STRUCTURAL CHANGE, EXCHANGE RATE AND THE ASYMMETRIC ADJUSTMENT OF RETAIL ENERGY PRICES IN EUROPE

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Abstract

This paper examines the role of structural change in the asymmetric adjustment of retail energy prices following changes in crude oil costs. The paper also examines the pattern of adjustment in retail energy prices when exchange rate is accounted for as part of the marginal cost of importing crude oil in European countries with high oil import dependency ratio. The paper shows that the results of Greenwood-Nimmo and Shin (2013) no longer hold when the structural change in the relationship between retail energy prices and crude oil costs is taken into the consideration. The paper also cautions that studies like Kristoufek and Lunackova (2014) that failed to account for exchange rate as part of the marginal cost of importing oil for countries with high oil import dependency ratio may be misleading. In fact, the results of this paper further indicate that once the exchange rate effect is taken into consideration, the possibility of rent-seeking behaviour in the gasoline markets of Italy and Spain disappears; while the rockets and feathers effect observed in most of the *ex*-tax gasoline, diesel, domestic heating oil and industrial fuel oil markets vanishes.

Keywords: rockets and feathers effect, asymmetric adjustment of energy prices, nonlinear ARDL Model, global financial crisis, antitrust policy

JEL Classification: Q43, D40, C22, F36, L40

1. Introduction

The continuous tumbling in crude oil prices, which started in the last quarter of 2013, has renewed global interest in the asymmetric price transmission from crude oil markets to various retail petroleum products markets. Monthly oil price statistics from the International Energy Agency (IEA) indicate that average cost of imported crude oil in the United States (U.S.) declined from 97.44 U.S. dollars *per* barrel in October 2013 to 38.76 U.S. dollars *per* barrel in November 2015. In fact, the wholesale spot price of Brent crude oil as at close of February 25, 2016 was 32.83 U.S. dollars *per* barrel. Specifically, given that crude oil is

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the main input in the production of gasoline, automotive diesel, domestic heating oil and low sulphur industrial fuel oil, there are global concerns that the prices of these petroleum products at pump may respond asymmetrically to the changes in crude oil prices. Grasso and Manera (2007) provide an authoritative survey of such asymmetry in the retail gasoline markets, especially in the U.S. and the UK.

Rockets and feathers effect is used to describe the behaviour of firms in markets witnessing asymmetric transmission of input costs to product prices in such a manner that allows firms to earn temporary excess profits. Specifically, it connotes that when firms are confronted with rising input costs, they rapidly adjust prices upwards; but when they are faced with decreasing costs, they adjust prices downwards very sluggishly. This represents an important form of market failure and raises serious antitrust issues that policy makers and governments cannot overlook. In fact, it is typical of markets witnessing practices that are detrimental to consumers' welfare, such as rent-seeking, uncompetitive pricing, collusion, product hoarding, and artificial shortage/scarcity of products, among others. Given the reality of this phenomenon, especially in the global retail energy sector, economists across the globe have investigated its prevalence using various methodologies. While some studies found evidence in support of the hypothesized asymmetric response of retail energy prices to changes in crude oil prices, others did not find any evidence of such asymmetry.

Notable studies include Bacon (1991) who used data from 1982–1989 and a quadratic quantity adjustment model to examine the UK retail gasoline market for evidence of the rockets and feathers hypothesis, thus supporting the hypothesized asymmetry. Unlike Bacon (1991), Manning (1991) used dataset for the period 1973–1988 and found evidence of asymmetry in the UK retail petrol market, though the evidence was virtually absent after four months. Even though Reilly and Witt (1998) used monthly UK data from 1982–1995 and an error correction modelling (ECM) framework to investigate the retail gasoline market, the findings are consistent with Bacon (1991) and Manning (1991). Borenstein, Cameron and Gilbert (1997, henceforth BCG) used U.S. data for the period 1986–1992 and ECMs to analyse price transmission at different points in the distribution chain and find that retail gasoline prices respond more quickly to increases than to decreases in crude oil prices. The asymmetry was attributed to production/inventory adjustment lags and market power of some sellers. Grasso and Manera (2007) studied the gasoline markets of France, Germany, Italy, Spain and UK over the period 1985–2003 using asymmetric ECM, autoregressive threshold ECM and ECM with threshold cointegration. The results indicate that all the models captured some evidence of asymmetric behaviour. Greenwood-Nimmo and Shin (2013, henceforth GS13) used the nonlinear ARDL framework to examine the UK gasoline, diesel, kerosene and gas oil markets over the period January 1999 to March 2013 and found evidence in support of the presumed asymmetry, which is largely obscured at pump where prices include both tax and duty, suggesting the possibility of firms using the tax system to conceal rent-seeking behaviour. Other studies that have found evidence in support of the rockets and feathers effect are Karrenbrock (1991) for U.S. gasoline market using ARDL framework; Balke, Brown and Yucel (1998) for U.S. gasoline market using ECM/ARDL; Asplund, Eriksson and Friberg (2000) for Swedish gasoline market using ECM; Chacra (2002) for Canadian gasoline, heating oil, natural gas and electricity markets using ECM framework; Borenstein and Shepard (2002) for U.S. gasoline market using lagged adjustment, partial adjustment and vector autoregression models; Salas (2002) for Philippines gasoline market using ordered probit, partial adjustment and vector error correction models; and Murry and Zhu (2008) for U.S. natural gas market using ECM framework.

Contrary to the above studies, Godby, Lintner, Stengos and Wandschneider (2000) used a Threshold Regression model in its error correction form and weekly data for January 1990 to December 1996 and found no evidence in support of the rockets and feathers effect in the Canadian gasoline markets. Bachmeier and Griffin (2003) used daily data for 1985–1998 for the U.S. gasoline market and found no evidence of asymmetry in the U.S. wholesale gasoline prices. Even though Honarvar (2009) used Crouching ECM approach, the results are consistent with Bachmeier and Griffin (2003) that there is no evidence of rockets and feathers effect in the U.S. gasoline market. In a similar study, Kristoufek and Lunackova (2014) re-examined the gasoline markets of Belgium, France, Germany, Italy, the Netherlands, the UK and the U.S using fractional integration, long-term memory, borderline (non-)stationarity as well as the frequently ECM framework and found no asymmetry in all markets apart from Belgium. However, unlike the studies above, the international comparison of gasoline markets by Galeotti, Lanza and Manera (2003) yielded widespread differences in both adjustment speeds and short-run responses of European markets to changes in crude oil prices. Other studies that have made remarkable contributions towards a more comprehensive understanding of asymmetric adjustment of retail energy prices following changes in crude oil costs are Johnson (2002), Lewis (2004), Radchenko (2005), Bettendorf, Van Der Geest and Varkevisser (2003), Perdiguero-Garcia (2010), and Chou, Chang and Hu (2013).

From the foregoing, we can deduce some facts which can be summarized as follows: None of the existing studies explicitly considered the possibility of structural change in the relationship between retail energy prices and crude oil costs. This gap is considered serious given that the global economy has witnessed several business cycles of varying durations in the past few decades. For instance, the 2007–2008 Global Financial Crisis (GFC) brought about substantial decline in oil prices between 2008Q3–2008Q4. Naturally, such shock will affect economic behaviour; and ignoring it means that the some of the existing studies in the literature may not be appropriate. Besides, none of the existing studies has explicitly considered how exchange rate, which is an additional marginal cost of importing oil for countries with high oil import dependency, affects the asymmetric adjustment of retail energy prices. This gap is quite understandable given that most of the existing studies have focussed mainly on the U.S., UK, and Canada that have substantial domestic oil production capacities so that the role of exchange rate can be generally considered unimportant. However, for some European Union countries like France, Germany, Italy and Spain that have high oil import dependency ratio ranging between 92.3–99.8% since 1990, it is important to consider the role of exchange rate for a more comprehensive understanding of the asymmetric response of retail energy prices to changes in crude oil costs. Above all, apart from GS13 that examined the possibility of using the tax system to conceal rent-seeking behaviour in the UK markets, no other study has investigated this possibility in the rest of the European Union member countries. It is the goal of this study to fill these observed gaps in the literature. The intuition behind our rent-seeking analysis is quite simple. If rockets and feathers effect is observed when *ex*-tax prices that are exclusive of tax and duty are used; and such observed rockets and feathers effect disappear when the pump prices that are inclusive of tax and duty are used, then there is strong evidence that retail firms may be using the tax system to hide their rent seeking behaviour. In other words, whenever asymmetry is obscured at the pump, it raises the possibility that firms may be manipulating the market to hide their rent-seeking behaviour[1].

2. The Data

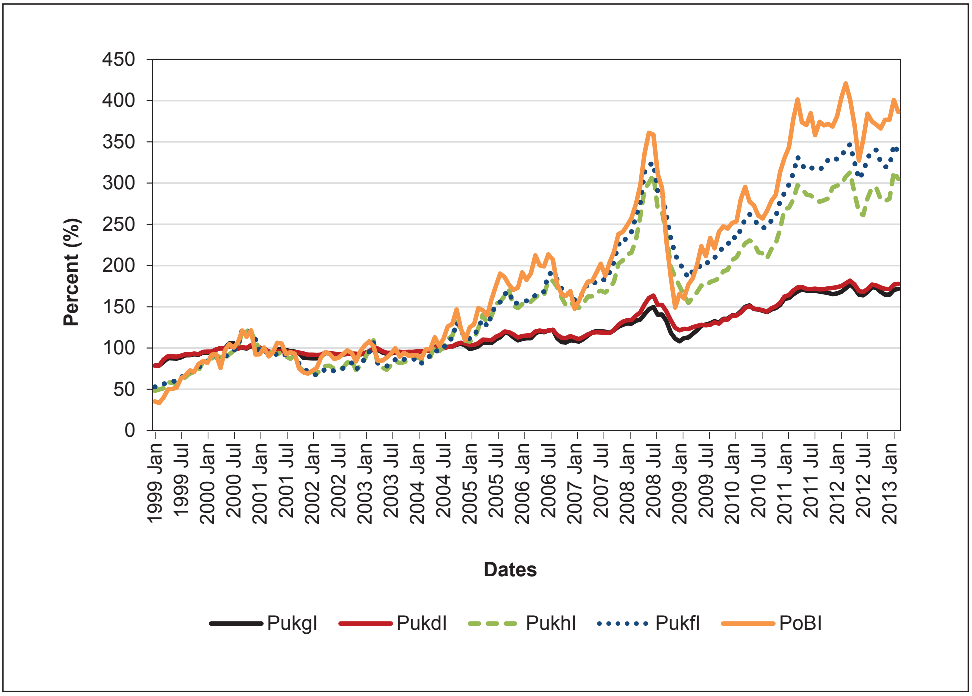
Data from the retail markets of UK, France, Germany, Italy and Spain are used. The choice of these countries is strictly based on the availability of credible data that are exclusive of tax and duty as well as data at pump (*i.e.* inclusive of all taxes and duty). Two categories of data were used in this study. The first category is the GS13 dataset for UK, which consists of monthly observations on the retail price of unleaded gasoline, diesel, kerosene and gas oil as well as the spot price of Brent crude oil. All the prices are measured in the local currency, that is, the British Pounds. The data covers the period 1999:1 to 2013:3; and comprises both *ex*-tax prices (*i.e.* exclusive of tax and duty) and pump prices (*i.e.* inclusive of tax and duty). This data was indexed to 2000 (*i.e.* 2000Y = 100) and logged prior to estimation. The second category of dataset consists of monthly observations from 2004:2 to 2016:1 on the retail prices of gasoline, automotive diesel, domestic/home heating oil, and low sulphur industrial fuel oil as well as the average costs of imported crude oil in France, Germany, Italy, and Spain. The availability of both *ex*-tax and pump prices for the various petroleum products facilitates deeper econometric analysis on the rent-seeking behaviour of firms in these markets. The second dataset was obtained from the International Energy Agency (IEA) Monthly Oil Price Statistics. To effectively track the asymmetries in the response of the retail prices to the changes in the costs of crude oil, we use the crude oil costs for the respective countries. Since the retail prices in France, Germany, Italy and Spain are measured in euros, we also convert the crude oil costs from U.S. dollars to euros, using the monthly exchange rate data obtained from OECD Statistics (Monthly Monetary and Financial Statistics, MEI). The retail prices were then indexed to year 2010 (*i.e*. 2010Y = 100) before the entire dataset was logged prior to estimation. Overall, all the prices are measured in the respective national currencies, while the data transformations were done to reduce noise in the data, improve the robustness of the estimates and ensure that the results retain obvious economic interpretations.

1 For ease of presentation, we shall denote the rockets and feathers effect as Effect A in the empirical results section, while the possibility of firms using the tax system to conceal rent-seeking behaviour will be denoted as Effect B.

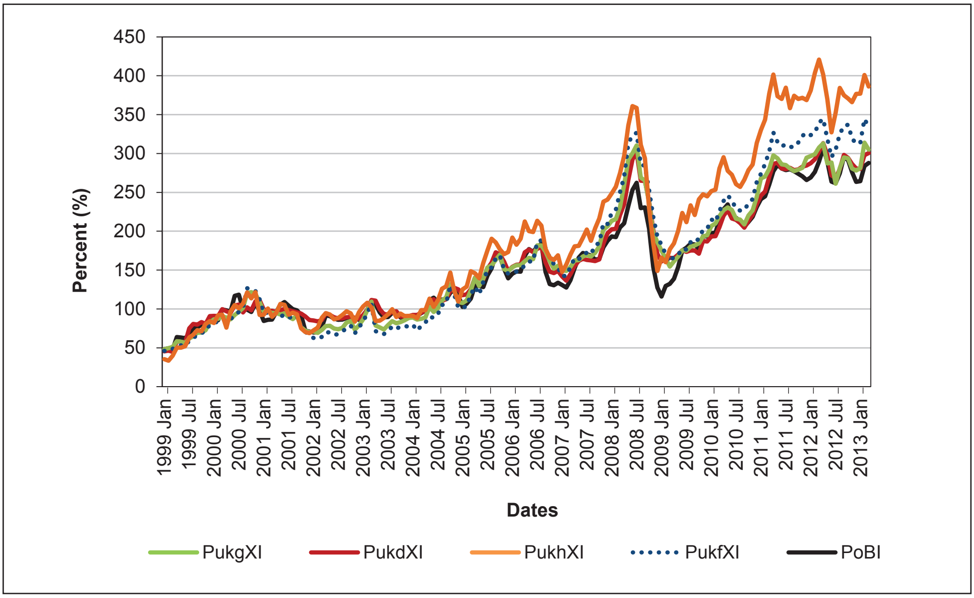
Figure 1 presents the time series plots of the data for UK. The crude oil costs and the pump prices of the retail products are shown in Panel A, while the crude oil costs and the *ex*-tax retail prices are shown in Panel B. The indexed representation of the data is used in all cases. The plots of the data for France are shown in Appendix 2, but to conserve space, we do not present the plots for Germany, Italy and Spain, since the patterns are quite similar to those of UK and France. In what follows, we summarize the stylized facts noticeable from Figure 1. Contrary to the hypothesized asymmetric relationship advanced by the rockets and feathers hypothesis in the relationship between these prices, the close comovement observed in Figure 1 suggests the existence of symmetric relationship between them. Two, the relatively close comovement between the retail energy prices and the crude oil costs suggests the existence of a stable long-run relationship between these variables. As part of our empirical analysis, we will verify the existence of this relationship using the bounds-testing procedure of Pesaran, Shin and Smith (2001, henceforth PSS) and the t_{BDM}-Statistic of Banerjee *et al.* (1998). Three, all the variables declined substantially from 2008Q3 until the end of 2008Q4, which coincides with the peak of the GFC. This decline is quite substantial and consistent with our presumed existence of structural change in the relationship between the retail prices and crude oil costs.

Figure 1 | Time Series Plots of the Data for UK

Panel A: With Pump Prices



Panel B: With *Ex*-tax Prices



Notes: Panel A plots the crude oil costs (*PoBI*) and pump prices of unleaded petrol/gasoline (*Pukgl*), diesel (*Pukdl*), home heating oil/kerosene (*Pukhl*), and fuel oil/gas oil (*Pukfl*), while Panel B plots the crude oil costs and the corresponding *ex*-tax prices of the retail products. Panel B is akin to Figure 1.a in GS13. The indexed representation of the data is used in all cases. The plots for France are shown in Appendix 2. To conserve space, we do not present the plots for Germany, Italy and Spain, since the patterns are quite similar. Notice the sharp decline in all cases around mid-2008, which aptly captures the shock due to the GFC.

Source: Authors, based on GS13 data.

3. Methodology

3.1 The Dummy Variable Model

Representing logged retail prices by r_t and logged crude oil costs as c_t, the relationship between the retail prices and the crude oil costs can be written as:

$$r_t = \alpha + \lambda c_t + \varepsilon_t \, . \tag{1}$$

Let D_t be a dummy variable taking a value of 0 for observations in 1999:1–2008:6 and 1 for observations in 2008:7–2013:3, where 2008:7 is our presumed breakpoint. Assuming 2008:8 to be the breakpoint, then D_t will take a value of 0 for observations in 1999:1–2008:7 and 1 for observations in 2008:8–2013:3.

The existence of structural change in the relationship between the retail prices and the crude oil costs can be deduced using following multiple regression model:

$$r_t = \alpha_1 + \alpha_2 D_t + \lambda_1 c_t + \lambda_2 \left(D_t c_t \right) + \varepsilon_t \, , \tag{2}$$

where: α_2 is the differential intercept; and λ_2 is the differential slope coefficient. If either the differential intercept or the differential slope coefficient is statistically significant, then we must reject the hypothesis of no structural change. Furthermore, if the differential intercept and the differential slope coefficient are jointly statistically significant, we should also reject the hypothesis of no structural change.

3.2 The Nonlinear ARDL (NARDL) Model

For the European countries that largely import crude oil in the spot market by paying U.S. dollar prices, there is need to account for exchange rates as part of the marginal cost. To do this, we integrate the effects of the crude oil costs and the exchange rates by constructing the crude oil costs measured in the respective national currency as $h_t = c_t + f_t$, where f_t is the logged foreign exchange rates (*i.e.* euro to U.S. dollar exchange rate). To analyse the asymmetric adjustment of retail prices following changes in crude oil costs, this study follows Shin, Yu and Greenwood-Nimmo (2013, henceforth SYG) and GS13 by adopting the asymmetric cointegrating relationship is of the form[2]:

$$r_t = \theta^+ h_t^+ + \theta^- h_t^- + \varepsilon_t \,, \tag{3}$$

where: r_t, which is assumed to be integrated of order one, I(1)[3], stands for the retail energy prices (including the prices of gasoline, automotive diesel, domestic heating oil and industrial fuel oil), while the regressor h_t stands for the crude oil cost which is decomposed as:

$$h_t = h_0 + h_t^+ + h_t^- \,, \tag{4}$$

where $h_t^+ = \sum_{j=1}^{t} max(\Delta h_j, 0)$ and $h_t^- = \sum_{j=1}^{t} min(\Delta h_j, 0)$ are partial sum processes of positive and negative changes in h_t, while h_0 is an initial threshold value that we assume to be zero following SYG. Δ is the first difference operator, while θ^+ and θ^- are the associated asymmetric long-run parameters. Our initial experimentation with the data indicate that decomposing the crude oil price in this way results in an approximate 58:42 split of observations in favour of the positive regime.

The NARDL(p,q) model associated with Equation 3 can be written in its level form as:

$$r_t = \sum_{j=1}^{p} \phi_j r_{t-j} + \sum_{j=0}^{q} \left(\theta_j^+ h_{t-j}^+ + \theta_j^- h_{t-j}^- \right) + \varepsilon_t \,, \tag{5}$$

where ϕ_j embed the autoregressive parameters; θ_j^+ and θ_j^- are the asymmetric distributed lag parameters; while ε_t is the independently and identically distributed white noise process with zero mean and constant variance, σ_ε^2. This study adopts the general-to-specific lag selection technique starting with an initial maximum lag length of 5 with a unidirectional

2 For convenience and without loss of generality, we do not include the deterministic regressors such as the constant.

3 The Zivot-Andrews unit root test results in Table 1 indicate that all the variables are indeed I(1).

5% decision rule (*i.e.* $p_{max} = q_{max} = 5$). This is consistent with GS13 and ensures that neither the model dynamics nor the functional form of the cointegrating relationship is arbitrarily misspecified. To capture speed of adjustment asymmetry as well as long-run and short-run asymmetries, we rewrite Equation 5 in its error correction form as:

$$\Delta r_t = \rho r_{t-1} + \theta^+ h_{t-1}^+ + \theta^- h_{t-1}^- + \sum_{j=1}^{p-1} \lambda_j \Delta r_{t-j} + \sum_{j=0}^{q-1} \left(\pi_j^+ \Delta h_{t-j}^+ + \pi_j^- \Delta h_{t-j}^- \right) + e_t , \qquad (6)$$

where ρ is the speed of adjustment; $\theta^+ = \sum_{j=0}^{q} \theta_j^+$ and $\theta^- = \sum_{j=0}^{q} \theta_j^-$; $\beta^+ = -\dfrac{\theta^+}{\rho}$ and $\beta^- = -\dfrac{\theta^-}{\rho}$ are the asymmetric long-run parameters; λ_j is the short-run autoregressive parameter; while π_j^+ and π_j^- are the positive and negative short-run parameters (GS13 provides a vivid description of these parameters). Though Equation 6 corrects perfectly for the potential weak endogeneity of nonstationary explanatory variables, we must emphasize that endogeneity is not an important feature here given that the countries of interest in this study have negligible oil production activities. Our empirical analyses are essentially based on three forms of asymmetry, namely: long-run, short-run and speed of adjustment asymmetries. Using the standard Wald coefficient restriction tests, we evaluate the null hypothesis of long-run symmetry $(\mathrm{H}_0 : \beta^+ = \beta^-)$ and that of short-run additive symmetry $\left(\mathrm{H}_0 : \sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^- \right)$.
We also use the NARDL model in Equation 6 to derive the asymmetric cumulative dynamic multiplier effects of a unit change in h_t^+ and h_t^- on r_t, which are respectively defined by:

$$m_s^+ = \sum_{j=0}^{s} \frac{\partial r_{t+j}}{\partial h_t^+}, \quad m_s^- = \sum_{j=0}^{s} \frac{\partial r_{t+j}}{\partial h_t^-}, \quad s = 0, 1, 2, \ldots \qquad (7)$$

By construction, as $s \to \infty$, $m_s^+ \to \beta^+$, and $m_s^- \to \beta^-$. We compute two standard error confidence intervals for the dynamic multipliers in order to evaluate the statistical significance of the short-run and long-run asymmetries and graphically illustrate the patterns of these asymmetries over a 12-month horizon (*i.e.* $s_{max} = 12$). Overall, the ability of the dynamic multipliers was exploited to illuminate the traverse from initial equilibrium, *via* short-run disequilibrium following a shock, to a new long-run equilibrium that makes them a commanding tool for the combined analysis of both short-run dynamic asymmetry and long-run response asymmetry.

Apart from the powerful dynamic multipliers derivable from the NARDL model initially advanced by SYG, there are other important features that have made the NARDL model in Equation 6 the preferred model for asymmetric price transmission analysis. It is linear in parameters and easily estimable by OLS; (ii) it accommodates combinations of both stationary and non-stationary variables; and (iii) the null hypothesis of no cointegrating relationship between the levels of r_t, h_t^+ and h_t^- (*i.e.* $\rho = \theta^+ = \theta^- = 0$) is easily tested using the bounds-testing approach of PSS, which remains valid irrespective of whether the regressors are I(0), I(1) or mutually cointegrated.

4. Empirical Results and Discussion

4.1 Testing for Structural Breaks

A major goal of this study is to determine if the GFC induced structural change in the relationship between retail energy prices and crude oil costs in the UK. To achieve this, all the variables used by GS13 were subjected to Zivot-Andrews unit root test to enable us capture both the orders of integration and the minimum breakpoint of each series. The results of the tests are presented in Table 1.

Table 1 | Zivot-Andrews Test Results

Variable	Order of Integration	Minimum Breakpoint
PukgX **(Unleaded Petrol, ex-Tax and Duty)**	I(1)	2009:2
PukdX **(Diesel, ex-Tax and Duty)**	I(1)	2008:8
PukhX **(Kerosene, ex-Tax and Duty)**	I(1)	2008:8
PukfX **(Gas Oil, ex-Tax and Duty)**	I(1)	2008:7
Pukg **(Unleaded Petrol, at pump)**	I(1)	2009:2
Pukd **(Diesel, at pump)**	I(1)	2008:8
Pukh **(Kerosene, at pump)**	I(1)	2008:8
Pukf **(Gas Oil, at pump)**	I(1)	2008:7
PoB **(Crude Oil)**	I(1)	2008:7

Note: The results in this table suggest that all the variables are not stationary at levels, and that most of the series witnessed their minimum structural break in August 2008, corresponding with the peak of the GFC.

Source: Authors' calculations, based on GS13 data.

The result above indicates that all the series are integrated of order one, I (I) suggesting that there may be a stable long-run relationship between the retail energy prices and the crude oil costs. Considering the last column of Table 1, majority of the series shows evidence of structural change in July and August 2008. On the premise of these results, we proceeded to test the relationship between the various retail energy prices and the crude oil costs for evidence of structural change considering the two presumed breakpoints, namely 2008:7 and 2008:8. The results are presented in Table 2.

Table 2 | Dummy Variable Model Estimation Results

Panel 1: Breakpoint at 2008:7

Dependent Variable	Test of Significance for Differential Intercept (H_0: $\alpha_2 = 0$)	Test of Significance for Differential Slope Coefficient (H_0: $\lambda_2 = 0$)	Test of Joint Significance (H_0: $\alpha_2 = \lambda_2 = 0$)
PukgX	–3.67 (0.00)***	3.87 (0.00)***	21.13 (0.00)***
PukdX	0.43 (0.67)	–0.35 (0.73)	2.98 (0.23)
PukhX	1.55 (0.12)	–1.53 (0.13)	2.44 (0.30)
PukfX	1.07 (0.29)	–0.98 (0.33)	2.46 (0.29)
Pukg	–10.15 (0.00)***	10.15 (0.00)***	103.24 (0.00)***
Pukd	–3.49 (0.00)***	3.97 (0.00)***	42.25 (0.00)***
Pukh	1.57 (0.12)	–1.56 (0.12)	2.49 (0.29)
Pukf	2.47 (0.01)**	–2.25 (0.03)**	11.89 (0.00)***

Panel 2: Breakpoint at 2008:8

Dependent Variable	Test of Significance for Differential Intercept (H_0: $\alpha_2 = 0$)	Test of Significance for Differential Slope Coefficient (H_0: $\lambda_2 = 0$)	Test of Joint Significance (H_0: $\alpha_2 = \lambda_2 = 0$)
PukgX	–3.61 (0.00)***	3.79 (0.00)***	20.12 (0.00)***
PukdX	0.54 (0.59)	–0.49 (0.62)	1.53 (0.46)
PukhX	1.64 (0.10)	–1.64 (0.10)	2.70 (0.26)
PukfX	1.13 (0.26)	–1.06 (0.29)	2.34 (0.31)
Pukg	–10.70 (0.00)***	10.63 (0.00)***	114.40 (0.00)***
Pukd	–3.31 (0.00)***	3.73 (0.00)***	32.64 (0.00)***
Pukh	1.67 (0.10)	–1.67 (0.10)	2.79 (0.25)
Pukf	2.53 (0.01)**	–2.32 (0.02)**	11.94 (0.00)***

Notes: Apart from the dummy variable, all variables were logged prior to estimation. All estimations were corrected for serial correlation and heteroscedasticity using the Newey-West HAC method. For the tests of significance for both the differential intercept and the differential slope coefficient, the *t*-statistics are reported following Equation 2, with the *p*-values in parenthesis. For the test of joint significance, the chi--square values are reported from the Wald test, with the *p*-values in parenthesis.
*** denotes rejection of test hypothesis at 1% level, while ** and * denote rejection at 5% and 10% levels respectively.
Notice that at pump, the existence of structural change has been established in all cases at the 5% level, except for the kerosene market. However, for the *ex*-tax prices, structural change has been found only in the gasoline market.
Overall, the results indicate some evidence of structural change in the relationship between the retail energy prices and crude oil costs in the UK.

Source: Authors' calculations, based on GS13 data.

From the results, it can be observed that there is no significant difference between Panels 1 and 2. Both *ex*-tax and pump prices of gasoline show evidence of structural change in their relationship with crude oil costs in July and August 2008, corresponding with the period of the GFC. In the case of diesel and gas oil, there is evidence of structural change only at pump. These evidences of structural change induced by the GFC indicate that the crisis, which led to considerable decline in oil prices between 2008Q3–2008Q4, substantially affected economic behaviour. These results are consistent with Reboredo (2012), which found that even though oil price–exchange rate dependence is in general weak, it rose substantially in the aftermath of the GFC. The results are also consistent with Barunik, Kocenda and Vacha (2016), which found that heterogeneity in correlations across a number of investment horizons between pairs of key traded assets (gold, oil, and stocks) is a dominant feature during times of economic downturn and financial turbulence, and that after the GFC, correlations among all three assets increase and become homogenous, coinciding with the structural breaks that are identified in specific correlation dynamics.

4.2 NARDL Estimation Results for UK

The nonlinear ARDL model was estimated over three periods, namely: 1999:1–2008:7 (i.e. before the structural change induced by the GFC); 2008:8–2013:1 (*i.e*. after the structural change arising from the GFC); and 1999:1–2013:1 (ignoring the structural change induced by the GFC). A summary of all the results are presented in Table 3 below while the accompanying cumulative dynamic multipliers are presented in Appendix 1.

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Table 3 | Summary of NARDL Estimation Results for the UK before and after the Structural Change induced by the GFC

Panel 1: Before the Structural Change (1999:1–2008:7)

	PukgX	*PukdX*	*PukhX*	*PukfX*	*Pukg*	*Pukd*	*Pukh*	*Pukf*
Estimated Coefficients								
ρ	−0.50***	−0.51***	−0.26***	−0.24***	−0.26***	−0.09*	−0.26***	−0.16***
β^+	0.75***	0.76***	1.06***	1.28***	0.33***	0.34*	1.06***	1.18***
β^-	0.76***	0.75***	1.13***	1.41***	0.35***	0.34*	1.13***	1.26***
$\sum_{q=1}^{q-1} \pi_j^+$	0.85***	0.20***	0.51***	0.65***	0.19***	0.24**	0.51***	0.51***
$\sum_{q=1}^{q-1} \pi_j^-$	0.28***	0.19**	0.93***	0.97***	0.23***	0.15**	0.93***	0.82***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	0.05	0.01	5.27**	11.36***	2.82*	0.00	5.27**	3.09*
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	8.28***	0.00	5.43**	2.32	0.15	1.06	5.46**	3.91**
Rockets & Feathers Effect (Effect A)	Present	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Rent–seeking Behaviour (Effect B)	Effect B detected only in the gasoline market since the rockets & feathers effect in *unldX* (*i.e. ex*–tax) disappeared in *unld* (*i.e.* at pump)							
Diagnostics								
F_{PSS}	18.97***	31.20***	8.44***	9.10***	6.33**	2.17	8.44***	6.95**
t_{BDM}	−7.39***	−9.47***	−4.55***	−4.60***	−4.25***	−1.84	−4.55***	−3.82 ***
BG Test (NR^2)	16.63	26.13**	7.84	5.36	12.82	16.76	7.84	6.76
$\bar{\mathcal{R}}^2$	0.63	0.61	0.64	0.64	0.60	0.43	0.64	0.63

Panel 2: After the Structural Change (2008:8–2013:1)

	PukgX	*PukdX*	*PukhX*	*PukfX*	*Pukg*	*Pukd*	*Pukh*	*Pukf*
Estimated Coefficients								
ρ	−0.44***	−0.48***	−0.41***	−0.53***	−0.39***	−0.36***	−0.32***	−0.64***
β^{+}	0.94***	0.88***	1.21***	0.95***	0.52***	0.56***	0.96***	0.80***
β^{-}	1.03***	0.90***	1.19***	0.93***	0.56***	0.61***	1.13***	0.79***
$\sum_{q=1}^{q-1} \pi_j^{+}$	0.73**	0.05***	0.20***	0.01***	0.29**	0.15**	0.61**	0.28***
$\sum_{q=1}^{q-1} \pi_j^{-}$	0.00	−0.25***	0.16	0.39***	0.16**	0.10**	0.29**	0.15***
Symmetry Tests								
$H_0: \beta^{+} = \beta^{-}$	1.09	0.14	0.53	0.13	1.28	1.74	2.40	0.21
$H_0: \sum_{q=1}^{q-1} \pi_j^{+} = \sum_{q=1}^{q-1} \pi_j^{-}$	8.08***	1.71	0.04	3.45*	1.02	0.22	1.86	0.60
Rockets & Feathers Effect (Effect A)	Present	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Rent–seeking Behaviour (Effect B)	Effect B detected only in the gasoline market since the rockets & feathers effect in *unldX* (*i.e. ex*–tax) disappeared in unld (*i.e.* at pump)							
Diagnostics								
F_{PSS}	5.43*	16.08***	8.25***	29.59***	6.16**	10.78***	8.64***	30.24***
t_{BDM}	−3.70**	−6.54***	−4.70***	−8.33***	−3.58**	−4.86***	−4.44***	−8.77***
BG Test (NR^2)	9.06	16.75	11.79	22.13**	9.09	12.70	10.48	18.76*
$\bar{\mathcal{R}}^2$	0.64	0.81	0.60	0.80	0.74	0.75	0.64	0.80

Panel 3: Full sample used by GS13 which ignored Structural Change (1999:1–2013:1)

	PukgX	***PukdX***	***PukhX***	***PukfX***	***Pukg***	***Pukd***	***Pukh***	***Pukf***
Estimated Coefficients								
ρ	−0.36***	−0.37***	−0.33***	−0.29***	−0.06**	−0.08***	−0.31***	−0.15***
β^+	0.78***	0.82***	1.00***	1.24***	0.32*	0.44***	1.01***	1.12***
β^-	0.78***	0.83***	1.05***	1.33***	0.27	0.45***	1.06***	1.18***
$\sum_{q=1}^{q-1} \pi_j^+$	0.76***	0.56***	0.75***	0.90***	0.37***	0.23***	0.75***	0.71***
$\sum_{q=1}^{q-1} \pi_j^-$	0.66***	0.17***	0.45***	0.34***	0.38***	0.27***	0.48***	0.68***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	0.05	1.28	6.71***	17.61***	1.11	0.07	6.89***	2.01
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	0.31	7.65***	4.07**	10.75***	0.03	0.32	3.74*	0.04
Rockets & Feathers Effect (Effect A)	Absent	Present	Present	Present	Absent	Absent	Absent	Absent
Rent–seeking Behaviour (Effect B)	Effect B detected in all the markets except for the gasoline market.							
Diagnostics								
F_{PSS}	13.82***	25.88***	18.58***	22.56***	3.04	6.06**	17.48***	6.64**
t_{BDM}	−6.37***	−8.50***	−7.07***	−7.37***	−2.41	−3.72**	−6.82***	−3.91***
BG Test (NR^2)	15.96	15.47	8.76	4.40	14.19	7.07	8.99	7.39
$\bar{\mathcal{R}}^2$	0.71	0.66	0.67	0.68	0.67	0.61	0.68	0.68

Notes: *Pukg*, *Pukd*, *Pukh* and *Pukf* denote the pump prices (*i.e.* inclusive of tax and duty) of gasoline, diesel, home heating oil/kerosene and fuel oil/gas oil; while *PukgX*, *PukdX*, *PukhX* and *PukfX* denote the *ex*-tax prices of gasoline, diesel, kerosene and gas oil in UK, respectively. The notation for the estimated coefficients relates to the NARDL model of Equation 6. The reported symmetry tests are standard Wald tests. The BG Test is the Breusch–Godfrey serial correlation test. The relevant k = 1 critical values reported by PSS for the t_{BDM} statistic are –2.91, −3.22, and –3.82 at the 10%, 5% and 1% levels. The equivalent critical values for the F_{PSS} statistic are 4.78, 5.73 and 7.84.
* denotes significance at the 10% level; ** denotes significance at the 5% level; while *** denotes significance at the 1% level.
The full sample results in Panel 3 correspond with the results of GS13 which ignored the existence of structural change in the relationship between the retail energy prices and crude oil costs; while the sub-sample results in Panels 1 and 2 explicitly considered the existence of structural change. Effect A tests for the null hypothesis of no rockets and feathers effect, while Effect B tests for the null hypothesis of no rent-seeking behaviour. Notice that Effect A and Effect B observed in diesel, kerosene and gas oil markets under GS13 vanished when the structural change effect is taken into the consideration. The cumulative dynamic multipliers corresponding to these results are shown in Appendix 1.

Source: Authors' calculations, based on GS13 data.

In the two sub periods (*i.e*. 1999:1–2008:7 and 2008:8–2013:1) for which the structural change induced by the GFC is taken into the consideration, there is strong evidence of the rockets and feathers effect as well as the possibility of firms using the tax system to conceal rent-seeking behaviour only in the gasoline market. However, in the full sample used by GS13 (*i.e*. 1999:1–2013:1) that did not take the existence of this structural change into the consideration, there is strong evidence of rockets and feathers effect as well as the possibility of firms using the tax system to conceal rent-seeking behaviour in three retail energy markets, namely diesel, kerosene and gas oil. This outcome suggests that once the structural change in the relationship between retail energy prices and the crude oil costs is taken into the consideration, the findings of GS13 for all the retail markets no longer hold. On the long-run asymmetry, it was found that the long-run asymmetry in the markets for kerosene (*ex*-tax and at pump) and gas oil (*ex*-tax) reported by GS13 for the full sample no longer holds in the second sub-period (2008:8–2013:1). Even though the observed speed of adjustment is generally sluggish (*i.e*. below 50%), it is relative more sluggish in the GS13 results in Panel 3 compared to our two sub periods in Panels 1 and 2. All in all, it can be inferred that once the important issue of structural change induced by the GFC is taken into account, the results in the established literature of GS13 are no longer tenable. For non-road fuels (*i.e*. kerosene and gas oil), the estimated long-run parameters of approximately 1.00 indicate that the consumers of these products in the UK are somewhat insulated from the fluctuations in the crude oil market in the long-run, which is consistent with GS13 and BCG. However, these estimated parameters are much lower for the road fuels (*i.e.* gasoline and diesel), particularly at pump where consumers are substantially exposed to the ups and downs of the crude oil market in the long-run.

4.3 NARDL Estimation Results for France:

Further, we estimated the nonlinear ARDL model over the period 2008:8–2016:1 taking into consideration the non-negligible role of the structural change induced by the GFC as established above. First, we estimated the model without adjusting for the impact of exchange rate. Second, we re-estimated the model by incorporating the exchange rate as part of the marginal costs of importing crude oil into the selected countries. The estimated results for France together with the accompanying cumulative dynamic multipliers are presented in Table 4.

Table 4 | NARDL Estimation Results for France (2008:8–2016:1)

Panel 1: Without Exchange Rate

	PfrgX	*PfrdX*	*PfrhX*	*PfrfX*	*Pfrg*	*Pfrd*	*Pfrh*	*Pfrf*
Estimated Coefficients								
ρ	−0.39***	−0.34***	−0.37***	−0.32***	−0.33***	−0.22***	−0.32***	−0.38***
β^+	0.72***	0.84***	0.81***	1.08***	0.36***	0.43***	0.70***	0.93***
β^-	0.60***	0.80***	0.75***	1.12***	0.28***	0.20***	0.61***	0.89***
$\sum_{q=1}^{q-1} \pi_j^+$	0.90***	0.70**	0.58**	1.44***	0.53**	0.70***	0.50***	1.39***
$\sum_{q=1}^{q-1} \pi_j^-$	0.56**	0.33**	0.28***	0.53***	0.17**	0.12**	0.26***	0.51***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	49.27***	10.14***	18.45***	1.65	37.24***	64.04***	32.45***	5.38**
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	4.36**	4.34**	2.45	16.00***	8.79***	24.61***	1.94	15.73***
Rockets & Feathers Effect (Effect A)	Present	Present	Absent	Present	Present	Present	Absent	Present
Rent–seeking Effect (Effect B)	Effect B not present in all cases since the rockets & feathers effect observed in *ex*–tax prices is also present in pump prices.							
Diagnostics								
F_{PSS}	7.34**	13.48***	17.68***	10.64***	5.56*	12.49***	13.18***	8.41***
t_{BDM}	−4.22***	−5.88***	−7.05***	−4.00***	−3.79**	−4.75***	−6.16***	−4.58***
BG Test (NR^2)	7.52	13.88	11.17	2.73	13.45	14.77	9.28	3.38
ARCH Test	6.91	15.15	7.30	12.72	5.86	0.88	10.59	14.51
DW	1.74	2.07	1.99	1.91	1.82	1.96	1.99	2.01
$\bar{\mathcal{R}}^2$	0.83	0.89	0.82	0.81	0.75	0.70	0.78	0.77

Panel 2: With Exchange Rate as Additional Marginal Cost

	PfrgX	*PfrdX*	*PfrhX*	*PfrfX*	*Pfrg*	*Pfrd*	*Pfrh*	*Pfrf*
Estimated Coefficients								
ρ	−0.62***	−0.37***	−0.36***	−0.29***	−0.39***	−0.24***	−0.34***	−0.34***
β^+	0.69***	0.84***	0.79***	1.03***	0.32***	0.35***	0.68***	0.88***
β^-	0.69***	0.92***	0.85***	1.24***	0.30***	0.21***	0.70***	0.98***
$\sum_{q=1}^{q-1} \pi_j^+$	0.16***	0.47***	0.20***	0.81***	0.29***	0.61***	0.20***	0.75***
$\sum_{q=1}^{q-1} \pi_j^-$	0.93***	0.77***	0.56***	0.90***	0.33***	0.22***	0.44***	0.84***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	0.04	24.66***	7.86***	23.23***	3.05*	33.02***	0.81	12.33***
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	9.15***	3.05*	3.67*	0.17	0.26	11.61***	2.19	0.20
Rockets & Feathers Effect (Effect A)	Absent	Absent	Absent	Absent	Absent	Present	Absent	Absent
Rent–seeking Effect (Effect B)	Effect B not present in all cases since rockets & feathers effect is observed only in the diesel market at pump.							
Diagnostics								
F_{PSS}	15.24***	13.65***	17.00***	9.65***	7.42**	7.03**	14.84***	8.67***
t_{BDM}	−6.42***	−6.23***	−6.61***	−3.95***	−4.58***	−4.09***	−6.38***	−4.46***
BG Test (NR^2)	11.50	14.56	18.60*	12.42	18.14	9.17	15.81	8.95
ARCH Test	8.73	13.98	12.84	3.76	5.38	1.46	12.62	4.45
DW	1.85	2.17	2.09	1.68	1.79	2.15	2.00	1.68
$\bar{R}^2$	0.78	0.79	0.70	0.69	0.69	0.61	0.67	0.66

Notes: *Pfrg*, *Pfrd*, *Pfrh* and *Pfrf* denote the pump prices (*i.e.* inclusive of tax and duty) of gasoline, diesel, heating oil and fuel oil in France; while *PfrgX*, *PfrdX*, *PfrhX* and *PfrfX* denote the *ex*-tax prices of gasoline, diesel, heating oil and fuel oil in France, respectively. The notation for the estimated coefficients relates to the NARDL model of Equation 6. The reported symmetry tests are standard Wald tests. The BG Test is the Breusch–Godfrey serial correlation test; while the ARCH Test is the standard heteroscedasticity test. The BG Test and the ARCH Test were performed at lag 12 since the data are monthly series. The relevant k = 1 critical values reported by PSS for the t_{BDM} statistic are −2.91, −3.22, and −3.82 at the 10%, 5% and 1% levels. The equivalent critical values for the F_{PSS} statistic are 4.78, 5.73 and 7.84. DW is the Durbin-Watson *d* statistic.
* denotes significance at the 10% level; ** denotes significance at the 5% level; while *** denotes significance at the 1% level.
Notice that in Panel 1, **Effect A** is observed in gasoline, diesel and fuel oil markets; but in Panel 2, it is observed only in the diesel market at pump. **Effect B** is not detected in both Panels.

Source: Authors' calculations, based on IEA Monthly Oil Price data.

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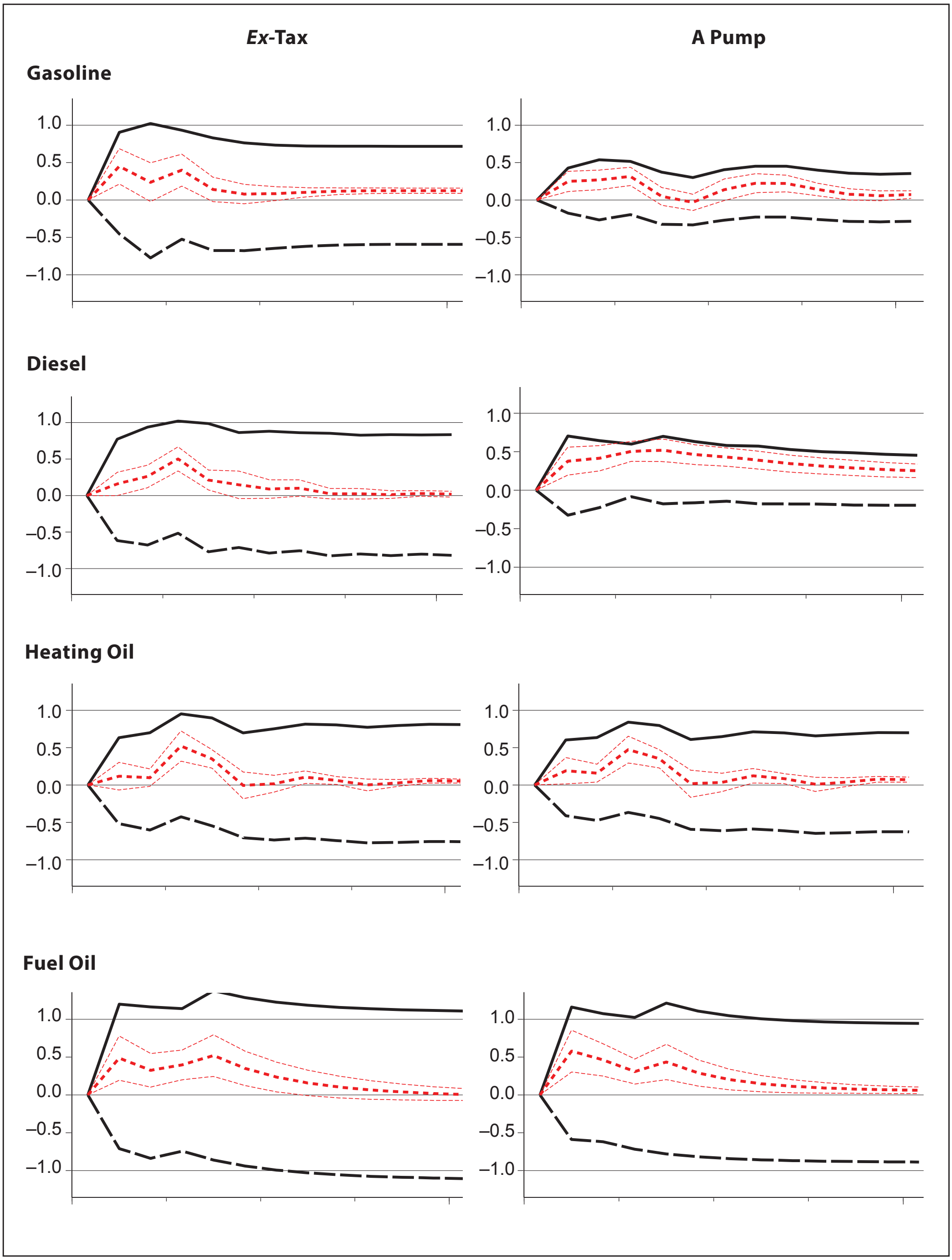
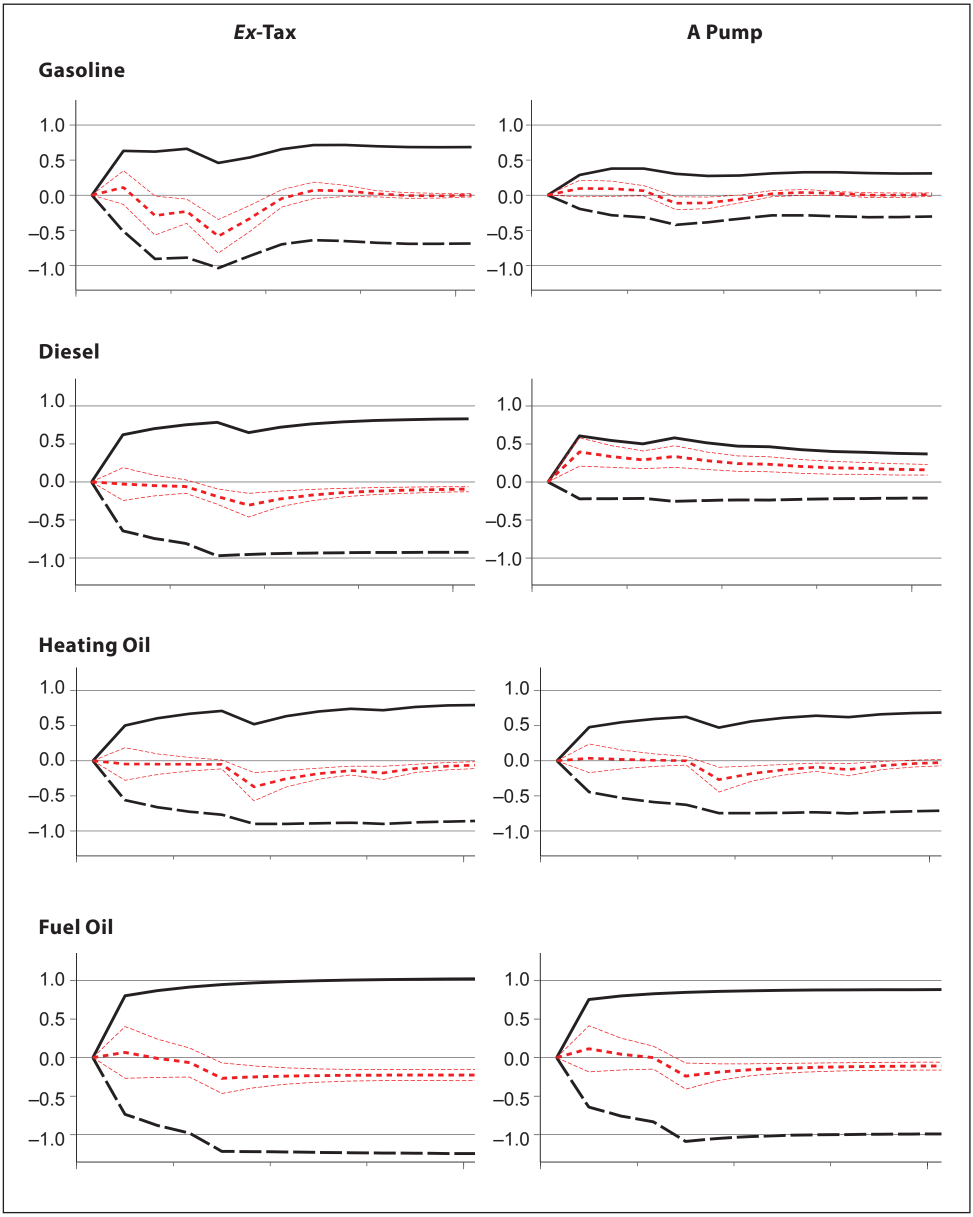
Figure 2 | Cumulative Dynamic Multipliers for France

Panel A: Without Exchange Rate



Panel B: With Exchange Rate as Additional Marginal Cost



Notes: Following GS13, the solid (dashed) black line is the cumulative dynamic multiplier with respect to a 1% positive (negative) change in the oil price, while the heavy dashed red line plots the difference between the two. The light dashed red lines report the two standard error confidence interval for the difference line computed by stochastic simulation. Tick marks on the horizontal axis represent three-month intervals, while the vertical axis is in percentage points.

Source: Authors, based on IEA Monthly Oil Price data.

In Panel 1, it was found that the speed of adjustment is quite sluggish (*i.e.* below 50%) and ranged between 32–39% and 22–38% for *ex*-tax prices and at pump, respectively. A closer examination reveals that it is even more sluggish for road fuels at pump than for *ex*-tax road fuel prices. This finding is in tandem with both GS13 and BCG. Such sluggish speed of adjustment is typical of markets witnessing weak competition, rent-seeking, extended periods of mispricing, and other collusive behaviours that are detrimental to consumers' welfare. Also, the long-run coefficients are relatively higher for *ex*-tax prices than for prices at pump. Since consumers generally observe the prices at pump, it means that they are to some extent vulnerable to the fluctuations in the crude oil markets in the long-run. Furthermore, the relatively higher long-run coefficients observed in the *ex*-tax prices are consistent with BCG and GS13, and also suggest that these prices relatively insulate the consumers from the ups and downs of the international crude oil market. Interestingly, the positive long-run parameters are higher than the corresponding negative ones in all cases, except for the *ex*-tax fuel oil market. This pattern of long-run asymmetry aptly indicates the presence of long-run rent-seeking, which is significant in all cases at the 5% level, except the *ex*-tax fuel oil market. A distinction was also made between road and non-road fuels with respect to the long-run coefficients at pump and it was found that the estimated long-run coefficients are relatively higher for non-road fuels at pump than for road fuels. This is consistent with the differences in the structure of these two markets which is consistent with Johnson (2002). There was also significant evidence of additively asymmetric dynamic adjustment in both the *ex*-tax and pump prices of road fuels at the 5% level. The cumulative dynamic multipliers in Panel A of Figure 2 capture these patterns graphically. It shows the rapid response of road fuel prices to positive changes in crude oil prices, and a sluggish response to negative changes. Such asymmetric patterns are indicative of the reality of the rockets and feathers effect in the French road fuel market. In the case of non-road fuel markets (*i.e.* heating oil and fuel oil), the rockets and feathers effect is observed only in the fuel oil market. Contrary to GS13, the patterns of short-run asymmetry across all the markets do not raise the possibility of firms using the tax system to conceal rent-seeking behaviour. This is because all the asymmetric patterns observed with *ex*-tax prices are not obscured at the pump. On Panel 2 of Table 4, which reports the estimation results incorporating the exchange rate as part of the marginal cost of importing oil, it was found that the speed of adjustment remained sluggish, ranging between 29–62% and 24–39% for *ex*-tax and pump prices, respectively. However, taking the exchange rate effect into the consideration, the result shows pervasive evidence of rockets and feathers effect earlier observed in the gasoline and industrial fuel oil markets disappeared; the rockets and feathers effect in the *ex*-tax price of diesel no longer exists; all the long-run asymmetries observed in both the *ex*-tax and pump prices of gasoline and heating oil as well as the *ex*-tax price of diesel and pump price of fuel oil vanished; and long-run rent-seeking is seen only in the diesel market at pump. These results indicate that the role of exchange rate in the asymmetric relationship between retail energy prices and crude oil costs for France cannot be called negligible.

4.4 NARDL Estimation Results for Italy, Spain and Germany

The NARDL estimation results for Italy, Spain and Germany are presented in Tables 5, 6 and 7, while the accompanying cumulative dynamic multipliers are presented in Figures 3, 4 and 5, respectively. Based on the asymmetries of interest in this study, the results are summarized as follows. For the Italian markets, once the exchange rate effect is taken into the consideration, then: (i) the possibility of retail firms using the tax system to obscure rent-seeking behaviour in the gasoline market vanishes (notice that in Panel 2 of Tables 5, Effect B is not observed); (ii) the significant evidence of rockets and feathers effect in the *ex*-tax prices of gasoline, diesel, and domestic heating oil as well as the pump price of domestic heating oil disappears; and (iii) the significant evidence of long-run asymmetry in the *ex*-tax and pump prices of heating oil as well as the *ex*-tax price of gasoline dies away. For the Spanish markets, the results indicate that as soon as the exchange rate effect is taken into the consideration: (i) the possibility of retail firms exploiting the tax system to conceal rent-seeking behaviour that was earlier observed in the gasoline market vanishes; (ii) the significant evidence of rockets and feathers effect earlier found in the *ex*-tax prices of gasoline and domestic heating oil disappears; and (iii) the long-run asymmetry earlier observed in both the *ex*-tax and pump prices of domestic heating oil as well as the *ex*-tax price of diesel dies away. For the German markets, the familiar patterns are also observed. We find that once the exchange rate effect is taken into account, then: (i) the significant evidence of the rockets and feathers effect in the *ex*-tax and pump prices of gasoline as well as the *ex*-tax price of diesel vanishes; (ii) the long-run asymmetry in the pump price of gasoline disappears; and (iii) the long-run asymmetry in the *ex*-tax price of diesel dies away.

The above results indicate that for these European countries that have very high oil import dependency ratio, accounting for exchange rate as part of the marginal cost of acquiring crude oil substantially alters the asymmetric relationship between retail energy prices and crude oil costs. This effectively means that previous studies such as Kristoufek and Lunackova (2014) that failed to consider the role of exchange rate may be misleading. Kristoufek and Lunackova (2014) studied some European gasoline markets (including Belgium, France, Germany, Italy, and the Netherlands) for possible asymmetric price adjustment using Brent crude oil as an exogenous production variable, but failed to account for exchange rate as part of the marginal cost of importing oil for these countries that have high oil import dependency ratio. They found evidence in support of the hypothesized asymmetry only in Belgium. The pervasive evidence of the rockets and feathers effect we have established in this study, especially in the absence of the exchange rate effect is consistent with Bacon (1991), BCG and GS13. Furthermore, the sluggish speed of adjustment observed in most of the retail energy markets is also consistent with GS13, and typical of markets witnessing weak competition and prolonged periods of mispricing.

Table 5 | NARDL Estimation Results for Italy (2008:8–2016:1)

Panel 1: Without Exchange Rate

	PitgX	*PitdX*	*PithX*	*PitfX*	*Pitg*	*Pitd*	*Pith*	*Pitf*
Estimated Coefficients								
ρ	−0.46***	−0.27***	−0.34***	−0.32***	−0.10**	−0.13***	−0.30***	−0.30***
β^+	0.63***	0.20***	0.76***	0.94***	0.48**	0.63***	0.47***	0.87***
β^-	0.56***	0.20***	0.67***	0.98***	0.35**	0.30***	0.40***	0.90***
$\sum_{q=1}^{q-1} \pi_j^+$	0.73***	0.59***	0.57***	0.87***	0.38***	0.64***	0.34***	0.80***
$\sum_{q=1}^{q-1} \pi_j^-$	0.46***	0.31***	0.19***	0.81***	0.25***	0.13***	0.12***	0.74***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	35.59***	1.67	56.09***	4.50**	18.75***	51.53**	57.90***	3.59*
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	4.45**	4.59**	12.17***	0.19	3.65*	22.32***	10.34***	0.25
Rockets & Feathers Effect (Effect A)	Present	Present	Present	Absent	Absent	Present	Present	Absent
Rent–seeking Effect (Effect B)	Effect B detected only in the gasoline market since the rockets & feathers effect observed in *ex*–tax price is obscured at pump.							
Diagnostics								
F_{PSS}	12.59***	8.48***	17.10***	6.07**	1.92	8.33***	15.01***	5.57*
t_{BDM}	−5.55***	−4.58***	−6.56***	−4.05***	−2.29	−3.36**	−6.09***	−3.92***
BG Test (NR^2)	8.66	11.37	4.47	11.26	6.04	17.86	5.00	10.77
$\bar{R}^2$	0.87	0.90	0.88	0.86	0.75	0.70	0.86	0.86

Panel 2: With Exchange Rate as Additional Marginal Cost

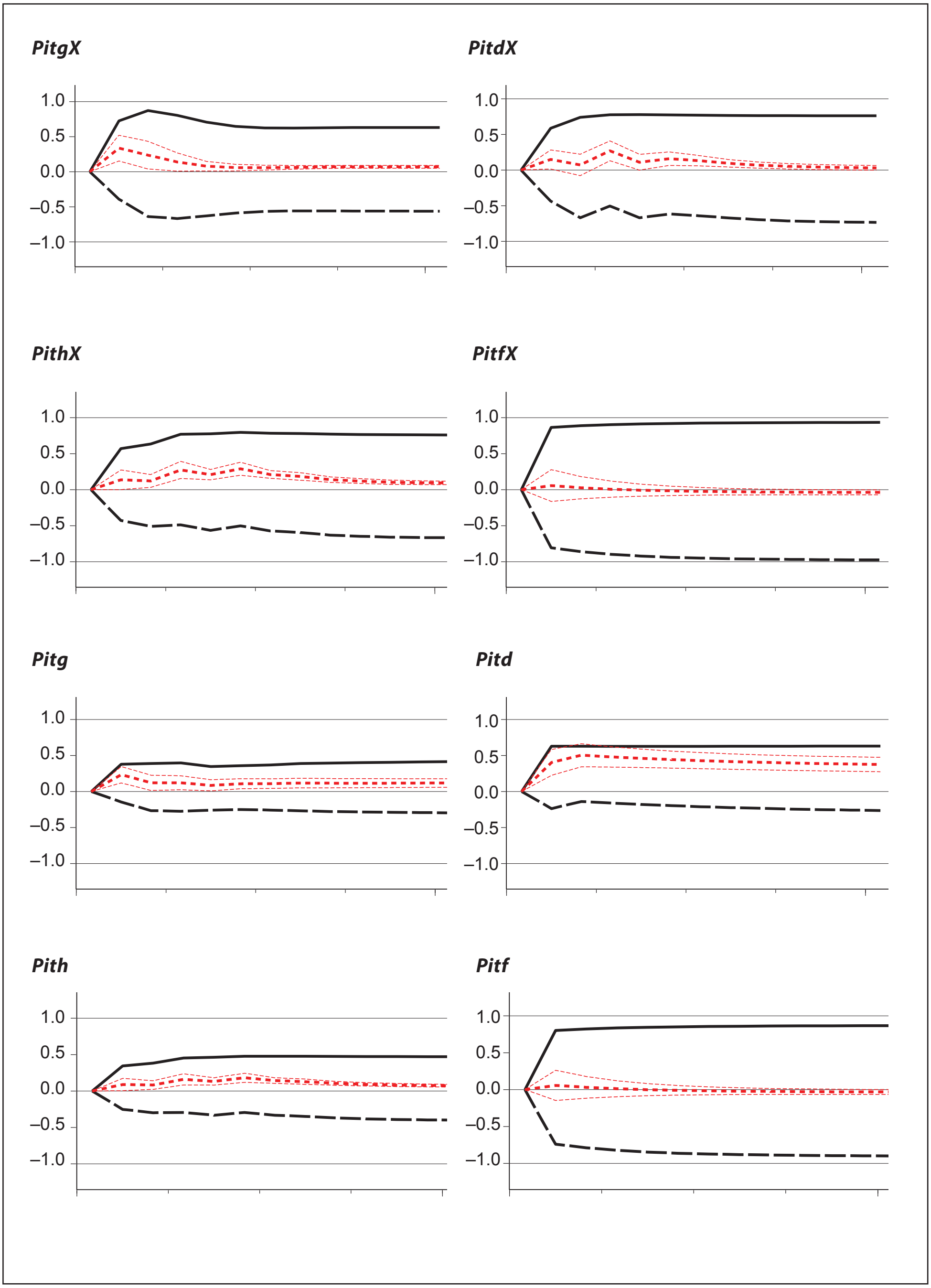
	PitgX	*PitdX*	*PithX*	*PitfX*	*Pitg*	*Pitd*	*Pith*	*Pitf*
Estimated Coefficients								
ρ	−0.49***	−0.21***	−0.29***	−0.18**	−0.15***	−0.15***	−0.25***	−0.17**
β^+	0.64***	0.73***	0.74***	0.98**	0.40**	0.55***	0.46***	0.90**
β^-	0.65***	0.85***	0.74***	1.14**	0.29**	0.33***	0.45***	1.05**
$\sum_{q=1}^{q-1} \pi_j^+$	0.35***	0.53***	0.44***	0.71***	0.29***	0.59***	0.27***	0.66***
$\sum_{q=1}^{q-1} \pi_j^-$	0.46***	0.58***	0.54***	0.82***	0.31***	0.17***	0.30***	0.75***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	1.13	20.89***	0.17	12.80***	19.16***	42.58***	0.12	11.82***
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	0.36	0.19	0.68	0.38	0.03	17.99***	0.21	0.29
Rockets & Feathers Effect (Effect A)	Absent	Absent	Absent	Absent	Absent	Present	Absent	Absent
Rent–seeking Effect (Effect B)	Effect B not detected in all cases.							
Diagnostics								
FPSS	10.99***	4.11	14.58***	2.17	3.11	7.67**	12.26***	2.04
tBDM	−5.52***	−3.27**	−6.30***	−2.36	−2.77	−3.59**	−5.73***	−2.32
BG Test (NR2)	15.33	11.11	11.12	8.28	12.53	15.24	11.11	7.77
$\bar{\mathcal{R}}^2$	0.79	0.83	0.82	0.75	0.69	0.68	0.80	0.74

Notes: *Pitg*, *Pitd*, *Pith* and *Pitf* denote the pump prices (*i.e.* inclusive of tax and duty) of gasoline, diesel, heating oil and fuel oil in Italy; while *PitgX*, *PitdX*, *PithX* and *PitfX* denote the *ex*-tax prices of gasoline, diesel, heating oil and fuel oil in Italy, respectively. Other notes in Table 4 apply. Notice that all the rockets and feathers effect (Effect A) observed in the *ex*-tax prices in Panel 1 disappeared in Panel 2. In addition, the rent-seeking effect (Effect B) observed in the gasoline market in Panel 1 also disappeared in Panel 2. This suggests that the role of exchange rate cannot be called unimportant in this country.

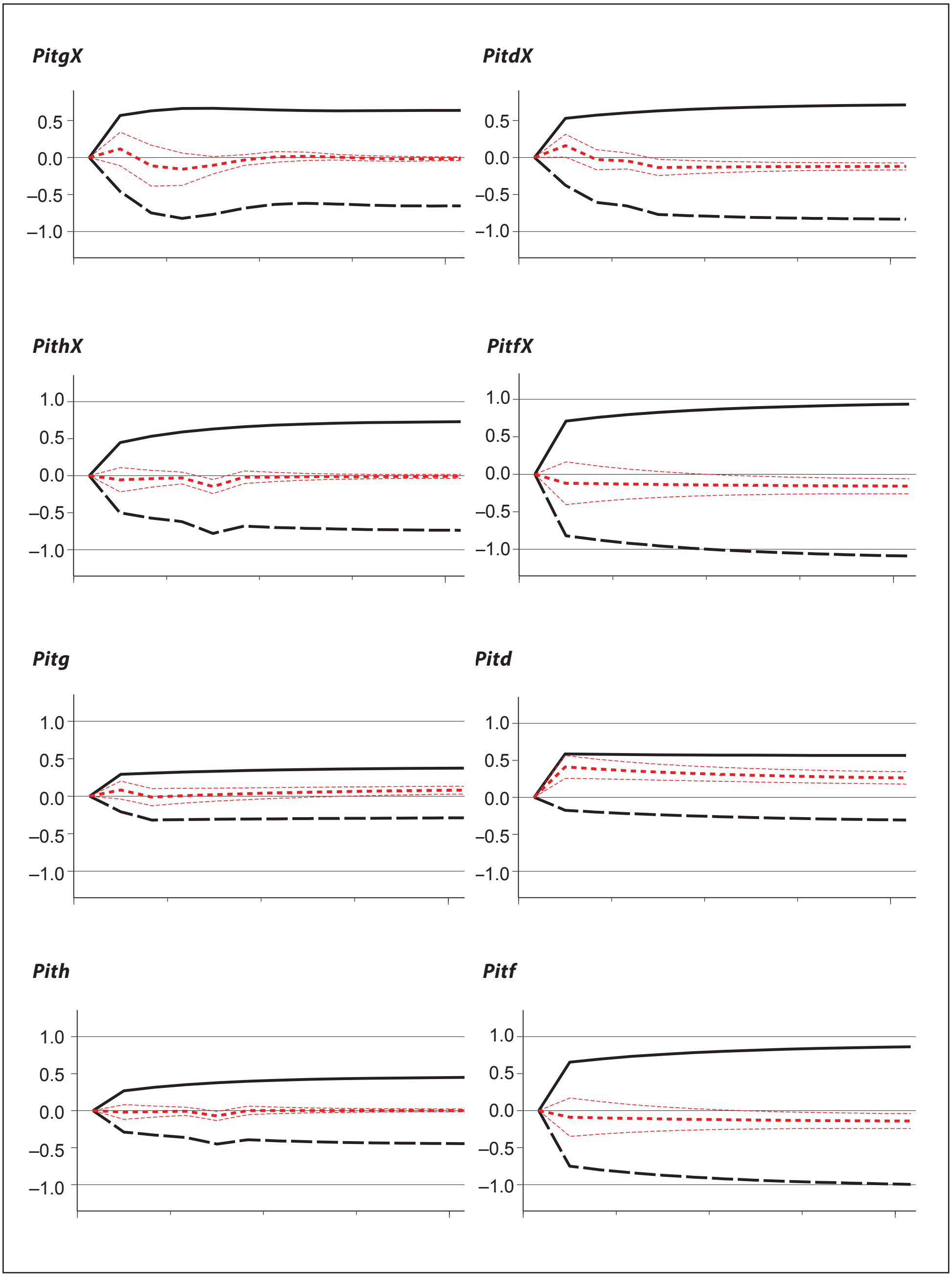
Source: Authors' calculations, based on IEA Monthly Oil Price data.

Figure 3 | Cumulative Dynamic Multipliers for Italy

Panel 1: Without Exchange Rate



Panel 2: With Exchange Rate as Additional Marginal Cost



Notes: The notations in Table 5 and the notes in Figure 2 apply.

Source: Authors, based on IEA Monthly Oil Price data.

Table 6 | NARDL Estimation Results for Spain (2008:8–2016:1)

Panel 1: Without Exchange Rate

	PspgX	*PspdX*	*PsphX*	*PspfX*	*Pspg*	*Pspd*	*Psph*	*Pspf*
Estimated Coefficients								
ρ	−0.51***	−0.30***	−0.46***	−0.41***	−0.61***	−0.31***	−0.45***	−0.41***
β^+	0.66***	0.74***	0.84***	0.90***	0.44***	0.45***	0.76***	0.87***
β^-	0.52***	0.62***	0.77***	0.92***	0.30***	0.24***	0.67***	0.88***
$\sum_{q=1}^{q-1} \pi_j^+$	0.83***	0.76**	0.99***	0.42***	0.40***	0.54***	0.78**	0.41***
$\sum_{q=1}^{q-1} \pi_j^-$	0.44***	0.52***	0.21***	0.44***	0.25***	0.15**	0.16**	0.41***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	119.32***	35.58***	37.71***	0.84	548.76***	92.00**	78.10***	0.46
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	6.40**	2.32	12.48***	0.01	3.26*	4.34**	10.53***	0.00
Rockets & Feathers Effect (Effect A)	Present	Absent	Present	Absent	Absent	Present	Present	Absent
Rent–seeking Effect (Effect B)	Effect B detected only in the gasoline market since the observed rockets & feathers effect in *ex*–tax price is obscured at the pump.							
Diagnostics								
F_{PSS}	12.04***	8.52***	21.30***	17.91***	15.23***	7.80**	21.48***	17.95***
t_{BDM}	−5.47***	−4.80***	−7.51***	−7.10***	−6.40***	−4.47***	−7.56***	−7.11***
BG Test (NR^2)	17.06	12.53	11.13	12.13	15.67	13.77	10.64	11.55
$\bar{\mathcal{R}}^2$	0.82	0.83	0.88	0.83	0.82	0.60	0.87	0.83

Panel 2: With Exchange Rate as Additional Marginal Cost

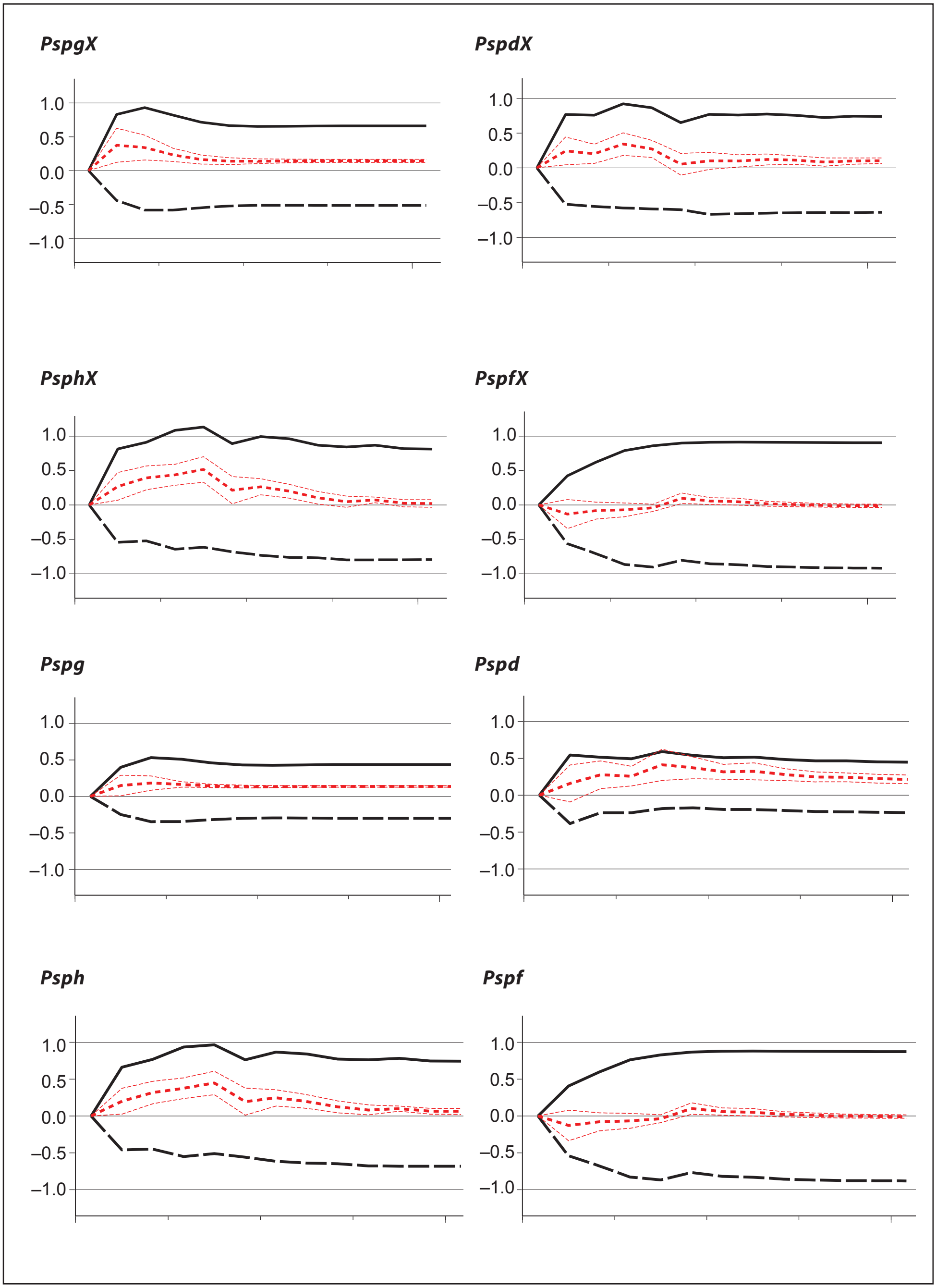
	PspgX	*PspdX*	*PsphX*	*PspfX*	*Pspg*	*Pspd*	*Psph*	*Pspf*
Estimated Coefficients								
ρ	−0.58***	−0.36***	−0.38***	−0.23***	−0.62***	−0.46***	−0.43***	−0.23***
β^+	0.64***	0.75***	0.85***	0.85***	0.41***	0.41***	0.75***	0.82***
β^-	0.58***	0.78***	0.93***	1.03***	0.34***	0.23***	0.76***	0.98***
$\sum_{q=1}^{q-1} \pi_j^+$	0.58***	0.57***	0.56***	0.21**	−0.08**	0.96***	0.26***	0.21**
$\sum_{q=1}^{q-1} \pi_j^-$	0.65***	0.44***	0.45***	0.86***	0.36**	0.44***	0.47***	0.82***
Symmetry Tests								
$H_0: \beta^+ = \beta^-$	18.99***	3.61*	27.85***	32.00***	123.52***	122.23***	1.66	30.40***
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	0.16	1.28	0.75	18.96***	6.48**	6.36**	1.87	18.31***
Rockets & Feathers Effect (Effect A)	Absent	Absent	Absent	Absent	Absent	Present	Absent	Absent
Rent–seeking Effect (Effect B)	Effect B is not observed in all cases.							
Diagnostics								
F_{PSS}	12.00***	16.52***	24.91***	9.98***	14.12***	10.70***	27.47***	9.88***
t_{BDM}	−5.99***	−6.54***	−7.85***	−4.56***	−6.48***	−5.46***	−8.06***	−4.56***
BG Test (NR²)	11.97	16.41	13.78	8.53	9.49	10.44	14.21	8.48
$\bar{R}^2$	0.74	0.81	0.82	0.79	0.74	0.58	0.76	0.78

Notes: *Pspg*, *Pspd*, *Psph* and *Pspf* denote the pump prices (*i.e.* inclusive of tax and duty) of gasoline, diesel, heating oil and fuel oil in Spain; while *PspgX*, *PspdX*, *PsphX* and *PspfX* denote the *ex*-tax prices of gasoline, diesel, heating oil and fuel oil in Spain, respectively. Other notes in Table 4 apply. Notice that all the rockets and feathers effect **(Effect A)** observed in the *ex*-tax prices in Panel 1 disappeared in Panel 2. In addition, the rent-seeking effect (**Effect B)** observed in the gasoline market in Panel 1 also disappeared in Panel 2. This suggests that the role of exchange rate cannot be called unimportant in this country.

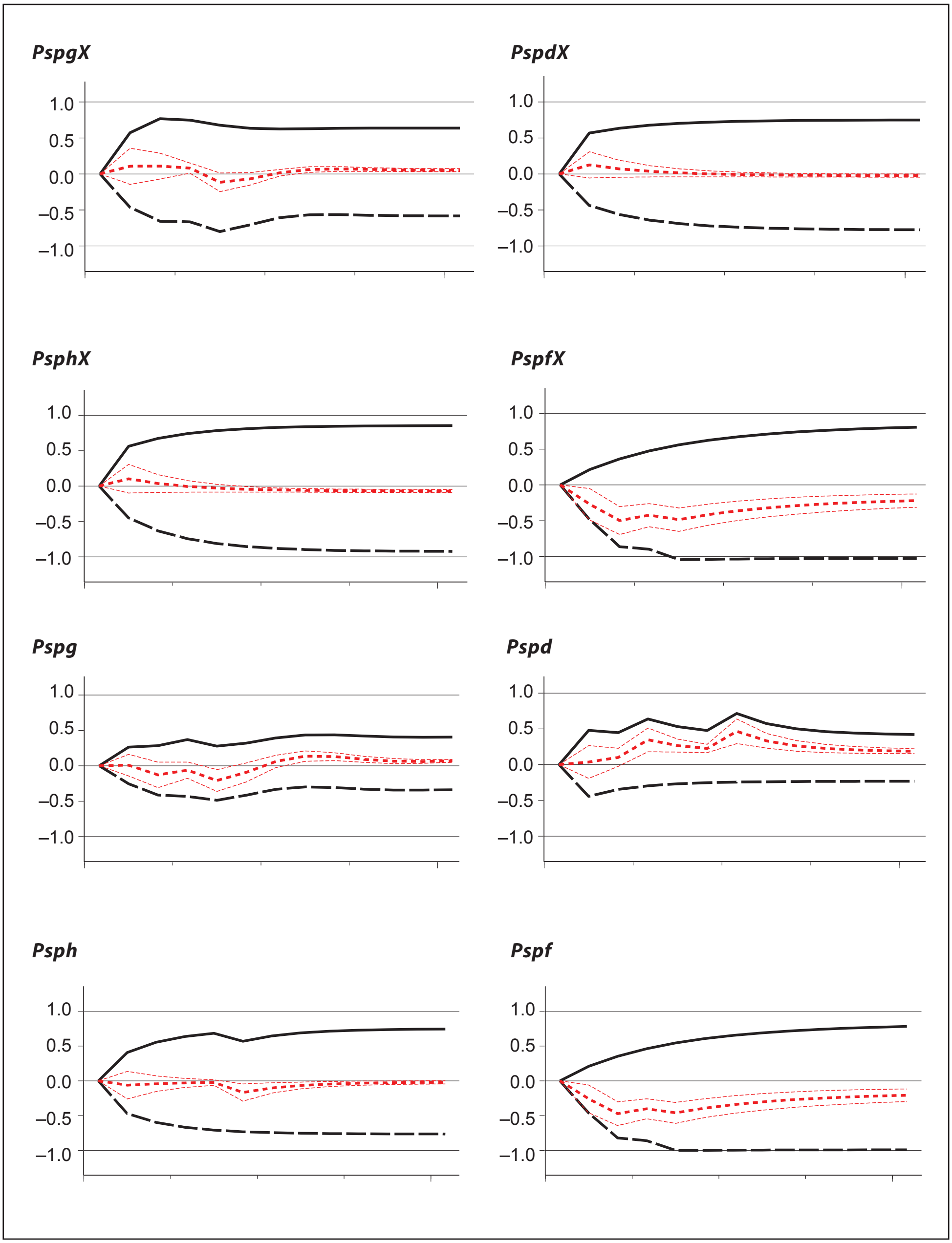
Source: Authors' calculations, based on IEA Monthly Oil Price data.

Figure 4 | Cumulative Dynamic Multipliers for Spain

Panel 1: Without Exchange Rate



Panel 2: With Exchange Rate as Additional Marginal Cost



Notes: The notations in Table 6 and the notes in Figure 2 apply.

Source: Authors, based on IEA Monthly Oil Price data.

Table 7 | NARDL Estimation Results for Germany (2008:8–f2016:1)

Panel 1: Without Exchange Rate

	PgmgX	*PgmdX*	*PgmhX*	*Pgmg*	*Pgmd*	*Pgmh*
Estimated Coefficients						
ρ	−0.35***	−0.28***	−0.23***	−0.32***	−0.12**	−0.22***
β^+	0.71***	0.85***	0.83***	0.33***	0.48***	0.74***
β^-	0.57***	0.81***	0.85***	0.27***	0.32***	0.76***
$\sum_{q=1}^{q-1} \pi_j^+$	1.18***	0.81***	0.61***	0.53***	0.70***	0.55***
$\sum_{q=1}^{q-1} \pi_j^-$	0.78***	0.42***	0.51***	0.30***	0.20***	0.45***
Symmetry Tests						
$H_0: \beta^+ = \beta^-$	45.23***	4.23**	1.14	28.62***	14.72***	0.95
$H_0: \sum_{q=1}^{q-1} \pi_j^+ = \sum_{q=1}^{q-1} \pi_j^-$	5.19**	8.27***	0.68	7.83***	23.32***	0.77
Rockets & Feathers Effect (Effect A)	Present	Present	Absent	Present	Present	Absent
Rent–seeking Effect (Effect B)	Effect B not detected in all cases since the observed rockets & feathers effect are not obscured at the pump.					
Diagnostics						
F_{PSS}	9.32***	11.91***	10.28***	6.76**	5.52*	10.30***
t_{BDM}	−4.73***	−5.13***	−4.51***	−4.09***	−2.62	−4.57***
BG Test (NR²)	9.49	7.74	6.42	9.20	5.95	6.13
$\bar{\mathcal{R}}^2$	0.81	0.81	0.83	0.77	0.73	0.84

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Panel 2: With Exchange Rate as Additional Marginal Cost

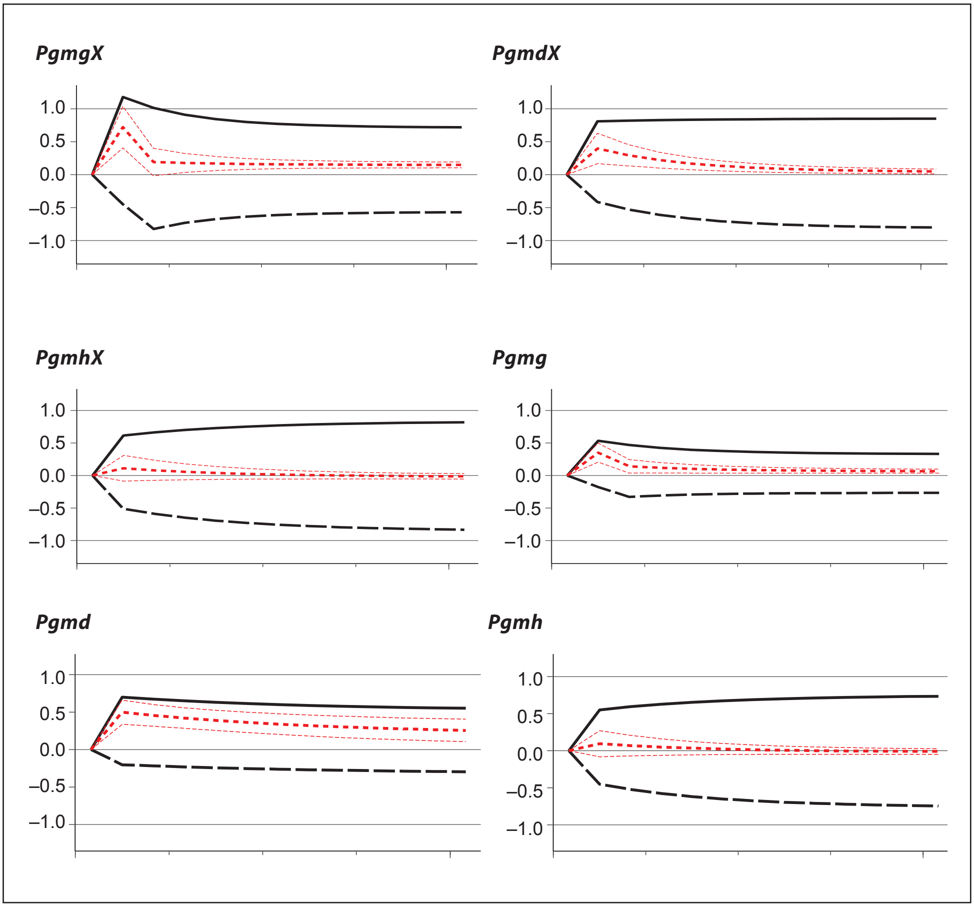
	PgmgX	*PgmdX*	*PgmhX*	*Pgmg*	*Pgmd*	*Pgmh*
Estimated Coefficients						
ρ	−0.57***	−0.40***	−0.33***	−0.51***	−0.38***	−0.32***
β^{+}	0.74***	0.85***	0.79***	0.34***	0.41***	0.71***
β^{-}	0.70***	0.91***	0.87***	0.33***	0.30***	0.78***
$\sum_{q=1}^{q-1} \pi_j^{+}$	0.50***	0.63***	0.30***	0.22**	1.16**	0.27***
$\sum_{q=1}^{q-1} \pi_j^{-}$	0.61***	0.49***	0.68***	0.13**	0.31**	0.60***
Symmetry Tests						
$H_0: \beta^{+} = \beta^{-}$	7.84***	17.05***	22.29***	1.11	73.89***	21.98***
$H_0: \sum_{q=1}^{q-1} \pi_j^{+} = \sum_{q=1}^{q-1} \pi_j^{-}$	0.21	1.18	6.23**	0.49	26.92***	6.03**
Rockets & Feathers Effect (Effect A)	Absent	Absent	Absent	Absent	Present	Absent
Rent–seeking Effect (Effect B)	Effect B not observed in all cases.					
Diagnostics						
$\mathbf{F_{PSS}}$	11.73***	17.26***	11.43***	9.87***	13.64***	11.23***
$\mathbf{t_{BDM}}$	−5.85***	−6.68***	−5.73***	−5.28***	−5.41***	−5.69***
BG Test (NR^2)	8.80	10.49	15.31	9.48	11.37	14.86
$\bar{\mathcal{R}}^2$	0.76	0.80	0.79	0.71	0.75	0.79

Notes: *Pgmg*, *Pgmd* and *Pgmh* denote the pump prices (*i.e*. inclusive of tax and duty) of gasoline, diesel and heating oil in Germany; while *PgmgX*, *PgmdX* and *PgmhX* denote the *ex*-tax prices of gasoline, diesel and heating oil in Germany, respectively. Fuel oil is excluded here due to lack of data. Other notes in Table 4 apply. Notice that all the rockets and feathers effect **(Effect A)** observed in the *ex*-tax prices in Panel 1 disappeared in Panel 2. However, the rent-seeking effect (**Effect B)** is not observed in both Panels 1 and 2. These results also suggest that the role of exchange rate is important in this country.

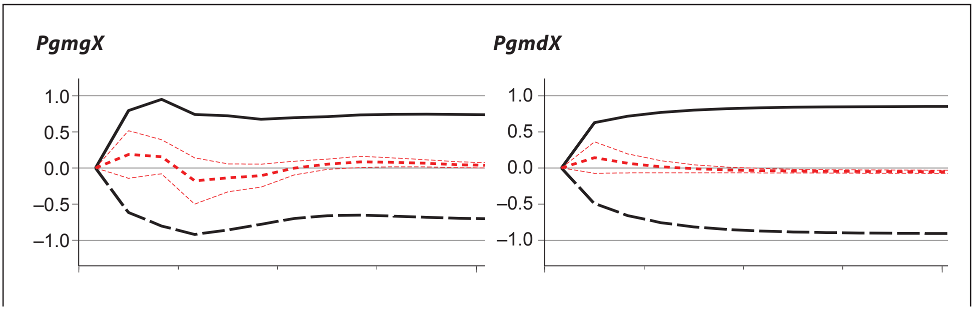
Source: Authors' calculations, based on IEA Monthly Oil Price data.

Figure 5 | Cumulative Dynamic Multipliers for Germany

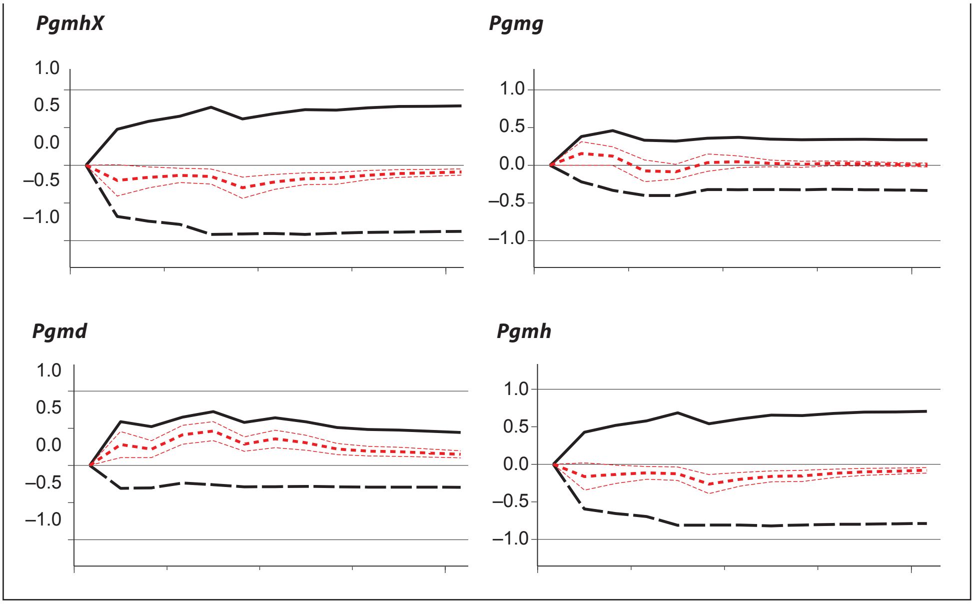
Panel 1: Without Exchange Rate



Panel 2: With Exchange Rate as Additional Marginal Cost



Panel 2 | Continuation



Notes: The notations in Table 7 and the notes in Figure 2 apply.

Source: Authors, based on IEA Monthly Oil Price data.

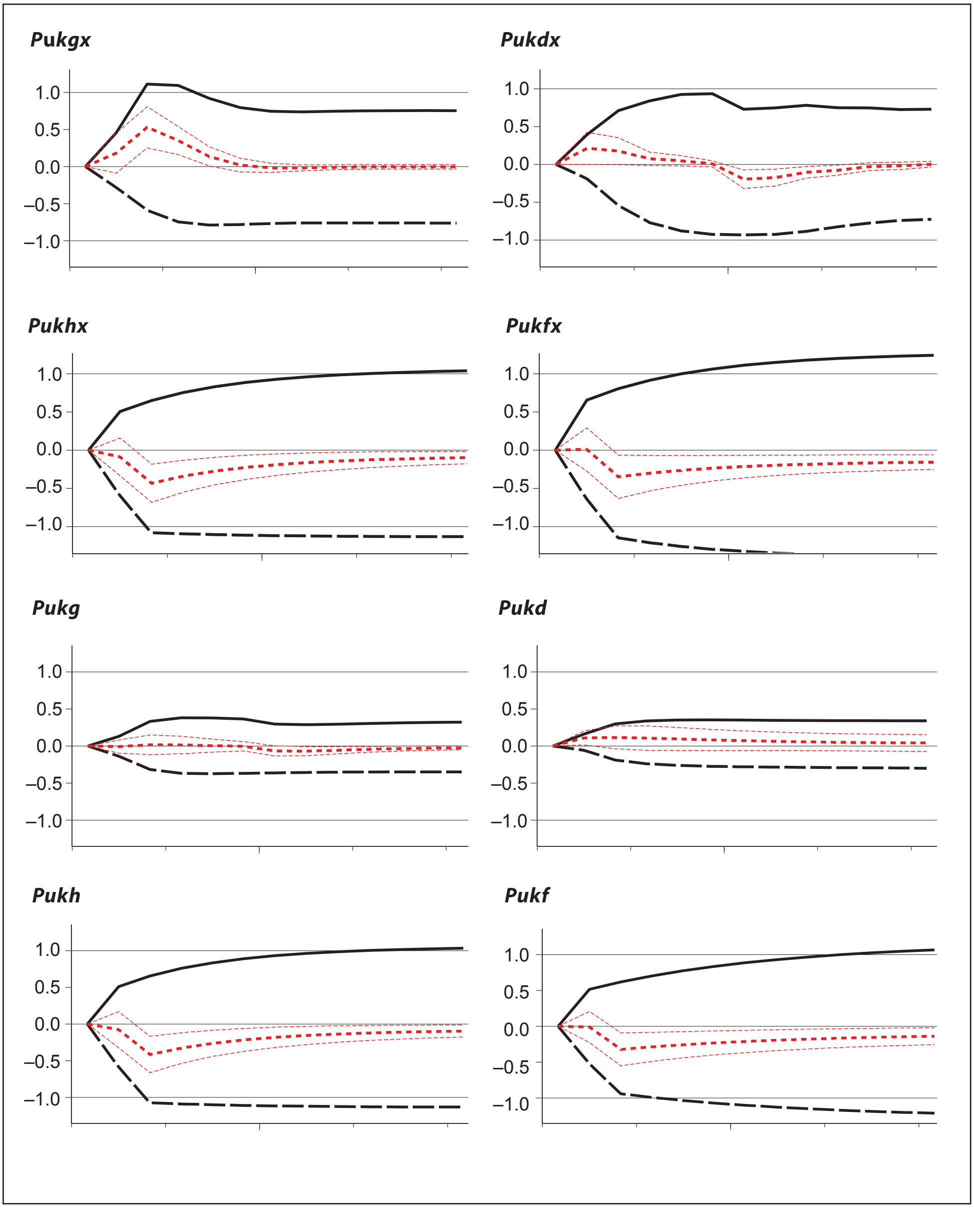
5. Conclusion

Using a dummy variable model, the study found some evidences of structural change induced by the GFC in the relationship between retail energy prices and crude oil costs. The results also indicate that once this structural change is taken into the consideration, the results of GS13 no longer hold. Adopting the nonlinear ARDL framework, the study found that for European countries with high oil import dependency ratio, the asymmetric relationship between retail energy prices and oil costs alters remarkably once the exchange rate is incorporated into the analysis as part of the marginal cost of importing crude oil. For most of the retail markets, the significant evidences of long-run rent-seeking and rockets and feathers effect disappeared as soon as the exchange rate is accounted for. Summarily put, our results show that for countries with negligible domestic oil production, the role of exchange rate in the retail energy price-oil cost asymmetric relationship can no longer be called unimportant. Lastly, the findings of this study indicate that the rockets and feathers effect is still a pervasive phenomenon in the road fuel markets of France, Germany, Italy and Spain; while the gasoline markets of Italy and Spain are fraught with the possibility of retail firms using the tax system to conceal rent-seeking behaviour. Based on the antitrust and consumer welfare implications of these findings, it is recommended that policy makers and regulators of the European retail energy markets should ceaselessly monitor and review their antitrust policies in order to safeguard consumers' welfare.

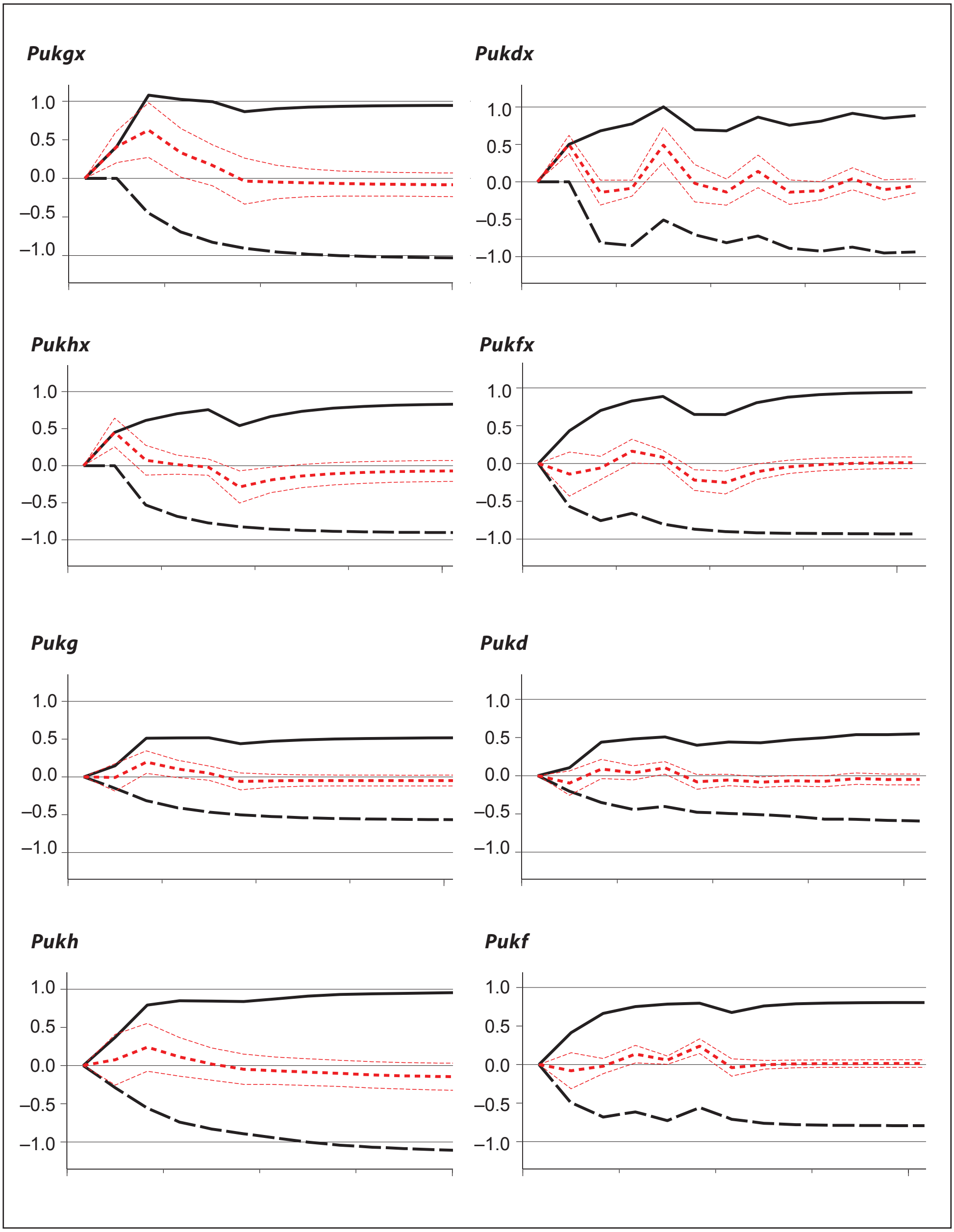
Appendices

Appendix 1 | Cumulative Dynamic Multipliers

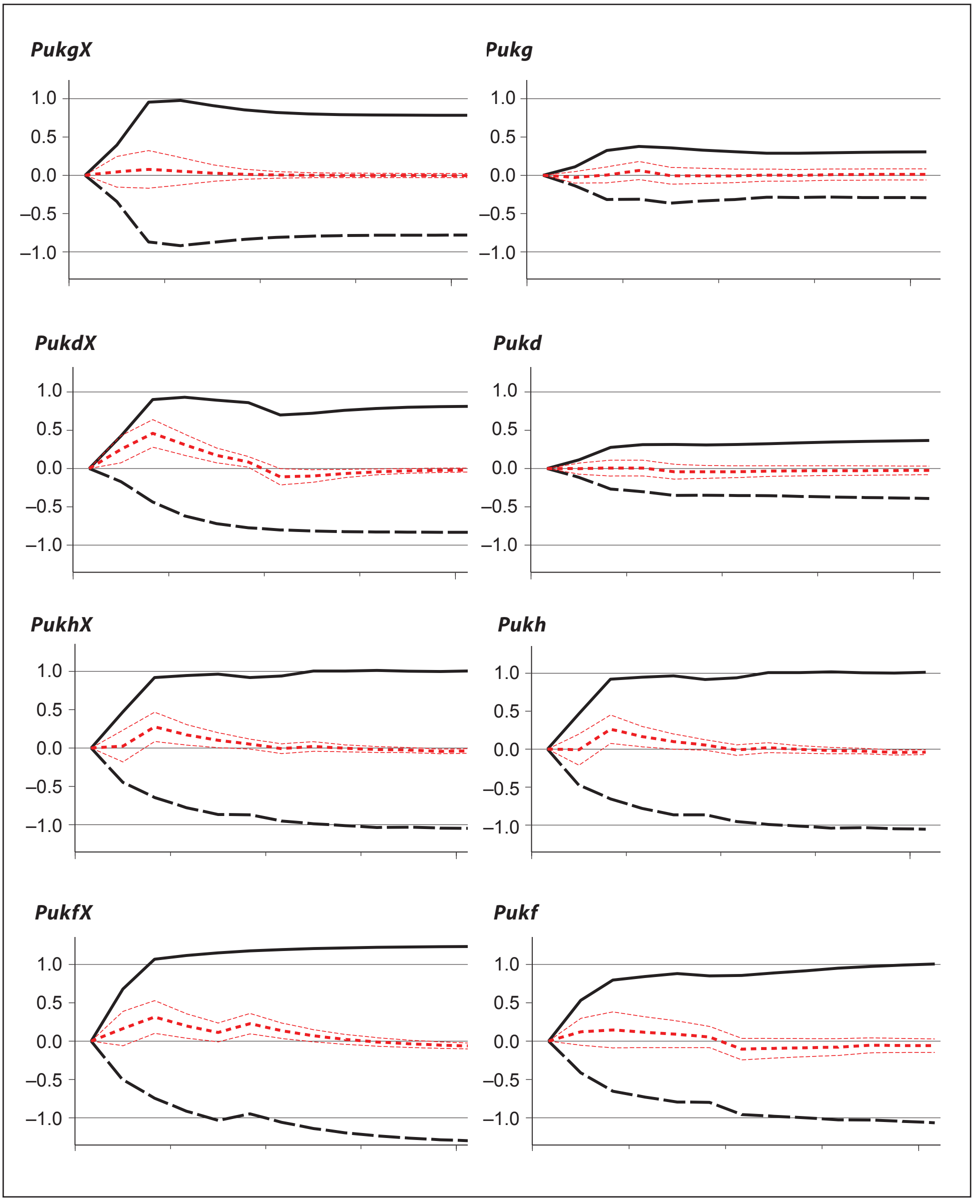
Panel 1:



Panel 2



Panel 3:

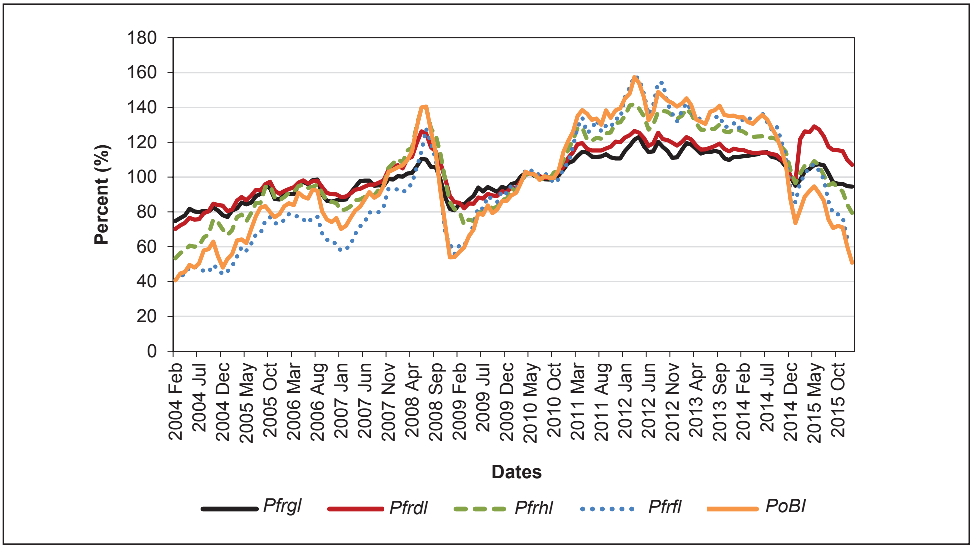


Notes: Following GS13, the solid (dashed) black line is the cumulative dynamic multiplier with respect to a 1% positive (negative) change in the oil price, while the heavy dashed red line plots the difference between the two. The light dashed red lines report the two standard error confidence interval for the difference line computed by stochastic simulation. Tick marks on the horizontal axis represent three-month intervals, while the vertical axis is in percentage points.

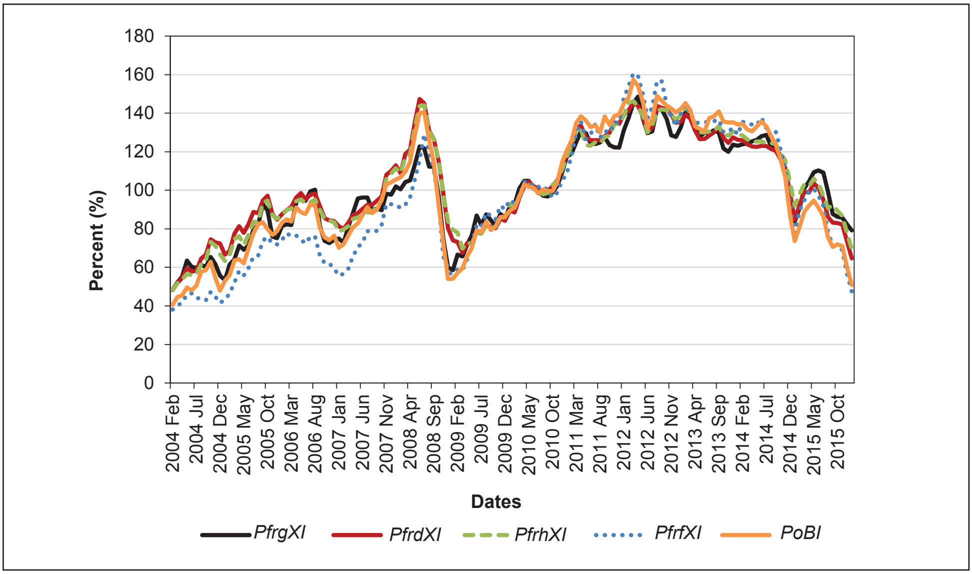
Source: Authors, based on GS13 data.

Appendix 2 | Time Series Plots of the Data for France

Panel A: With Pump Prices



Panel B: With *Ex*-tax Prices



Notes: Panel A plots the crude oil costs (*PoBl*) and pump prices of gasoline (*Pfrgl*), diesel (*Pfrdl*), heating oil (*Pfrhl*), and fuel oil (*Pfrfl*); while Panel B plots the crude oil costs and *ex*-tax prices of gasoline (*PfrgXl*), diesel (*PfrdXl*), heating oil (*PfrhXl*), and fuel oil (*PfrfXl*). The indexed representation of the data is used in all cases. To conserve space, we do not present the plots for Germany, Italy and Spain, since the patterns are quite similar. Notice the sharp decline in all cases around mid-2008, which aptly captures the shock due to the GFC.

Source: Authors, based on IEA Monthly Oil Price data.

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