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Analysis of Brand Influence in the Rockets and Feathers Effect Using Disaggregated Data

Abstract

This paper studies price asymmetries (the 'rockets and feathers effect') at the firm level using an approach that fundamentally differs from the previous literature**.** The research analyses the Spanish oil market, using more than 11 million daily price records from December, 23, 2014, to December 31, 2017. We apply the most common econometric approach to investigate asymmetry, the error correction model, and find asymmetries for all brands, either classic brands or low-cost flag brands. Classic brands make price adjustments in shorter periods, whereas supermarket brands, as well as independent and low-cost brands, correct prices only slowly. This research makes an original contribution to the study of the rockets and feathers phenomenon using brands as the units of analysis. The speed of price adjustments is especially relevant to understanding oil market price dynamics.

Keywords: Oil pricing; price adjustments; rockets and feathers; oil market

1. Introduction

The liberalization of the oil sector has led to the emergence of new brands and new types of service stations that have altered the market's configuration and rules, shifting from an oligopolistic status quo towards free competition. The literature on this topic has consequently employed different strategies to identify whether the price-setting behaviour of gasoline retailers differs significantly from the perfectly competitive ideal (Kihm et al., 2016). Moreover, it is widely accepted that, in unregulated markets, an increase in the number of firms hinders collusion: the higher the number of brands, the greater the potential benefits of deviating from a collusive agreement (e.g. Motta, 2004). The same holds for firm heterogeneity: the more firms differ, for example, in terms of market share, the harder it is to collude (Dijkstra et al., 2017).

The literature is also very rich in terms of studies analysing the asymmetry of retail price responses to increases and decreases in wholesale prices in the oil market, namely, the 'rockets and feathers' effect.[1] This

[1] The effect is named this way to explain that increases in the price of oil are immediately transferred to the final price at the gas station (to the consumers), as if it were a rocket, but drops in oil prices are transmitted more slowly to the retailers, like a feather falling, slowed down by air resistance. Asymmetries imply that, when fuel prices increase, domestic prices at gas stations, before taxes, react faster than when international prices decline. According to neoclassical theory, prices are transmitted symmetrically for optimal resource allocation, with companies that seek to maximize profits in a competitive market adapting their prices to new cost conditions immediately and symmetrically. Price

phenomenon has been connected to crude oil and retail prices since 1991, with Bacon's (1991) famous article on the UK market, and immediately after Kirchgässner and Kübler (1992) published their article on the German market. Since then, a sizeable literature has developed evaluating empirical evidence with respect to such asymmetries in the transmission of prices from petrol to gas stations (i.e. Borenstein et al., 1997; Brown and Yücel, 2000; Radchenko, 2005; Panagiotidis and Rutledge, 2007). The research on the rockets and feathers effect differs by country, sample period and data frequency, econometric model, and research question (Kristoufek and Lunackova, 2015).

Several papers – most prominently those of Verlinda (2008) and, more recently, Eleftheriou et al. (2018) – have highlighted the strong influence of local market conditions and spatial dependence in rockets and feathers behaviour. Verlinda, using weekly data, finds that brand identity, proximity to rival stations, and local market features and demographics influence a station's predicted price–response asymmetry. Recently, Cardoso et al. (2016), using weekly prices to study the Brazilian oil market, has shown positive price asymmetry in spatial competition, suggesting that price asymmetry is a firm-level feature and should therefore be tested at the firm level, and not at the country, state, or city level, as is customary in the rockets and feathers literature. Gas stations with higher margins, fewer rivals nearby, and non-white flags (branded gas stations) have a higher probability of exhibiting positive asymmetry. Cardoso et al. (2016) indicate that being a white flag (unbranded gas stations) decreases the probability of exhibiting positive asymmetry. These authors' results also associate positive price asymmetry with company brands.

The study of the asymmetry of fuel prices (i.e. rockets and feathers effect) is important to determine the current competitiveness level of the retail fuel market and whether companies maintain strong market power. Such brand market power can lead to collusive behaviour, as indicated by Bacon's (1991, p. 211) seminal paper examining the industry for evidence of noncompetitive pricing and collusive behaviour. In the most recent inquiry, a major point of concern is the suggestion that companies used their market power to set prices unjustifiably high relative to costs. In particular, it was suggested that, when faced with cost increases, companies rapidly adjust prices upwards, but, when faced with cost decreases, they adjust prices downwards more slowly, thus permitting a temporary level of high profits.

The literature specifically on the rockets and feathers effect in Spain is sparse, and the findings tend to be inconclusive, with mixed results since the initial papers (e.g. Galeotti et al., 2003; Perdiguero, 2006; Contín-Pilart et al., 2008, 2009; Balaguer and Ripollés, 2012). All these studies were performed during and after the liberalization of the oil sector in Spain, when the Spanish petrol market underwent major restructuring, transforming from a state monopoly run by Campsa (now Repsol) to a completely free market in less than two decades (Perdiguero and Borrell, 2007; Perdiguero, 2010, 2012; Jiménez et al., 2013). At present, all the segments that make up the industry (refining, transportation, distribution, and retail) are fully liberalized (Karagiannis et al., 2015). Despite this optimistic view, some scholars observe imperfect competence, particularly in the retail market (Contín-Pilart et al., 2004). Bello and Contín-Pilart (2012) suggest that 'traditional practices' from the monopoly era persist since the Spanish market was liberalized. Additionally, the landscape has dramatically changed, with important legislative reform accompanying the enactment of Law 11/2013 of 26 July. Among other issues, the new law stipulates that, in exclusive supply contracts between retailers, there can be no exclusive clauses that, individually or jointly, directly or indirectly, affect the retail price of the fuel. Because of this legal measure, already in force since July 2014, retail oil companies, that is, service stations or gas stations, need to establish their own pricing methods, changing the status quo of the Spanish market. These legislative changes, incurring a true market shock, and the inconclusive results of previous studies justify our new analysis revisiting the rockets and feathers effect in Spain with a novel approach (using disaggregated data and focusing in the brands).

In this context, the purpose of this paper is twofold: first, to assess the role of brands in the rockets and feathers effect in the Spanish market, observing the price influence of the new types of stations that have emerged within the liberalization framework, and, second, to assess the influence of data disaggregation (daily

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asymmetries are therefore linked to less competitive markets and imply a different wealth distribution from that which could be obtained under symmetry, since it alters the timing and/or magnitude of the welfare changes associated with price changes (Meyer and von Cramon-Taubade, 2004).

prices) in the results. Our research question therefore asks what role brands play in establishing prices; the evolution, symmetry, and speed of adjustment of prices; and, therefore, the influence of prices in the rockets and feathers effect in Spain.

The results show asymmetry for all the brands studied, both classic and supermarket brands, as well as for low-cost brands and aggregated independent stations. On the other hand, the speed of price adjustment is observed to be much higher among classic brands than among the rest of them. Therefore, we make multiple contributions to the academic literature on the liberalization of oil retail pricing. Importantly, we delve into the study of the speed of price adjustments when studying the interlinkage between brands and the rockets and feathers effect. We can thus evaluate differences in asymmetry between brands, which is not possible when analysing the rockets and feathers effect at a unified level in geographical areas or complete markets. Additionally, this is one of the first papers about brand influence in the rockets and feathers effect in the Spanish market. It is also novel in its use of daily prices in this context, especially when estimations with aggregated data clearly tend to overestimate the persistence of shocks (Balaguer and Ripollés, 2012) and can lead to a loss of efficiency in econometric estimates that is sufficiently large to hide the rockets and feathers phenomenon (Balaguer and Ripollés, 2016).

This study comprises five sections. Section 2 reviews the literature about price adjustments and price asymmetry in the oil markets. Section 3 presents the method of analysis and the data sample. Section 4 presents the empirical analysis and results. Finally, Section 5 draws conclusions and presents the paper's implications for retail oil sectoral strategy, as well as limitations and avenues for future research.

2. Literature review

The wider corpus of empirical studies on oil retail pricing is focused on the U.S. market, using theoretical models developed from game theory, as well as different empirical approaches with time series and panel data (e.g. Borenstein, 1991; Zimmerman, 2012; Aboura and Chevallier, 2017). There is also a growing literature in Europe (Galeotti et al., 2003), with examples from different countries — such as Germany (Kreuz and Müsgens, 2016; Kihm et al., 2016), the United Kingdom (Ning and Haining, 2003), Austria (Pennerstorfer, 2009), Italy (Andreoli-Versbach and Franck, 2015), the Netherlands (Lach and Moraga-González, 2017), Belgium (Van Meerbeeck, 2003), Spain (Palencia-González, 2016b), and the 'tight oligopoly' in Serbia (Veselinovic et al., 2016) – as well as other geographical contexts, such as Canada (e.g. Eckert, and West, 2005; Godby et al., 2000; Suvankulov et al., 2012), New Zealand (Liu et al., 2010), Chile (Balmaceda and Soruco, 2008), and Australia (i.e. Wang, 2015; De Roos and Katayama, 2013).

We can determine different areas of focus in the oil market literature. Eckert (2013) suggests distinguishing between studies focusing on price dynamics, on the one hand, and studies analysing the determinants of price levels, on the other hand. Accordingly, we can establish four research categories. The first group comprises studies analysing the asymmetry of retail price responses to increases and decreases in wholesale prices (Verlinda, 2008; Liu et al., 2010; Karagiannis et al., 2015; Blair et al., 2017). The second group analyses different issues related to Edgeworth cycles, with mixed results (Maskin and Tirole, 1988; Noel, 2007; Noel and Chu, 2015). The third research area concentrates on the impact of vertical relations and regulations on retail gasoline prices (Barron and Umbeck, 1984; Hastings, 2004). Finally, the fourth research category analyses station-level price dispersion and examines the extent to which price differences can be explained by differences in station characteristics or by differences in the level of local competition (i.e. Barron et al., 2004; Clemenz and Gugler, 2006; Haucap et al., 2016, 2017). For example, Moraga-Gonzalez and Lach (2009) investigate how the distribution of prices changes with the number of competitors in the Netherlands, showing that competition has an asymmetric effect on prices and that consumers' competitive gains depend on their shopping behaviour. In particular, studies focusing on dynamic pricing behaviour and the characteristics of price cycles, as well as those analysing station-level price dispersion and the determinants of price levels, have received substantial attention (i.e. Eckert 2013; Noel and Chu 2015; Haucap et al., 2017); however , as has been indicated, very few study these topics in the context of the rockets and feathers phenomenon.

Verlinda (2008) sheds light on the possible causes of price–response asymmetry in retail gasoline prices. In particular, the effects of branding, geographic isolation, and other site-level characteristics that further differentiate stations are consistent with an explanation based on tacit pricing coordination among stations. New research (Remer, 2015) indicates that the gains from consumer search are inversely related to the magnitude of the price asymmetry. Remer (2015) confirms this relation by quantifying the connection between market price dispersion and the degree of price asymmetry; markets with a broader price range or variance (both positively correlated with gains from search) are found to adjust more slowly to cost increases and faster to decreases. Local market power has also been investigated by Koch et al. (2015): in regions where gasoline retailers do not face strong competition from neighbouring rivals, retailers succeed in raising price margins permanently (for the long run), and not just temporarily (for the short run), as suggested by the rockets and feathers phenomenon. Other authors consider rockets and feathers observations to be better explained by product-specific differences in menu costs (Loy et al., 2016).

Deltas (2008) finds positive rockets and feathers asymmetry for some U.S. states, where retail prices respond faster to wholesale price changes in states with smaller price–cost margins. Nowakowski and Karasiewicz (2016) investigate the relation between market structure and market behaviour characteristics (e.g. market concentration, the presence of networks operated by global corporations, the presence of vertically integrated companies, the presence of hypermarket gasoline stations, and consumption levels) and price–cost margins, based on the example of the European Union retail gasoline market. Their research supports the findings of prior studies, finding a positive influence of market concentration on price–cost margins. It can be argued that brands facing wholesale changes take into account these price–cost margins in the adequacy of their prices, thus influencing the rockets and feathers phenomenon.

The literature also considers that local marker power can discriminate between prices (Livingston and Levitt, 1959; Borenstein, 1991; Shepard, 1993). Generally, we observe that the local market configuration, which depends on the number of competitors (Van Meerbeeck, 2003) or flag brands (Pennerstorfer, 2009), has an influence on the variability of prices. More recently, Kihm et al. (2016) have shown that the influence of the Brent price on gas prices in Germany becomes stronger as the degree of local competition increases, as measured by variation in market concentration, the density of competing stations, and spatial isolation from competing stations. Although their results clearly indicate that gas station price setting deviates from what would be expected under perfect competition, the magnitude of this deviation does not appear to warrant such a drastic restriction on price setting flexibility.

In any case, given evidence of the influence of brands and the number of competitors in the price–cost margins and the adjustment of prices, we consider, as a working hypothesis, that the symmetry and speed of the adjustment (movements of the rockets and feathers type) are related to firm brands.

3. Methodology and data

3.1 Method of analysis

In terms of methods of analysis, the most common econometric approach to investigate asymmetry is the error correction model (ECM), based on the two-step procedure of Engle and Granger (1987). The model has been frequently applied in multiple investigations and widely disseminated (Dbouk and Jamali, 2018), especially after its use by Borenstein et al. (1997), which has influenced many subsequent studies and serves as a key reference. We follow this classic model, since it is widely accepted and allows comparisons of the results with other studies. Recent studies using this method and small variations thereof include those of Apergis and Vouzavalis (2018) for some European markets, Frondel et al. (2019) for Germany, Campbell and Mixon (2017) and Remer (2015) for the United States, and Chen et al. (2017) for China. The method proposed by Borenstein et al. (1997) allows potential spurious correlation problems to be minimized for nonstationary time series (in mean and/or variance). However, the indicated method requires compliance with the following conditions:

i) The time series are integrated of order one, I(1), that is, they are not stationary in levels but are stationary in differences of order one.

ii) The time series in levels can be combined linearly in a stationary manner. Therefore, as a starting point for the analysis, whether the series are nonstationary in levels or first differences must be checked. These checks are carried out by comparing the augmented Dickey–Fuller (ADF) and Philips–Perron (PP) unit root test results. In both cases, the null hypothesis is that the series is nonstationary in levels and, therefore, there exists a unit root.

Condition ii) is achieved by estimating the long-term relation between diesel sales and purchase prices:

$$PBT_t = \beta_0 + \beta_1 IQ_t + \varepsilon_t \qquad (1)$$

For diesel A, the price before taxes, PBT, is estimated from the international quotation, IQ, of Brent oil. The fundamental reason for predicting the price before taxes with the parameters estimated in (1) is the very strong correlation between the international weekly price of Brent oil and the international weekly price of diesel A (>98%, as calculated by Palencia-González, 2016a). The correlation between the daily Brent price and the price after taxes is above 96% (Palencia-González, 2016b). Figure 1 illustrates the evolution of Brent prices and the different brands' prices after taxes. Thus, equation (1) constitutes the long-term model, which is also the first stage of the ECM, where PBT_t and IQ_t are, respectively, the observed pretax price and the international quotation in week t, with model residuals ε_t and parameters β_0 and β_1.

Next we analyse the stationarity of the residuals obtained in the long-term model, applying the augmented ADF and PP tests again. If we the residuals we obtain are stationary, we can conclude that the price series, IQ, and PBT are cointegrated and evolve together in the long term.

In the second stage of the ECM, we check whether the price series have deviations in the short term in relation to the long-term model. In this stage, the proposed specification for the estimation is as follows:

$$\Delta PBT_t = \delta\hat{\varepsilon}_{t-1} + \sum_{i=0}^{n} \beta_i^+ \Delta IQ_{t-i}^+ + \sum_{i=0}^{m} \beta_i^- \Delta IQ_{t-i}^- + u_t \qquad (2)$$

where ΔPBT_t is the first difference of the pretax prices, that is, weekly price differences; $\Delta IQ_t^+ = \max\{\Delta IQ_t, 0\}$ and $\Delta IQ_t^- = \max\{\Delta IQ_t, 0\}$ are positive and negative weekly differences, respectively; and the $\hat{\varepsilon}_{t-1}$ terms are the residuals obtained in the first stage that are incorporated into the specification with a lag. It is thus possible to capture whether increases and decreases in the international price are transferred differently to the sale prices, and, if so, there would be evidence of asymmetries that will be positive if $\beta_i^+ > \beta_i^-$ and negative in the opposite case.

It is evident that, in equation (2), the number of lags to include in both summations (n and m) must be determined, and the choice will be based on the value of the Schwarz information criterion, following Contín et al. (2008). Wald's test will be used to compare the existence of asymmetries and their equality or non-equality ($\beta_i^+ = \beta_i^-$). Finally, the cumulative functions are constructed from

$$Ac_n^+ = Ac_{n-1}^+ + \beta_n^+ + \delta(Ac_{n-1}^+ - \rho_1) \qquad (3)$$

$$Ac_n^- = Ac_{n-1}^- + \beta_n^- + \delta(Ac_{n-1}^- - \rho_1) \qquad (4)$$

Obviously, equation (2) could also incorporate the past dynamics of the dependent variable, according to the following specification:

$$\Delta PBT_t = \delta\hat{\varepsilon}_{t-1} + \sum_{i=0}^{n} \beta_i^+ \Delta IQ_{t-i}^+ + \sum_{i=0}^{m} \beta_i^- \Delta IQ_{t-i}^- + \sum_{i=0}^{r} \gamma_i \Delta PBT_{t-i} + u_t \qquad (5)$$

where ΔPBT_{t-i} is the daily difference (which can range from a lag of one to r) in PBT.

To test the robustness of our work, we carry out a regression (panel model with fixed effects) with dummy variables introduced for each of the brands, as well as their interactions with increments and decrements of IQ. We thus obtain an unrestricted specification with (B*KI) + (B*KD) + 1 parameters to estimate, considering B (the number of brands) and KI and KD (the numbers of increments and decrements, respectively), as follows:

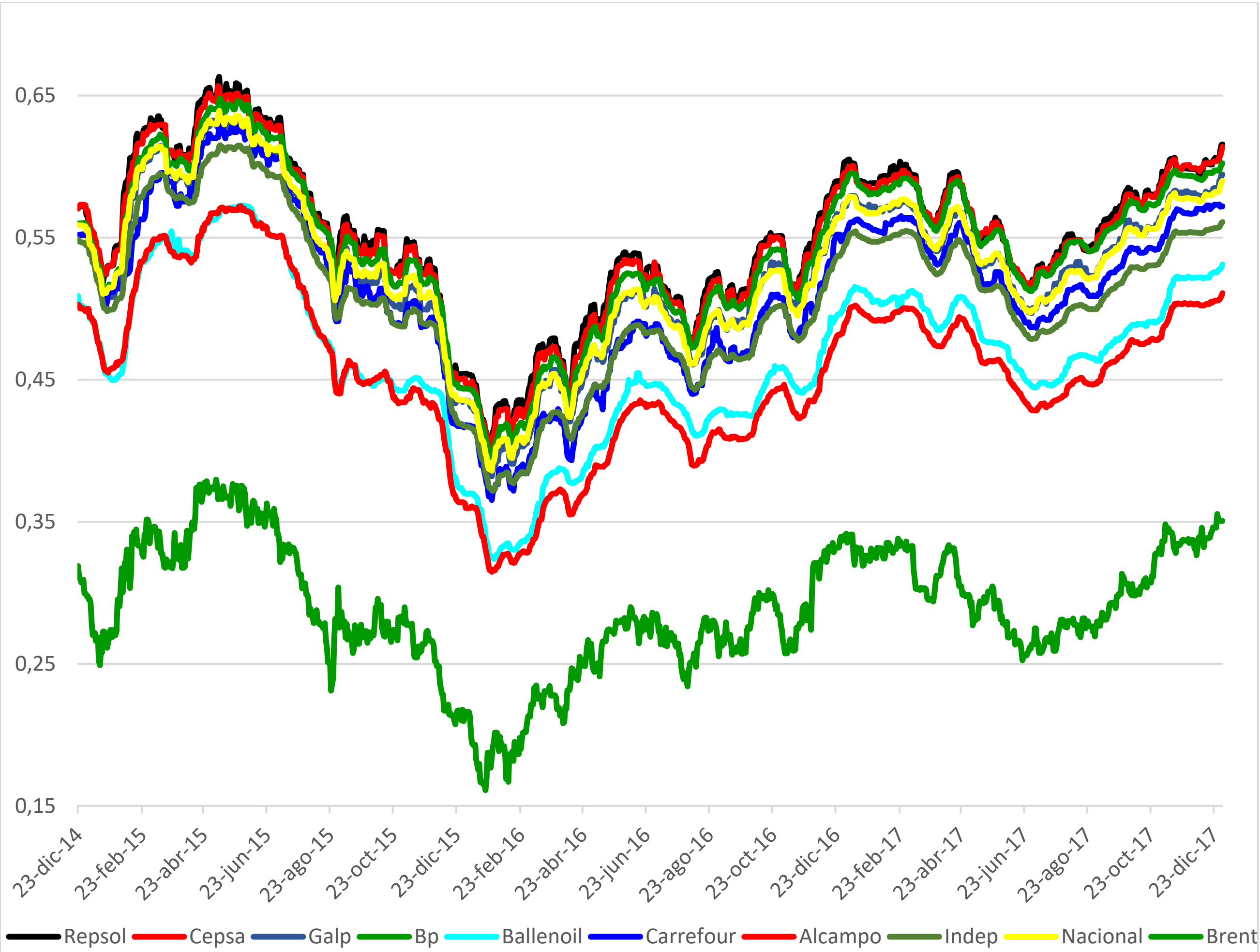
$$\Delta PBT_{jt} = \sum_{j=1}^{k} \sum_{i=0}^{n} \beta_{ji}^{+} IBQ_{jt-i}^{+} + \sum_{j=1}^{k} \sum_{i=0}^{n} \beta_{ji}^{-} IBQ_{jt-i}^{-} + u_t \quad (6)$$

The variables are the result of the interactions of each brand with the increases and decreases in the international price $IBQ_{jt-i}^{+} = B_j \cdot \Delta IQ_{t-i}^{+}$, $IBQ_{jt-i}^{-} = B_j \cdot \Delta IQ_{t-i}^{-}$.

3.2 Data sample

For our data sample, we compiled the daily prices of all oil stations in Spain between December 23, 2014, and December 31, 2017 (three years). The data comprise 1,106 files, with over 9,000 stations, yielding more than 10 million daily diesel prices from Monday to Sunday.[2] We start our study on December 23, 2014, because a structural change that took place in the Spanish market due to a relevant regulatory change enacted in July 2014 (law 11/2013 of 26 July).

Figure 1. Prices per brand, before taxes



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[2] These data were obtained daily from the website geoportalgasolineras.es of the Ministry of Industry, Energy and Tourism.

We have established a sample space consisting of a wide range of companies, detailed in Table 1. The sample includes four classic companies with substantial market power and very recognizable brands – Repsol, Cepsa, Galp, and BP, that is, the classic brands – with a total market share of over 56% (see Table 1); a low-cost brand (Ballenoil); two important nationwide supermarket chains, namely, Carrefour and Alcampo (Auchamps); and independent stations (Indep) constituting a wide sample of various brands with a presence in the market. Figure 1 shows their price evolution and includes the Brent price and the average price of all gas stations in the country ('Nacional'), for better comparison. Figure 1 also shows that the average daily price is higher for the classic brands than for the other (low-cost, supermarket, and independent) agents, leading us to consider that brands could play a role in price adjustments and their evolution. One can also observe that the classic brands have average prices above the national average; only Galp has prices similar to the national average; on the other hand, the prices of supermarket chain and independent stations are below the national average, as is the case for low-cost stations.

Table 1. Number of stations per brand and year

	2015		2016		2017		All	
Brand	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**
Repsol	3187	34,90%	3156	33,38%	3123	32,25%	3156	33,50%
Cepsa	1341	14,69%	1366	14,45%	1384	14,29%	1363	14,47%
Galp	550	6,02%	542	5,73%	550	5,68%	547	5,81%
BP	384	4,21%	395	4,18%	423	4,37%	400	4,25%
Ballenoil	54	0,59%	72	0,76%	88	0,91%	71	0,75%
Carrefour	117	1,28%	122	1,29%	138	1,43%	126	1,34%
Alcampo	50	0,55%	53	0,56%	54	0,56%	52	0,55%
Indep	1774	19,43%	1852	19,59%	1899	19,61%	1841	19,54%
Others	1674	18,33%	1896	20,06%	2024	20,90%	1864	19,79%
National	9131	100%	9454	100%	9683	100%	9420	100%

The descriptive statistics are presented in Table 2 and show that the average prices for the classic companies are higher, and the lowest prices are for the low-cost flag stations and one of the hypermarkets. The differences between the hypermarkets lie in their discount policies: while one (Alcampo) offers a discount in the price at the time of purchase and thus offers lower prices, the other (Carrefour) does so through discounts afterwards. On the other hand, the prices of independent operators can be verified as being between those of the classic flags and of the low-cost operators, and somewhat below the national average.

Table 2. Price Before Taxes: Descriptive statistics

	2014					2015				
Brand	Mean	Median	Std Dev	Min	Max	Mean	Median	Std Dev	Min	Max
Repsol	0,578	0,572	0,045	0,454	0,663	0,501	0,509	0,045	0,401	0,603
Cepsa	0,575	0,572	0,052	0,448	0,657	0,497	0,505	0,045	0,402	0,596
Galp	0,556	0,552	0,053	0,433	0,636	0,477	0,489	0,045	0,382	0,574
Bp	0,568	0,560	0,052	0,444	0,648	0,490	0,501	0,045	0,395	0,588
Ballenoil	0,496	0,494	0,053	0,370	0,573	0,413	0,425	0,044	0,324	0,503
Carrefour	0,547	0,546	0,054	0,417	0,630	0,455	0,465	0,044	0,365	0,552
Alcampo	0,494	0,495	0,056	0,363	0,572	0,398	0,409	0,042	0,315	0,488
Indep	0,542	0,544	0,051	0,417	0,615	0,454	0,465	0,042	0,372	0,544
Nacional	0,560	0,558	0,052	0,435	0,639	0,478	0,488	0,043	0,386	0,574

	2016					2014-2016				
Brand	Mean	Median	Std Dev	Min	Max	Mean	Median	Std Dev	Min	Max
Repsol	0,571	0,577	0,026	0,516	0,616	0,550	0,550	0,055	0,401	0,663
Cepsa	0,570	0,576	0,025	0,516	0,614	0,548	0,548	0,055	0,402	0,657
Galp	0,550	0,556	0,025	0,497	0,594	0,528	0,529	0,056	0,382	0,636
Bp	0,566	0,571	0,024	0,512	0,602	0,542	0,542	0,056	0,395	0,648
Ballenoil	0,489	0,491	0,024	0,445	0,531	0,466	0,463	0,057	0,324	0,573
Carrefour	0,537	0,542	0,025	0,487	0,573	0,513	0,515	0,059	0,365	0,630
Alcampo	0,475	0,478	0,024	0,428	0,511	0,456	0,455	0,059	0,315	0,572
Indep	0,527	0,530	0,024	0,479	0,561	0,508	0,506	0,056	0,372	0,615
Nacional	0,549	0,554	0,025	0,497	0,590	0,529	0,527	0,055	0,386	0,639

The different brands are not distributed symmetrically in geographic location or across local markets, which can influence the degree of asymmetric cost pass-through (Verlinda, 2008; Lewis, 2011). This information on market shares and market compositions can mitigate concerns related to this identification issue, since all classic and hypermarket brands have a solid and widespread presence throughout the country.

Regarding the level of aggregation of the data sample, there is broad consensus that the dynamics exhibited by a time series for heterogeneous individuals can differ markedly from those displayed by a time series derived from aggregation of the data, thus compromising the validity of the estimations when the latter time series is used (Pesaran and Smith, 1995; Pesaran, 2003). In our case, since we have complete daily information available from December 23, 2014, to December 31, 2017, we opt for daily analysis, especially considering that intraday price fluctuations are mainly driven by demand factors and competition (Haucap et al., 2016).

4. Empirical analysis and results

The long-term equations for each of the brands take on the values in Table 3, where standard errors are in parentheses and all values have a significance of 1%.

Table 3. Long-term equations per brand

Variable	Nacional	Repsol	Cepsa	Galp	Bp	Ballenoil	Carrefour	Alcampo	Indep.
const	0.186*** (0.008)	0.205*** (0.007)	0.202*** (0.007)	0.182*** (0.009)	0.198*** (0.009)	0.123*** (0.011)	0.154*** (0.010)	0.100*** (0.011)	0.169*** (0.010)
QI	1.190*** (0.027)	1.195*** (0.023)	1.196*** (0.024)	1.198*** (0.028)	1.190*** (0.028)	1.190*** (0.036)	1.246*** (0.034)	1.232*** (0.039)	1.173*** (0.033)
Adj R^2	0.900	0.920	0.915	0.899	0.897	0.863	0.861	0.841	0.865
Observ	1103								

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We need to verify that the time series are integrated of order 1, that is, they are not stationary in levels but, rather, in differences. The next step, therefore, is to analyse the stationarity of the residuals obtained in the long-term model. Accordingly, we check whether the series are stationary or not in levels and first differences. For this purpose, we use the unit root contrasts of the augmented ADF and PP tests. The results are presented in Appendix A (Table A.1), including the brand results and p-values. These values imply rejection of the null hypothesis, which indicates that the residuals are stationary. Consequently, the IQ and PBT series are cointegrated, and their prices evolve jointly in the long term.

In the second stage, the ECM itself is adjusted by means of equation (4). It is evident that, in this stage, the number of lags to include in both summations (n and m) must be chosen, and the decision will be based on the value of the Schwarz information criterion, following Contín et al. (2008). The results of this analysis are shown in Table 4.

In this case, all the F-statistics have a significance of 1%. Therefore, there is evidence of asymmetries in all cases for this period of analysis. Figure A.1 in Appendix A shows the cumulative functions by brand, Table A.2 presents the results of the analysis for the inertial model, and Table A.3 presents the results for the panel model with fixed effects (to test robustness).

Table 4. Second stage of ECM

Variable	Nacional	Repsol	Cepsa	Galp	Bp	Ballenoil	Carrefour	Alcampo	Indep.
$\hat{\varepsilon}_{t-1}$	−0.016*** (0.004)	−0.038*** (0.007)	−0.027*** (0.005)	−0.030*** (0.005)	−0.010** (0.004)	−0.012*** (0.004)	−0.031*** (0.005)	−0.008*** (0.003)	−0.007** (0.003)
ΔIQ_t^+	−0.0247* (0.013)	−0.038 (0.024)	−0.012 (0.023)	−0.028 (0.022)	−0.022 (0.017)	−0.024* (0.014)	−0.058 (0.038)	−0.015 (0.016)	−0.024** (0.011)
ΔIQ_{t-1}^+	−0.006 (0.021)	−0.016 (0.035)	−0.002 (0.027)	−0.061** (0.028)	−0.020 (0.017)	−0.031** (0.015)	−0.048** (0.024)	−0.039*** (0.014)	−0.014 (0.013)
ΔIQ_{t-2}^+	0.146*** (0.017)	0.240*** (0.029)	0.178*** (0.025)	0.115*** (0.029)	0.058*** (0.018)	0.000 (0.017)	−0.009 (0.028)	0.026* (0.015)	0.047*** (0.013)
ΔIQ_{t-3}^+	0.105*** (0.017)	0.118*** (0.028)	0.092*** (0.024)	0.098*** (0.024)	0.117*** (0.016)	0.031* (0.018)	0.050** (0.024)	0.026** (0.013)	0.069*** (0.011)
ΔIQ_{t-4}^+	0.107*** (0.019)	0.137*** (0.033)	0.122*** (0.025)	0.097*** (0.029)	0.101*** (0.017)	0.061*** (0.014)	0.024 (0.020)	0.038*** (0.013)	0.064*** (0.015)
ΔIQ_{t-5}^+	0.141*** (0.016)	0.178*** (0.033)	0.118*** (0.024)	0.129*** (0.024)	0.131*** (0.015)	0.049** (0.020)	0.141*** (0.026)	0.066*** (0.014)	0.096*** (0.012)
ΔIQ_{t-6}^+	0.088*** (0.014)	0.058** (0.026)	0.083*** (0.019)	0.089*** (0.022)	0.112*** (0.015)	0.058*** (0.015)	0.119*** (0.022)	0.096*** (0.014)	0.088*** (0.012)
ΔIQ_{t-7}^+	0.075*** (0.0153)	0.076*** (0.025)	0.033 (0.024)	0.066** (0.028)	0.108*** (0.017)	0.083*** (0.016)	0.094*** (0.026)	0.080*** (0.014)	0.089*** (0.014)
ΔIQ_{t-8}^+	0.096*** (0.0159)		0.121*** (0.023)	0.085*** (0.023)	0.105*** (0.014)	0.102*** (0.014)	0.113*** (0.025)	0.131*** (0.015)	0.096*** (0.011)
ΔIQ_{t-9}^+	0.042*** (0.0157)				0.057*** (0.014)	0.064*** (0.013)		0.081*** (0.012)	0.056*** (0.009)
ΔIQ_{t-10}^+					0.023* (0.013)	0.052*** (0.014)		0.035*** (0.011)	0.023*** (0.009)
ΔIQ_{t-11}^+					0.047*** (0.016)	0.065*** (0.013)		0.051*** (0.015)	0.055*** (0.014)
ΔIQ_{t-12}^+					0.043*** (0.016)	0.067*** (0.017)		0.049*** (0.012)	0.058*** (0.011)
ΔIQ_{t-13}^+					0.052*** (0.015)	0.039*** (0.012)		0.059*** (0.014)	0.051*** (0.011)
ΔIQ_{t-14}^+						0.037*** (0.012)		0.049*** (0.015)	0.041*** (0.011)
ΔIQ_{t-15}^+						0.047*** (0.015)		0.045*** (0.014)	0.036*** (0.012)
ΔIQ_t^-	−0.017 (0.017)	−0.014 (0.030)	−0.043* (0.025)	0.012 (0.022)	−0.03 (0.015)	−0.001 (0.011)	0.034 (0.024)	0.017 (0.011)	0.002 (0.011)
ΔIQ_{t-1}^-	−0.011 (0.019)	−0.036 (0.031)	0.031 (0.027)	−0.067*** (0.025)	−0.015 (0.016)	−0.018 (0.015)	−0.030 (0.026)	0.011 (0.014)	−0.004 (0.012)
ΔIQ_{t-2}^-	0.105*** (0.019)	0.210*** (0.030)	0.168*** (0.025)	−0.030 (0.023)	−0.006 (0.018)	0.015 (0.019)	−0.032 (0.025)	−0.007 (0.014)	0.010 (0.013)
ΔIQ_{t-3}^-	0.150*** (0.019)	0.223*** (0.032)	0.169*** (0.027)	0.093*** (0.022)	0.108*** (0.016)	0.011 (0.015)	0.094*** (0.025)	0.013 (0.015)	0.067*** (0.012)
ΔIQ_{t-4}^-	0.087*** (0.017)	0.086*** (0.030)	0.062** (0.028)	0.066*** (0.024)	0.134*** (0.016)	0.018 (0.016)	0.065** (0.027)	0.062*** (0.013)	0.079*** (0.012)
ΔIQ_{t-5}^-	0.100*** (0.018)	0.106*** (0.030)	0.105*** (0.022)	0.125*** (0.023)	0.122*** (0.017)	0.045*** (0.017)	0.069*** (0.023)	0.061*** (0.014)	0.088*** (0.014)
ΔIQ_{t-6}^-	0.130*** (0.017)	0.151*** (0.031)	0.125*** (0.023)	0.153*** (0.022)	0.164*** (0.016)	0.091*** (0.015)	0.136*** (0.022)	0.096*** (0.014)	0.105*** (0.012)
ΔIQ_{t-7}^-	0.064*** (0.017)		0.095*** (0.023)	0.092*** (0.024)	0.112*** (0.016)	0.050*** (0.015)	0.074** (0.036)	0.079*** (0.013)	0.071*** (0.012)
ΔIQ_{t-8}^-	0.051*** (0.020)			0.042 (0.027)	0.098*** (0.018)	0.054*** (0.018)		0.076*** (0.016)	0.079*** (0.015)
ΔIQ_{t-9}^-	0.055*** (0.019)			0.084*** (0.026)	0.059*** (0.020)	0.083*** (0.017)		0.084*** (0.021)	0.065*** (0.016)

ΔIQ_{t-10}^{-}	0.046*** (0.015)				0.064*** (0.017)	0.041** (0.019)		0.052*** (0.016)	0.059*** (0.013)
ΔIQ_{t-11}^{-}					0.040*** (0.014)	0.048*** (0.017)		0.059*** (0.011)	0.046*** (0.011)
ΔIQ_{t-12}^{-}					0.027** (0.016)	0.050*** (0.016)		0.047*** (0.015)	0.041*** (0.014)
ΔIQ_{t-13}^{-}						0.043*** (0.014)		0.018 (0.014)	0.025** (0.010)
ΔIQ_{t-14}^{-}						0.064*** (0.016)		0.023* (0.013)	0.038*** (0.013)
ΔIQ_{t-15}^{-}						0.024* (0.013)		0.037** (0.015)	0.025* (0.013)
Adj R^2	0.515	0.382	0.394	0.346	0.553	0.430	0.285	0.520	0.598
Schwarz	-10897.39	-9675.21	-10151.99	-10168.24	-10994.27	-11032.62	-9979.50	-11351.74	-11653.17
T. Wald	2.593*** (0.004)	2.640** (0.015)	6.711*** (0.000)	6.220*** (0.000)	2.933*** (0.000)	3.949*** (0.000)	4.620*** (0.000)	4.418*** (0.000)	2.894*** (0.000)

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Notes: N=1103. In the coefficients the standard error is in parentheses. Standard errors are robust to heteroscedasticity. The ***, **, * indicates that the corresponding null hypothesis is rejected at the 1%, 5%, 10% level of significance respectively. For the Wald test the p-values are shown in parenthesis.

5. Conclusions

Since the liberalization of the oil sector, the appearance of multiple types of companies coexisting with the companies that emerged from classic monopolies has altered the configuration of the market and its rules, shifting from an oligopolistic status quo towards free competition. The new types of brands have introduced new market dynamics that warrant study, including the determination of prices and their subsequent adjustment, including their speed and symmetry.

In this paper, using a diverse bundle of firm brands with disaggregated daily prices (from Monday to Sunday), we verify asymmetries in all the cases of the classic brands, hypermarkets, and low-cost flags that tested. We also observe that the classic brands perform price adjustments within shorter time intervals, whereas the supermarkets, independent brands, and cooperatives correct their prices more slowly. Classic brands that have more market power make their adjustments at higher speeds. They have more information. On the other hand, the rest of the operators must be supplied by big brands, and their reaction times are slower. We also note that the classic brands have higher average daily prices than the other agents (low-cost brands, supermarkets, cooperatives, etc.), thus revealing clearly different behaviours. This result is consistent with the literature (Balmaceda and Soruco, 2008), but the results on brand adjustment speed at the country level are a novel contribution.

Regarding the presence of asymmetries in all cases, our study distances itself from others by the use of daily data. The aggregation of the time series could sometimes explain why the rockets and feathers effect has not been unambiguously determined, even though it could actually be relevant (Balaguer and Ripollés, 2016). There is broad consensus that the dynamics exhibited by time series for heterogeneous individuals can differ markedly from those displayed by a time series derived from an aggregation of the data, thus compromising the validity of estimations when the latter time series are used (Pesaran and Smith, 1995; Pesaran, 2003). Inadequate temporal disaggregation could result in the omission of important short time lags, which can introduce significant bias in the estimates (Geweke, 1978). The average weekly data estimates also suffer from temporal aggregation bias (Bachmeier and Griffin, 2003; Chua et al., 2017). The discernment of these effects to reach precise conclusions constitutes a clear field of future research.

Additionally, it is worth noting that the adjustment speeds are different, with faster price adjustment among the classic brands, versus slower adjustment among supermarket chains, for example. This finding opens up new avenues of research on adjustment speeds and generally allows for comparisons between the different market players. The speeds of adjustment might not be merely opportunistic (Valadkhani and Smyth, 2018). Another area of research that deserves empirical investigation concerns the impact of the speed of the cost adjustments and inventories (Antoniou et al., 2017; Bayer and Ke, 2018) in the speed of price adjustments.

Our results have clear implications for the market. Given that asymmetries are detected in all brands, market imperfections are indicated, showing that the legislative changes introduced in 2013 (and effective as of mid-2014) have not been fully internalized. The results also have implications for consumers, given the price differences between companies, and differences in the speed of price adjustment are reported as well.

At the moment and in view of the data and the results, one cannot conclude that the appearance of new brands and types of service stations are sufficient to guarantee full competition. One of the possible causes is that these new brands mostly do not directly import the fuel and must be supplied by the classic brands in a wholesale role, which implies the dependence of the entire market on the three major fuel-importing companies. A greater number of importers could reduce that dependence.

This article has limitations, largely the result of the complexity of the method of analysis and the availability of data. Greater detail of the economic impact of price asymmetries and discrepancies in the speed of price adjustment would be a very significant additional contribution, one that is hardly achievable with the method selected in this paper. In any case, the results we obtain are, in themselves, genuine and of value to both scholars and practitioners.

Despite this study's exploratory nature, it makes an original contribution with a brand new perspective, using brands as the units of analysis; in particular, the speed of price adjustment is a relevant input to understand oil market price dynamics.

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APPENDIX A

Table A.1. Dickey-Fuller (ADF) and Philips-Perron (PP)

T. ADF	Nacional	Repsol	Cepsa	Galp	Bp	Ballenoil	Carrefour	Alcampo	Indep.
IQ	-0.009 (0.680)								
dIQ	-25.538*** (0.000)								
PBT	0.026 (0.691)	0.090 (0.711)	0.062 (0.703)	0.082 (0.709)	0.060 (0.702)	0.046 (0.698)	-0.052 (0.666)	-0.089 (0.653)	-0.059 (0.663)
dPBT	-8.70*** (0.000)	-14.56*** (0.000)	-11.47*** (0.000)	-8.49*** (0.000)	-8.40*** (0.000)	-7.16*** (0.000)	-9.08*** (0.000)	-7.42*** (0.000)	-7.12*** (0.000)
uhat	-6.37*** (0.000)	-6.23*** (0.000)	-6.91*** (0.000)	-7.05*** (0.000)	-6.83*** (0.000)	-5.68*** (0.000)	-5.85*** (0.001)	-5.08*** (0.000)	-5.64*** (0.000)

Test PP	Nacional	Repsol	Cepsa	Galp	Bp	Ballenoil	Carrefour	Alcampo	Indep.
IQ	-0.085 (0.654)								
dIQ	-36.078*** (0.000)								
PBT	0.088 (0.710)	0.103 (0.715)	0.130 (0.724)	0.163 (0.207)	0.161 (0.733)	0.053 (0.699)	0.018 (0.688)	-0.086 (0.654)	-0.025 (0.097)
dPBT	-19.12*** (0.000)	-26.27*** (0.000)	-25.98*** (0.000)	-24.53*** (0.000)	-15.79*** (0.000)	-22.88*** (0.000)	-25.36*** (0.000)	-19.33*** (0.000)	-15.80*** (0.000)
uhat	-6.73*** (0.000)	-8.32*** (0.000)	-7.69*** (0.000)	-7.00*** (0.000)	-6.90*** (0.000)	-5.82*** (0.000)	-5.82*** (0.000)	-5.12*** (0.000)	-5.57*** (0.000)

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Notes: The p-values are shown in parenthesis. The ***, **, * indicates that the corresponding null hypothesis is rejected at the 1%, 5%, 10% level of significance respectively.

Table A.2. ECM with Inertial model

Variable	Nacional	Repsol	Cepsa	Galp	Bp	Ballenoil	Carrefour	Alcampo	Indep.
$\hat{\varepsilon}_{t-1}$	−0.017*** (0.003)	−0.043*** (0.007)	−0.027*** (0.005)	−0.024*** (0.005)	−0.014*** (0.003)	−0.016*** (0.003)	−0.030*** (0.005)	−0.008*** (0.002)	−0.007*** (0.002)
ΔIQ_t^+	−0.024* (0.013)	−0.017*** (0.024)	−0.013 (0.023)	−0.024 (0.020)	−0.026* (0.014)	−0.021* (0.012)	−0.057 (0.037)	−0.008 (0.015)	−0.019* (0.010)
ΔIQ_{t-1}^+	−0.003 (0.020)	−0.013 (0.034)	−0.002 (0.027)	−0.059** (0.026)	−0.027 (0.018)	−0.023 (0.014)	−0.02 (0.025)	−0.034** (0.015)	−0.012 (0.012)
ΔIQ_{t-2}^+	0.141*** (0.016)	0.237*** (0.029)	0.177*** (0.025)	0.127*** (0.029)	0.048*** (0.017)	0.002 (0.016)	0.007 (0.029)	0.032** (0.013)	0.045*** (0.013)
ΔIQ_{t-3}^+	0.062*** (0.017)	0.106*** (0.029)	0.091*** (0.025)	0.103*** (0.022)	0.090*** (0.014)	0.028* (0.015)	0.053** (0.025)	0.025 (0.014)	0.063*** (0.010)
ΔIQ_{t-4}^+	0.082*** (0.021)	0.131*** (0.036)	0.122*** (0.025)	0.107*** (0.028)	0.070*** (0.017)	0.063*** (0.014)	0.016 (0.020)	0.034*** (0.012)	0.061*** (0.014)
ΔIQ_{t-5}^+	0.114*** (0.017)	0.176*** (0.032)	0.118*** (0.024)	0.150*** (0.026)	0.109*** (0.017)	0.050*** (0.016)	0.134*** (0.026)	0.054*** (0.012)	0.089*** (0.011)
ΔIQ_{t-6}^+	0.053*** (0.014)		0.083*** (0.018)	0.118*** (0.024)	0.086*** (0.016)	0.052*** (0.012)	0.105*** (0.021)	0.091*** (0.012)	0.076*** (0.012)
ΔIQ_{t-7}^+	0.052*** (0.015)		0.033 (0.024)	0.093*** (0.030)	0.086*** (0.019)	0.068*** (0.014)	0.085*** (0.025)	0.060*** (0.015)	0.080*** (0.013)
ΔIQ_{t-8}^+	0.079*** (0.016)		0.121*** (0.023)	0.093*** (0.025)	0.064*** (0.015)	0.085*** (0.013)	0.099*** (0.025)	0.102*** (0.014)	0.074*** (0.012)
ΔIQ_{t-9}^+						0.037*** (0.011)		0.046*** (0.012)	
ΔPBT_{t-1}^+	0.233*** (0.052)	0.057 (0.052)	0.010 (0.054)	−0.033 (0.046)	0.328*** (0.058)	−0.051 (0.078)	−0.003 (0.041)	0.040 (0.064)	0.201*** (0.064)
ΔPBT_{t-2}^+				−0.037 (0.040)	−0.144*** (0.054)	−0.101 (0.064)		0.035 (0.047)	−0.131** (0.052)
ΔPBT_{t-3}^+				−0.010** (0.043)	0.043 (0.053)	0.038 (0.044)		0.018 (0.037)	0.051 (0.051)
ΔPBT_{t-4}^+				−0.089** (0.037)	−0.101** (0.045)	0.174*** (0.039)		0.045 (0.041)	−0.034 (0.036)
ΔPBT_{t-5}^+				−0.002 (0.052)	0.057 (0.041)	0.074* (0.041)		0.145** (0.057)	0.055 (0.043)
ΔIQ_t^-	−0.020 (0.017)	−0.040 (0.029)	−0.044* (0.025)	0.014 (0.020)	−0.010 (0.014)	0.006 (0.011)	0.033 (0.023)	0.003 (0.012)	−0.009 (0.010)
ΔIQ_{t-1}^-	0.008 (0.019)	−0.056* (0.031)	0.031 (0.026)	−0.042* (0.025)	−0.002 (0.015)	−0.026* (0.015)	−0.042 (0.026)	0.008 (0.015)	−0.001 (0.012)
ΔIQ_{t-2}^-	0.104*** (0.018)	0.197*** (0.032)	0.171*** (0.026)	−0.018 (0.022)	0.002 (0.015)	0.015 (0.017)	−0.049* (0.027)	−0.002 (0.015)	0.018 (0.011)
ΔIQ_{t-3}^-	0.130*** (0.020)	0.214*** (0.034)	0.172*** (0.028)	0.098*** (0.024)	0.106*** (0.015)	0.016 (0.013)	0.086*** (0.024)	0.018 (0.014)	0.067*** (0.012)
ΔIQ_{t-4}^-	0.050*** (0.016)	0.077*** (0.027)	0.064** (0.027)	0.048* (0.025)	0.084*** (0.015)	0.017 (0.014)	0.049* (0.026)	0.056*** (0.013)	0.061*** (0.010)
ΔIQ_{t-5}^-	0.080*** (0.017)	0.090*** (0.028)	0.105** (0.022)	0.110*** (0.022)	0.072*** (0.016)	0.031** (0.013)	0.056** (0.022)	0.049*** (0.014)	0.072*** (0.013)
ΔIQ_{t-6}^-	0.107*** (0.017)	0.147*** (0.031)	0.126*** (0.024)	0.142*** (0.025)	0.104*** (0.016)	0.083*** (0.014)	0.123*** (0.023)	0.072*** (0.013)	0.083*** (0.012)
ΔIQ_{t-7}^-	0.035** (0.017)		0.096*** (0.024)	0.092*** (0.027)	0.057*** (0.017)	0.040*** (0.015)	0.054 (0.036)	0.057*** (0.013)	0.049*** (0.013)
ΔIQ_{t-8}^-	0.033* (0.019)			0.065** (0.026)	0.066*** (0.018)	0.039*** (0.014)		0.055*** (0.015)	0.063*** (0.015)
ΔIQ_{t-9}^-	0.050*** (0.018)			0.075*** (0.025)		0.053*** (0.016)		0.050** (0.021)	0.040*** (0.015)
ΔPBT_{t-1}^-	0.189*** (0.057)	0.015 (0.044)	−0.015*** (0.046)	0.102* (0.053)	0.333*** (0.055)	0.080*** (0.053)	0.209*** (0.056)	0.178*** (0.059)	0.199*** (0.069)
ΔPBT_{t-2}^-				−0.018 (0.053)	−0.073 (0.052)	0.020*** (0.044)		0.096** (0.045)	−0.101** (0.047)
ΔPBT_{t-3}^-				−0.044 (0.050)	0.077* (0.045)	0.180*** (0.059)		0.037 (0.049)	0.129*** (0.050)
ΔPBT_{t-4}^-				0.059 (0.046)	−0.055*** (0.040)	0.045*** (0.052)		−0.072 (0.043)	−0.028 (0.040)
ΔPBT_{t-5}^-				−0.007 (0.040)	0.077* (0.040)	0.027*** (0.051)		0.201*** (0.044)	0.080 (0.049)
Adj R^2	0.532	0.374	0.393	0.395	0.553	0.472	0.298	0.538	0.645
Schwarz	−10936.04	−9660.644	−10138.16	−10169.81	−10994.27	−11133.70	−9988.022	−11399.55	−11791.88
T Wald	2.878*** (0.002)	5.436*** (0.000)	6.267*** (0.000)	3.372*** (0.000)	1.945* (0.050)	4.874*** (0.000)	6.650*** (0.000)	3.041*** (0.001)	3.435*** (0.000)

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Notes: N=1102. In the coefficients the standard error is in parentheses. Standard errors are robust to heteroscedasticity. The ***, **, * indicates that the corresponding null hypothesis is rejected at the 1%, 5%, 10% level of significance respectively. For the Wald test the p-values are shown in parenthesis.

Table A.3. FE Model

Variable	Repsol	Cepsa	Galp	Bp	Ballenoil	Carrefour	Alcampo	Indep.
ΔIQ_t^+	-0.043** (0.019)	-0.022 (0.230)	-0.027 (0.136)	-0.038** (0.036)	-0.027 (0.133)	-0.070*** (0.000)	-0.017 (0.363)	-0.025 (0.176)
ΔIQ_{t-1}^+	0.025 (0.187)	0.036* (0.053)	-0.011 (0.571)	-0.031* (0.097)	-0.018 (0.331)	0.002 (0.915)	-0.031* (0.092)	-0.006 (0.738)
ΔIQ_{t-2}^+	0.286*** (0.000)	0.209*** (0.000)	0.067*** (0.000)	0.144*** (0.000)	0.013 (0.489)	0.035* (0.053)	0.033* (0.076)	0.053*** (0.004)
ΔIQ_{t-3}^+	0.152*** (0.000)	0.118*** (0.000)	0.127*** (0.000)	0.131*** (0.000)	0.040** (0.031)	0.096*** (0.000)	0.033* (0.076)	0.074*** (0.000)
ΔIQ_{t-4}^+	0.156*** (0.000)	0.139*** (0.000)	0.110*** (0.000)	0.124*** (0.000)	0.069*** (0.000)	0.045** (0.015)	0.048*** (0.009)	0.072*** (0.000)
ΔIQ_{t-5}^+	0.192*** (0.000)	0.132*** (0.000)	0.141*** (0.000)	0.147*** (0.000)	0.066*** (0.000)	0.163*** (0.000)	0.075*** (0.000)	0.103*** (0.000)
ΔIQ_{t-6}^+	0.073*** (0.000)	0.091*** (0.000)	0.121*** (0.000)	0.101*** (0.000)	0.071*** (0.000)	0.134*** (0.000)	0.106*** (0.000)	0.094*** (0.000)
ΔIQ_{t-7}^+	0.074*** (0.000)	0.038** (0.040)	0.113*** (0.000)	0.079*** (0.000)	0.092*** (0.000)	0.112*** (0.000)	0.085*** (0.000)	0.092*** (0.000)
ΔIQ_{t-8}^+	0.091*** (0.000)	0.122*** (0.000)	0.107*** (0.000)	0.085*** (0.000)	0.107*** (0.000)	0.111*** (0.000)	0.135*** (0.000)	0.099*** (0.000)
ΔIQ_{t-9}^+	0.017 (0.346)	0.051*** (0.005)	0.057*** (0.002)	0.055*** (0.003)	0.064*** (0.001)	0.042** (0.023)	0.078*** (0.000)	0.052*** (0.005)
ΔIQ_{t-10}^+	-0.012 (0.517)	0.016 (0.369)	0.024 (0.184)	0.039** (0.033)	0.054*** (0.003)	-0.001 (0.935)	0.041** (0.025)	0.028 (0.125)
ΔIQ_{t-11}^+	0.030 (0.104)	0.039** (0.034)	0.051*** (0.005)	0.053*** (0.004)	0.069*** (0.000)	0.072*** (0.000)	0.059*** (0.001)	0.062*** (0.001)
ΔIQ_{t-12}^+	0.040** (0.030)	0.047** (0.010)	0.047** (0.010)	0.038** (0.039)	0.071*** (0.000)	0.067*** (0.000)	0.049*** (0.007)	0.059*** (0.001)
ΔIQ_{t-13}^+	0.017 (0.352)	0.006 (0.742)	0.050*** (0.006)	0.022 (0.239)	0.041** (0.026)	0.052*** (0.004)	0.061*** (0.001)	0.052*** (0.005)
ΔIQ_{t-14}^+	0.025 (0.177)	0.049*** (0.009)	0.039** (0.035)	0.043** (0.022)	0.034* (0.066)	0.085*** (0.000)	0.046** (0.014)	0.043** (0.022)
ΔIQ_{t-15}^+	-0.015 (0.431)	-0.009 (0.635)	0.016 (0.373)	0.027 (0.151)	0.051*** (0.006)	0.013 (0.470)	0.049*** (0.009)	0.038** (0.039)
ΔIQ_t^-	-0.021 (0.310)	-0.041** (0.045)	-0.001 (0.968)	0.013 (0.530)	0.002 (0.932)	0.040** (0.047)	0.018 (0.364)	0.001 (0.950)
ΔIQ_{t-1}^-	0.014 (0.504)	0.053*** (0.009)	-0.003 (0.885)	-0.034* (0.095)	-0.003 (0.898)	-0.009 (0.666)	0.018 (0.385)	-0.000 (0.999)
ΔIQ_{t-2}^-	0.245** (0.000)	0.189*** (0.000)	0.006 (0.780)	0.006 (0.757)	0.030 (0.134)	-0.014 (0.472)	0.009 (0.658)	0.021 (0.288)
ΔIQ_{t-3}^-	0.257*** (0.000)	0.190*** (0.000)	0.120*** (0.000)	0.121*** (0.000)	0.026 (0.193)	0.114*** (0.000)	0.024 (0.228)	0.077*** (0.000)
ΔIQ_{t-4}^-	0.111*** (0.000)	0.084*** (0.000)	0.146*** (0.000)	0.095*** (0.000)	0.042** (0.035)	0.110*** (0.000)	0.073*** (0.000)	0.089*** (0.000)
ΔIQ_{t-5}^-	0.124*** (0.000)	0.123*** (0.000)	0.127*** (0.000)	0.150*** (0.000)	0.057*** (0.005)	0.109*** (0.000)	0.066*** (0.001)	0.091*** (0.000)
ΔIQ_{t-6}^-	0.175*** (0.000)	0.146*** (0.000)	0.167*** (0.000)	0.178*** (0.000)	0.103*** (0.000)	0.183*** (0.000)	0.105*** (0.000)	0.112*** (0.000)
ΔIQ_{t-7}^-	0.042** (0.039)	0.115*** (0.000)	0.117*** (0.000)	0.115*** (0.000)	0.063*** (0.002)	0.115*** (0.000)	0.086*** (0.000)	0.078*** (0.000)
ΔIQ_{t-8}^-	0.036* (0.078)	0.045** (0.028)	0.102** (0.000)	0.069*** (0.001)	0.071*** (0.000)	0.073*** (0.000)	0.089*** (0.000)	0.087*** (0.000)
ΔIQ_{t-9}^-	0.049** (0.015)	0.036* (0.071)	0.067*** (0.001)	0.091*** (0.000)	0.105*** (0.000)	0.075*** (0.000)	0.099*** (0.000)	0.077*** (0.000)
ΔIQ_{t-10}^-	0.042** (0.037)	0.045** (0.025)	0.066*** (0.001)	0.047** (0.017)	0.058*** (0.003)	0.087*** (0.000)	0.058*** (0.003)	0.062*** (0.002)
ΔIQ_{t-11}^-	-0.010 (0.620)	0.011 (0.566)	0.041** (0.039)	0.064*** (0.001)	0.063*** (0.002)	0.004 (0.847)	0.064*** (0.001)	0.048** (0.016)
ΔIQ_{t-12}^-	0.008 (0.690)	0.023 (0.251)	0.025 (0.202)	0.024 (0.237)	0.057*** (0.005)	0.003 (0.862)	0.051** (0.011)	0.042** (0.037)
ΔIQ_{t-13}^-	0.004 (0.840)	0.017 (0.395)	0.013 (0.519)	0.013 (0.507)	0.054*** (0.007)	0.001 (0.974)	0.020 (0.307)	0.026 (0.193)
ΔIQ_{t-14}^-	-0.001 (0.966)	-0.021 (0.287)	0.027 (0.175)	0.031 (0.119)	0.070*** (0.001)	0.029 (0.145)	0.031 (0.127)	0.043** (0.033)
ΔIQ_{t-15}^-	-0.009 (0.634)	-0.003 (0.872)	0.005 (0.788)	-0.029 (0.152)	0.022 (0.267)	-0.019 (0.341)	0.035* (0.082)	0.022 (0.272)

Prepared by authors.

Notes: In the coefficients the standard error is in parentheses. The ***, **, * indicates that the corresponding null hypothesis is rejected at the 1%, 5%, 10% level of significance respectively.

Figure A.1 Cumulative functions by brand