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EUROPEAN GASOLINE MARKETS: PRICE TRANSMISSION ASYMMETRIES IN MEAN AND VARIANCE

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European Gasoline Markets: Price Transmission Asymmetries in Mean and Variance

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Abstract

The main objective of this paper is to analyse the different sources of asymmetric price transmissions in the fuel market for France, Germany and Spain. During the last decades, the EU has carried out several common energy policies to achieve more efficient and competitive markets. However, given the specific characteristics of each country, the question we want to address is if fuel prices across EU members behave differently in response to different market structures. Oil operators have been targeted by competition authorities for conducting non-competitive practices. To figure out whether the common complaint that gasoline prices adjust differently to positive or negative input price changes, dynamic asymmetric models for the mean and variance are developed for each country. Several asymmetric specifications for the mean and variance are considered and the best specification combines double threshold error correction models (DT-ECM) for the mean with asymmetric EGARCH plus dummy variables for the conditional variance. We show that French gasoline prices behave more competitively, adjusting quicker to the long-run equilibrium and with higher price volatility. This outcome is consistent with the strong presence of hypermarkets following low-cost pricing strategies in France.

Keywords: *Competition, Gasoline Price Asymmetries, Rockets and Feathers, Nonlinear Error Correction, GARCH, EGARCH, GJR-GARCH, Log-GARCH.*

JEL classification: B23, C24, C52, D43, L13, L71.

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1. Introduction

Competition and pricing behaviour on retail gasoline markets is a highly debated topic among media, consumers, as well as regulatory and antitrust authorities in several countries around the world. There is a general consumer complaint that retail gasoline prices respond much faster to raises in wholesale prices than to reductions. Some authors determine that there is empirical evidence proving this price mechanism is truly present, rather than being a merely customers´ misperception (OECD, 2013).

The asymmetric price transmission phenomenon has been observed in many markets. Under this price setting, commonly known as "rockets and feathers", prices usually adjust much faster to input costs increases than to input costs decreases.

These potential detrimental effects on consumers are what have drawn the attention of competition authorities in different countries. The Bundeskartellamt (German Antitrust Agency) studied the retail sale of gasoline and diesel at petrol stations in 2011 concluding that the German fuel sector is not truly competitive and that there is a dominant oligopoly in the regional petrol stations market (Bundeskartellamt, 2011). According to the Bundeskartellamt report, fuel prices are greater than they should be in a competitive equilibrium. It concludes the need for a persistent attention in this market and proposes to stop any future merger between large oil companies. With regard to the Spanish automotive sector, the CNMC[2] expressed its concerns about the lack of competition in the gasoline market. In fact, the competition authority has fined Repsol, Cepsa and BP for price-fixing among petrol stations several times (CNMC, 2015).

The main objective of this paper is to examine the presence of asymmetric price adjustments for the gasoline market. Thus, it will determine if there is empirical evidence supporting consumers´ thoughts that retail prices react quicker to input price rises or whether people pay more attention when prices increase.

Firstly, this study presents an international comparison of gasoline price behaviour by employing recent weekly data from January 2011 until May 2017 for France, Germany and Spain.

Secondly, the econometric methodology used to assess general price asymmetries consists on studying asymmetries from two main sources. On one hand, asymmetries in the mean through the double threshold error correction models (DT-ECM), introduced by Escribano and Torrado (2018) and on the other, with the asymmetric price patterns in the conditional variance by employing GARCH, EGARCH, GJR-GARCH and Log-GARCH models with dummy variables.

In order to do that, *Subsection 1.1* describes the characteristics of the countries under study. *Section 2* summarizes previous literature about the "rockets and feathers" phenomenon. *Section 3* attempts to explain the potential economic theory of price asymmetries. *Section 4* describes the variables employed to develop the empirical methodology built in *Section 5*. Finally, *Section 6* presents the main conclusions.

[2] CNMC: Comisión Nacional de los mercados y la Competencia.

1.1. Countries under study

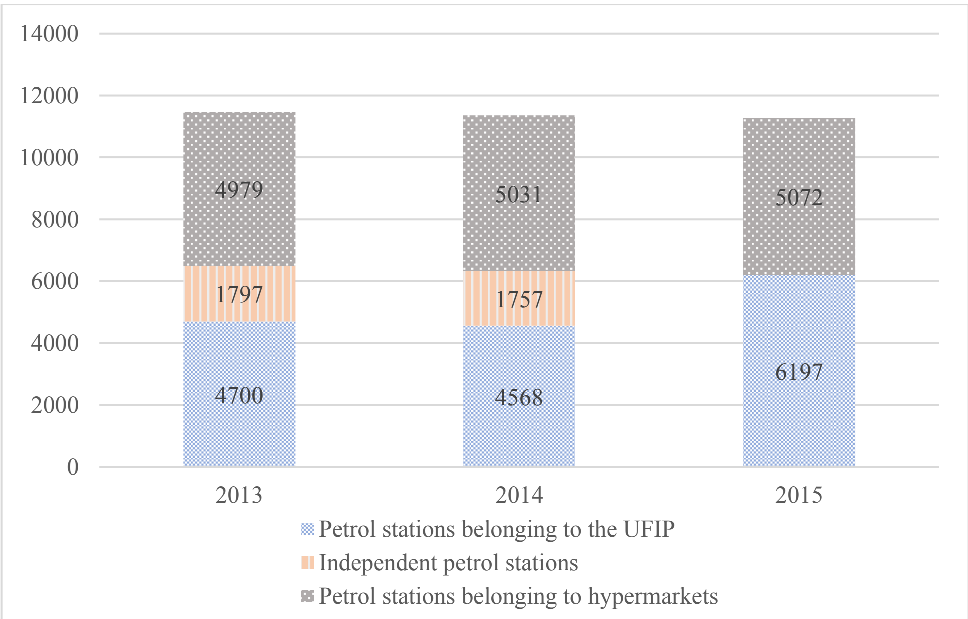
Among all the countries within the European Union, France, Germany and Spain are the selected countries examined in this paper. The reason behind electing these three countries is explained below.

France

The main characteristic of the French gasoline market is the strong presence of gasoline stations belonging to hypermarkets and supermarkets. Supermarkets have been growing in size and in the range of products offered over the last fifty years in Europe. However, in the case of petrol stations, France is the pioneer. In the 1960s, the French Government imposed strict limits on the imported amount of gasoline, this pushed prices upwards. At this point, Carrefour realised that it could take advantage of its corporate structures and it would be able to import the fuel that oil companies were not. Therefore, Carrefour opened the continent´s first gasoline station attached to a supermarket in the 60s. The initial growth was slow, but over the next decades French hypermarkets captured nearly half of the retail market, forcing independent retailers to go bankruptcy (see *Figure 1*).

Furthermore, in 2011, Total S.A., which is the current largest gas station operator in France, decided to follow the strategy of hypermarkets by creating a new chain, Total Access. Between 2011 and 2014, 600 petrol stations were rebranded and set more competitive prices (Chamayou, 2017).

Figure 1: Number of Petrol Stations in France by Distribution Network

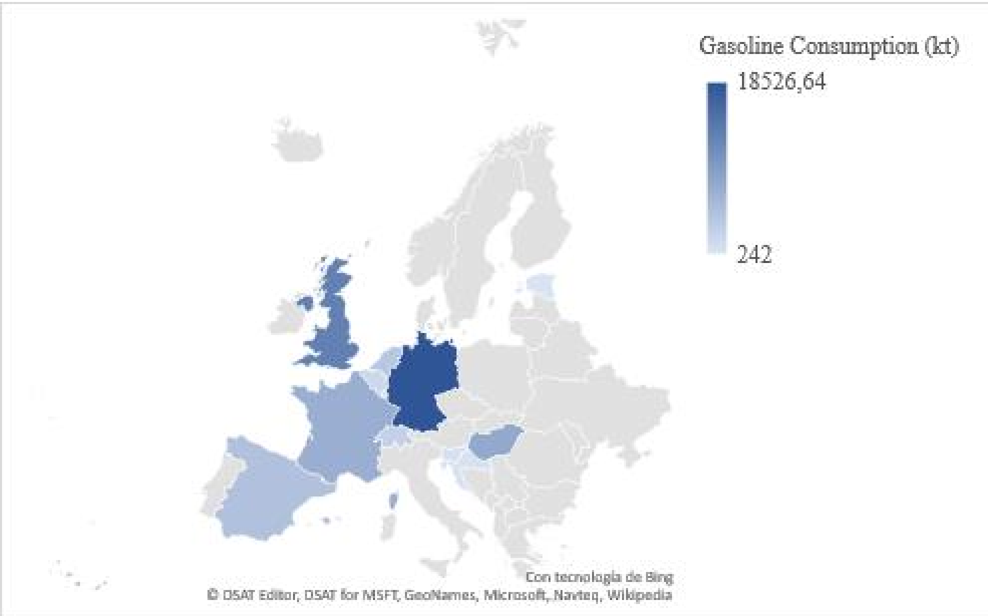


Source: Own elaboration based on data provided by Union Française des Industries Pétrolièrs (UFIP).

Germany

The German automotive industry is one of the key pillars of its economy and according to the annual report of UPEi[3], Germany is the EU country with the highest gasoline consumption (see *Figure 2*). Furthermore, it has a largely deregulated oil market. There are several companies operating along this vertically integrated market, including independents in the refining and the retail stages. The government does not own any of the companies operating downstream or upstream the oil sector (IEA, 2012). In spite of the fact of being characterized as a deregulated market, the Bundeskartellamt stated that the German fuel sector was not truly competitive in 2011.

Figure 2: Gasoline Consumption 2014



Source: Own elaboration based on the Comité Professionnel du Pétrole and BAFA reports. Note. The units of consumption are kt (1 kt = 1 000 000 kg).

Spain

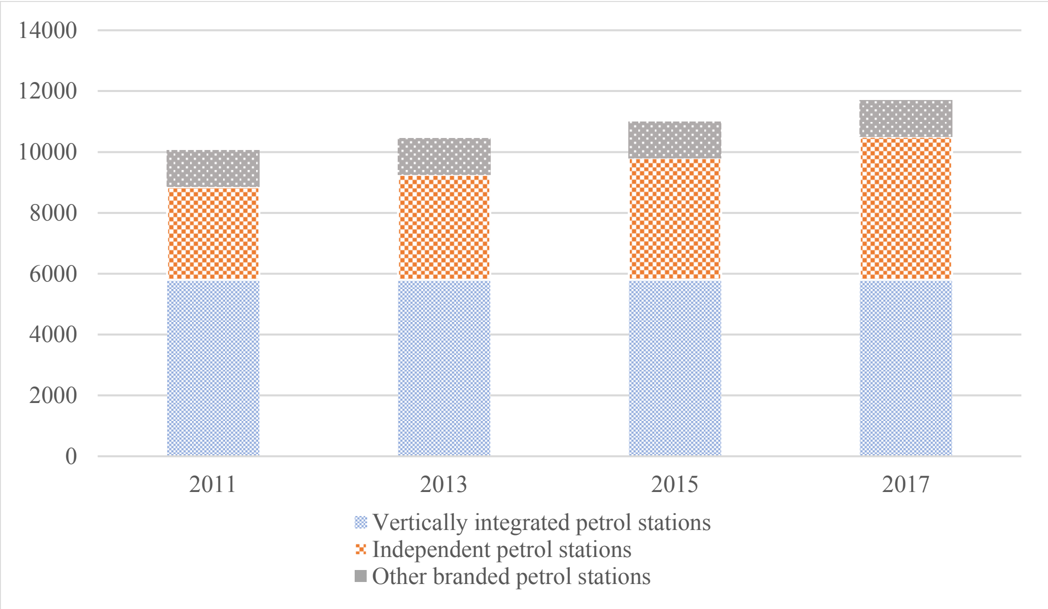
In comparison to other European countries, the Spanish liberalization process of the gasoline market took more time. During the 1927-1992 period, the government monopoly, which was CAMPSA[4], was in charge of operating the petrol market. This public monopoly was vertically integrated, from the upstream segment till the final settlement of retail prices following the orders from the national government. In 1985, there were 0,93 petrol stations per 100 km in Spain, while that number was 6,4 in France and 22 in the Netherlands (Correljé, 1994). From 1985 onwards, the market suffered from a liberalization process in which new private market operators emerged.

Over the last years, the number of petrol stations has been growing in Spain (see *Figure 3:* Number of Petrol Stations in Spain by Market Operators. The majority of market operators are still vertically integrated (Repsol, Cepsa and BP) and present in the refinery process. The amount of vertically integrated petrol stations together with other branded petrol stations

[3] UPEi is the association of European independent fuel suppliers.
[4] CAMPSA: Compañía Arrendataria del Monopolio de Petróleos Sociedad Anónima.

have been almost constant from 2011 until 2017, while the number of independent operators has increased (CNMC, 2019).

Figure 3: Number of Petrol Stations in Spain by Market Operators



Source: Comisión Nacional de los Mercados y la Competencia (CNMC).

2. Literature Review

Prior to the development of an empirical model to determine whether price asymmetries exist for the three countries under study, it is crucial to examine what previous literature have found regarding the "rockets and feathers" phenomenon. Different studies in the gasoline market generally differ in the following aspects: the period under scrutiny, the country involved, the frequency of the data and the empirical nonlinear model (*Table 1*).

The most common methodology when tackling the presence of the rockets and feathers is to study the asymmetries in the mean using the types of Nonlinear Error Correction Model (ECM) introduced by Escribano (1986, 1987, 2004) and extended in Escribano and Granger (1998) and Escribano and Pfann (1998). One of the pioneering works in this field is the one of Bacon (1991) with ex-Rotterdam spot prices in the UK market, finding quicker adjustments to the equilibrium if oil prices are rising. Manning´s (1991) research look at UK retail prices rather than spot prices. He founds non-persistent asymmetry for the 1973-1988 period.

Lanza (1991) addresses the German market during 1980-1990 period and distinguishes two stages of the price formation mechanism. Additional studies for Germany were conducted by Kirchgässner and Kübler (1992). The authors consider two different periods, i) 1972-1980 and ii) 1980-1989. The asymmetries are only allowed for the short run dynamics. The results show asymmetries for the former period, but no asymmetries in the latter.

Duffy-Deno (1996) find asymmetries in the US fuel sector applying an ECM to weekly data during 1989-1993. The focus of Borenstein at al. (1997) is again on the US for the 1986-1990 period. The study confirms that prices react more rapidly when crude oil prices are increasing rather than decreasing. More concretely, it only takes 4 weeks to return to the long-run equilibrium prices when there is a positive oil shock. However, when the shock is negative 8 weeks are required. The UK market is revisited by Reilly and Witt (1998) with monthly data from 1982 till 1995 focusing on possible asymmetries driven by the $/£ exchange rate and by crude oil price changes. Galeotti et al. (2003) study the adjustments of the retail gasoline prices to crude oil price shocks for France, Germany, Italy, Spain and the UK. The main contribution of this paper is the country-comparison employing a two-stage approach for the price transmission mechanisms. These different stages allow them to figure out whether asymmetries occur at the refinery level or at the distribution stage. The methodology applied consists on an ECM and bootstrapping on monthly data for 1985-2000 period. The study concludes with symmetric responses in the case of Germany, U.K. and Italy and asymmetric behaviour for France and Spain. Grasso and Manera (2007) offer an international perspective as well by studying the same five countries, but employing different ECM models for 1985-2003. Under this study asymmetries depend on the country and on the model used. Short-run asymmetries are easily supported when the TAR-ECM[5] model is applied in comparison to the asymmetric ECM. Hannan and Berger (1991) show how deposit rates behave more rigidly when the stimulus for a deposit rate change is upward than downward. Furthermore, Neumark and Sharpe (1992) proves that it is in concentrated markets, where interest rates on deposits raise slower in response to increases on market interest rates than to a decrease. An alternative methodology is to study the asymmetric behaviour in the variance through GARCH or EGARCH models. Bettendorf et al. (2009) analysed the Dutch retail gasoline market by applying an Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) model for 1996-2004.

The Spanish case has been studied by Cotín-Pillart (2008) in two different periods: i)1993-1998 and ii)1998-2005. Regarding the first period, changes in spot gasoline prices are symmetrically transmitted to retail prices. However, asymmetric responses arise in the second period. More general price nonlinearities in mean are considered by the use of the nonlinear error correction models of Escribano (1985, 1986, 1987 and 2004), Escribano and Granger(1998) and Escribano and Pfann (2998), by jointly relating the nonlinearity in the ECM to the increases or decrease in the international oil price (rockets and feathers hypothesis). In particular Escribano and Torrado (2018) consider a nonlinear three-dimensional logistic-ECM models (Double threshold-ECM). The main goal of this paper is to study the international reactions in retail European prices to changes in the prices of oil with a joint estimation of the asymmetry parameters of the conditional mean, using Double Threshold-ECM models, and allowing also for asymmetries in their conditional variance.

[5] TAR-ECM refers to the Threshold Autoregressive Error Correction Model..

Table 1: Summary Literature Review

Study	Country	Period	Data Frequency	Model	Conclusion
Bacon (1991)	GB	1982-1989	Biweekly	ECM	Asymmetries
Lanza (1991)	DE	1980-1990	Monthly	ECM	Asymmetries
Kirchgässner and Kübler (1992)	DE	1972-1989	Monthly	ECM with short-run asymmetries	Short-run asymmetries during 1972-1980 No asymmetries during 1980-1990
Duffy-Deno (1996)	US	1989-1993	Weekly	ECM	Asymmetries
Reilly and Witt (1998)	GB	1982-1995	Monthly	ECM with short-run asymmetries	Asymmetries
Borenstein et al. (1997)	US	1986-1992	Biweekly	ECM	Asymmetries
Asplund et al. (2000)	SE	1980-1996	Monthly	ECM with short-run asymmetries	Short-run asymmetries
Godby et al. (2000)	CA	1990-1996	Weekly	ECM	Symmetric behaviour
Salas (2002)	PH	1999-2002	Weekly	Ordered Probit, PAM and VECM	Asymmetries
Galeotti et al. (2003)	DE, ES, FR, GB and IT	1985-2000	Monthly	ECM	Asymmetries
Grasso and Manera (2007)	DE, ES, FR, GB and IT	1985-2003	Monthly	ECM, Threashold ECM and TAR-ECM	Symmetries/asymmetries depending on de model and the country
Cotín-Pilart et al. (2008)	SP	1993-2005	Weekly	ECM	Symmetries/asymmetries depending on the period
Balmaceda and Soruco (2008)	CL	2001-2004	Weekly	ECM	Asymmetries
Bettendorf et al. (2009)	NL	1996-2004	Daily	ECM and EGARCH	Short-run asymmetries
Polemis (2012)	GR	1988-2006	Monthly	ECM with short-run asymmetries	Short-run and long-run asymmetries
Asane-Otoo and Schneider (2015)	DE	2003-2013	Daily and Weekly	ECM	Asymmetries and symmetries
Qin et al. (2016)	US	1993-2012	Weekly	ECM	Asymmetries via commodity and financial markets.
Mann (2016)	US	2008-2011	Daily	Threshold ECM and GJR-GARCH	Rejects the rockets and feathers phenomenon.
Chua et al. (2017)	AU	2007-2014	Daily and Weekly	Threshold ECM, GARCH and GJR	Asymmetries found only in 4/28 retail gas stations.
Cook and Fosten (2018)	US and NZ	1985-1998 2004-2017	Daily and Weekly	ECM and NARDL	Asymmetries
Escribano and Torrado (2018)	SP	2011-2016	weekly	DT-ECM, LOGISTIC	Asymmetries

Source: Own elaboration.

3. Economic Theory under Asymmetric Price Transmission (APT)

Asymmetric price transmission (APT) has been a subject of considerable attention in different markets. First, because APT may point out to the existence of gaps in economic theory (Peltzman, 2000). Second, APT may have substantial welfare and policy implications. Asymmetric price transmission implies that either buyers are not benefiting from input price falls or sellers are not raising their prices when input costs increase in comparison with a symmetric situation (Meyer and Cramon-Taubadel, 2004). It alters the size and timing of the welfare changes associated to price rises or price falls.

With an extensive number of studies showing that downstream gasoline prices react more quickly to crude oil price increases than to decreases, economists have proposed numerous explanations for this price behaviour. Consumer search costs, market power, inventory management, accounting practices or the behaviour of mark-ups over business cycles are just examples of it (Brown and Yucel, 2000).

3.1. Consumer Search Costs

According to Borenstein (1991) and Peltzman (2000), consumer search costs are one of the causes of the asymmetric response. Given the homogeneity of gasoline, the main element that differentiate filling stations is their location. Each petrol station enjoys a locational monopoly, which is limited by consumer search. Consumers search costs are defined as the energy, time and money spent by customers when they look for a product.

On the one hand, when wholesale gasoline prices increase, the owner of each petrol station tries to maintain his profit margins by rapidly passing the rise to customers. On the other hand, if wholesale prices decrease, each petrol station slowly passes the decrease to consumers.

Furthermore, there is another point that should be considered. It is common that the costs associated to an intense search are much higher for most customers that the corresponding cost savings from finding a cheaper price. Thus, the time spent and the transport costs arising from reaching the cheapest petrol station are probably much larger than the money saved. Imperfect consumer information together with the existence of travel costs generate market power (Lewis, 2011).

3.2. Market Power: Anti-competitive practices like tacit collusion

The majority of APT publications explain asymmetries through non-competitive market structures. Market power is plausibly the main concern of those who find out that gasoline prices react more rapidly to oil price increases than to falls. The abuse of market power could lead to collusion and, in that case, competition authorities should be concern about it. According to Article 101 TFEU, all agreements between companies and concerted practices that affect competition between MS[6] by directly or indirectly fixing prices, should be forbidden.

Brown and Yücel (2000) and Balke et al. (1998) point out that APT can arise when oligopolistic firms engage in tacit (unspoken) collusion to maintain higher margins.

[6] MS: Member States.

The main factors that facilitate collusion are: high concentration, the existence of barriers to entry, cross ownership, multimarket contact, the homogeneity of products and having stable markets (Motta, 2004). In the case of the gasoline market, based on the Herfindahl-Hirschman Index (HHI)[7], the market is more concentrated in Spain and Germany than in France (see *Table 2*). According to the Guidelines on the applicability of Article 81 of the EC Treaty to horizontal cooperation agreements, a market with a HHI above 1800 is highly concentrated. Therefore, as Germany and Spain are close to this value, they can be stated that these markets are concentrated while France is not.

Table 2: Market Shares (Share of Petrol Stations in %)

Operators in the Petrol Market	France	Germany	Spain
Operators with refining industry			
BP	3%	24%	6%
Cepsa	-	-	15%
Elan	12%	-	-
Enni (Agip)	2%	-	-
Esso	5%	7%	-
Jet	-	10%	-
Total	20%	7%	-
Repsol	-	-	32%
Shell	2%	22%	-
Total	**44%**	**70%**	**53%**
Operators without refining industry			
Avia	5%	-	-
Disa	-	-	5%
Galp	-	-	5%
Independientes	-	9%	22%
Hypermarkets	45%	1%	3%
Others	6%	20%	12%
Total	**56%**	**30%**	**47%**
HHI	**1456**	**1780**	**1902**

Note. It shows the market shares for France and Spain in 2015 and 2012 for Germany. Source: Own calculation based on UFIP (Union Française des Industries Pétrolières), Energie Informations Dienst (EID) and Asociación Española de Operadores de Productos Petrolíferos (AOP).

Several market operators are vertically integrated across the supply and distribution chain (see *Figure 4*). Furthermore, gasoline is a homogeneous and inelastic product, where the main difference resides on location or services offered (shops and/or restaurants). According to the Lerner index[8], the fact that gasoline demand is inelastic may allow oil companies to increase prices without losing a large proportion of their customers.

Price transparency plays a dual role. On the one hand, having transparent markets allows consumers to choose the petrol station with the lowest prices, what increases competition. On the other hand, transparency helps to sustain collusion, signalling when competitors are deviating from the collusive equilibrium. French, German and Spanish gas stations have the obligation to provide their daily gasoline prices to the corresponding institution in each country. That institution (DGCCRF[9] for France[10], Bundeskartellamt for

[7] $HHI = \sum_{i=1}^{n} s_i^2 = \sum_{i=1}^{n} \left(\frac{q_i}{Q}\right)^2$, being q_i the quantity sold by company "i" and Q, the total quantity in the market.

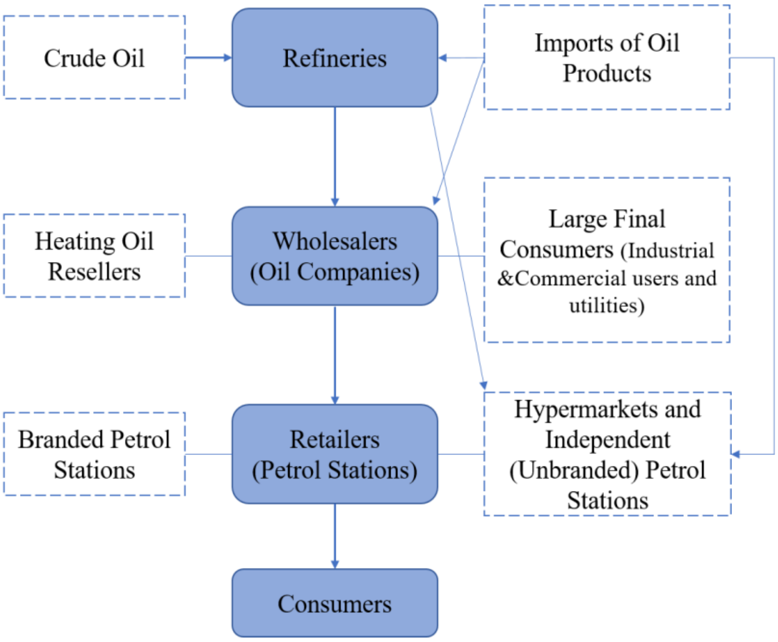
[8] The Lerner index (L) under Cournot Competition is defined as follows: $L_i = \frac{p-c_i}{p} = \frac{s_i}{\varepsilon}$, being ε the demand elasticity and s_i, the market share of company "i".

[9] DGCCRF: Direction Générale de la Concurrence, de la Consommation et de la Répression des Fraudes.

[10] The petrol stations distributing more than 500 m^3 have the obligation to inform their real-time prices.

Germany[11] and Ministerio de Industria, Comercio y Trabajo for Spain) is the one in charge of publicly publish this information.

Figure 4: Market Structure



Source: Own elaboration.

Besides the structural analysis of the market, it is crucial to look at behavioural indicators that help antitrust authorities to figure out whether collusive practices are present in the market or not. This is what *Section 5* will develop.

3.3. Adjustment Costs and Menu Costs

Apart from consumer search costs and market power, there are other explanations for the asymmetries found in gasoline markets. Inventory management, accounting practices[12] and refinery adjustment costs are just examples of these alternative views. If these costs are asymmetric to increases or decreases in prices and/or quantities, APT may arise.

For instance, oil companies may view the effect of unexpected changes on their short-run costs inventories as asymmetric (Borenstein, Cameron and Gilbert, 1997). If operational costs are increasing when inventories are below normal operating levels and the upstream firm decreases its supply, gasoline prices sharply increase to prevent a loss of inventory. At the same time, a raise in inventories above the normal operating level has a small effect on costs, the company may reduce its selling prices at a lower speed when it suffers an increase in upstream supply.

[11] The Bundeskartellamt proposed a new digital price comparison system in which consumers can access price information to find its cheaper alternative.
[12] Balke *et al*. (1998) stated that accounting methods like FIFO can lead to APT.

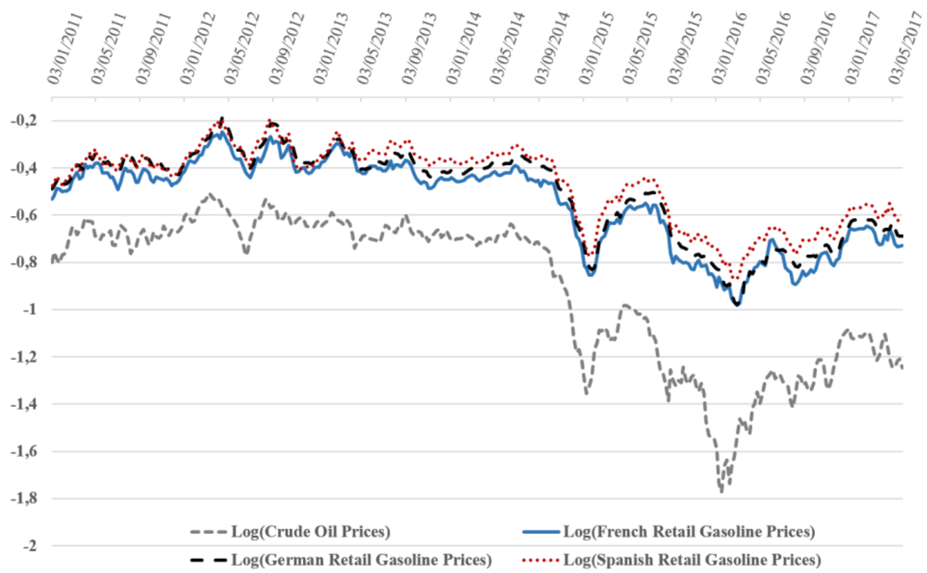
4. Data

With the aim of studying the potential asymmetric price behaviour in the EU fuel market, weekly data from January 2011 until May 2017 is employed, which involves 335 observations.

As the rockets and feathers phenomenon studies the behaviour of downstream prices with respect to changes in upstream prices, we need input and output prices. The variable used as an input price is the crude oil price (CR). In the European market the reference price for crude oil is given by the Brent Spot Price FOB[13] ($\$/barrel$) obtained from the US Energy Information Administration (EIA). As the price is in \$, the €/\$ exchange rate (ER) is required. In this case, the exchange rate has been retrieved from the European Central Bank. For upstream prices, the variables applied are the pre-tax retail price of 95 octane gasoline for France (R_F), Germany (R_G) and Spain (R_S). The pre-tax retail prices are an average of the 95 octane gasoline prices ($€/1000L$) provided by the Weekly Oil Bulletin. These three variables are transformed into €/1L (see descriptive statistics in *Table A-1* of *Appendix A).* Variables in capital letters represent the series in levels and the lowercase letters refer to the series in logarithms (cr, er, r_f, $r_g$and r_s).

According to economic theory, the difference between retail and crude oil prices is the margin obtained by the firms operating in the industry. *Figure 5* shows the relationship between retail gasoline prices for Spain, Germany and France. As it can be seen, the Spanish pre-tax gasoline prices are above German and French prices. This difference across countries has been exacerbated since 2013. Thus, Spanish oil companies may be obtaining higher margins than those achieved in Germany or France.

Figure 5: Variables Representation in Logarithms



Source. Own elaboration. It is likely that series are cointegrated since they move together over time.

[13] FOB: Free On Board. The FOB type contract specified that the price quoted by a certain seller includes all charges related to placing the products on board at the port of departure established by the buyer.

5. Model Specification and Empirical Results

As explained in *Section 2*, most of studies dealing with the rockets and feather phenomenon employ an Error Correction Model (ECM) methodology given the existing cointegration between input and output prices. *Subsection 5.1* studies how retail gasoline prices behave when modelled under symmetric specifications. Then, asymmetries in mean and in variance are allowed in *Subsection 5.2*.

5.1. Linear and Symmetric Models

When dealing with ECM models, it is important to examine the order of integration of the series. *Table 3* shows the results of using ADF tests for unit roots and it is found that all log-variables are integrated of order one, I(1), as expected. Furthermore, from the results of *Table 3*, it can be rejected that oil prices are I(2). Thus, all prices and the exchange rate are I(1).

Given that all variables are integrated of order one and applying the Granger´s representation theorem, there might be linear combinations of the series that are stationary, I(0) (Engle and Granger, 1987). As the variables are non-stationary in levels, the Johansen Cointegration test is performed to verify if there is more than one long-run relationship between retail gasoline prices, the exchange rate and crude oil prices. The results of the test are reported in *Table 4.* The trace statistic confirms the existence of one cointegrating relation for each of the three countries under study.

Table 3: Augmented Dickey Fuller (ADF) Test

	(i)	(ii)	(iii)		(i)	(ii)	(iii)
r_{fr}	-2.873 (0.172)	-1.317 (0.622)	-0.052 (0.664)	Δr_{fr}	-13.406 (0.000)	-	-
r_{gr}	-2.876 (0.171)	-1.393 (0.586)	-0.118 (0.642)	Δr_{gr}	-10.700 (0.000)	-	-
r_s	-2.805 (0.196)	-1.485 (0.539)	-0.224 (0.605)	Δr_s	-13.317 (0.000)	-	-
cr	-2.708 (0.233)	-1.033 (0.742)	-0.909 (0.321)	Δcr	-14.108 (0.000)	-	-
er	-2.567 (-0.295)	-0.971 (0.764)	0.540 (0.832)	Δer	-15.804 (0.000)	-	-

Note. The general expression of the ADF test is given by the following formula, $\Delta y_t = \alpha_0 + \alpha_1 t + \rho y_{t-1} + a_t$ *. The ADF checks the order of integration of the variables where the three null hypotheses test for* ($H_0\colon \rho = 0$) *under different parametric specifications: (i): with intercept and trend; (ii): with intercept only and (iii): without intercept and trend. In all the cases, we fail to reject the null hypothesis of unit root according to the MacKinnon´s critical values with a non-significant trend and intercept.*

Table 4: Johansen (1991) Cointegration Test

Hypothesized No.of CE (s)	Trace Statistic	5% Critical Value	p-value
France			
None	30.988	29.797	0.036
At most 1	7.506	15.494	0.519
At most 2	0.513	3.841	0.473
Germany			
None	39.222	29.797	0.003
At most 1	8.188	15.494	0.445
At most 2	0.510	3.841	0.475
Spain			
None	35.598	29.797	0.009
At most 1	8.726	15.494	0.391
At most 2	0.485	3.841	0.485

Note. The trace yield to the same results for the 3 countries, one cointegrating equation at the 0.05 level.

Equation (1) represents the cointegrating relationship in which the dependent variable, the logarithm of retail gasoline price of France, Germany and Spain (r_{ft}, r_{gt}, and r_{st}) is explained by the logarithm of crude oil prices (cr_t) and the logarithm of the exchange rate (er_t). This long-run equilibrium is estimated by Fully Modified Least Squares (FM-OLS). Then, to figure out if there is a linear combination of prices I(0), an ADF test is performed on the residuals (ect_{ft}, $ect_{gt}$and ect_{st}) arising from *Equation (1)*. The results show that residuals are stationary, confirming that variables are cointegrated (see *Table 5*).

Long-run equilibrium (cointegrating equation):

$$r_{it} = a_0 + a_1 cr_t + a_2 er_t + ect_{it} \qquad (1)$$

Table 5: FM-OLS Cointegrating Relationships

	France r_{ft}	Germany r_{gt}	Spain r_{st}
c	0.060	0.110***	0.096**
cr_t	0.611***	0.622***	0.552***
er_t	0.207**	0.215***	0.258***
ADF ect_{it}	-5.415*** (0.000)	-5.507*** (0.000)	-5.975*** (0.000)

*Note. "***", "**" and "*" represent significance at a 1%, 5% and 10% levels, respectively. The Engle-Granger test refers to the ADF tests performed over the residuals from the cointegrating relationship for each country. As the null is rejected, residuals are I(0) and cointegration exists.*

Equation (2) represents the traditional ECM under which the first difference of retail gasoline prices is explained by the error correction term derived from *Equation (1)*, the contemporaneous and lagged effects of crude oil prices and exchange rate plus the lags of the dependent variable, which is the retail price of gasoline.

In order to know if conditional variance models can be employed, the ARCH test is performed[14]. Given the presence of heteroscedasticity in the series (see *Figure B-1* in *Appendix B*), generalized autoregressive conditional heteroscedasticity (GARCH) is employed[15] to get consistent and efficient estimates. A GARCH(1,1) model is applied over the residuals from *Equation (2)*, ϵ_{it}, which are distributed with mean cero and variance σ_{it}^2. The GARCH(1,1) model allows the conditional variance to be explained as an ARMA process as shown in *Equation (3)*.

Error Correction Model (ECM):

$$\Delta r_{it} = c_0 + \sum_{h=0}^{k} \gamma_h \Delta cr_{t-h} + \sum_{j=0}^{q} \delta_j \Delta er_{t-j} + \sum_{l=1}^{p} \theta_l \Delta r_{it-l} + \beta ect_{it-1} + \epsilon_{it} \quad (2)$$

$$\epsilon_{it\,/It-1} \sim N\,(0, \sigma_{it}^2)$$

GARCH (1,1):

$$\sigma_{it}^2 = \alpha_0 + \alpha_1 \epsilon_{it-1}^2 + \alpha_2 \sigma_{it-1}^2 \quad (3)$$

Table 6 reports the ECM estimates corrected for heteroscedasticity through a GARCH(1,1) specification. According to the literature regarding Error Correction Models, the coefficient of the error correction term of *Equation (2)* indicates the velocity of adjustment towards the long-run equilibrium model. Thus, France recovers the long-run equilibrium faster than Germany and Spain.

Table 6: ECM Estimates

	France	**Germany**	**Spain**
Linear terms			
c	-0.001	-0.000	0.001
Δcr_{t-1}	0.170***	0.110***	0.266***
Δcr_{t-2}	0.144***	0.170***	-0.015
Δer_t	-	-0.103*	-
Δer_{t-1}	0.131*	-	-
Δr_{t-1}	0.112***	0.242***	0.302***
Δr_{t-2}	-	0.098**	-
Error Correction terms			
ect_{t-1}	-0.112***	-0.081***	-0.104***
Variance equation			
	GARCH	GARCH	GARCH
c	0.000**	0.000***	0.000***
ϵ_{it-1}^2	0.226***	0.252***	0.565***
σ_{it-1}^2	0.678***	0.615***	-0.119**
Goodness of fit and specification tests			
AIC	-5.394	-6.096	-5.668
BIC	-5.291	-5.979	-5.565
HQ	-5.353	-6.054	-5.627
Ljung-Box Q test	13.362	7.026	12.088
R^2	0.437	0.592	0.488

*Note. "***", "**" and "*" stand for significance at a 1%, 5% and 10% levels, respectively. The "–" represent the absence of those variables in some of the models. Those terms where omitted following the values of the information criteria. The Ljung–Box Q test confirms the lack of autocorrelation (8 lags employed).*

[14] This test is a Lagrange multiplier (LM) test for autoregressive conditional heteroscedasticity (ARCH) in the residuals (Engle, 1982). As the p-value=0.009, the null of homoskedasticity is rejected.

[15] The ARCH model was introduced by Robert F. Engle in 1982 and the GARCH by T. Bollerslev (1986).

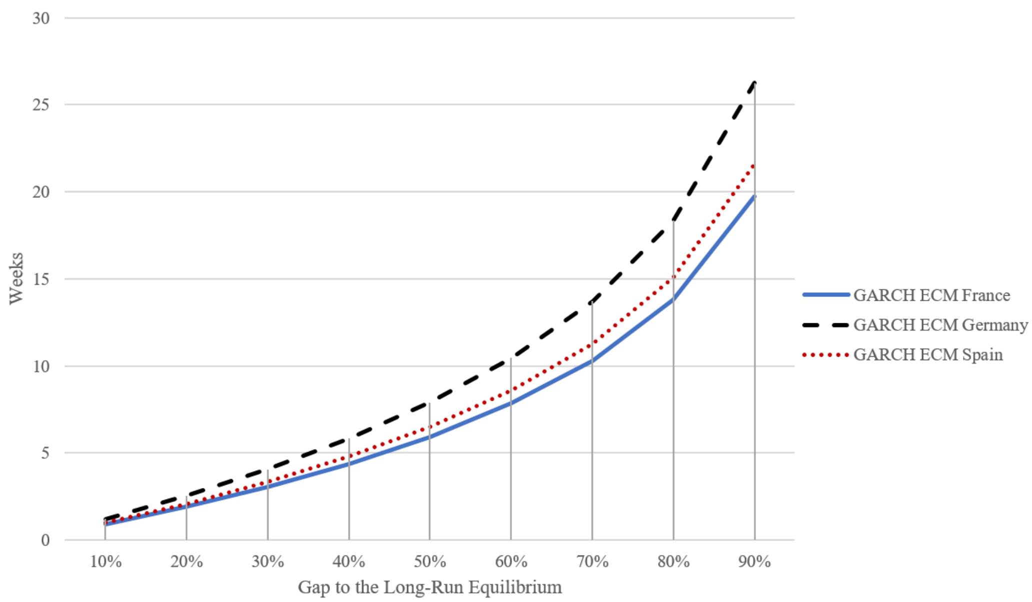
Measuring the Adjustment towards the Equilibrium across Countries

Given the estimates from *Table 6,* the focus is placed on how the pass-through pricing is translated into consumers depending on the country. *Figure 6* portrays the number of weeks required to close the gap between current and equilibrium prices. These values are computed by applying the approach of Galeotti et al. (2003) of *Equation (4).* The "x" refers to the gap between current and equilibrium prices that is reverted once the disequilibrium arises. This "x" is defined by "p_t", which is the current price, "p_t^*", which represents the long-run (equilibrium) price and "p_0", which is the initial price. The denominator contains the "β" parameter, showing the speed of adjustment towards the long-run equilibrium and it is given by the coefficient of the error correction term appearing in *Equation (2).*

$$Weeks = \frac{\ln\left(\frac{p_t - p_t^*}{p_0 - p_t^*}\right)}{\beta} = \frac{\ln(1-x)}{\beta} \tag{4}$$

As it is shown in *Figure 6,* the adjustment to the long-run equilibrium is quicker in France than in Spain or Germany. This result, obviously, coincides with the highest speed found for France in *Table 6*. The reason behind a more rapid readjustment to equilibrium may be due to the more competitive market structure for the retail gasoline industry in France. For instance, in the case of the ECM in France, it takes 10.316 weeks to close the gap between current and long-run equilibrium prices by 70%, while 13.728 weeks are required for Germany and 11.283 for Spain (see *Figure 6*).

Figure 6: GARCH ECM Adjustments to the Long-Run Equilibrium



Note. Own elaboration based on the ECM estimates.

5.2. Non-linear and Asymmetric Models: Asymmetric Error Correction Model

To capture the potential price asymmetries existing in the retail gasoline market, the specification departures from the ECM described in *Equation (2).* The difference is that it splits the error correction term in two terms (ect_{it}^+ and ect_{it}^-), where $ect_{it}^+ = ect_{ft} \geq 0$,

$ect_{gt} \geq 0$, $ect_{st} \geq 0$ and $ect_{it}^{-} = ect_{ft} < 0$, $ect_{gt} < 0$, $ect_{st} < 0$. This is the base for the Asymmetric Error Correction Model (A-ECM) and it is the classical model applied when studying long-run asymmetries in the mean (see *Equation (5)*).

The main advantage of the EGARCH model is the logarithmic specification, which relaxes the positive restriction among the parameters. Another advantage is the incorporation of asymmetries. The asymmetric response is introduced by the term $\frac{\epsilon_{it-1}}{\sigma_{it-1}}$. When there is a negative shock, the impact on the logarithm of the conditional variance is $\alpha_1 - \gamma_1$. However, when the shock is positive, the effect is $\alpha_1 + \gamma_1$. The difference with traditional variance models is that an additional regressor is included, $dumcrpos_t$. This explanatory variable is a dummy variable, representing when crude oil prices are increasing $dumcrpos_t = 1$ if $\Delta cr_t \geq 0$) or decreasing ($dumcrneg_t = 1$ if $\Delta cr_t < 0$).

Asymmetric Error Correction Model (A-ECM):

$$\Delta r_{it} = c_0 + \sum_{h=0}^{k} \gamma_h \Delta cr_{t-h} + \sum_{j=0}^{q} \delta_j \Delta er_{t-j} + \sum_{l=1}^{p} \theta_l \Delta r_{it-l} + \beta^{+} ect_{it-1}^{+} + \beta^{-} ect_{it-1}^{-} + \epsilon_{it} \quad (5)$$

$$\epsilon_{it} \sim N\,(0, \sigma_{it}^2)$$

GARCH (1,1) with dumcrpos:

$$\sigma_{it}^2 = \alpha_0 + \alpha_1 \epsilon_{it-1}^2 + \alpha_2 \sigma_{it-1}^2 + \lambda^{+} dumcrpos_t \quad (6)$$

EGARCH (1,1) with dumcrpos:

$$log(\,\sigma_{it}^2) = \alpha_0 + \alpha_1 \left|\frac{\epsilon_{it-1}}{\sigma_{it-1}}\right| + \gamma_1 \frac{\epsilon_{it-1}}{\sigma_{it-1}} + \varphi_1 log(\sigma_{it-1}^2) + \lambda^{+} dumcrpos_t \quad (7)$$

Table 7: Asymmetries in mean and variance

	France			Germany			Spain		
Linear terms in the mean									
c	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	0.000	0.001	0.001
Δcr_{t-1}	0.140***	0.182***	0.190***	0.081***	0.111***	0.103***	0.257***	0.270***	0.283***
Δcr_{t-2}	0.141***	0.141***	0.132***	-0.159***	0.161***	0.168***	0.066**	-0.022	-0.007
Δer_t	-	-	-	-0.146**	-0.105*	-0.117**	-	-	-
Δer_{t-1}	0.156*	0.132*	0.117*	-	-	-	-	-	-
Δr_{t-1}	0.117**	0.134*	0.145***	0.181***	0.237***	0.260***	0.113**	0.317***	0.243***
Δr_{t-2}	-	-	-	0.146**	0.100**	0.095	-	-	-
Asymmetric ECM terms in the mean									
ect^{+}_{t-1}	-0.099**	-0.076*	-0.067*	-0.088***	-0.072***	-0.070***	-0.119***	-0.142***	-0.138***
ect^{-}_{t-1}	-0.177**	-0.141***	-0.143***	-0.130***	-0.096***	-0.088***	-0.098***	-0.078**	-0.083**
Asymmetries in the conditional variance									
		$GARCH$ +dumcrpos	$EGARCH$ +dumcrpos		$GARCH$ +dumcrpos	$EGARCH$ +dumcrpos		$GARCH$ +dumcrpos	$EGARCH$ +dumcrpos
c	-	0.000***	-2.608***	-	0.000***	-1.981***	-	0.000***	-8.727***
ϵ^2_{it-1}	-	0.288***	-	-	0.257***	-	-	0.601***	-
σ^2_{it-1}	-	0.572***	-	-	0.588***	-	-	-0.112**	-
$\frac{\epsilon_{it-1}}{\sigma_{it-1}}$	-	-	-0.063	-	-	-0.060	-	-	0.008
$\left\lvert\frac{\epsilon_{it-1}}{\sigma_{it-1}}\right\rvert$	-	-	0.548***	-	-	0.463***	-	-	0.749***
$log(\sigma^2_{it-1})$	-	-	0.715***	-	-	0.807***	-	-	0.022
$dumcrpos_t$	-	-0.000***	-0.385***	-	-0.000**	-0.226***	-	-0.000**	-0.479***
Goodness of fit and specification tests									
AIC	-5.330	-5.406	-5.426	-5.990	-6.101	-6.115	-5.570	-5.667	-5.671
BIC	-5.250	-5.280	-5.289	-5.898	-5.963	-5.966	-5.501	-5.554	-5.545
HQ	-5.298	-5.356	-5.371	-5.953	-6.045	-6.056	-5.542	-5.623	-5.621
Ljung-Box Q test	11.223	12.247	12.368	4.600	6.244	5.905	6.810	14.345	10.494
R^2	0.442	0.437	0.435	0.597	0.590	0.590	0.509	0.484	0.496

*Note. "***", "**" and "*" stand for significance at a 1%, 5% and 10% levels, respectively. The "–" represent the absence of those variables in some of the models. Those terms where omitted following the values of the information criteria. The Ljung–Box Q test confirms the lack of autocorrelation (8 lags employed).*

The estimates of *Equations (5)-(7)* for France, Germany and Spain are presented in *Table 7*[16]. According to Granger and Lee (1989), the first step when looking for asymmetries is that the coefficients associated to them should be individually significant.

Notice that once we allow also for asymmetries in the variance, the nonlinearities in the mean changes. See for example the different nonlinearities found in oil prices for Spain in Escribano and Torrado (2018). The F-statistics for the potential asymmetries derived from the A-ECM. Under the null ($H_0: \beta_i^+ = \beta_i^-$), the velocity of adjustment towards the long-run equilibrium is the same independently on whether prices are overestimated or underestimated. Therefore, according to the traditional asymmetric error correction model, there are no long-run asymmetries in any country.

Double-Threshold Error Correction Model

Instead of allowing for single type of asymmetries in the mean with the traditional A-ECM, we consider the Double-Threshold Error Correction Model (DT-ECM) for the mean, following Escribano and Torrado (2018), and we extend it here to allow for asymmetries also in the conditional variance. Under this method, asymmetries in the mean are arising from positive or negative input (oil) price changes are considered, together with whether prices are above or below their long run-equilibrium levels. Interactions between crude oil dummy variables and the error correction terms are used to gain more flexibility ($ect_{it-1}^+ * dumcrpos_t$, $ect_{it-1}^+ * dumcrneg_t$, $ect_{it-1}^- * dumcrpos_t$ and $ect_{it-1}^- * dumcrneg_t$). Besides this non-linear specification, linear short-run dynamics are included as with the ECM and the A-ECM, following the same criteria. The functional form of the DT-ECM is shown in *Equation (8).*

Furthermore, to control for conditional heteroscedasticity, apart from employing GARCH (1,1), EGARCH(1,1) and GJR-GARCH(1,1) we consider asymmetric Log-GARCH(1,1) models, see *Equation (9)* and *Equation (10)* respectively. GJR-GARCH model was introduced by Glosten et al. (1993) with the aim of capturing asymmetries between positive and negative shocks on the variance. As it is shown in *Equation (9),* the difference with the GARCH model resides on the I_{t-1} term, which is a dummy variable taking the *value of 1 when the shock is negative* ($\epsilon_{it-1} < 0$). When α_3 is positive and statistically significant, the leverage effect is present. Besides the GJR-GARCH models, Log-GARCH models have proved to be an interesting class of models for the conditional variance that allow us to include additional explanatory variables while guarantying that the estimated variance is positive, see for example Sucarrat and Escribano (2018) and Sucarrat et al (2018). This model has been especially useful when studying electricity prices see Escribano and Sucarrat (2018). A further advantage of using Log-GARCH models is that it is robust to jumps and spikes, which explains part of variance dynamics, without imposing restrictive positivity constraints in the parameters.

Double-Threshold Error Correction Model (DT-ECM):

[16] Engle (1982) showed that it is possible to simultaneously estimate the mean and the variance of a certain series.

$$\Delta r_{it} = c_0 + \sum_{h=0}^{k} \gamma_h \Delta cr_{t-h} + \sum_{j=0}^{q} \delta_j \Delta er_{t-j} + \sum_{l=1}^{p} \theta_l \Delta r_{it-l} + \beta^{++} ect_{it-1}^{+} * dumcrpos_t + \beta^{+-} ect_{it-1}^{+} * dumcrneg_t + \beta^{-+} ect_{it-1}^{-} * dumcrpos_t + \beta^{--} ect_{it-1}^{-} * dumcrneg_t + \epsilon_{it} \quad (8)$$

$$\epsilon_{it} \sim N\ (0, \sigma_{it}^2)$$

GJR-GARCH (1,1) with dumcrpos:

$$\sigma_{it}^2 = \alpha_0 + \alpha_1 \epsilon_{it-1}^2 + \alpha_2 \sigma_{it-1}^2 + \alpha_3 \epsilon_{it-1}^2 I_{t-1} + \lambda^{+} dumcrpos_t \quad (9)$$

Log-GARCH (1,1) with dumcrpos:

$$log(\sigma_{it}^2) = \alpha_0 + \alpha_1 \log(\epsilon_{it-1}^2) + \varphi_1 log(\sigma_{it-1}^2) + \lambda^{+} dumcrpos_t \quad (10)$$

The estimates of *Equations (6)-(10)* for France, Germany and Spain are presented in *Table 9* and *Table 11*. Under the DT-ECM, two aspects are taken into account, the sign of the error correction term and the dummy variable of crude oil prices, indicating whether input prices increase or decrease. Interestingly, in 100% of the cases, the coefficients associated to $dumcrpos$ are greater than those related to $dumcrneg$. Thus, the speed of adjustment towards the long-run equilibrium is higher when oil prices are rising than when they are falling for France, Germany and Spain. Furthermore, in 67% of the cases, the speed of adjustment towards equilibrium is faster when the error correction term is below the equilibrium level.

Table 9: DT-ECM in the mean with asymmetries in the conditional variance

	France				Germany				Spain			
Linear terms in the conditional mean												
c	-0.001	-0.001	-0.001	-0.002	-0.000	-0.000	-0.000	-0.000	0.000	0.001	0.000	0.000
Δcr_{t-1}	0.137***	0.180***	0.190***	0.197***	0.080***	0.120***	0.106***	0.131***	0.257***	0.264***	0.267***	0.263***
Δcr_{t-2}	0.144***	0.144***	0.119***	0.116***	0.155***	0.150***	0.162***	0.141***	0.097***	0.104***	0.092***	0.110***
Δer_{t}	-	-	-	-	-0.158**	-0.113**	-0.127**	-0.111**	-	-	-	-
Δer_{t-1}	0.150*	0.122*	0.119*	0.147*	-	-	-	-	-	-	-	-
Δr_{t-1}	0.111*	0.129***	0.160***	0.171***	0.187***	0.276***	0.254***	0.321***	-	-	-	-
Δr_{t-2}	-	-	-	-	0.139**	0.065	0.091*	0.038	0.106***	0.060	0.060	0.058
Nonlinear and asymmetric terms in the conditional mean												
$ect_{t-1}^{+} * dumcrpos$	-0.106*	-0.113**	-0.125***	-0.097***	-0.118***	-0.108***	-0.104***	-0.092***	-0.134**	-0.138***	-0.137***	-0.138***
$ect_{t-1}^{+} * dumcrneg$	-0.098**	-0.060	-0.057	-0.053	-0.075***	-0.044*	-0.050*	-0.030	-0.098**	-0.094**	-0.087**	-0.096**
$ect_{t-1}^{-} * dumcrpos$	-0.202***	-0.156***	-0.160***	-0.173***	-0.158***	-0.121***	-0.109***	-0.112***	-0.129***	-0.122***	-0.128***	-0.119***
$ect_{t-1}^{-} * dumcrneg$	-0.138**	-0.102*	-0.091	-0.080	-0.078	-0.085***	-0.084***	-0.069**	-0.060	-0.050	-0.063	-0.051
Conditional variance												
		$GARCH$ +dumcrpos	$\boldsymbol{EGARCH}$ +dumcrpos	$GJR\ GARCH$ +dumcrpos		$GARCH$ +dumcrpos	$\boldsymbol{EGARCH}$ +dumcrpos	$GJR\ GARCH$ +dumcrpos		$GARCH$ +dumcrpos	$\boldsymbol{EGARCH}$ +dumcrpos	$GJR\ GARCH$ +dumcrpos
c	-	0.000***	-3.842***	0.000***	-	0.000***	-2.104***	0.000***	-	0.000***	-4.740***	0.000***
ϵ_{it-1}^{2}	-	0.300***	-	-0.013	-	0.300***	-	0.095	-	0.193***	-	0.255***
σ_{it-1}^{2}	-	0.566***	-	-0.006	-	0.396***	-	0.140	-	0.426***	-	0.489***
$\frac{\epsilon_{it-1}}{\sigma_{it-1}}$	-	-	-0.132*	-	-	-	-0.098	-	-	-	0.006	-
$\left\lvert\frac{\epsilon_{it-1}}{\sigma_{it-1}}\right\rvert$	-	-	0.588***	-	-	-	0.479***	-	-	-	0.443***	-
$log(\sigma_{it-1}^{2})$	-	-	0.567***	-	-	-	0.795***	-	-	-	0.457***	-
$\epsilon_{it-1}^{2}\, I_{t-1}$	-	-	-	0.502***	-	-	-	0.499**	-	-	-	-0.104
$dumcrpos_{t}$	-	-0.000**	-0.425**	-0.000***	-	-0.000*	-0.223**	-0.000***	-	-0.000**	-0.498***	-0.000***
Goodness of fit and specification tests												
AIC	-5.321	-5.400	**-5.421**	-5.402	-5.993	-6.102	**-6.116**	-6.112	-5.573	-5.627	**-5.631**	-5.623
BIC	-5.218	-5.251	**-5.260**	-5.242	-5.879	-5.942	**-5.956**	-5.940	-5.482	-5.489	**-5.482**	-5.474
HQ	-5.280	-5.341	**-5.357**	-5.338	-5.948	-6.038	**-6.052**	-6.043	-5.537	-5.572	**-5.571**	-5.563
Ljung-Box Q test	11.611	12.627	8.185	14.724	5.012	4.400	3.851	3.454	5.250	4.515	5.379	4.779
R^2	0.444	0.438	**0.432**	0.431	0.603	0.592	**0.595**	0.583	0.517	0.514	**0.514**	0.513

*Note. "***", "**" and "*" stand for significance at a 1%, 5% and 10% levels, respectively. The "–" represent the absence of those variables in some of the models. Those terms where omitted following the values of the information criteria. The Ljung–Box Q test confirms the lack of autocorrelation (8 lags employed).*

As individual significance it is not enough to determine the presence of an asymmetric behaviour, F-tests are performed to analyse whether the coefficients of the error correction terms statistically diverge. *Table 10* shows the F-statistics for the potential long-run asymmetries derived from the DT-ECM. Under the nulls $H_0\colon \beta_i^{++} = \beta_i^{+-}$and $H_0\colon \beta_i^{-+} = \beta_i^{--}$, the velocity of adjustment towards the long-run equilibrium is the same independently on whether crude oil prices are rising or falling. Furthermore, under the nulls $H_0\colon \beta_i^{++} = \beta_i^{-+}$and $H_0\colon \beta_i^{+-} = \beta_i^{--}$, there is a symmetric adjustment when prices are overestimated or underestimated independently of the price change of crude oil.

From the F-tests of *Table 9* and the magnitude of the coefficients associated to the error correction terms of *Table 10*, certain conclusions can be drawn. Firstly, as the p-values are greater than 5% for the four tests in France, the null hypothesis cannot be rejected. Therefore, no long-run mean asymmetries are present in this country. Secondly, in Spain and Germany, the null $H_0\colon \beta_i^{-+} = \beta_i^{--}$ can be rejected at a 1% significance level. This implies that whenever retail gasoline prices for these two countries are below the equilibrium level, the adjustment to the long-run equilibrium is much faster whenever crude oil prices raise ($\beta_i^{-+} > \beta_i^{--}$). Thirdly, Spain presents another type of asymmetry, $\beta_s^{+-} > \beta_s^{--}$. When crude oil prices are decreasing, Spanish retail gasoline prices adjust quicker when they are above the long-run relationship. The asymmetries found for Spain and Germany may be explained by the economic theories shown in *Section 3*, like the presence of consumer search costs or the existence of market power.

Table 10: F-statistics for DT-ECM Asymmetries

	France	Germany	Spain
$H_0 : \beta^{++}=\beta^{+-}$	0.908	0.332	0.587
$H_0 : \beta^{-+}=\beta{-}{-}$	0.237	0.004	0.002
$H_0 : \beta^{++}=\beta^{-+}$	0.259	0.574	0.946
$H_0 : \beta^{+-}=\beta^{--}$	0.610	0.645	0.010

Note. The first sign in the β superscript determines if the error correction term is positive (+) or negative (-). The second sign of the superscript represents whether the crude oil is raising (+) or falling (-). Entries represent the p-values from the F-test, where the null hypothesis represent a symmetric adjustment. Under the null, the coefficients are equal, meaning, same velocity towards the equilibrium.

Table 11: LOG-GARCH Estimates

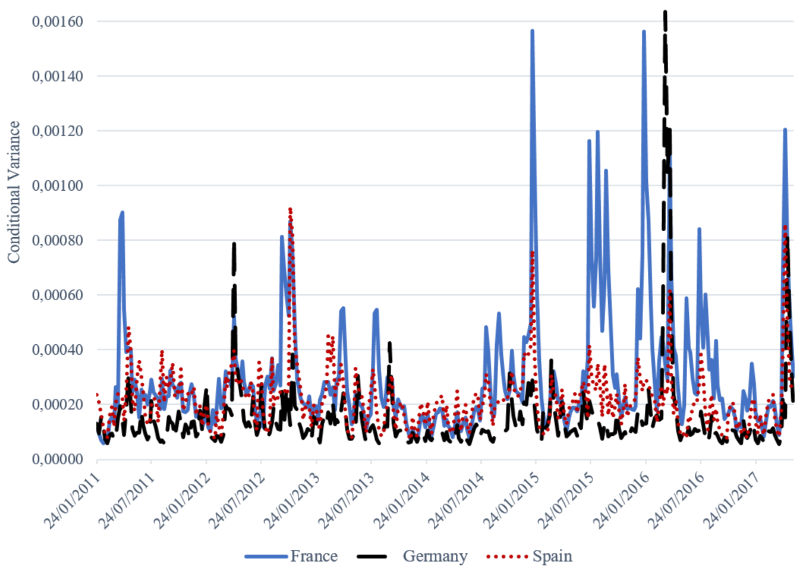
	France $log(\sigma^2_{frt})$	**Germany** $log(\sigma^2_{gt})$	**Spain** $log(\sigma^2_{st})$
α_0	-0.015***	-0.105***	-0.738***
$log(\epsilon^2_{it-1})$	0.031*	0.157***	0.093*
$log(\sigma^2_{it-1})$	0.949***	-0.393*	-0.003
$dumcrpos_t$	-0.197***	-0.570***	-0.488**
AIC	-5.321	-5.993	-5.573
BIC	-5.218	-5.879	-5.482

*Note. "***", "**" and "*" stand for significance at a 1%, 5% and 10% levels, respectively.*

From the conditional variance models, we determine that the coefficient associated to $dumcrpos$ is negative and statistically different from zero for any of the variance specifications. This implies that when input prices increase, the volatility of retail gasoline prices decreases. Thus, market participants may react in a coordinated way. Nevertheless, if crude oil prices decrease, there is higher price volatility since not all operators behave in the same manner. Some retailers will decrease prices more or less than others. This behaviour is consistent with collusive agreements. In the case that input cost increases everybody raises prices quickly to demonstrate its loyalty to the cartel members. However, in case of input price decreases, cartel members are more cautious in reducing prices, since this conduct could be understood as a deviation from the cartel agreement and could lead to a price war.

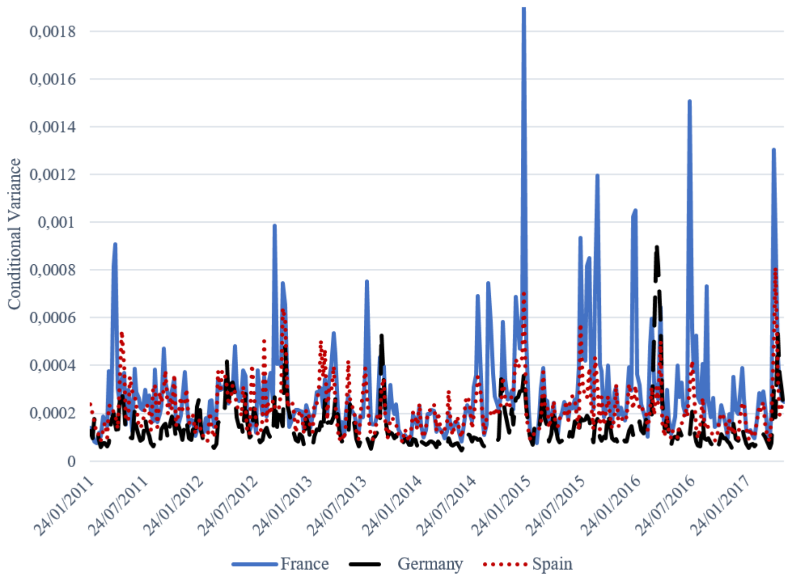
From the nonlinear and asymmetric models some conclusions are drawn. With regard to the asymmetries in the mean, the French market may be more competitive due to the lack of asymmetries in the error correction term. This result is consistent with the outcomes arising from the models in the variance. It can be stated that France is much more volatile than the other two countries (*Figure 7* and *Figure 8*). If the market is more competitive, output prices rapidly adjust to input price increases and decreases.

Figure 7: Conditional Variance of the GARCH Models for France, Germany and Spain



Note. The French conditional variance of the GARCH model is much volatile than in Germany or Spain.

Figure 8: Conditional Variance of the EGARCH Models for France, Germany and Spain



Note. As in Figure 6, the French conditional variance of the EGARCH model is much volatile than in Germany or Spain.

6. Conclusion

This paper examines the general consumer complaint that retail gasoline prices respond much faster to raises in crude oil prices than to reductions. It presents an international comparison of gasoline price behaviour by employing recent weekly data from January 2011 until May 2017 for France, Germany and Spain.

We show that allowing for asymmetries in variance reduces the degree of asymmetries in the conditional mean, as we can see by comparing the results of this paper with those of Escribano and Torrado (2018) where they only consider nonlinearities in the conditional mean.

Furthermore, this paper studies how retail gasoline prices behave when modelling simultaneously nonlinear in the conditional mean and asymmetric specifications in variance. Most asymmetric ECMs have studied the rockets and feathers phenomenon through the conditional mean. Under this approach, not many asymmetries are found. Instead of studying asymmetries in the mean with the traditional asymmetric ECM, we use a double threshold model (DT-ECM) that considers whether international oil prices are above or below long-run equilibrium price levels and it accounts for positive or negative oil price changes as well.

From the conditional mean specification, results show no asymmetries in France. However, asymmetries are found for Spain and Germany. Whenever retail gasoline prices for these two countries are below the long-run equilibrium level, the adjustment to the long-run equilibrium is much faster when crude oil prices are increasing. Furthermore, Spain presents another type of asymmetry. When crude oil prices are decreasing, Spanish retail gasoline prices adjust quicker when they are above the long-run equilibrium level.

These asymmetries found for Spain and Germany could be explained by the presence of consumer search costs or the existence of market power. From the conditional variance models we determine that the asymmetries are statistically different from zero for any of the variance specifications. The best model for the variance, based on the information criteria (AIC, BIC and HQ) is the EGARCH with dummies. These models imply that when input (oil) prices increase, the volatility of retail gasoline prices decreases. Thus, market participants may react in a coordinated way (collusive behaviour). Nevertheless, if crude oil prices decrease, there is higher price volatility and not all operators behave in the same manner. Some retailers will decrease prices more than others. Again, this behaviour may corresponds with some collusive agreements. When the input cost (oil) increases, everybody raises prices quickly to demonstrate its loyalty to the cartel members. However, in case of input price decreases, cartel members are more cautious in reducing prices, since this conduct could be understood as a deviation from the cartel agreement and could lead to a price war.

Therefore, our results show that French gasoline prices behave more competitively, adjusting much quickly to the long-run equilibrium and with higher price volatility. This outcome is consistent with the strong presence of hypermarkets following low cost pricing strategies in France.

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Appendix A

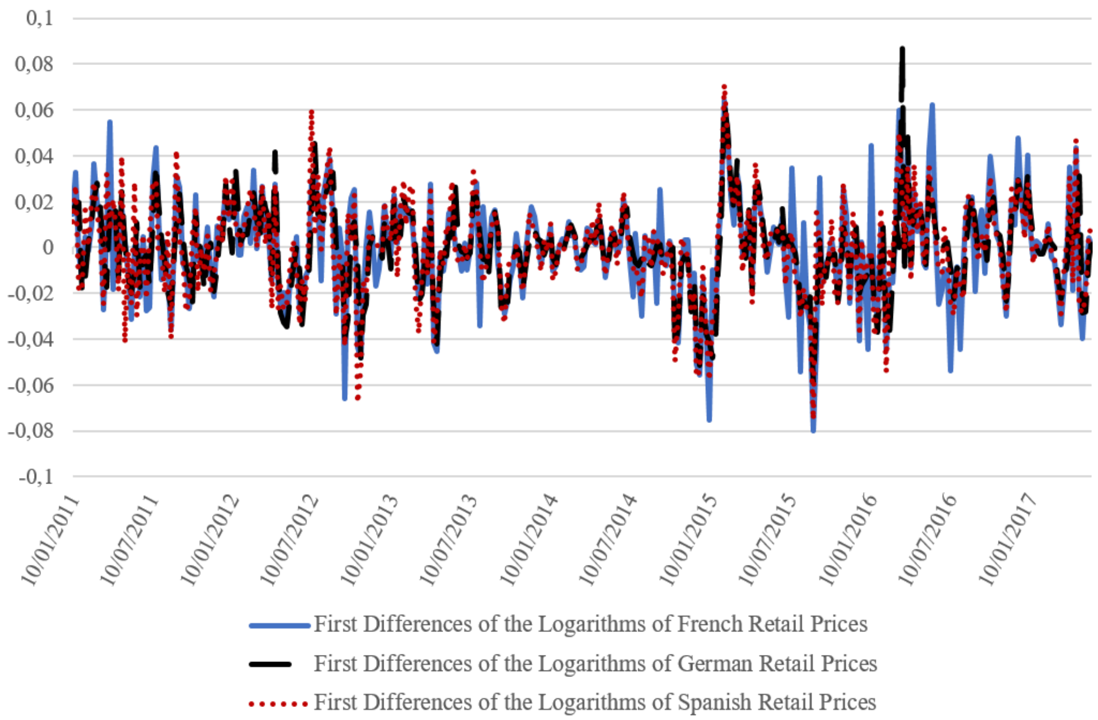
Table A-1: Descriptive Statistics

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
r_f	0.590	0.632	0.780	0.374	0.103	335
r_g	0.614	0.662	0.829	0.375	0.108	335
r_s	0.637	0.674	0.819	0.418	0.098	335
cr	0.420	0.486	0.604	0.160	0.120	335
er	0.809	0.775	0.959	0.673	0.081	335

Note. The table reports variables in levels while the empirical models developed in Section 5 use the first differences of logarithms.

Appendix B

Figure B-1: First Differences of the series in logarithms



Note. Volatility clustering is present, with periods of higher volatility than others.

Figure B-2: Standardized Residuals from GARCH and EGARCH Models for France, Germany and Spain