215***	(0.004)	0.188***	(0.015)			0.051***	(0.017)
π_7^+	0.137***	(0.004)	0.145***	(0.004)						
π_8^+	0.246***	(0.004)	0.167***	(0.005)						
π_9^+	0.009***	(0.005)	0.176***	(0.005)						
π_{10}^+	-0.008***	(0.004)	0.002***	(0.004)						
π_{11}^+	0.073***	(0.003)	0.075***	(0.003)						
π_{12}^+	0.042***	(0.003)	0.026***	(0.003)						

Catalonia — MG-CCE

	Repsol		Cepsa		BP		Other brands, expensive		Other brands, cheap	
λ_1	-0.239***	(0.005)	-0.270***	(0.006)	-0.147***	(0.021)	-0.077***	(0.008)	-0.034***	(0.011)
λ_2	-0.143***	(0.005)	-0.145***	(0.004)	-0.028*	(0.016)	0.012**	(0.005)	0.034***	(0.010)
λ_3	-0.145***	(0.004)	-0.166***	(0.004)	-0.042***	(0.010)	-0.024***	(0.007)	-0.002	(0.008)
λ_4	-0.126***	(0.004)	-0.152***	(0.004)	-0.037**	(0.016)	-0.010*	(0.005)	-0.004	(0.012)
λ_5	-0.136***	(0.004)	-0.157***	(0.005)	-0.032***	(0.008)	-0.008*	(0.004)	0.004	(0.005)
λ_6	-0.111***	(0.003)	-0.12***	(0.004)	0.005	(0.007)	-0.010***	(0.003)	0.015***	(0.004)
λ_7	0.159***	(0.004)	0.082***	(0.003)	0.193***	(0.026)	0.169***	(0.014)	0.060***	(0.012)
λ_8	-0.030***	(0.003)	-0.011***	(0.002)	0.027***	(0.009)	0.027***	(0.005)	0.018***	(0.005)
λ_9	-0.056***	(0.003)	-0.078***	(0.003)	-0.001	(0.013)	-0.007***	(0.002)	0.013***	(0.004)
λ_{10}	-0.103***	(0.003)	-0.075***	(0.004)	-0.004	(0.006)	-0.022***	(0.005)	0.009*	(0.006)
λ_{11}	-0.057***	(0.003)	-0.059***	(0.003)	-0.029***	(0.006)	-0.024***	(0.004)	0.009	(0.006)
λ_{12}	-0.056***	(0.002)	-0.071***	(0.002)	0.001	(0.004)	-0.015***	(0.004)	0.012**	(0.006)
λ_{13}	-0.056***	(0.002)	-0.007***	(0.002)	-0.033	(0.022)	-0.014***	(0.005)	0.003	(0.003)
λ_{14}	0.151***	(0.003)	0.097***	(0.002)	0.107***	(0.021)	0.115***	(0.01)	0.034***	(0.011)
λ_{15}	0.038***	(0.002)	0.031***	(0.002)	0.032***	(0.011)	0.035***	(0.004)	0.003	(0.004)
λ_{16}					-0.002	(0.011)	-0.003	(0.004)	-0.003	(0.002)
λ_{17}					-0.025**	(0.011)	-0.001	(0.004)	0.001	(0.005)
λ_{18}					-0.017***	(0.005)			0.001	(0.006)
π_0^+	0.054***	(0.003)	0.062***	(0.003)	-0.010	(0.029)	0.017*	(0.009)	-0.009**	(0.005)
π_1^+	-0.026***	(0.004)	0.060***	(0.005)	-0.045*	(0.025)	-0.13***	(0.009)	-0.056***	(0.011)
π_2^+	0.330***	(0.008)	0.251***	(0.007)	0.001	(0.062)	-0.064***	(0.017)	-0.010	(0.011)
π_3^+	0.072***	(0.005)	0.090***	(0.004)	0.127***	(0.025)	0.052***	(0.015)	0.013	(0.018)
π_4^+	0.203***	(0.006)	0.196***	(0.005)	-0.012	(0.033)	-0.078***	(0.012)	-0.030***	(0.009)
π_5^+	0.193***	(0.005)	0.198***	(0.005)	0.016	(0.058)	-0.023**	(0.010)	0.007	(0.013)
π_6^+	0.236***	(0.005)	0.212***	(0.005)	0.190***	(0.016)			0.051***	(0.017)
π_7^+	0.132***	(0.005)	0.141***	(0.004)						
π_8^+	0.241***	(0.005)	0.165***	(0.006)						
π_9^+	0.007	(0.005)	0.172***	(0.006)						
π_{10}^+	-0.011***	(0.004)	-0.001	(0.003)						
π_{11}^+	0.070***	(0.005)	0.073***	(0.003)						
π_{12}^+	0.039***	(0.003)	0.024***	(0.003)						

Table 5 (continued)

π_{13}^{+}	0.052***	(0.003)	0.001***	(0.003)							0.050***	(0.004)	-0.002	(0.003)						
π_{14}^{+}	0.087***	(0.004)	0.064***	(0.004)							0.087***	(0.004)	0.063***	(0.004)						
π_{15}^{+}	0.078***	(0.003)	0.112***	(0.003)							0.075***	(0.004)	0.111***	(0.003)						
π_{0}^{-}	-0.105***	(0.004)	-0.033***	(0.003)	0.076	(0.058)	0.036***	(0.010)	0.042***	(0.013)	-0.104***	(0.004)	-0.033***	(0.003)	0.070	(0.056)	0.036***	(0.010)	0.042***	(0.013)
π_{1}^{-}	-0.145***	(0.004)	-0.035***	(0.004)	-0.200***	(0.030)	-0.200***	(0.010)	-0.110***	(0.011)	-0.155***	(0.006)	-0.035***	(0.004)	-0.200***	(0.030)	-0.201***	(0.010)	-0.111***	(0.011)
π_{2}^{-}	0.191***	(0.005)	0.077***	(0.005)	-0.126***	(0.036)	-0.173***	(0.014)	-0.050***	(0.014)	0.184***	(0.005)	0.075***	(0.005)	-0.124***	(0.037)	-0.175***	(0.014)	-0.050***	(0.013)
π_{3}^{-}	0.213***	(0.004)	0.234***	(0.007)	0.025	(0.072)	-0.043**	(0.018)	-0.027*	(0.014)	0.207***	(0.004)	0.232***	(0.007)	0.028	(0.073)	-0.044**	(0.017)	-0.028**	(0.014)
π_{4}^{-}	0.208***	(0.003)	0.216***	(0.006)	0.141***	(0.034)	0.009	(0.014)	-0.004	(0.011)	0.202***	(0.004)	0.213***	(0.006)	0.139***	(0.035)	0.008	(0.013)	-0.004	(0.011)
π_{5}^{-}	0.274***	(0.005)	0.229***	(0.006)	0.161***	(0.022)	0.126***	(0.011)	0.049***	(0.017)	0.269***	(0.006)	0.226***	(0.007)	0.160***	(0.022)	0.124***	(0.011)	0.049***	(0.017)
π_{6}^{-}	0.210***	(0.004)	0.196***	(0.006)	0.108***	(0.023)			0.026**	(0.013)	0.205***	(0.005)	0.192***	(0.006)	0.108***	(0.023)			0.026**	(0.013)
π_{7}^{-}	0.149***	(0.004)	0.160***	(0.005)							0.144***	(0.005)	0.157***	(0.006)						
π_{8}^{-}	0.091***	(0.004)	0.130***	(0.004)							0.089***	(0.004)	0.127***	(0.004)						
π_{9}^{-}	0.091***	(0.004)	0.095***	(0.003)							0.088***	(0.004)	0.093***	(0.004)						
π_{10}^{-}	0.169***	(0.004)	0.159***	(0.003)							0.166***	(0.004)	0.157***	(0.004)						
π_{11}^{-}	0.068***	(0.003)	0.106***	(0.003)							0.063***	(0.004)	0.103***	(0.003)						
π_{12}^{-}	0.049***	(0.003)	0.079***	(0.004)							0.045***	(0.004)	0.076***	(0.004)						
π_{13}^{-}	0.040***	(0.003)	0.090***	(0.003)							0.037***	(0.004)	0.089***	(0.003)						
π_{14}^{-}	0.164***	(0.004)	0.104***	(0.003)							0.162***	(0.004)	0.103***	(0.003)						
π_{15}^{-}	-0.047***	(0.004)	-0.046***	(0.004)							-0.047***	(0.004)	-0.047***	(0.004)						
ρ	-0.075***	(0.002)	-0.089***	(0.003)	-0.123***	(0.010)	-0.182***	(0.006)	-0.095***	(0.006)	-0.085***	(0.011)	-0.106**	(0.053)	-0.125***	(0.010)	-0.208***	(0.016)	-0.094***	(0.006)
θ^{+}	0.953***	(0.005)	0.955***	(0.004)	1.001***	(0.012)	0.986***	(0.005)	1.011***	(0.014)	0.944***	(0.123)	0.807***	(0.400)	0.989***	(0.025)	0.871***	(0.061)	1.015***	(0.017)
θ^{-}	0.929**	(0.005)	0.931***	(0.005)	0.992***	(0.018)	0.967***	(0.006)	1.004***	(0.016)	0.919***	(0.120)	0.786***	(0.390)	0.975***	(0.029)	0.854***	(0.060)	1.008***	(0.020)
δ	0.045***	(0.001)	0.054***	(0.002)	0.076***	(0.005)	0.113***	(0.004)	0.053***	(0.004)	0.049***	(0.002)	0.055***	(0.002)	0.076***	(0.006)	0.114***	(0.004)	0.053***	(0.004)
Obs.	208,428		132,636		7,895		64,739		31,580		208,428		132,636		7,895		64,739		31,580	
(N x T)	(132 x 1579)		(84 x 1579)		(5 x 1,579)		(41 x 1,579)		(20 x 1,579)		(132 x 1579)		(84 x 1579)		(5 x 1,579)		(41 x 1,579)		(20 x 1,579)	
F_{PPS}	1243.47		902.49		324.41		944.04		265.23		631.35		921.04		367.89		1258.63		260.74	
H_0: $\theta^{+} = \theta^{-}$	506.27	[0.000]	471.16	[0.000]	4.34	[0.064]	174.75	[0.000]	5.54	[0.019]	4.39	[0.036]	107.11	[0.000]	4.93	[0.027]	4.39	[0.036]	4.93	[0.027]

Standard errors are in parenthesis and p-values in brackets. The optimal lag length has been selected by minimizing the Akaike Information Criteria. We denote ***, **, * to indicate statistical significance at the 1%, 5% and 10% levels, respectively. Regressions include step dummy variables to control for changes in the Spanish VAT rate on fuels (1st June 2010 and 1st September 2012) and the hydrocarbon special tax in Catalonia (1st April 2012). N and T refer, respectively, to the cross-sectional and temporal observations of the panel data.

Table A1. Tax rates on diesel fuel

	In force from
Value added tax	
16%	1st January 2006
18%	1st July 2010
21%	1st September 2012
Special hydrocarbon taxes (€/liter)	
General section:	
0.307	13th June 2009
State section:	
0.024	1st January 2002
Regional section:	
0.017 (Madrid)	1st January 2002
0.024 (Catalonia)	1st January 2002
0.048 (Catalonia)	1st April 2012

Author's own elaboration from information from the Spanish *Ministry of Finance and Public Administration*.

Table C1. Unit root tests on the alternative measures of retail price dispersion

	Breitung-Das	Phillips-Perron		Augmented Dickey-Fuller	
Model with constant					
Citywide dispersion in Madrid	-45.397***				
Citywide dispersion in Catalonia	-34.401***				
ΔCitywide dispersion in Madrid	-130.000***				
ΔCitywide dispersion in Catalonia	-100.000***				
ZIP-code dispersion in Madrid	-55.061***				
ZIP-code dispersion in Catalonia	-33.769***				
ΔZIP-code dispersion in Madrid	-140.000***				
ΔZIP-code dispersion in Catalonia	-110.000***				
Regional standard deviation in Madrid		-3.710***	(7)	-2.886**	(7)
Regional standard deviation in Catalonia		-2.655*	(7)	-2.835*	(17)
ΔRegional standard deviation in Madrid		-51.056***	(7)	-11.976***	(14)
ΔRegional standard deviation in Catalonia		-36.758***	(7)	-10.667***	(21)
Model with constant and trend					
Citywide dispersion in Madrid	-64.655***				
Citywide dispersion in Catalonia	-46.151***				
ΔCitywide dispersion in Madrid	-160.000***				
ΔCitywide dispersion in Catalonia	-120.000***				
ZIP-code dispersion in Madrid	-74.630***				
ZIP-code dispersion in Catalonia	-46.568***				
ΔZIP-code dispersion in Madrid	-170.000***				
ΔZIP-code dispersion in Catalonia	-130.000***				
Regional standard deviation in Madrid		-7.926***	(7)	-5.673***	(7)
Regional standard deviation in Catalonia		-6.552***	(7)	-5.692***	(10)
ΔRegional standard deviation in Madrid		-51.039***	(7)	-13.209***	(6)
ΔRegional standard deviation in Catalonia		-36.747***	(7)	-11.851***	(13)

We denote ***, **, * to indicate the rejection of the null hypothesis of non-stationarity at 1%, 5% and 10% levels of significance, respectively. The optimal lag length (in parenthesis) is based on the Newey-West Criterion for the Phillips-Perron test, and the Schwarz Information Criterion for the Augmented Dickey-Fuller test. The critical values are obtained from MacKinnon (1991).

Table D1. Robustness check for Eq. (1)

	Madrid						Catalonia					
	Citywide disp., MG-CCE		ZIP-code disp., MG-CCE		Regional SD, OLS		Citywide disp., MG-CCE		ZIP-code disp., MG-CCE		Regional SD, OLS	
γ_1	0.484***	(0.008)	0.474***	(0.009)	0.758***	(0.025)	0.575***	(0.011)	0.581***	(0.01)	0.948***	(0.025)
γ_2	0.083***	(0.004)	0.075***	(0.006)	0.059*	(0.031)	0.057***	(0.004)	0.059***	(0.004)	0.001	(0.034)
γ_3	0.011***	(0.002)	0.016***	(0.005)	-0.005	(0.031)	-0.013**	(0.005)	-0.018***	(0.006)	-0.082**	(0.034)
γ_4	0.027***	(0.003)	0.018***	(0.004)	0.053*	(0.031)	0.018***	(0.006)	0.021***	(0.006)	-0.011	(0.034)
γ_5	0.008***	(0.002)	0.016***	(0.004)	0.003	(0.031)	0.013***	(0.004)	0.015***	(0.004)	0.075**	(0.034)
γ_6	0.014***	(0.003)	0.007*	(0.004)	0.060*	(0.031)	-0.001	(0.004)	0.003	(0.004)	0.035	(0.033)
γ_7	0.122***	(0.005)	0.106***	(0.005)	0.146***	(0.031)	0.107***	(0.006)	0.098***	(0.006)	0.193***	(0.033)
γ_8	-0.051***	(0.004)	-0.043***	(0.004)	-0.107***	(0.024)	-0.058***	(0.004)	-0.049***	(0.004)	-0.198***	(0.023)
γ_9	-0.012***	(0.002)	-0.003	(0.003)			-0.007**	(0.004)	-0.011***	(0.004)		
γ_{10}	-0.003	(0.002)	-0.005**	(0.003)			-0.007**	(0.003)	-0.005	(0.003)		
γ_{11}	0.008***	(0.002)	0.010***	(0.003)			0.011***	(0.002)	0.014***	(0.002)		
γ_{12}	0.001	(0.002)	-0.001	(0.003)			-0.008***	(0.002)	-0.007***	(0.003)		
γ_{13}	0.003	(0.002)	0.005*	(0.003)			0.001	(0.003)	0.004	(0.003)		
γ_{14}	0.086***	(0.004)	0.069***	(0.004)			0.045***	(0.003)	0.041***	(0.003)		
γ_{15}	-0.032***	(0.003)	-0.023***	(0.003)								
β_0^+	0.007***	(0.002)	0.006***	(0.002)	0.019**	(0.008)	0.015***	(0.002)	0.013***	(0.002)	0.022***	(0.007)
β_1^+	-0.001	(0.002)	-0.001	(0.002)	-0.011	(0.008)	0.001	(0.002)	-0.001	(0.002)	0.005	(0.007)
β_2^+	0.038***	(0.004)	0.035***	(0.004)	0.071***	(0.008)	0.044***	(0.004)	0.039***	(0.004)	0.060***	(0.007)
β_3^+	-0.01***	(0.003)	-0.006*	(0.003)	-0.016*	(0.009)	0.009***	(0.002)	0.009***	(0.002)	0.001	(0.007)
β_4^+	0.012***	(0.003)	0.011***	(0.003)	0.020**	(0.008)	0.019***	(0.002)	0.017***	(0.002)	0.014**	(0.007)
β_5^+	0.015***	(0.003)	0.015***	(0.002)	0.036***	(0.008)	0.018***	(0.003)	0.016***	(0.002)	0.017**	(0.007)
β_6^+	0.004**	(0.002)	0.007***	(0.002)	0.018**	(0.009)	0.016***	(0.002)	0.014***	(0.002)	0.033***	(0.007)
β_7^+	-0.002	(0.002)	-0.002	(0.002)			0.004*	(0.002)	0.005***	(0.002)		
β_8^-	0.005**	(0.002)	0.002	(0.002)			0.006***	(0.002)	0.003	(0.002)		
β_9^+	-0.011***	(0.002)	-0.010***	(0.002)			-0.007***	(0.002)	-0.005***	(0.002)		
β_{10}^+	-0.004*	(0.003)	-0.002	(0.002)			-0.003*	(0.002)	-0.002	(0.002)		
β_{11}^+	0.002	(0.002)	0.002	(0.001)			0.003**	(0.002)	0.002	(0.002)		
β_{12}^+	0.001	(0.003)	0.001	(0.003)			-0.008***	(0.002)	-0.008***	(0.001)		
β_{13}^+	0.005***	(0.002)	0.008***	(0.002)			0.004***	(0.002)	0.004***	(0.001)		
β_{14}^+	0.003*	(0.002)	0.003*	(0.001)								
β_0^-	-0.01***	(0.002)	-0.008***	(0.002)	-0.017**	(0.008)	-0.015***	(0.002)	-0.012***	(0.002)	-0.015**	(0.006)
β_1^-	0.002	(0.002)	0.002	(0.002)	0.007	(0.008)	0.002	(0.002)	0.001	(0.002)	-0.008	(0.007)
β_2^-	0.005	(0.003)	-0.001	(0.003)	-0.003	(0.008)	-0.004*	(0.002)	-0.007***	(0.002)	0.006	(0.006)
β_3^-	0.008**	(0.003)	0.003	(0.003)	0.017**	(0.008)	0.005*	(0.003)	0.003	(0.003)	0.029***	(0.006)
β_4^-	0.004	(0.002)	0.001	(0.002)	0.010	(0.008)	0.008***	(0.002)	0.005**	(0.002)	0.029***	(0.006)
β_5^-	0.009***	(0.002)	0.005***	(0.002)	0.020**	(0.008)	0.013***	(0.002)	0.012***	(0.002)	0.032***	(0.007)
β_6^-	-0.002	(0.002)	-0.002	(0.002)	-0.001	(0.008)	0.003	(0.002)	0.003	(0.002)	0.010	(0.007)
β_7^-	0.003*	(0.002)	0.004***	(0.002)			0.009***	(0.002)	0.009***	(0.001)		
β_8^-	-0.003	(0.002)	0.001	(0.002)			0.005**	(0.002)	0.006***	(0.002)		
β_9^-	0.006***	(0.002)	0.007***	(0.001)			0.010***	(0.002)	0.010***	(0.002)		
β_{10}^-	0.006***	(0.002)	0.003	(0.002)			0.005**	(0.002)	0.002	(0.002)		
β_{11}^-	-0.005***	(0.002)	-0.003**	(0.002)			-0.001	(0.001)	0.001	(0.002)		
β_{12}^-	-0.002	(0.002)	0.001	(0.002)			0.008***	(0.002)	0.009***	(0.002)		
β_{13}^-	-0.007***	(0.002)	-0.007***	(0.002)			-0.006***	(0.001)	-0.006***	(0.001)		
β_{14}^-	-0.002	(0.001)	-0.002**	(0.001)								
α	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.001***	(0.000)
Obs. (N x T)	522,649 (331x1,579)		522,649 (331x1,579)		1,579		577,914 (366 x 1,579)		577,914 (366 x 1,579)		1,579	

Standard errors are in parenthesis. The optimal lag length has been selected by minimizing the AIC. We denote ***, **, * to indicate statistical significance at the 1%, 5% and 10% levels, respectively. Regressions include step dummy variables to control for changes in the Spanish VAT rate on fuels (1st June 2010 and 1st September 2012), and the hydrocarbon special tax in Catalonia (1st April 2012). N and T refer, respectively, to the cross-sectional and temporal observations of the panel data.

Table E1. Panel unit root test on retail prices

	Breitung-Das
Model with constant	
rp_{it} in Madrid	-1.258
rp_{it} in Catalonia	-1.232
Δrp_{it} in Madrid	-64.893***
Δrp_{it} in Catalonia	-20.330***
Model with constant and trend	
p_{it} in Madrid	-1.076
p_{it} in Catalonia	-1.272
Δp_{it} in Madrid	-77.416***
Δp_{it} in Catalonia	-67.936***

We denote ***, **, * to indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table G1. Robustness check for the MG-CCE estimates from Eq. (2) with asymmetric speed

	Madrid													
	Expensive		Cheap		Repsol		Cepsa		BP		Other brands, expensive		Other brands, cheap	
λ_1	-0.235***	(0.009)	-0.165***	(0.014)	-0.230***	(0.004)	-0.290***	(0.006)	-0.270***	(0.014)	-0.239***	(0.015)	-0.193***	(0.013)
λ_2	-0.111***	(0.007)	-0.030***	(0.007)	-0.124***	(0.003)	-0.158***	(0.004)	-0.144***	(0.009)	-0.140***	(0.015)	-0.085***	(0.009)
λ_3	-0.106***	(0.005)	-0.050***	(0.006)	-0.113***	(0.003)	-0.167***	(0.004)	-0.112***	(0.007)	-0.159***	(0.011)	-0.106***	(0.009)
λ_4	-0.081***	(0.004)	-0.036***	(0.005)	-0.076***	(0.002)	-0.141***	(0.003)	-0.144***	(0.009)	-0.141***	(0.008)	-0.082***	(0.007)
λ_5	-0.078***	(0.006)	-0.020***	(0.005)	-0.085***	(0.003)	-0.131***	(0.004)	-0.071***	(0.005)	-0.100***	(0.014)	-0.050***	(0.008)
λ_6	-0.037***	(0.004)	0.002	(0.005)	-0.039***	(0.002)	-0.078***	(0.003)	-0.028***	(0.004)	-0.092***	(0.013)	-0.011*	(0.007)
λ_7	0.225***	(0.005)	0.170***	(0.009)	0.230***	(0.003)	0.110***	(0.003)	0.159***	(0.007)	0.154***	(0.007)	0.151***	(0.011)
λ_8	0.029***	(0.004)	0.015**	(0.007)	0.021***	(0.002)	0.035***	(0.002)	-0.005	(0.005)	-0.007	(0.007)	0.018***	(0.006)
λ_9	-0.014***	(0.004)	-0.017***	(0.005)	-0.003	(0.002)	-0.026***	(0.002)	-0.001	(0.005)	-0.051***	(0.014)	-0.004	(0.006)
λ_{10}	-0.063***	(0.005)	-0.029***	(0.005)	-0.077***	(0.003)	-0.032***	(0.002)	-0.003	(0.004)	-0.041***	(0.013)	-0.023***	(0.005)
λ_{11}	-0.03***	(0.003)	-0.024***	(0.004)	-0.028***	(0.002)	-0.022***	(0.003)	-0.036***	(0.004)	-0.002	(0.002)	-0.015***	(0.004)
λ_{12}	-0.046***	(0.004)	-0.035***	(0.006)	-0.035***	(0.002)	-0.057***	(0.002)	-0.028***	(0.005)	-0.014	(0.021)	-0.02***	(0.006)
λ_{13}	-0.041***	(0.004)	-0.014***	(0.005)	-0.048***	(0.003)	0.009***	(0.002)	0.003	(0.006)	-0.038***	(0.009)	-0.013**	(0.005)
λ_{14}	0.149***	(0.007)	0.123***	(0.009)	0.165***	(0.003)	0.100***	(0.002)	0.072***	(0.005)	0.083***	(0.017)	0.102***	(0.009)
λ_{15}	0.036***	(0.004)	0.022***	(0.005)	0.035***	(0.002)	0.022***	(0.002)	0.031***	(0.007)	0.016	(0.023)	0.010*	(0.005)
λ_{16}	-0.028***	(0.007)	0.002	(0.005)	-0.042***	(0.003)	0.011***	(0.002)	0.018***	(0.004)	0.001	(0.012)	0.002	(0.006)
λ_{17}			-0.010*	(0.005)	0.014***	(0.002)	-0.019***	(0.002)	-0.034***	(0.004)	-0.018**	(0.007)	0.005	(0.005)
λ_{18}			-0.012***	(0.004)	-0.008***	(0.002)	-0.022***	(0.002)	-0.016***	(0.004)	-0.021***	(0.008)	-0.012***	(0.004)
λ_{19}					-0.003	(0.002)	0.015***	(0.002)	-0.036***	(0.003)	-0.028***	(0.004)	-0.018***	(0.005)
λ_{20}							-0.008***	(0.002)	-0.001	(0.005)	-0.014	(0.016)	0.072***	(0.006)
λ_{21}							0.069***	(0.002)	0.073***	(0.005)	0.076***	(0.021)	-0.193***	(0.013)
π_0^+	-0.235***	(0.007)	-0.165***	(0.014)	0.067***	(0.005)	0.040***	(0.004)	0.079***	(0.016)	-0.008	(0.020)	-0.048***	(0.018)
π_1^+	-0.111***	(0.010)	-0.030***	(0.007)	0.009	(0.006)	0.116***	(0.006)	-0.007	(0.012)	0.005	(0.016)	-0.066***	(0.014)
π_2^+	-0.106***	(0.018)	-0.050***	(0.006)	0.295***	(0.011)	0.278***	(0.006)	0.206***	(0.014)	0.100*	(0.060)	0.042*	(0.022)
π_3^+	-0.081***	(0.009)	-0.036***	(0.005)	0.052***	(0.008)	0.125***	(0.004)	0.125***	(0.011)	0.089*	(0.050)	0.161***	(0.022)
π_4^+	-0.078***	(0.009)	-0.020***	(0.005)	0.158***	(0.005)	0.209***	(0.005)	0.117***	(0.009)	0.120***	(0.039)	0.016	(0.010)
π_5^+	-0.037***	(0.010)	0.002	(0.005)	0.158***	(0.008)	0.212***	(0.005)	0.184***	(0.012)	0.119***	(0.035)	0.038***	(0.011)
π_6^+	0.225***	(0.006)	0.170***	(0.009)	0.190***	(0.004)	0.202***	(0.005)	0.224***	(0.009)	0.260***	(0.020)	0.190***	(0.021)
π_7^+	0.029***	(0.007)			0.144***	(0.004)	0.143***	(0.005)	0.144***	(0.009)	0.159***	(0.039)	0.142***	(0.013)
π_8^+							0.171***	(0.004)	0.153***	(0.011)	0.173***	(0.029)	0.066***	(0.011)
π_9^+							0.163***	(0.003)	0.137***	(0.008)	0.195***	(0.016)	0.149***	(0.009)
π_{10}^+							-0.011***	(0.004)			0.135***	(0.021)		
π_{11}^+											0.043*	(0.023)		
π_{12}^+											0.080***	(0.023)		

Table G1 (continued)

π_0^-	-0.054***	(0.010)	-0.031*	(0.018)	-0.075***	(0.009)	-0.006*	(0.003)	-0.056***	(0.016)	0.048*	(0.025)	0.061***	(0.010)
π_1^-	-0.106***	(0.008)	-0.051***	(0.019)	-0.144***	(0.003)	-0.018***	(0.003)	-0.047***	(0.009)	-0.091**	(0.037)	-0.109***	(0.011)
π_2^-	0.152***	(0.022)	0.055**	(0.022)	0.188***	(0.009)	0.127***	(0.006)	0.022***	(0.008)	-0.085***	(0.032)	-0.064***	(0.009)
π_3^-	0.252***	(0.016)	0.135***	(0.018)	0.250***	(0.006)	0.283***	(0.007)	0.209***	(0.017)	0.077**	(0.037)	0.031*	(0.018)
π_4^-	0.224***	(0.009)	-0.003	(0.015)	0.213***	(0.005)	0.257***	(0.005)	0.238***	(0.011)	0.117***	(0.012)	0.128***	(0.018)
π_5^-	0.262***	(0.007)	0.023*	(0.014)	0.266***	(0.006)	0.267***	(0.005)	0.258***	(0.010)	0.234***	(0.024)	0.196***	(0.021)
π_6^-	0.185***	(0.007)	0.171***	(0.016)	0.188***	(0.004)	0.22***	(0.005)	0.244***	(0.011)	0.209***	(0.019)	0.135***	(0.011)
π_7^-	0.125***	(0.005)			0.121***	(0.003)	0.167***	(0.005)	0.155***	(0.008)	0.219***	(0.017)	0.152***	(0.009)
π_8^-							0.102***	(0.003)	0.119***	(0.008)	0.197***	(0.020)	0.164***	(0.013)
π_9^-							0.077***	(0.003)	0.060***	(0.008)	0.121***	(0.020)	0.053***	(0.007)
π_{10}^-							0.123***	(0.004)			0.067**	(0.032)		
π_{11}^-											0.109***	(0.030)		
π_{12}^-											0.125***	(0.020)		
ρ^+	-0.109***	(0.019)	-0.124***	(0.020)	-0.114***	(0.025)	-0.070***	(0.010)	-0.095***	(0.016)	-0.178***	(0.042)	-0.099***	(0.022)
ρ^-	-0.108***	(0.019)	-0.124***	(0.020)	-0.112***	(0.025)	-0.071***	(0.010)	-0.097***	(0.016)	-0.182***	(0.042)	-0.101***	(0.021)
θ^+	0.500***	(0.097)	0.711***	(0.121)	0.561***	(0.104)	0.653***	(0.095)	0.519***	(0.138)	0.232***	(0.135)	0.748***	(0.162)
θ^-	0.489***	(0.098)	0.671***	(0.115)	0.562***	(0.105)	0.608***	(0.088)	0.501***	(0.135)	0.219***	(0.122)	0.716***	(0.153)
δ	0.034***	(0.002)	0.052***	(0.005)	0.041***	(0.003)	0.028***	(0.001)	0.030***	(0.004)	0.014**	(0.011)	0.045***	(0.004)
Obs.	60,002		47,370		233,692		108,951		39,475		7,895		36,317	
(N x T)	(38 x 1,579)		(30 x 1,579)		(148 x 1,579)		(69 x 1,579)		(25 x 1,579)		(5 x 1,579)		(23 x 1,579)	
F_{PPS}	449.90		228.52		942.40		864.13		465.01		96439.97		181.10	
$H_0: \theta^+ = \theta^-$	3.51	[0.061]	17.86	[0.000]	0.08	[0.776]	30.84	[0.000]	8.59	[0.003]	0.79	[0.375]	6.46	[0.011]
$H_0: \rho^+ = \rho^-$	0.47	[0.492]	1.93	[0.165]	7.09	[0.008]	16.67	[0.000]	23.89	[0.000]	342.66	[0.000]	2.18	[0.139]

Table G1 (continued)

	Catalonia													
	Expensive		Cheap		Repsol		Cepsa		BP		Other brands, expensive		Other brands, cheap	
λ_1	-0.192***	(0.006)	-0.035***	(0.012)	-0.161***	(0.003)	-0.189***	(0.005)	-0.155***	(0.023)	-0.096***	(0.009)	-0.025**	(0.011)
λ_2	-0.064***	(0.004)	0.036***	(0.010)	-0.040***	(0.003)	-0.041***	(0.003)	-0.032**	(0.015)	0.003	(0.005)	0.042***	(0.010)
λ_3	-0.072***	(0.003)	0.001	(0.007)	-0.053***	(0.003)	-0.046***	(0.002)	-0.039***	(0.013)	-0.029***	(0.007)	0.005	(0.007)
λ_4	-0.044***	(0.003)	0.001	(0.011)	-0.009***	(0.002)	-0.025***	(0.002)	-0.034**	(0.015)	-0.012**	(0.006)	0.001	(0.012)
λ_5	-0.045***	(0.003)	0.005	(0.005)	-0.052***	(0.002)	-0.041***	(0.003)	-0.029***	(0.008)	-0.009**	(0.004)	0.008	(0.005)
λ_6	-0.022***	(0.002)	0.014***	(0.004)	-0.033***	(0.002)	-0.011***	(0.002)	0.007	(0.007)	-0.012***	(0.003)	0.015***	(0.004)
λ_7	0.192***	(0.006)	0.065***	(0.013)	0.226***	(0.004)	0.184***	(0.003)	0.182***	(0.028)	0.166***	(0.014)	0.058***	(0.012)
λ_8	0.038***	(0.003)	0.017***	(0.005)	0.019***	(0.002)	0.056***	(0.003)	0.029**	(0.012)	0.021***	(0.005)	0.019***	(0.005)
λ_9	-0.015***	(0.002)	0.014***	(0.004)	-0.007***	(0.002)	-0.035***	(0.002)	-0.002	(0.013)	-0.012***	(0.002)	0.015***	(0.004)
λ_{10}	-0.052***	(0.003)	0.006	(0.007)	-0.083***	(0.002)	-0.046***	(0.003)	0.001	(0.005)	-0.027***	(0.004)	0.010*	(0.005)
λ_{11}	-0.032***	(0.002)	0.007	(0.007)	-0.038***	(0.002)	-0.041***	(0.003)	-0.026***	(0.005)	-0.027***	(0.005)	0.010	(0.006)
λ_{12}	-0.042***	(0.002)	0.010*	(0.006)	-0.030***	(0.002)	-0.060***	(0.002)	0.005	(0.006)	-0.017***	(0.004)	0.012**	(0.006)
λ_{13}	-0.023***	(0.003)	0.001	(0.003)	-0.044***	(0.002)	0.011***	(0.002)	-0.031	(0.022)	-0.015***	(0.005)	0.001	(0.003)
λ_{14}	0.133***	(0.004)	0.039***	(0.012)	0.175***	(0.003)	0.117***	(0.003)	0.088***	(0.021)	0.113***	(0.010)	0.035***	(0.012)
λ_{15}	0.042***	(0.002)	0.004	(0.004)	0.035***	(0.002)	0.037***	(0.002)	0.027**	(0.012)	0.031***	(0.004)	0.004	(0.004)
λ_{16}	-0.020***	(0.003)	-0.005	(0.004)	-0.054***	(0.002)	-0.001	(0.001)	0.002	(0.011)	-0.007*	(0.004)	-0.003	(0.002)
λ_{17}	-0.009***	(0.003)	0.001	(0.005)	0.017***	(0.002)			-0.021*	(0.013)			-0.002	(0.004)
λ_{18}	-0.008***	(0.002)							-0.019***	(0.006)				
λ_{19}									-0.017	(0.013)				
λ_{20}									-0.002	(0.007)				
λ_{21}									0.093***	(0.013)				
π_0^+	0.066***	(0.006)	-0.001	(0.008)	0.073***	(0.004)	0.087***	(0.004)	-0.052	(0.036)	-0.006	(0.011)	-0.010	(0.007)
π_1^+	0.012*	(0.007)	-0.050***	(0.012)	-0.020***	(0.004)	0.078***	(0.005)	-0.036	(0.024)	-0.100***	(0.009)	-0.059***	(0.009)
π_2^+	0.201***	(0.013)	0.006	(0.017)	0.280***	(0.007)	0.225***	(0.008)	0.012	(0.062)	-0.027*	(0.015)	-0.008	(0.011)
π_3^+	0.055***	(0.006)	0.009	(0.016)	-0.028***	(0.005)	0.009**	(0.004)	0.147***	(0.026)	0.083***	(0.015)	0.014	(0.017)
π_4^+	0.083***	(0.008)	-0.022*	(0.011)	0.108***	(0.004)	0.098***	(0.005)	0.001	(0.033)	-0.056***	(0.011)	-0.029***	(0.011)
π_5^+	0.090***	(0.007)	0.020	(0.015)	0.141***	(0.004)	0.106***	(0.004)	0.028	(0.056)	-0.007	(0.009)		
π_6^+	0.176***	(0.005)							0.192***	(0.015)				
π_0^-	-0.025***	(0.007)	0.040***	(0.013)	-0.122***	(0.004)	-0.021***	(0.004)	0.061	(0.051)	0.041***	(0.011)	0.046***	(0.012)
π_1^-	-0.131***	(0.006)	-0.095***	(0.010)	-0.173***	(0.004)	-0.07***	(0.005)	-0.161***	(0.026)	-0.14***	(0.01)	-0.099***	(0.011)
π_2^-	0.081***	(0.013)	-0.026	(0.018)	0.203***	(0.005)	0.049***	(0.005)	-0.089***	(0.034)	-0.122***	(0.015)	-0.045***	(0.015)
π_3^-	0.193***	(0.011)	-0.001	(0.018)	0.231***	(0.005)	0.235***	(0.008)	0.053	(0.070)	0.015	(0.017)	-0.018	(0.014)

Table G1 (continued)

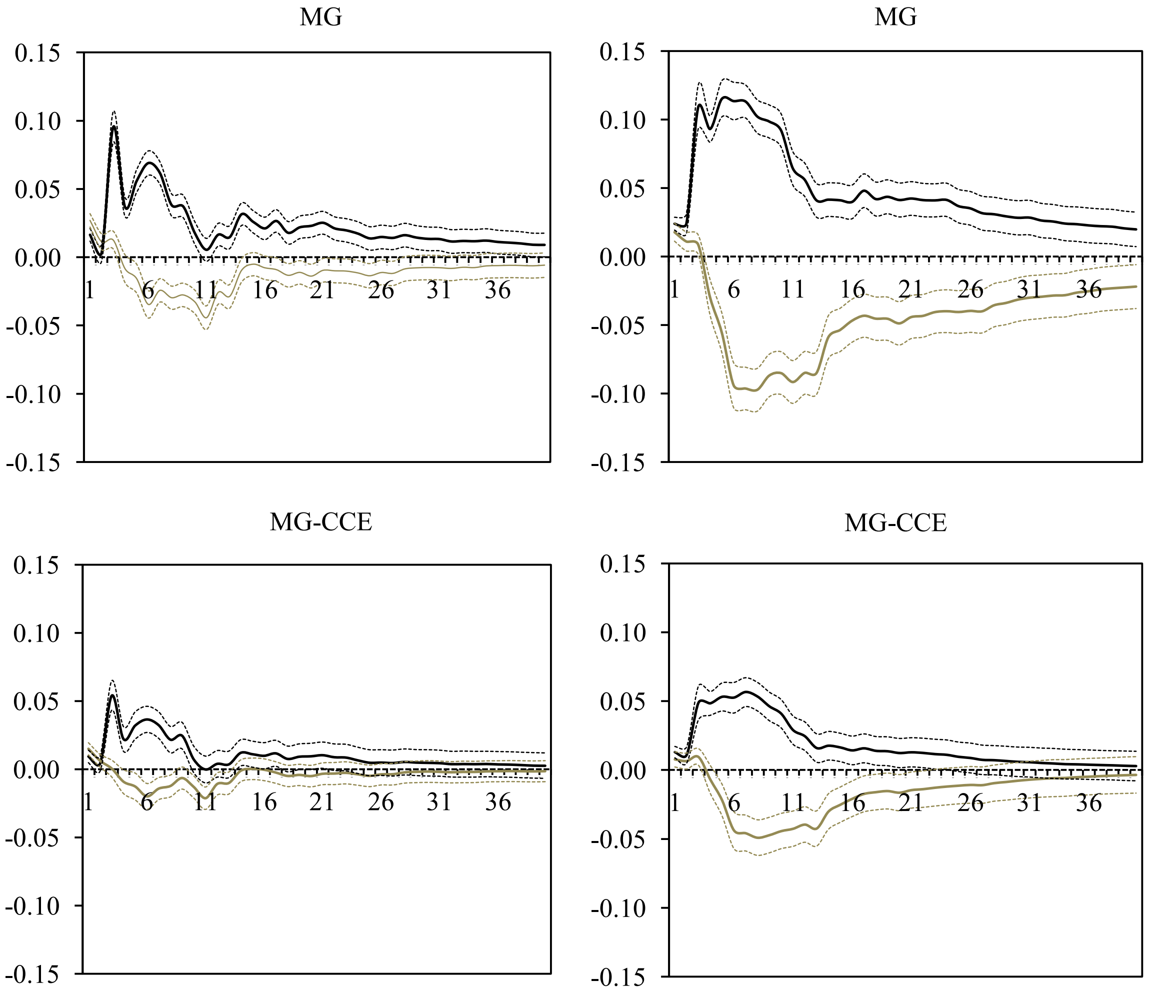
π_4^-	0.177***	(0.007)	0.014	(0.012)	0.179***	(0.004)	0.190***	(0.006)	0.156***	(0.027)	0.063***	(0.013)	0.009	(0.010)
π_5^-	0.217***	(0.006)	0.064***	(0.017)	0.229***	(0.005)	0.178***	(0.006)	0.178***	(0.014)	0.172***	(0.012)		
π_6^-	0.163***	(0.005)							0.126***	(0.017)				
ρ^+	-0.116***	(0.025)	-0.088***	(0.006)	-0.110***	(0.011)	-0.136**	(0.054)	-0.105***	(0.007)	-0.159***	(0.015)	-0.106***	(0.007)
ρ^-	-0.117***	(0.025)	-0.087***	(0.006)	-0.109***	(0.011)	-0.135**	(0.054)	0.100***	(0.010)	-0.162***	(0.015)	-0.078***	(0.006)
θ^+	0.814***	(0.177)	1.060***	(0.016)	0.838***	(0.090)	0.746***	(0.298)	1.052***	(0.049)	0.746**	(0.289)	1.065***	(0.016)
θ^-	0.784***	(0.170)	0.987***	(0.008)	0.852***	(0.092)	0.734***	(0.295)	0.952***	(0.037)	0.734**	(0.295)	0.987***	(0.008)
δ	0.057***	(0.002)	0.559***	(0.008)	0.056***	(0.002)	0.061***	(0.002)	0.063***	(0.006)	0.061***	(0.002)	0.557***	(0.008)
Obs.	214,744		33,159		208,428		132,636		7,895		64,739		31,580	
(N x T)	(136 x 1,579)		(21 x 1,579)		(132 x 1,579)		(84 x 1,579)		(5 x 1,579)		(41 x 1,579)		(20 x 1,579)	
F_{PPS}	1246.84		487.83		1219.74		1126.64		1996.05		695.53		524.15	
$H_0: \theta^+ = \theta^-$	10.83	[0.001]	16.12	[0.000]	4.51	[0.034]	11.98	[0.000]	16.62	[0.000]	113.89	[0.000]	19.10	[0.000]
$H_0: \rho^+ = \rho^-$	0.06	[0.807]	2.75	[0.097]	4.12	[0.043]	40.67	[0.000]	0.29	[0.591]	68.73	[0.000]	1.74	[0.187]

Standard errors are in parenthesis and p-values are reported in brackets. The optimal lag length has been selected by minimizing the AIC. We denote ***, **, * to indicate statistical significance at the 1%, 5% and 10% levels, respectively. Regressions include step dummy variables to control for changes in the Spanish VAT rate on fuels (1st June 2010 and 1st September 2012) and the hydrocarbon special tax in Catalonia (1st April 2012). N and T refer, respectively, to the cross-sectional and temporal observations of the panel data.

Figure(s)

Figure 1. Dynamic responses of retail price dispersion at regional level

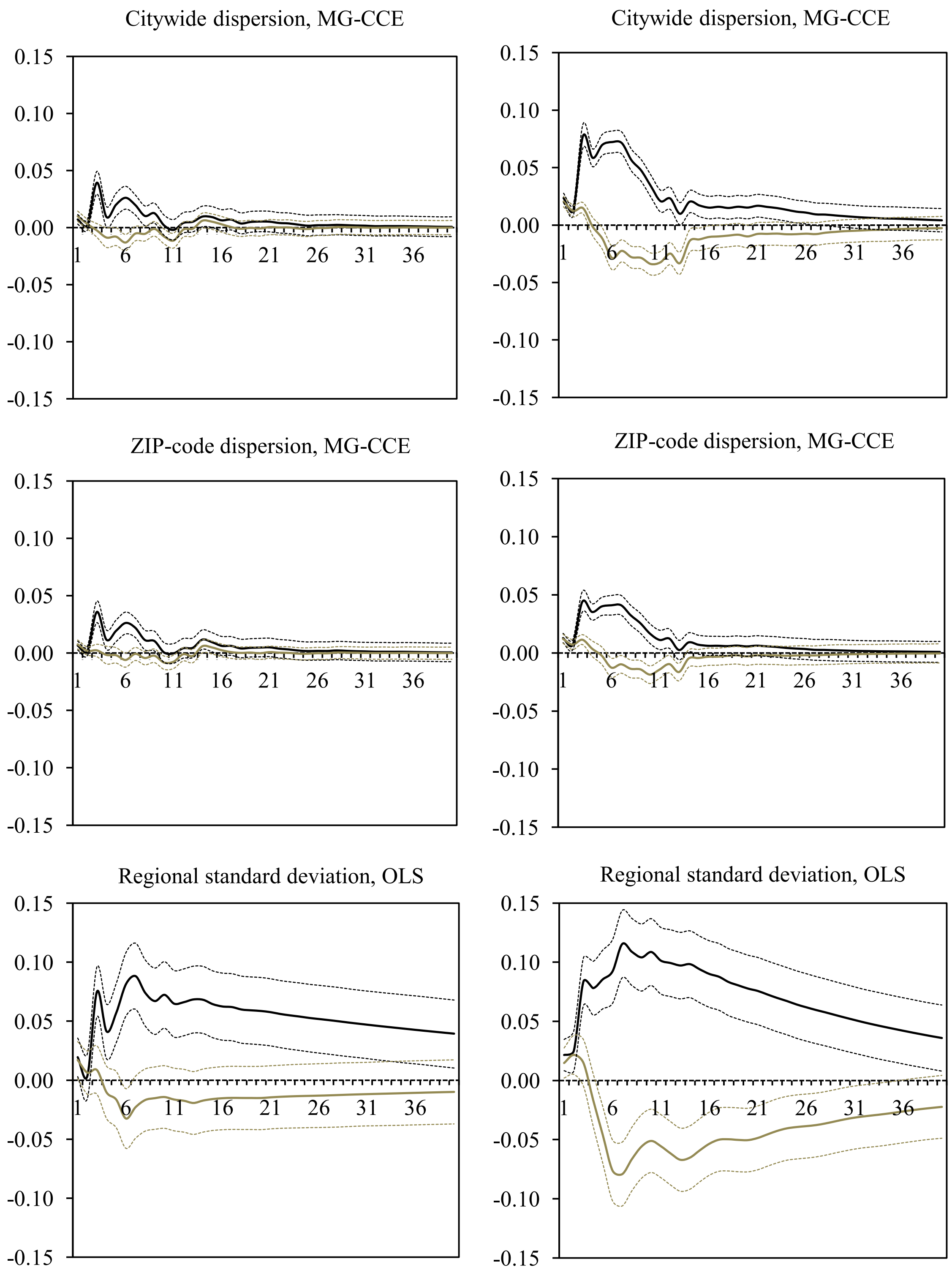
a) Madrid b) Catalonia



The solid black and grey lines represent the cumulative response of retail price dispersion to a unit positive and negative change in wholesale prices, respectively. Dashed lines denote their corresponding 95% confidence intervals.

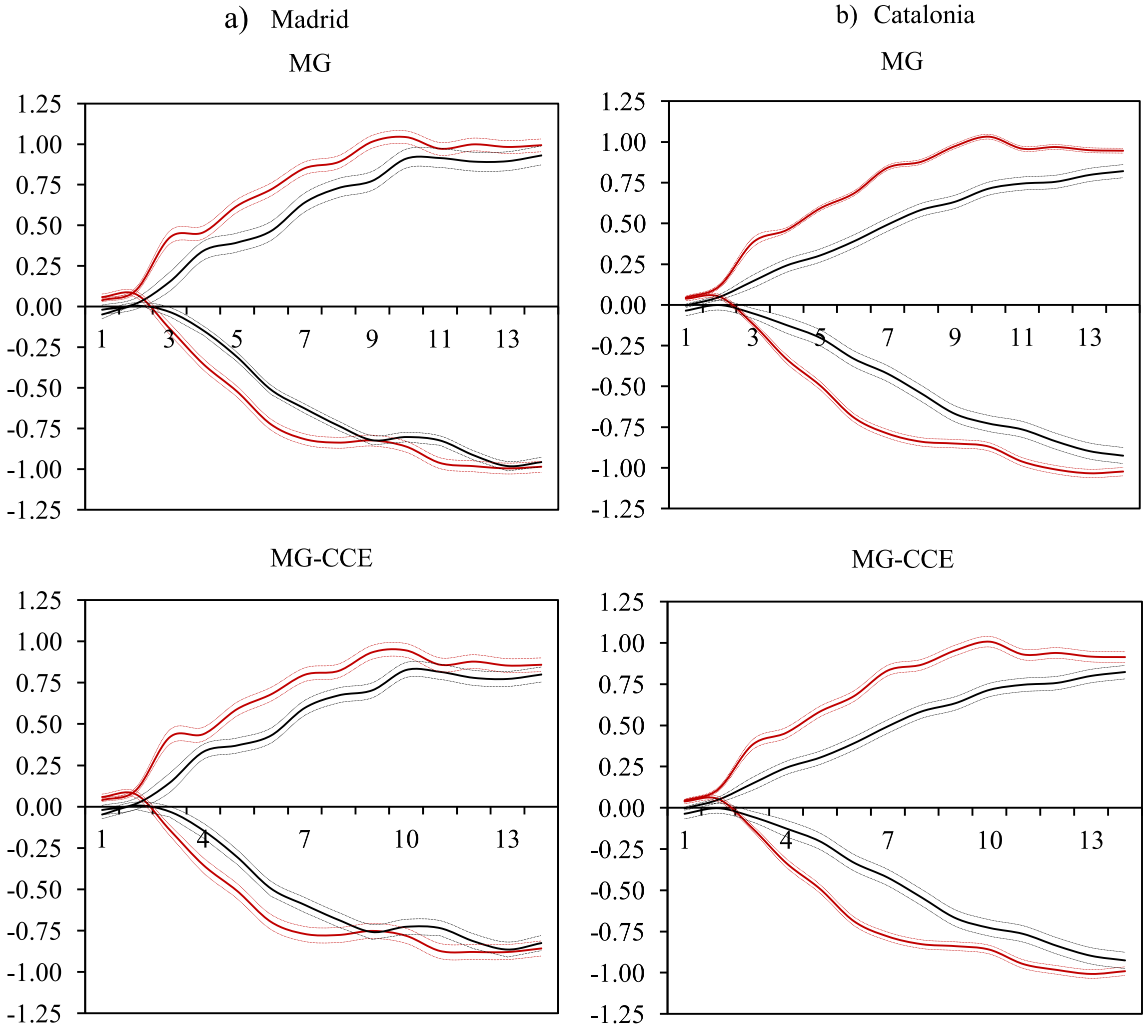
Figure 2. Robustness checks for dynamic responses of retail price dispersion

a) Madrid b) Catalonia



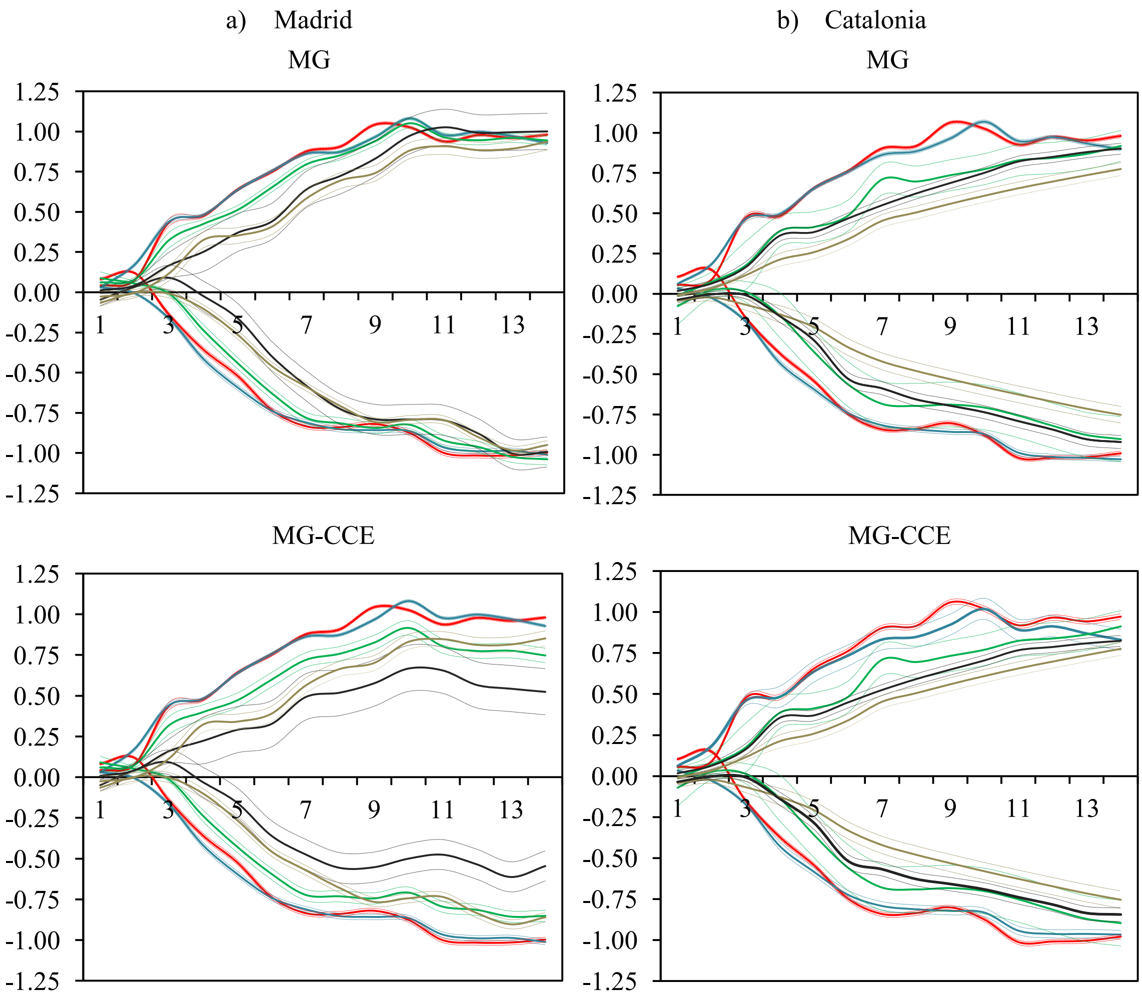
The solid black and grey lines represent the cumulative response of retail price dispersion to a unit positive and negative change in wholesale prices, respectively. Dashed lines denote their corresponding 95% confidence intervals.

Figure 3. Response of retail prices for expensive and cheap stations at regional level



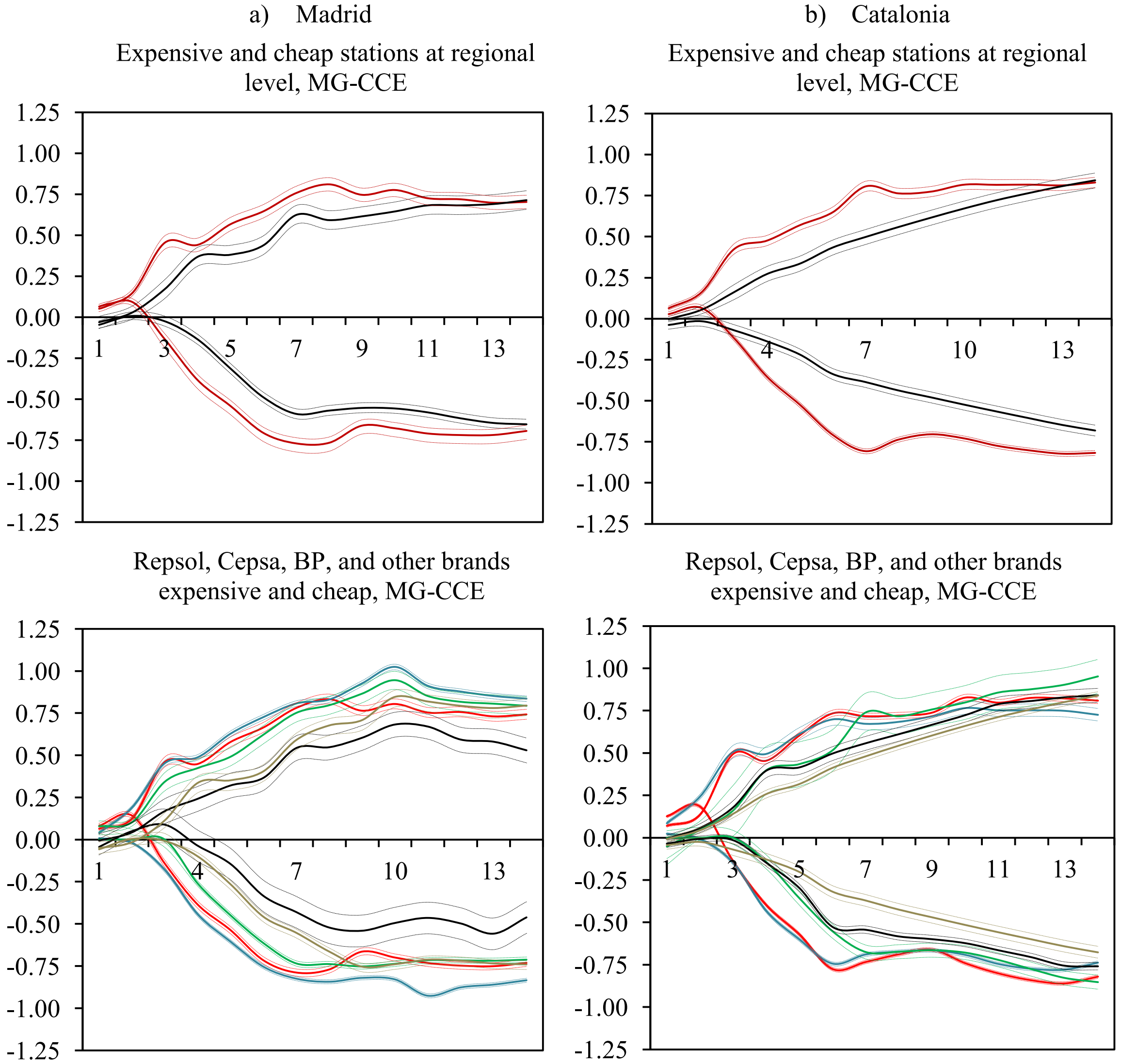
The increasing and decreasing solid lines represent the cumulative retail price responses to a unit positive and negative change in wholesale prices, respectively. The dark red (black) colors correspond to those petrol stations denoted as expensive (cheap) because their daily prices are above (below) the daily cross-sectional mean of each region during equal or more than 90% of days covering the sample period. Dashed lines symbolize the corresponding 95% confidence intervals.

Figure 4. Response of retail prices for Repsol, Cepsa, BP, and other expensive and cheap brands at regional level



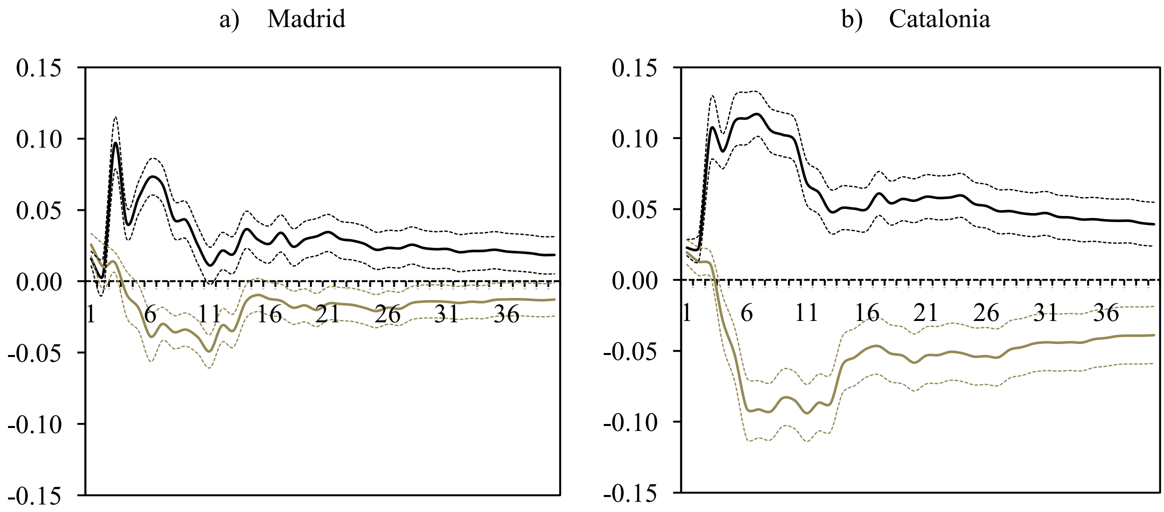
The increasing and decreasing solid lines represent the cumulative retail price responses to a unit positive and negative change in wholesale prices, respectively. On the one hand, light red, blue and green color lines correspond respectively to those petrol stations belonging to Repsol, Cepsa, and BP. On the other hand, dark grey (light grey) color lines correspond to the remaining gas stations of the sample that are denoted as expensive (cheap) prices because their daily prices are above (below) the daily cross-sectional mean of each region during equal or more than 90% of days covering the sample period. Dashed lines symbolize the corresponding 95% confidence intervals.

Figure 5. Robustness check of the response of retail prices from an extended version of Eq. (2) allowing for asymmetries in the speed



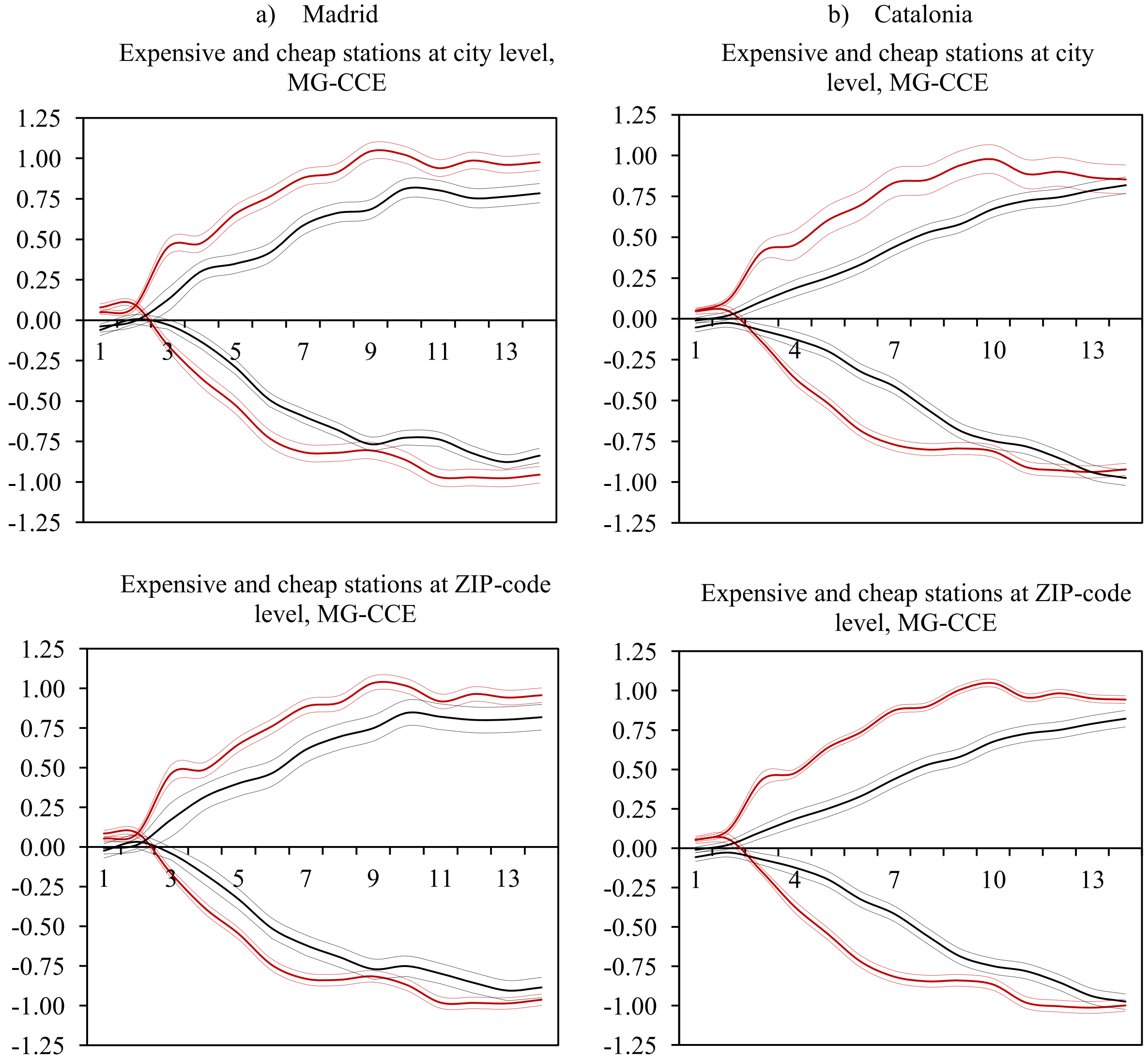
The increasing and decreasing solid lines represent the cumulative retail price responses to a unit positive and negative change in wholesale prices, respectively. At the top of the Figure, dark red and black color lines correspond respectively to expensive and cheap stations at regional level. At the bottom of the Figure, bright red, blue and green color lines refer respectively to those petrol stations belonging to Repsol, Cepsa, and BP; while black (grey) color lines correspond to the remaining gas stations of the sample that are denoted as expensive (cheap) at regional level. Dashed lines symbolize the corresponding 95% confidence intervals.

Figure B1. Dynamic responses of retail price dispersion at regional level (based on the fixed effects estimates for Eq. (1) with clustered standard errors by both city and brand)



The solid black and grey lines represent the cumulative response of retail price dispersion to a unit positive and negative change in wholesale prices, respectively. Dashed lines denote their corresponding 95% confidence intervals.

Figure F1. Response of retail prices for expensive and cheap stations at city and ZIP-code level



The solid lines represent the cumulative retail price responses to a unit positive and negative change in wholesale prices, respectively. The dark red (black) colors correspond to those petrol stations denoted as expensive (cheap) because their daily prices are above (below) the daily cross-sectional mean of each city or ZIP-code during equal or more than 90% of days covering the sample period. Dashed lines symbolize the corresponding 95% confidence intervals.

Appendix A. Diesel fuel taxes in Spain

Diesel fuel prices in Spain are levied by a general indirect tax on consumption and a set of excise duties. On the one hand, the indirect tax on consumption corresponds to the value added tax (VAT), which presents a common rate to the entire territory ranging from 16% to 21% during the analyzed period. On the other hand, the excise duties are composed by three special hydrocarbon taxes: a general section (0.307 €/litres), a State section (0.024 €/litres) and a regional section, which can differ between Madrid and Catalonia in accordance to the criteria of the autonomous governments. Table A1 summarises the Spanish taxation structure for diesel fuel from 1st May 2010 to 26th August 2014.

[Please, insert Table A1 about here]

According to previous information, fuel taxes have been excluded from retail prices by using the following equation:

$$rp_{it} = \frac{p_{it}}{1 + VAT_t} - (SHT_{it}) \qquad (A1)$$

where rp_{it} represents the net-of-tax retail price for each seller i and each time period t, p_{it} is the gross-of-tax price, VAT_t is the value added tax, and SHT denotes the special hydrocarbon taxes.

Appendix B. Estimates from Eq. (1) based on fixed effects

[Please, insert here Figure B1]

Appendix C. Stationarity properties of the alternative measures of price dispersion

Table C1 reports the results of the Augmented Dickey-Fuller and Phillips-Perron unit root tests applied to the citywide dispersion, ZIP-code dispersion and the standard deviation of daily retail prices. As can be seen, they suggest that these measures of price dispersion in Madrid and Catalonia are stationary. Therefore, similarly than before, we cannot assume the existence of a long-run relationship between the standard deviation of retail prices and the wholesale price.

[Please, insert Table C1 about here]

Appendix D. Robustness check for Eq. (1)

[Please, insert here Table D1]

Appendix E. Stationary properties of panel data on retail prices

The Table E1 reports the results for the Breitung and Das (2005) panel unit root tests on retail prices. As can be seen, the null hypothesis of non-stationarity cannot be rejected for the level of the variable in any case. However, when we take first differences, the null hypothesis of non-stationarity is rejected at the 1% level of significance. Then, test results suggest that retail prices are integrated of order one, I(1), both in Madrid and Catalonia.

[Please, insert Table E1 about here]

Appendix F. Expensive and cheap stations at city and zip-code level

[Please, insert here Figure F1]

Appendix G. Robustness check for Eq. (2)

[Please, insert here Table G1]