Asymmetric Price Transmission of International Shocks in the Brazilian Fuel Market

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Abstract

We analyse the transmittal of international prices to the gasoline and diesel prices at the refinery charged by the Brazilian major petroleum and fuel producer - Petrobras. The main concern is to test if whether the company adjusts its prices symmetrically, i.e., if prices go up after positive shocks to the same extent as they slump after negative shocks. The results might indicate usage of market power in adjusting prices in a context in which the company and the government pursue a competitive setting for the domestic fuel market, in a way that fuel prices closely follow the international prices and foreign competition is viable. The evidence gathered in a bunch of estimates shows signs of positive asymmetry in the transmission of international shocks to gasoline prices from July 2018 to June 2019. On the other hand, the price policy for diesel showed to be symmetric in most of the time. When asymmetry was found, it was negative, meaning that decreases in international prices were being passed-through more easily. These findings suggest that the company probably has more leeway to exert positive price asymmetry in the market of gasoline.

Keywords: Fuel market, asymmetric price transmission, energy economics.

Resumo

Analisamos a transmissão de preços internacionais para os preços da gasolina e do diesel cobrados na refinaria pela maior produtora de petróleo e combustíveis no Brasil - Petrobrás. A principal preocupação é testar se a empresa ajusta seus preços simetricamente, ou seja, se os preços sobem após choques positivos na mesma medida em que caem após choques negativos. Os resultados podem indicar o uso do poder de mercado no ajuste de preços em um contexto em que a empresa e o governo buscam um cenário competitivo para o mercado doméstico de combustíveis, de forma que a concorrência externa seja viável. As evidências reunidas em diversas estimativas mostram sinais de assimetria positiva na transmissão de choques internacionais para os preços da gasolina de julho de 2018 a junho de 2019. Por outro lado, a política de preços do diesel mostrou-se simétrica na maioria das vezes. Quando a assimetria foi encontrada, foi negativa, ou seja, reduções nos preços internacionais estavam sendo repassadas mais facilmente. Esses resultados sugerem que a empresa provavelmente tem maior liberdade para exercer assimetria positiva de preços no mercado de gasolina.

Palavras-chave: Mercado de combustíveis, transmissão assimétrica de preços, economia da energia.

Área ANPEC: Área 7 - Economia Internacional
JEL Classification: F30 · Q41 · L71 · C22

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1. Introduction

It is not rare the assertion that final consumers perceive prices increases more often than decreases, and it has not been any different in the Brazilian automotive fuel market in recent years. In the process that made automotive gasoline step up from 2.75 BRL per liter in 2012 to 5.00 in late 2019, consumers often alleged that the upstream prices increases were being passed-through more easily than the decreases. In the Brazilian case, the transmittal of a price shock from international prices to the final retail prices depends on the response of many intermediate players. In this study, we seek to understand price transmission at the very first stage of the price distribution, i.e., from international prices - petroleum, fuel, and currency - to the wholesale prices charged at Petrobras' refineries in Brazil.

We focus our attention on the new Petrobras' price policy adopted in 2016, which states that the wholesale prices of both gasoline and diesel would vary vis-à-vis the international fundamentals, mainly the exchange rate, the import prices of oil and the import parity price of foreign fuel. Accordingly, the fuel prices are a direct function of these international prices. Such a policy was aimed to deliver more transparency and a competitive design for the domestic fuel market. However, it is still unclear how prices precisely vary to international fundamentals. Particularly, a company with such an outstanding marketing share may indulge itself to raise prices easier and more frequently than to lower them. The demand for fuel is acknowledged as inelastic, as a decrease in prices could be offset by a low-opportunity-cost decrease in the profit margin. This practice might increase the company's profitability, attracting potential shareholders, and skyrocketing the company's value in the stock market, which is seen as one of the pursuing values since a new administration took office.

With daily data of automotive fuel at the Petrobras' refineries, nominal exchange rate (NER), international prices of crude oil, gasoline, and diesel, we propose a simple adjustment function to test whether price asymmetry was present in the pass-through from international prices to the wholesale prices from 2016 to 2019. In the empirical model, if the estimates for the increases and decreases of international prices are statistically different from each other and the effect of an increase is larger, we have a clue that the company still uses its huge power to keep prices above the equilibrium level, even after been claimed that the market is now competitive (i.e., domestic prices of refined fuel follow import prices). The work has its relevance because i) price asymmetry is a recurring topic of discussion as consumers often have the impression that positive changes in oil prices are easier passed-through to retail fuel prices than negative ones; ii) the rule that drives readjustments and the company's pricing policy is not fully opened in terms of how frequent and to which extent the changes in international price are embedded in fuel prices; iii) the company has a history of political interventions on its price policy and it is still uncertain how appropriately the new administration dealt with such issue; iv) any sign of asymmetric pass-through might indicate the extent of market power held by Petrobras and v) it is a topic that often sparks feverish discussions within the Brazilian society.

Besides this introduction, in the next section, the paper presents the reader a short overview of the main findings in the empirical literature; section three describes the Brazilian fuel market and the main overturns in the pricing policy. Section four describes the methodological approach, section five depicts how we gathered and treated the data and section six discusses the results. Finally, we conclude the study in section seven, highlighting the main contributions and addressing future investigations.

2. Literature Overview

The literature on asymmetric price transmission (APT) is broad within the areas of agricultural and energy economics. The survey by Meyer & Von Cramon-Taubadel (2004) is a natural guideline. Firstly, one should note that there are different sorts of symmetry on price transmission. It could be whether vertical or horizontal/spatial: the former regards different degrees of transmission throughout the marketing chain – from wholesalers to retailers, while the latter comprehends different transmissions among different firms/regions, but in the same level of distribution. It could also have different magnitude and speed. The asymmetry of magnitude is defined as the difference in intensity of response to an increase or a decrease in the upstream prices and the asymmetry of speed is the difference between response times of new readjustments.

To this day, surprisingly there were not much research on the economics of fuel price transmission in the Brazilian market. Serigati (2014) argued that the price policy at the time (i.e, before 2014) brought an overwhelming competitive pressure to bear on the ethanol sector. As the ethanol is a substitute for gasoline, the sector's competitiveness and profitability were being hindered by the controlled price policy for gasoline and diesel. After simulations of hypothetical paths for the domestic fuel prices, he concluded that an ideal price policy to foster the ethanol sector would be the one that associates the readjustments to the international price of oil and exchange rate, which would be the actual policy only in 2016, as we mentioned.

Silva's (2003) major concern was to analyse how the price strategy was being carried out since the market liberalisation in 2002. Among her conclusions was the fact that the prices of gasoline, diesel, and LPG (liquid petroleum gas) were not in line with international prices, especially in the periods of elections (2002) and the Iraq war (2003), when was natural to expect higher international volatility. Therefore, the discretionary price policy was said to be a non-neutral mechanism used to cushion international shocks, as it reinforced the company's massive market power. A further conclusion regards new possibilities for price policy at the time, including the French mechanism based on a "trigger" for fuel taxes whenever the international prices rise above a certain threshold. The point argued was that a shock-absorber mechanism is necessary, although it could be properly formalised to keep a certain level of competitiveness inwards and avoid political interests.

Rodrigues et al. (2018) is an important correlated work. They also studied the asymmetric behaviour in Brazilian fuel market, but instead of price transmission, the authors focused on price response, which is how fuel demand respond to price variations. They sought to estimate demand functions for automotive fuel (gasoline, ethanol and compressed natural gas - CNG)[1] to show that the inclusion of asymmetric price transmission (APR) enhances the ability to predict how fuel demand will respond to a certain policy that affects fuel prices.

When it comes specifically to the asymmetry of price transmissions, Uchôa (2008), estimating Threshold Autoregressive (TAR) models, confirmed the hypothesis of positive asymmetry in the transmission of international shocks at the retail level: when gasoline prices are above its long-run equilibrium path, it tends to remain there longer than when it is below. Da Silva et al. (2014) sought to analyse the pass-through from distributors to the retail sector, which is the downstream part of the distribution chain. With disaggregated data for municipalities, they showed that the asymmetry does not happen nationally, but only in a portion of the cities (30% of the sample), as the conclusions were in terms of symmetry in the transmittal.

In the international literature, several works studied the asymmetric responses on fuel prices, as we will only discuss few of them and only acknowledge others. Borenstein et al. (1997) tested and confirmed that retail gasoline prices respond more quickly to increases than to decreases in crude oil prices in three points of the distribution chain. The evidence was that the adjustment of spot gasoline markets to changes in crude oil prices appears to be responsible for a fraction of the asymmetry. The asymmetry in the adjustment of retail gasoline to terminal price changes also contributes with a significant fraction. Among the possible sources of asymmetry are production/inventory adjustment lags and market power of some sellers. Bachmeier & Griffin (2003) challenged the results in Borenstein et al. (1997) by estimating an error-correction model with daily spot gasoline and crude-oil price data over the period 1985-1998. Adopting a more standard estimation approach and using daily instead of weekly data was sufficient to eliminate most of the evidence of asymmetry.

Kpodar & Abdallah (2017) gathered retail prices from 162 countries from 2000 to 2014 to conclude that declines in crude oil prices lead to smaller effects on retail gasoline prices than increases in crude oil prices, pointing to a positive asymmetry in the fuel price pass-through. Some of the recent works that also deserve mention are Asane-Otoo & Schneider (2015) for Germany; Fasoula & Schweikert (2018) for Austria; Balaguer & Ripollés (2012) for Spain; Bettendorf et al. (2003) for the Netherlands; Wlazlowski (2001) and Bermingham & O'Brien (2011) for the UK; Meyler (2009) and De Salles (2014) for selected European countries and finally Radchenko & Tsurumi (2006), Deltas (2008) and Honarvar (2009) for the US.

Diversely from the recent domestic literature, we focus on wholesale prices, which gives a clearer time series data, free from distributors margins, transportation costs, and taxes. The usage of the recently available Petrobras' daily data is also a novelty, as we will be able to check the behavior of a specific prominent company, instead of the average behavior of several companies, captured by the usual aggregated data from market fuel provided by ANP. Finally, the empirical strategy is a recent improvement on cointegration literature and provides an intuitive tool for assessing asymmetry. In this matter, we followed Atil et al. (2014) to investigate the transmittal of international prices to fuel prices in a NARDL-based framework. We discuss the methods in section 4.

3. Characteristics of the Brazilian fuel market

The Brazilian fuel market has nowadays two preeminent players. The ANP (National Agency of Petroleum, Natural Gas and Biofuels) is the federal government agency linked to the Ministry of Mines and Energy responsible for the regulation of the oil sector. Its operations began in 1998 and encompass several functions: oil and natural gas exploration and production; refining, processing, transportation and storage of these elements and their derivatives; distribution and trade, monitoring and inspecting the market, among many others. The Petrobras (Petróleo Brasileiro S.A.) is a publicly-held company operating on an integrated basis and specialising in the oil, natural gas, and energy industry. It was the 8th largest energy company in the world in 2016, with a production of 2.55 million barrels of oil (BOE) per day and an enterprise value of $132 billion.[2] In general, the government can be a player on the fuel market by the interplay of both institutions, despite Petrobras being also a share company, which means it has to be both transparent and efficient towards the society and profitable and sustainable towards its stockholders. The fulfilment of

[1] Diesel is not a typical small automotive fuel in Brazil, as the fleet is composed majority by flex vehicles that run with either gasoline and ethanol. Diesel is instead more commonly used in trucks.

[2] See <https://bit.ly/2LRdzl5>

both goals is the root of several discussions in the Brazilian economic policy, as the inefficiencies and the interference representing political interests often sparks the debate of possible privatisation.

Created in 1953, the Petrobras used to have a monopoly over the Brazilian oil market. In 1997, however, a congress law[3] permitted other companies to operate in the same activities performed by Petrobras. Thereafter, several companies began the extraction and production of petroleum, such as Shell, Chevron, Statoil, Repsol, among others. Nevertheless, in the refining stage, the domestic company remained with a considerable share, holding 88.2% of the oil refineries. Moreover, the three refineries owned by foreign companies produce less than 5% of the total gasoline made in the country. Albeit the company had lost a part of its share in the domestic market of fuel in recent years, it still has considerable market power, supplying 77% and 79% of the domestic market of gasoline and diesel, respectively. These facts show how Petrobras still has quite a considerable share in the energy market, despite there being more than 20 years of openness to foreign competitiveness.

The price policies on gasoline and diesel were mostly similar since 2016, although there is an important difference that we will address below. Before 2016, the government used to intervene in the price strategy, providing subsidies in order to cushion the local economy against shocks in the international markets and also to hamper inflation, as the derivatives are inputs entrenched in the whole structure of the economy. Besides being long-dated, this price strategy became notorious in the period (2011-16), when the company's prices were "frozen" despite the international price of crude oil increased throughout the period. The company was thus able to hold a magnificent degree of price competitiveness, making the competition a hard endeavour for foreign companies.

On the other side, the aforementioned price strategy, alongside corruption scandals, deteriorated the company's reputation and slumped its value in the stock markets. In 2016, a new administration took office. As a result, the whole fuel prices strategy became more flexible as the wholesale prices would reflect the international movements on fuel, oil barrel price, and exchange rates. This new price policy is what we call phase 01 and it is characterised - with exceptions - by a new price per month, generally defined in the middle of the month. This new price should embed the variations on international prices and other refinery-level costs since the last readjustment. This phase lasted for almost 6 months and had 9 price adjustments for the gasoline and 10 for diesel.

In July 2017, the company adjusted its strategy in order to have daily adjustments (phase 02). The official explanation was that the previous frequency was incapable of tracking international volatility. Thus, prices now could be changed whenever it's necessary, but the adjustments are limited to a band of +- 7%. On the company's official website, one can find a description of the price policy, in line with what we just mentioned. Firstly, in the section "10 answers to your questions about gasoline price":

> *"The fuels derived from the petroleum are commodities and has its prices attached to the international markets, with quotations varying daily. [. . .] In an environment of open economy and price freedom, we face the competition of fuel importers, whose prices are also attached to the international market. Thus, the price variations at the refinery are important for us to effectively compete in the domestic market."*

Then also in the section "Price Policy for Gasoline and Diesel":

> *"Our price policy for gasoline and diesel sold to distributors is based on the import parity price, formed by these products' international prices plus the costs that importers would have, such as transportation and port fees, for example. Parity is necessary because the Brazilian fuel market is open to free competition, and distributors may choose to import the products. In addition, the average price includes a margin that covers risks (such as exchange rate and price volatility)." [. . .] "Using international market prices as a benchmark, we analyse our share of the domestic market and periodically decide whether the prices practised at the refineries will be maintained, reduced or increased."*[4]

This new scheme lingered for almost a year and, in practice, it was not totally daily, as in 10% and 7% of the working days in this period saw the gasoline and diesel prices respectively remaining constant. Nevertheless, the standard deviations increased in a threefold proportion compared to phase 01, as table 01 shows.

In May 2018, the Brazilian economy was hit by a massive strike carried out by truck drivers in the whole country. Among their claims were the increasing costs with diesel when compared to the prices charged for the freight service, which was held constant.[5] Indeed, the diesel price was consecutively readjusted upward as a result of the increasing costs of crude oil, the devalued exchange rate and the several taxes charged throughout its distribution chain. This situation was squeezing their margins up to the point that some drivers had no positive profit after deducting all their

[3] See law number 9,478, from 6th August 1997.

[4] The first stretch is our own translation, while the second is originally presented in English.

[5] The freight prices were not set in terms of the operational costs. As a main outcome after the negotiations, the congress approved minimum freight prices.

costs. Moreover, adjusting to a new price every day was a costly process. After negotiations between government agencies and drivers union, the price policy changed again. This time though, gasoline and diesel would follow different patterns.

From late May on, gasoline prices remained in phase 02 (daily readjustments), but diesel price was constrained by a legal deal established with drivers, which we call phase 03*. The agreement, called "subsidy program in diesel commercialisation" initially guaranteed that the retail price would fall 0.46 BRL per liter and would remain at this level for sixty days and it would be readjusted once a month therefrom. The wholesale prices fell in a different amount though: during the ten-day period of negotiations, the wholesale prices successively fell 0.036 BRL (-1.54%), 0.23 BRL (-10.0%), and 0.07 BRL (-3.33%). The subsidy kept valid the remainder of 2018. For gasoline, phase 02 lingered a month further than diesel, until early July. Despite not facing an opposing and organised opposition as the truck drivers exerted on diesel prices, the gasoline prices seemed to be swayed by the context. Following the inverse of what was done between phases 01 and 02, this time the company slowed the pace of readjustments, although this change was not officially released in the media. Gasoline price's phase 03 had an increase in the frequency of short periods without new prices, with new adjustments, on average, every 2.75 working days, which is approximately two prices per week.

Finally, with the subsidy program coming to an end by December 31st, 2018, the diesel price entered into phase 04, which is analogous to gasoline's phase 03. The rule for this phase was marked by the company's claim that it would hold the diesel price fixed for up to 7 days, regardless of how volatile the markets are. Indeed, the data show consistency in such a claim, as a new price was chosen every 6.75 days on average throughout this period.

Figures 01 and 02 below shows the patterns of fuel prices as described above. What differs them was the fact that the diesel was the main ingredient of a social deadlock caused by a strike, which made the policies different from that moment on. Thus, phase 03* was the main divergence of fuel prices from the international prices on the period October/2016 - July/2019. Apart from this phase, automotive fuel prices in Brazil followed the fundamentals provided by the international markets, with different frequencies in the readjustments, as we shall see in section 5.

Table 01 - Descriptive statistics by phases of the price policy

(a) - Gasoline

		Price		**Adjustments**					
	Working days	Average	Std Dev	N	Max.	Min.	Increases	Decreases	Zero
Phase 01	178	1.4928	0.0597	9	8.10%	-5.90%	3	6	169
Phase 02	249	1.5970	0.2011	223	5.10%	-3.93%	121	102	26
Phase 03	233	1.8480	0.2434	85	5.61%	-7.16%	47	38	148
Total	*660*	*1.6575*	*0.2419*	*317*	*8.10%*	*-7.16%*	*171*	*146*	*343*

(b) - Diesel

		Price		**Adjustments**					
	Working days	Average	Std dev	N	Max.	Min.	Increases	Decreases	Zero
Phase 01	178	1.6699	0.0738	10	9.50%	-10.40%	4	6	168
Phase 02	227	1.8023	0.1824	212	4.40%	-10.00%	119	93	15
Phase 03*	147	2.0890	0.1734	8	13.03%	-15.28%	4	4	139
Phase 04	108	2.1282	0.1292	16	4.84%	-6.00%	12	4	92
Total	*660*	*1.8838*	*0.2368*	*246*	*13.03%*	*-15.28%*	*139*	*107*	*414*

Source: author's own calculations with data from Petrobras and ANP.

Figure 01
Wholesale gasoline prices and phases of the price policy
(BRL R$)

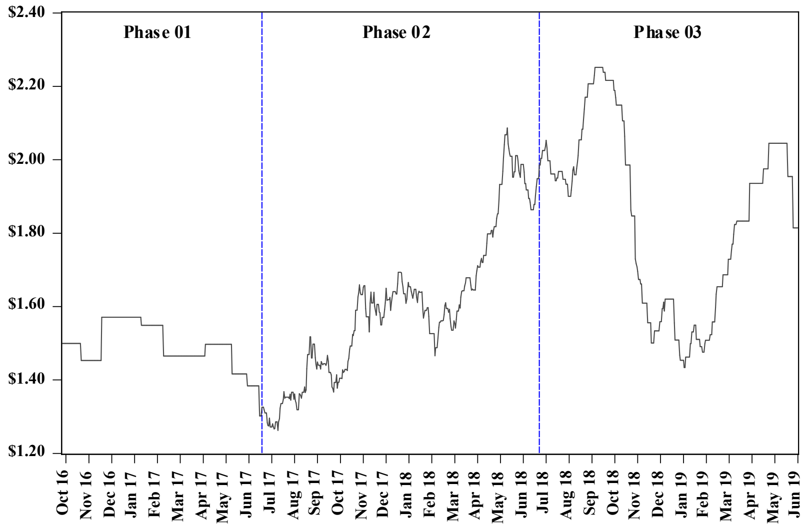
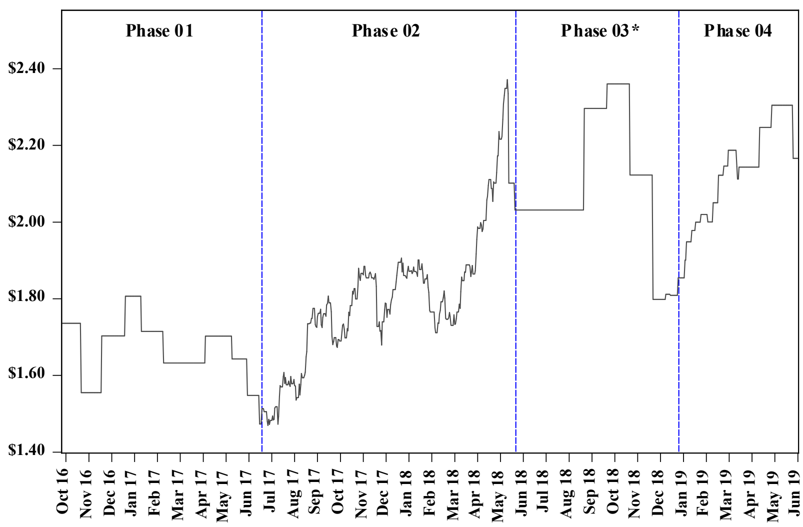


Figure 02
Wholesale diesel prices and phases of the price policy
(BRL R$)

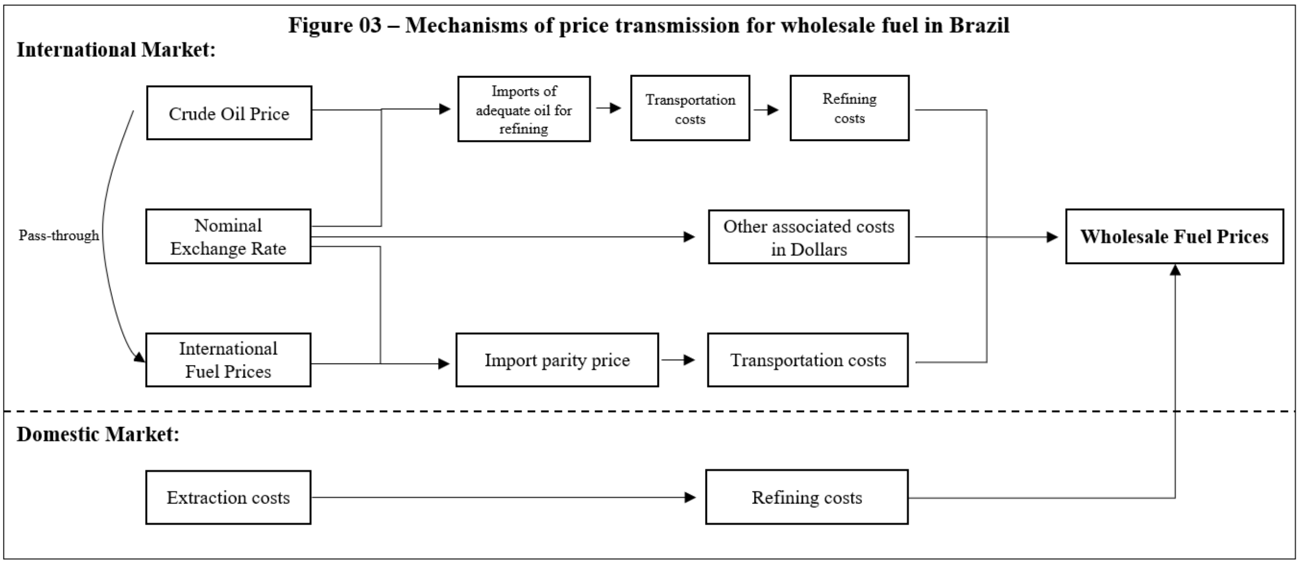


In short, figure 03 tries to draw a simplified scheme of price transmission for fuel, focusing on the international mechanisms. Following what the company states as the official policy and how ANP designs the market, we regard three main branches of price shocks within the international environment. First, note that the refined oil is a blend of domestic and imported sources. Note that, despite being a major producer of petroleum, Petrobras is also an importer. This is due to the fact that Brazilian oil does not have the desired chemical properties for being refined with low costs. This leads us to the first transmission channel, which departs from shocks in the international price of oil[6]. Everything remaining constant, an increase in the international price of oil sparks the import prices for the next contracts. Moreover, structural increases in the price of crude oil have intricate consequences in terms of pass-through effects to a country's price chain, as it affects not only the production of fuel, as the production of other refined products and the manufacture in general. Lastly, notice also that variations in the oil price are passed-through to the international price of fuel, which we comment below.

[6]The price of oil appropriate for refining is given by both WTI - originated from U.S. oil fields, primarily in Texas, Louisiana, and North Dakota - and the Brent Crude - from oil fields in the North Sea.

Moving downwards in the figure, we have the currency channel. Aside from affecting the other branches, the nominal exchange rate represents itself a broad chain of costs, as diverse extraction and refining costs can be denominated in foreign currencies. Notice, however, that this mechanism can be, first, sluggish, as the imports of equipment occur from time to time and immediate swings in the exchange rate may not affect the cost structure in the short run, and second, partially offset by the interplay in future markets via hedging. As there might be an important long-run relationship between exchange rates and wholesale prices, this channel will be regarded lately in our empirical specification.

Finally, international fuel prices are the main benchmark that the domestic market should follow in order to accomplish a competitive setting. It allows for different players to import fuel from other countries and, after adding transportation costs, sell them at a competitive price, which was not possible when monopolistic practices kept prices below the equilibrium level. From what the company claimed, the wholesale prices would, to some extent, keep track of the international fuel prices. However, the two first channels might interpose themselves in the process of daily readjustments. Next, we try to shed some light on the asymmetry behind these mechanisms.



4. Methodology

The literature on the topic uses a wide range of empirical tools to address symmetry responses on fuel markets. Frey & Manera (2007) thoroughly identified them, stressing that each econometric model is specialised to capture a subset of asymmetries and each asymmetry is properly assessed with a subset of econometric models. They can be divided into five broad classes: autoregressive distributed lag (ARDL) model, partial adjustment models (PAM), error correction model (ECM), the whole class of regime-switching models, vector autoregressive (VAR) and error correction models (ECM). A recent improvement on cointegration techniques that were not available at the time of Frey's and Manera's survey is the NARDL model by Shin et al. (2014), which i) allows cointegration tests without the typical concerns on unit roots testing, ii) allows the investigation of at least three types of asymmetries and iii) has desirable small-sample properties and its lag structure helps to deal with residual serial correlation and endogenous regressors (Narayan, 2005). Firstly, we show the derivation of an error correction model applicable to the transmission of international shocks to fuel prices.

4.1. Cumulative adjustment functions

To test for the possibility that gasoline prices varies diversely towards increases and decreases on its international determinants, we propose a function that captures the rate at which gasoline prices adjust to crude oil and exchange rate changes, similar to Borenstein et al. (1997). To do this, let us first assume a simple linear long-run relationship:

$$P = \phi_0 + \phi_1 P^{INT} + \phi_2 E + \epsilon \tag{1}$$

where P is the fuel price at the refinery, in liters, P^{INT} is the main international price that drives the readjustments, E is the nominal effective exchange rate and ϵ is a normal and i.i.d. error term. An important feature of this function is that it assumes a time-invariant adjustment process during the sample period (i.e., the adjustment coefficients are constant regardless the absolute magnitude of the change on oil prices and exchange rates, the period of the month and year and so on). Defining $\Delta P_t = P_t - P_{t-1}$; $\Delta P_t^{INT} = P_t^{INT} - P_{t-1}^{INT}$ and $\Delta E_t = E_t - E_{t-1}$ and considering ΔP_t^t as the price adjustment in t due to changes in the international prices in t yields:

$$\begin{aligned} \Delta P_t^t &= \alpha_0 \Delta P_t^{INT} + \beta_0 \Delta E_t \\ \Delta P_{t+1}^t &= \alpha_1 \Delta P_t^{INT} + \beta_1 \Delta E_t \\ &\vdots \\ \Delta P_{t+n}^t &= \alpha_n \Delta P_t^{INT} + \beta_n \Delta E_t \end{aligned}$$

The adjustment dynamics depicted above shows that it takes n periods to the crude oil prices and exchange rate shocks in t to be fully passed-through to the gasoline prices. The total change in refinery gasoline price in any period t will thus depend on the changes on prices in the previous n periods:

$$\Delta P_t \;=\; \Delta P_t^t \;+\; \Delta P_t^{t-1} \;+\; ... \;+ \Delta P_t^{t-n} \;=\; \sum_{i=0}^{n} \alpha_i \Delta_{P_{t-i}^{INT}} \;+\; \beta_i \Delta E_{t-i} \tag{2}$$

Where for simplification we assume that both oil prices and exchange rate have the same n lags of adjustment. Equation 2, however, implies symmetric adjustment. In order to capture different effects from increases and decreases on oil prices and currency, we can instead assume:

$$\begin{aligned} \Delta P_t^t &= \alpha_0^+ \Delta P_t^{INT} + \beta_0^+ \Delta E_t \\ \Delta P_{t+1}^t &= \alpha_1^+ \Delta P_t^{INT} + \beta_1^+ \Delta E_t \\ &\vdots \\ \Delta P_{t+n}^t &= \alpha_n^+ \Delta P_t^{INT} + \beta_n^+ \Delta E_t \end{aligned}$$

If $\Delta P_t^{INT} > 0$ and $\Delta E_t > 0$;

$$\begin{aligned} \Delta P_t^t &= \alpha_0^- \Delta P_t^{INT} + \beta_0^- \Delta E_t \\ \Delta P_{t+1}^t &= \alpha_1^- \Delta P_t^{INT} + \beta_1^- \Delta E_t \\ &\vdots \\ \Delta P_{t+n}^t &= \alpha_n^- \Delta P_t^{INT} + \beta_n^- \Delta E_t \end{aligned}$$

If $\Delta P_t^{INT} < 0$ and $\Delta E_t < 0$;

The same reasoning goes for the other two cases (if $\Delta P_t^{INT} < 0$ and $\Delta E_t > 0$ and then if $\Delta P_t^{INT} > 0$ and $\Delta E_t < 0$). Defining:

$$\begin{aligned} \Delta P_t^{int+} \;&=\; max\left\{\Delta P_t^{INT}, 0\right\};\; \Delta P_t^{int-} \;=\; min\left\{\Delta P_t^{INT}, 0\right\} \\ \Delta E_t^{+} \;&=\; max\left\{\Delta E_t, 0\right\};\; \Delta E_t^{-} \;=\; min\left\{\Delta E_t, 0\right\}, \end{aligned} \tag{3}$$

and assuming different lags of adjustment for crude oil prices and exchange rate, a straightforward empirical model for assessing asymmetric adjustments in the gasoline price would then be:

$$\Delta P_t \;=\; \sum_{i=0}^{n} (\alpha_i^+ \Delta P_{t-i}^{int+} \;+\; \alpha_i^- \Delta P_{t-i}^{int-}) \;+\; \sum_{s=0}^{m} (\beta_s^+ \Delta E_{t-s}^+ \;+\; \beta_s^- \Delta E_{t-s}^-) \;+ \tag{4}$$

The key feature of an asymmetric lag response structure is its intertemporal independence. Allowing for different effects of increases and decreases implies that an increase in an explanatory variable followed by a decrease of the same amount does not imply a reversal on gasoline prices, as it could continue to rise in $t + 1$ (this happens when $\beta_0^+ > \beta_1^-$).

The following step is to change the lag adjustment model in 4 into a partial adjustment model. Doing so implies that there is a long-run relationship towards which the changes on gasoline prices tend to revert at a low speed. The most common partial adjustment structure is achievable with an error correction term, which is the lagged residual from the long-run relationship described in 1. The error correction model is:

$$\Delta P_t = \sum_{i=0}^{n}(\alpha_i^{+}\Delta P_{t-i}^{int+} + \alpha_i^{-}\Delta P_{t-i}^{int-}) + \sum_{s=0}^{m}(\beta_s^{+}\Delta E_{t-s}^{+} + \beta_s^{-}\Delta E_{t-s}^{-}) + + \theta_1(P_{t-1} - \phi_0 - \phi_1 P_{t-1}^{INT} - \phi_2 E_{t-1}) + \epsilon_t \quad (5)$$

4.2. NARDL model

One of the most simple ways to reach an empirical identification from the adjustment function stressed above is via the cointegration approach of a NARDL model. Assuming again the relationship implied in 1, one can right the following conditional error correction model (CECM):

$$\Delta p_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p}\gamma_{1i}\Delta p_{t-i} + \sum_{i=0}^{q_2}\gamma_{2i}\Delta p_{t-i}^{INT} + \sum_{i=0}^{q_3}\gamma_{3i}\Delta e_{t-i} - \theta EC_{t-1} + u_t \quad (6)$$

$$EC_{t-1} = \frac{\beta_1}{\theta}p_{t-1} - \left(\frac{\beta_2}{\theta}p_{t-1}^{INT} + \frac{\beta_3}{\theta}e_{t-1}\right) \quad (7)$$

where EC is an error correction term and also the cointegrating relationship between p_t, p_t^{INT} and e_t and θ is the speed of adjustment at which any short-run disequilibrium converges towards the long-run relationship. The unrestricted model can be written as:

$$\Delta p_t = \alpha_0 + \alpha_1 t + \beta_1 p_{t-1} + \beta_2 p_{t-1}^{INT} + \beta_3 e_{t-1} + + \sum_{i=1}^{p}\gamma_{1i}\Delta p_{t-i} + \sum_{i=0}^{q_2}\gamma_{2i}\Delta p_{t-i}^{INT} + \sum_{i=0}^{q_3}\gamma_{3i}\Delta e_{t-i} + u_t \quad (8)$$

which is the CEC form of a VAR model. In traditional time series econometrics, the cointegration of the system depicted above typically all variables in the VAR to be I(1) (see Engle & Granger, 1987 and Phillips & Ouliaris, 1990). Therefore, the standard procedure requires a series of unit root tests in each of the variables, which is subject to misclassification, as the tests might suffer from different weaknesses. In order to avoid such problems, the cointegration approach developed by Pesaran et al. (2001) is robust to whether the variables are $I(0)$ or $I(1)$. The null hypothesis to be tested is of no cointegration: $\beta_1 = \beta_2 = \beta_3 = 0$. The bound test has two critical significance values: the lower one is based on the assumption that all of the variables are $I(0)$ and the upper bound critical value is based on the assumption that all variables are $I(1)$. Therefore, if the F_{PSS} statistics lie above the upper bound, one can assert the presence of a long-run relationship in the system as the null hypothesis is rejected. If it is beyond the lower bound, the null is not rejected and there is no cointegration. Finally, if the values lie in between the bounds, the test is inconclusive. In this case, is standard in the literature to check the significance of the EC term given by the coefficient θ, comparing its t-statistics to the critical values of Banerjee et al. (1998).

A crucial feature of this modelling tool is the needlessness of testing for a unit root, given that the new critical values account for variables with both orders of integration. According to Nieh & Wang (2005), owing to its advantages of solving the typical problem of integration that has been a substantial focus for the time series literature and for dealing with the small-sample issue, the ARDL bound test has largely been applied in several studies in recent years.

We study the asymmetric effects by decomposing threshold variables. This method has been rising in popularity recently Verheyen (2012); Bahmani-Oskooee & Aftab (2017); Nusair (2017); Bahmani-Oskooee & Gelan (2018); Lourenço & Vasconcelos (2018, 2019):

$$p_t^{int(+)} = \sum_{s-1}^{t}\Delta p_s^{int(+)} = \sum_{s=1}^{t} max(\Delta p_s^{INT}, 0) \quad (9)$$

$$p_t^{int(-)} = \sum_{s-1}^{t}\Delta p_s^{int(-)} = \sum_{s=1}^{t} min(\Delta p_s^{INT}, 0) \quad (10)$$

These variables are often called cumulative sums. The one with superscript (+) indicates the positive decomposition, i.e., it accumulates all the increases in international fuel prices and the variable defined with superscript (-) captures all the decreases on these prices. The four terms described above replace the original variables in equation 6 in what is called the nonlinear ARDL (NARDL) model.

Finally, a proper specification of the regressors affecting the daily price adjustment is needed. As we saw in figure 03, there are different mechanisms affecting wholesale prices. Thus, we define the third branch - related to the company's pursuing a competitive setting in the domestic market - as the benchmark model and thus only the international prices of fuel will be decomposed as in equations 09 and 10. In the following three specifications, the first two branches - the transmittal of crude oil and exchange rates - are also regarded, but we keep them in the symmetric notation[7]. This leads to four specifications:

Model A: $(p_t^{int(+)},\ p_t^{int(-)})$

Model B: $(p_t^{int(+)},\ p_t^{int(-)},\ e_t)$

Model C: $(p_t^{int(+)},\ p_t^{int(-)},\ p_t^{(oil)})$

Model D: $(p_t^{int(+)},\ p_t^{int(-)},\ p_t^{(oil)},\ e_t)$

The asymmetry is simply asserted by a Wald test: in the long run (between coefficients β_j), and in the short run, which could be the contemporaneous effect (between coefficients γ_{ji}, $i = 0$) and the cumulative effect (between the values given by $\sum_{i=0}^{q_j} \gamma_{ji}$), where for all cases j indexes the threshold variables only.

5. Data Description

In early 2018, Petrobras gave open access to daily prices of fuel at the oil refineries, i.e., free of taxes, transportation costs, mark-ups of the final supplier, and other costs in the chain of distribution that might be embedded into final retail prices. These prices are our measure of wholesale prices, as it is the upstream price that distributors pay if they buy domestic fuel, that is to say if they do not import from elsewhere.

tBesides fuel prices, we gathered the spot nominal exchange rate between the Brazilian Real (BRL) and US dollars (USD), expressed as $\frac{BRL}{USD}$ and the West Texas Intermediate crude oil in dollars. As a proxy for the international prices of automotive fuel, we selected the prices of regular gasoline and ultra-low-sulfur no. 2 diesel as reported by the U.S. Energy Information Administration (EIA). These prices are collected in two different spots - the Golf Coast and the New York Harbor. As they showed to be quite similar and in order to work with a single time series, we averaged them. The time series are plotted in figure 04 and they show[8] - especially in the period of daily adjustments (phase 02) - considerably similar trends, as the nominal exchange rate, the prices of oil and the fuel prices at the Golf Coast and NY Harbor were indeed passed-through to the wholesale gasoline and diesel prices in some extent. The similar pattern between the domestic currency and the barrel prices is due to the fact that the BRL is considered to be a commodity currency.[9]

In the sample period (October 2016 to June 2019), the exchange rate depreciated from around 3.15 BRL/USD up to a peak of 4.18 by July 2018. The barrel price showed a similar increasing trend from mid-2017 to late-2018. Since November 2018, both decreased and stabilised in the first months of 2019, but at a new level when compared to 2016. Particularly, the exchange rate shows a typical sign of a structural break. The period that runs from October 2018 until the end of the sample is notorious for showing some signs of dissociation between the oil price and the NER. That is, the strong downturn seen in oil prices in the last three months of that year was not accompanied by a similar trend in the exchange rate. Lastly, the international prices of fuel had similar trends and accompanied the movements seen in the crude oil plot. Notice, however, that after the peak in October 2018, the prices of gasoline plummeted next to the sample minimum and a few months later peaked again to over 2.20 BRL. the diesel price remained more unwavering, somewhere slightly above the sample average (1.71 BRL). In terms of correlation, the gasoline price remained closer to the oil prices when compared to diesel (0.88 *vs* 0.85).

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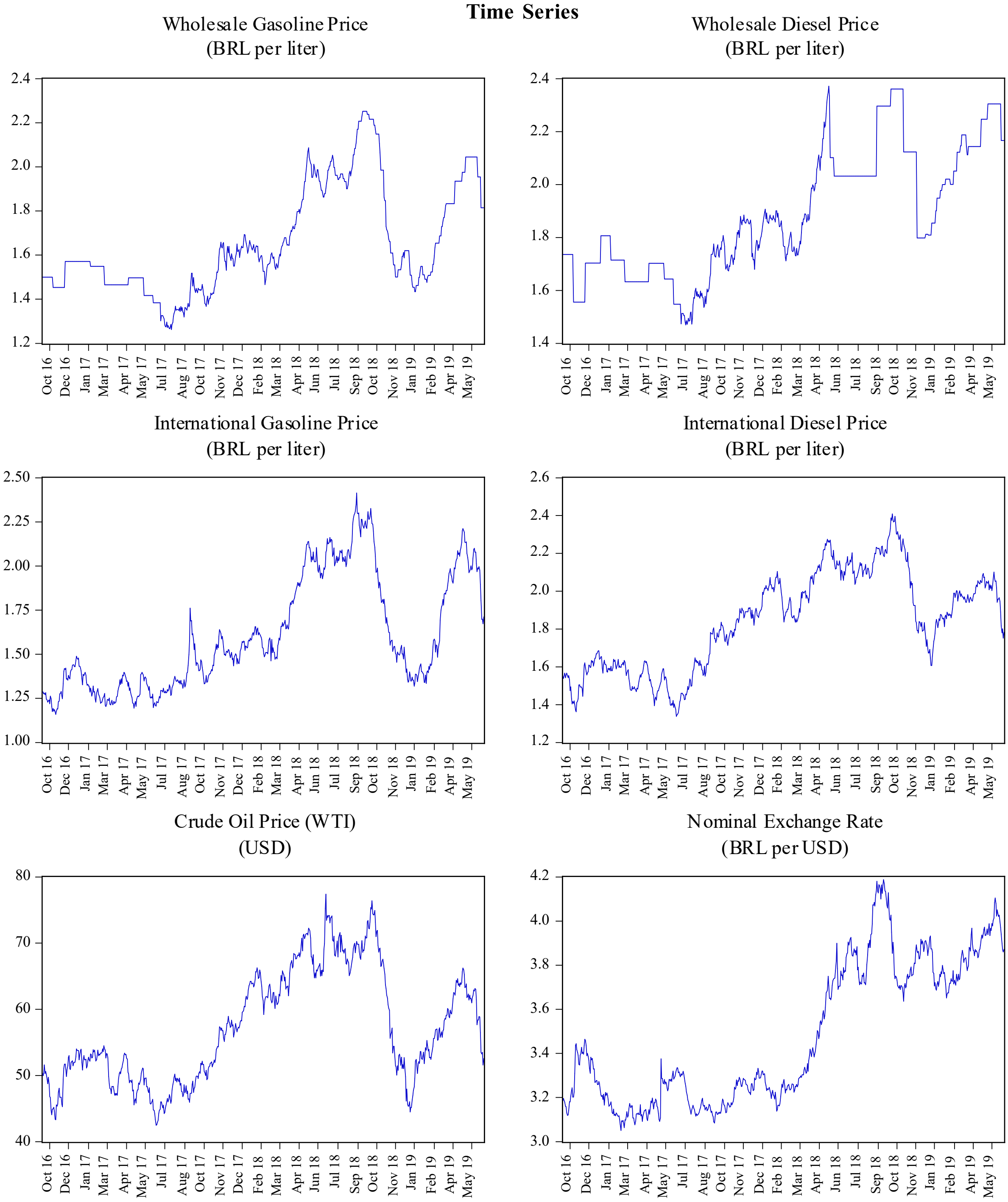
[7] There are not much guideline in the literature about the usage of cumulative sums in more than one variable. Intuitively, we disregarded it because fuel prices, oil and exchange rates have all similar trends in our sample and, therefore, their cumulative sums could possibly bring multicollinearity to the models. Nonetheless, the intuition brought fourth in equation 05 is still captured because p_{int} is the fuel prices in BRL, i.e., its asymmetric decomposition embeds the nominal exchange rate.

[8] Notice that the original data on international price of fuel is given by USD per gallon. In figure 04 we show them in BRL per liter (1 US gallon = 3.7854 liter).

[9] A commodity currency is said to co-move with the world prices of primary commodity products, due to the domestic countries' dependency on the export of raw materials. Moreover, a part of the literature investigates the feedback and spill-over effects between them, as the close relationship between currencies and commodities is a known stylised fact in international finance, although its causes demand further investigations. See de Castro Albert et al. (2014); Beckmann et al. (2017).

Figure 04
Time Series



6. Results

The daily sample on domestic fuel prices has a particular feature: it has data from Tuesdays to Saturdays. This means that the prices on Mondays are the same over the past weekend and the changes in markets on Monday are taken into account in the new price only by Tuesdays. Keeping the sample with a 6-day range would generate a lot of missing data on Saturdays, as the financial markets are closed and we would have no data for exchange rates and barrel prices. As a way to circumvent this issue, we dragged the gasoline price series back one day to match the weekdays. Thus, the period Tue-Sat becomes Mon-Fri, as if the new price released on Tuesday morning was actually released on Monday night. This makes sense as the idea behind daily readjustments is that they depend on the figures seen in the financial market when it closes the day before. In terms of interpretation, the contemporaneous effect in the error correction form (in t) captures the one-day-lag effect. Analysing the short-run structure allows the understanding of how quickly the prices are adjusted.

The daily time series offers enough information to estimate the models in different time frames, without the need to resource to the small-sample properties of the Pesaran et al.'s bounds test. Thus, based on figures 01 and 02, we computed the NARDL models in three periods for the gasoline and four for the diesel. For each period, the estimated equation assumed different specifications regarding the choices of covariates, as already mentioned. Tables 02 and 03 below depicts the results for the gasoline and diesel, respectively. As one can see, we show three sets of parameters, that can all be seen in equation 08. This representation of the NARDL model shows how short-run adjustments converge to a possible long-run equilibrium. Thus, the long-run coefficients can be taken into account if the model cointegrates, i.e., if the value for F_{PSS} is above a certain bound as calculated by Pesaran et al. (2001), which means that the processes are governed by a common factor. In this regard, the information on price practises provided before leads us to assume that the company's behaviour is dictated by what happens in the short-run structure. The long-run coefficients are simply the final convergence after all short-run effects die out.

The estimates for phase 01 showed mild evidence of cointegration, which means one should assess carefully the long-run terms. This result is expected as prices in that phase used to remain at the same level for approximately 20 days, that is, they were not converging to an equilibrium generated by a long-run relationship between international and wholesale prices.

Nevertheless, phase 02 shows a different pattern, as the four models had strong evidence of cointegration. This was when the company started to pursue daily readjustments. Interestingly, these models present pieces of evidence in favour of long-run asymmetry in this period: the average point estimate for increases in international prices were 0.87, compared to only 0.51 to the decreases and, what is more important, they showed to be statistically different. What this unveils is that potentially almost all the effect of a 1% increase in international gasoline prevails in the long run, whilst the transmission is incomplete after a 1% decrease. The short-run structure shows a similar picture in the contemporaneous effect, i.e., the effect seen one day after the change in international prices. The cumulative short-run effect, however, is symmetrical and tells us that the company refreshed its wholesale prices at around 25% after both increases and decreases of international gasoline.

Then, in phase 03, the pace of adjustments slackened (one new price every three days) and the long-run asymmetry vanished. The short-run structure reveals, however, some signs of asymmetric price policy. The cumulative effect had a negative sign for decreases in the international price, which means that they are being passed-through in the opposite direction[10]. That is, in this period a decrease in the international price of gasoline resulted in an increase in wholesale prices, in what is a sign of departure from what the company usually claims.

Diesel's phase 01 model is not much different from gasoline's. There is no clear short-run asymmetry, although the specifications show slightly stronger evidence of cointegration. Phase 02 showed consistent symmetry in both long and short run, with the exception of model C. A relevant feature was that, in phase 02, the price policy for diesel was more sensitive to the international prices than the gasoline - the cumulative effect in the short run represented a pass-through of 65% in average. Indeed, diesel price was adjusted more often in that phase (93% of the days, against 89%) and had a larger average change (0.21% *vs* 0.17%), which indicates that the international volatility was being passed-through to a larger extent.

Following, phase 03* was characterised by steady prices for longer periods as a result of the government's subsidy program. The short-run coefficients show some evidence of positive asymmetry, firstly with positive values for $p^{int(+)}$ in models A and B and, secondly, with negatives values for $p^{int(-)}$ in models C and D. As prices were slumped after the strike in May 2018 (see figure 02), it was natural to see the positive asymmetry in the period, due to the fact that prices were set below its equilibrium level. Therefore, decreases in the international prices needed not to be accounted for in new prices, but increases did.

Finally, phase 04 followed a scheme similar to gasoline's phase 03. However, the price policy again presented some differences. This time, the models had evidence of negative asymmetry, i.e., decreases in international prices were passed-through to a larger extent. This shows that the price police for automotive fuel still suffered organised pressures from the society, as the company failed to keep a policy of symmetric readjustments.

Overall, the estimates regarding the whole sample showed that the positive asymmetry found in phase 03 for gasoline prevailed in some cases even accounting for a larger period (see models B and D). Notwithstanding, the price policy for diesel seemed to be symmetric throughout the total sample. The positive asymmetry perceived in phase 03*, as a result of the price level being below the equilibrium, was offset by a negative asymmetry in the ensuing phase.

Although the roles played by the exchange rate and price of oil are secondary in the asymmetric price transmission, their inclusion and exclusion in the models did have effects on the estimates. In the second phase of gasoline, for example, the inclusion of crude oil prices as a regressor enhanced the goodness of fit in different instances (see appendix A). What is more, the gasoline price holds both short- and long-run relationship with oil prices. For the former, 16% of a change in the WTI oil price was embedded into the wholesale price of gasoline[11].

[10] Recall how one should interpret signs in the NARDL model. The negative threshold decomposition must be read with opposite signs, because its marginal change is always negative. So a negative coefficient combined to a negative marginal change yields a positive final effect.

[11] For simplicity, we did not show the coefficients of both p^{oil} and e. The complete output can be requested from the author.

Table 02 - Results - Asymmetry on Price Transmission of Gasoline

Specification				Cointegration		Long run			Short run contemporaneous			Short run cumulative		
Phase	**Model**	**Lags**	**Trend**	F_{PSS}	ECM	$p^{int(+)}$	$p^{int(-)}$	**Wald**	$\Delta p^{int(+)}$	$\Delta p^{int(-)}$	**Wald**	$\sum \Delta \mathbf{p}^{int(+)}$	$\sum \Delta \mathbf{p}^{int(-)}$	**Wald**
1	A	(1,6,0)	No	2.213	-0.052**	0.486*	0.596**	5.932**	-0.084	0.031*	3.653*	-0.025	0.031*	0.094
1	B	(1,6,0,0)	No	1.989	-0.067***	0.131	0.208	-	-0.108*	0.013	3.875**	-0.066	0.013	-
1	C	(1,4,5,6)	No	2.136	-0.070***	0.408**	0.505**	10.971***	-0.075	0.063	-	0.263*	-0.354**	5.743**
1	D	(1,5,0,0,6)	No	1.479	-0.070***	0.049	0.126	-	-0.107*	0.008	3.211*	0.074	0.008	-
2	A	(1,2,2)	Yes	6.770 ‡	-0.124***	1.001***	0.623***	5.379**	0.087	0.101	-	0.233	0.343	0.854
2	B	(1,0,0,2)	Yes	11.356 ‡	-0.198***	0.773***	0.421***	13.840***	0.147***	0.086***	10.684***	-	-	-
2	C	(1,2,2,0)	Yes	5.733 ‡	-0.134***	0.935***	0.500***	7.603***	0.087	0.084	-	0.230***	0.322***	0.621
2	D	(1,0,0,2,0)	Yes	9.561 ‡	-0.204***	0.756***	0.376***	14.719***	0.149***	0.080***	10.697***	-	-	-
3	A	(6,4,5)	Yes	6.515 ‡	-0.120***	0.543***	0.961***	2.537	-0.101	0.077	-	0.362**	-0.214	4.694**
3	B	(6,4,5,0)	Yes	6.506 ‡	-0.142***	0.317**	0.545***	0.967	-0.129*	0.017	1.439	0.321**	-0.339**	6.321**
3	C	(6,4,5,2)	Yes	6.138 ‡	-0.130***	0.511***	0.980***	3.231*	-0.058	0.093	-	0.477***	-0.192	6.269**
3	D	(6,4,5,0,2)	Yes	6.212 ‡	-0.150***	0.313**	0.508**	0.650	-0.093	0.024	-	0.411**	-0.315*	7.6694***
Total	A	(1,4,2)	Yes	6.144 ‡	-0.040***	1.097***	0.679***	1.940	-0.013	0.075*	1.620	0.406***	0.239***	2.109
Total	B	(1,4,2,0)	Yes	7.137 ‡	-0.061***	0.664***	0.174	5.749**	-0.018	0.034	-	0.399***	0.178***	3.949**
Total	C	(1,3,2,0)	Yes	6.833 ‡	-0.054***	1.053***	0.536***	4.923**	-0.016	0.070*	1.541	0.324***	0.231***	0.641
Total	D	(1,4,2,0,6)	Yes	7.028 ‡	-0.004***	0.673***	0.151	10.390***	-0.008	0.034	-	0.374***	0.167***	3.360*

Phase 1: October 14th 2016 - July 3rd 2017;
Phase 2: July 4th 2017 - July 2nd 2018;
Phase 3: July 3rd 2018 - June 6th 2019;
Notes:
Wald tests are not computed if both variables are non-significant at 10% level; when the short-run lag structure is 0 for a given variable, its contemporaneous effect is the same as the cumulative, so the coefficients are repeated; the order of variables in the lag structure is the dependent followed by the order as reported in the end of section 4; choices of including the deterministic trend followed both economic intuition and quality of fit;
10% significance (*)
5% significance (**)
1% significance (***)
Cointegration at 10% level (±)
Cointegration at 5% level (†)
Cointegration at 1% level (‡)

Table 03 - Results - Asymmetry on Price Transmission of Diesel

Specification				Cointegration		Long run			Short run contemporaneous			Short Run cumulative		
Phase	**Model**	**Lags**	**Trend**	F_{PSS}	**ECM**	$p^{int(+)}$	$p^{int(-)}$	**Wald**	$\Delta \mathbf{p}^{int(+)}$	$\Delta \mathbf{p}^{int(-)}$	**Wald**	$\sum \Delta \mathbf{p}^{int(+)}$	$\sum \Delta \mathbf{p}^{int(-)}$	**Wald**
1	A	(1,6,6)	No	4.632 ±	-0.088***	0.978***	0.956***	0.004	-0.133	0.090	-	-0.244	-0.277	-
1	B	(1,6,6,0)	No	3.538	-0.094***	0.472	0.460	-	-0.171*	0.050	1.495	-0.269	-0.309	-
1	C	(1,6,6,2)	No	4.547 †	-0.120***	0.925***	0.914***	0.189	-0.119	0.096	-	-0.194	-0.463	-
1	D	(1,6,6,0,2)	No	3.617 ±	-0.120***	1.015	1.003	-	-0.108	0.106	-	-0.184	-0.462	-
2	A	(1,2,2)	Yes	3.852	-0.109***	1.003***	0.909***	0.008	0.022	0.135*	0.917	0.673***	0.775***	0.528
2	B	(1,2,2,2)	No	3.636	-0.132***	1.108***	1.140***	2.105	0.118	0.222**	0.936	0.604***	0.708***	0.506
2	C	(1,2,2,2)	No	2.752	-0.102***	0.907***	1.001***	8.638***	0.027	0.156**	1.170	0.664***	0.753***	0.425
2	D	(1,2,2,2,0)	No	3.725 ±	-0.147***	1.102***	1.109***	0.550	0.098	0.204**	0.901	0.549***	0.667***	0.641
3*	A	(1,0,2)	No	7.451 ‡	-0.158***	1.007***	0.933***	2.264	0.154***	0.231*	0.414	0.154***	-0.045	0.623
3*	B	(1,0,2,0)	No	5.561 †	-0.160***	1.068***	1.003***	0.544	0.162**	0.246*	0.433	0.162**	-0.028	0.001
3*	C	(2,1,6,1)	No	8.517 ‡	-0.270***	1.091***	1.014***	5.455**	-0.075	0.290*	1.645	-0.075	-1.216**	4.810**
3*	D	(2,1,6,0,1)	No	6.846 ‡	-0.270***	0.989***	0.896***	3.490**	-0.098	0.237	1.319	-0.098	-1.341**	5.107**
4	A	(1,2,5)	Yes	5.316 †	-0.239***	1.092***	0.696***	1.240	-0.032	0.177*	1.141	0.155	-0.415	-
4	B	(1,1,0,6)	Yes	7.364 ‡	-0.291***	1.196***	0.775***	2.166	-0.140	0.232***	5.719**	-0.140	0.232***	5.719**
4	C	(1,2,5,0)	Yes	4.219 †	-0.241***	1.108***	0.666***	1.122	-0.032	0.174**	1.080	0.153	-0.414	-
4	D	(1,1,0,6,0)	Yes	6.115 ‡	-0.295***	1.216***	0.712***	2.138	-0.137	0.215**	4.793**	-0.137	0.215**	4.793**
Total	A	(1,4,2)	No	6.080 †	-0.053***	0.556***	0.549***	0.066	-0.068	0.212***	6.946***	0.445***	0.312***	0.434
Total	B	(1,4,2,0)	No	4.553 †	-0.053***	0.549*	0.543*	0.019	-0.068	0.212***	6.860***	0.445***	0.312***	0.438
Total	C	(1,4,2,0)	No	4.570 †	-0.053***	0.572***	0.564***	0.029	-0.066	0.211***	6.718**	0.449***	0.310***	0.467
Total	D	(1,4,2,0,0)	No	3.651 ±	-0.053***	0.559**	0.550**	0.003	-0.066	0.210***	6.604**	0.449***	0.309***	0.476

Phase 1: October 14th 2016 - July 3rd 2017;
Phase 2: July 4th 2017 - May 21st 2018;
Phase 3*: June 1st 2018 - December 31st 2018;
Phase 4: January 1st 2019 - June 6th 2019

Notes:

Wald tests are not computed if both variables are non-significant at 10% level; when the short-run lag structure is 0 for a given variable, its contemporaneous effect is the same as the cumulative, so the coefficients are repeated; the order of variables in the lag structure is the dependent followed by the order as reported in the end of section 4; choices of including the deterministic trend followed both economic intuition and quality of fit;

10% significance (*)
5% significance (**)
1% significance (***)
Cointegration at 10% level (±)
Cointegration at 5% level (†)
Cointegration at 1% level (‡)

Notice also that in the estimates of the complete sample, the aforementioned positive asymmetry was only asserted after including the price of petroleum. For the diesel, phase 03* had variation in the estimates after the inclusion of the nominal exchange rate and phase 04 after considering oil price.

6.1. Robustness

The way we specified the transmission channels provides itself a broad range of models that we can look at (tables 02 and 03 show 36 specifications in total). Nevertheless, an important caveat in several applied time series models regards the inclusion of deterministic terms. In this matter, theory and practice can both help out in the proper choice of model specification. Thus, whenever the price policy was characterised by staggered price dynamics, we decided to leave the deterministic trend out of the model (this was the case in phase 1 for gasoline and 1 and 3* for diesel). On the other hand, when prices showed clear signs of a slope, we tested the inclusion of a time trend (phases 2, 3, and total for gasoline and 4 for diesel). This way, we assumed that, in periods where the fuel prices are climbing up or slumping down, the price dynamic is not fully explained by international shocks and, if there is an unobserved covariate influencing this upward/downward dynamics, the deterministic trend component can roughly account for it. For all cases though, we used this intuition as a benchmark guideline and let the data speak to themselves. Whenever the inclusion of a trend enhanced the performance of models and the trend itself was strongly significant, we chose to keep them.

A final comment addresses how the trend can be included. When deterministic terms affect the cointegrating relationship dynamics, they are said to be restricted to a linear combination of the elements in the cointegrating vector. It is present in the levels equation, which is estimated as a first-step before joining the error correction term in the conditional error correction form of the NARDL model. Otherwise, they enter only in the CEC form without affecting the long-run dynamics (in this case, they are unrestricted). Given the characteristics of our series and based on what we stated in the previous paragraph, we opted for a restricted time trend, i.e., a time trend that only affects the long run. This way, the short-run coefficients are little altered by them. In table 04, we included/removed the trend in those phases where the dependent variable has noticeable slopes. We highlighted (⋆) what changed:

Table 04 - Robustness check

(a) - Gasoline

		Baseline estimates		***Robustness check***	
Phase	Model	Trend	Short run asymmetry	Trend	Short run asymmetry
2	A	Yes	None	No	None
2	B	Yes	None	No	Positive ⋆
2	C	Yes	None	No	None
2	D	Yes	None	No	Positive ⋆
3	A	Yes	Positive	No	Positive
3	B	Yes	Positive	No	Positive
3	C	Yes	Positive	No	Positive
3	D	Yes	Positive	No	Positive
Total	A	Yes	None	No	None
Total	B	Yes	Positive	No	Positive
Total	C	Yes	None	No	None
Total	D	Yes	Positive	No	Positive

(b) - Diesel

		Baseline estimates		***Robustness check***	
Phase	Model	Trend	Short run asymmetry	Trend	Short run asymmetry
2	A	Yes	None	No	None
2	B	No	None	Yes	None
2	C	No	None	Yes	None
2	D	No	None	Yes	None
4	A	Yes	None	No	None
4	B	Yes	Negative	No	Negative
4	C	Yes	None	No	None
4	D	Yes	Negative	No	Negative
Total	A	No	None	Yes	None
Total	B	No	None	Yes	None
Total	C	No	None	Yes	None
Total	D	No	None	Yes	None

7. Conclusions

This study intended to investigate asymmetry in the transmittal of international fundamentals to the wholesale price of two important fuels in Brazilian behemoth oil company Petrobras from 2016 to 2019. What motivated the work was the company's claim that the price policy would strictly follow the international prices of fuel. In this setting, the domestic market would become more competitive, which means that foreign companies would be able to import refined fuel and sell at a competitive level, regardless of the still outstanding market share held by the major domestic company.

To achieve the goal, we employed a simple asymmetric adjustment function that can be straightforwardly identified by a nonlinear autoregressive distributed lag model (NARDL). With daily prices of wholesale and international fuel, nominal exchange rates and crude oil, we estimated adjustment functions for three different phases of the price policy for gasoline and four for diesel. In short, the estimates point to the fact that Petrobras' price policy for gasoline was symmetric from October 2016 to mid-2018. Therefrom, we found consistent evidence that the transmittal was asymmetric. Considering the whole sample, international shocks on gasoline prices were transmitted to wholesale prices within the next two to six working days in a proportion of 35-40% for positive shocks and 18-24% to negative ones. Moreover, in the long run, the prices seem to converge to an unbalanced relationship, which can be interpreted as prices not coming back to the same level after the occurrence of positive and negative shocks in the same proportion.

On the other hand, the price of diesel showed a looser adherence to international prices in the long run. However, in the run-up to the strike in May 2018, international prices were being almost fully passed-through to wholesale prices (60%-70% in just two days). In the subsequent period - from May to December 2018 - the price policy was swayed by a governmental program and deals settled with consumers, represented mainly by truck drivers. In this phase, as the price was way below its equilibrium level, positive shocks on international diesel were easily passed through. The results showed that, even after this period, the price of diesel seemed to hold negative asymmetry, meaning that decreases in international prices are passed-through to a larger extent when compared to increases. On the overall, 30-45% of international shocks were transmitted to wholesale prices in a symmetric fashion.

What this piece of evidence shows is that the company probably has more leeway to exert positive asymmetric transmission in the gasoline market, which, despite its importance, is less organised in terms of classes of workers and unions. We consider also the hypothesis that the company might have used the gasoline price to offset the losses (if there were any) from the subsidy program in diesel commercialisation.

There is still a lot to be studied in order to answer if there is an asymmetry in the final retail prices paid by consumers at the fuel stations. As we go down the distribution chain, more complexities appear, and more players are involved, in a way that international shocks tend to be more offset. One interesting topic being discussed at both society and academia is the presence of fuel cartels, i.e., informal organisations that uses their power as oligopolistis to tacitly control fuel prices. As an intersection with what we studied here, one can perceive spatial clusters of positive price asymmetry as a sign of large market power and, along with other evidence, collusive behaviour. We hope to study such questions in the future.

References

Asane-Otoo, E., & Schneider, J. (2015). Retail fuel price adjustment in germany: A threshold cointegration approach. *Energy Policy*, *78*, 1–10.

Atil, A., Lahiani, A., & Nguyen, D. K. (2014). Asymmetric and nonlinear pass-through of crude oil prices to gasoline and natural gas prices. *Energy Policy*, *65*, 567–573.

Bachmeier, L. J., & Griffin, J. M. (2003). New evidence on asymmetric gasoline price responses. *Review of Economics and Statistics*, *85*, 772–776.

Bahmani-Oskooee, M., & Aftab, M. (2017). On the asymmetric effects of exchange rate volatility on trade flows: New evidence from us-malaysia trade at the industry level. *Economic Modelling*, *63*, 86–103.

Bahmani-Oskooee, M., & Gelan, A. (2018). Exchange-rate volatility and international trade performance: Evidence from 12 african countries. *Economic Analysis and Policy*, *58*, 14–21.

Balaguer, J., & Ripollés, J. (2012). Testing for price response asymmetries in the spanish fuel market. new evidence from daily data. *Energy Economics*, *34*, 2066–2071.

Banerjee, A., Dolado, J., & Mestre, R. (1998). Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of time series analysis*, *19*, 267–283.

Beckmann, J., Czudaj, R., & Arora, V. (2017). The relationship between oil prices and exchange rates: theory and evidence. *US Energy Information Administration working paper series*, (pp. 1–62).

Bermingham, C., & O'Brien, D. (2011). Testing for asymmetric pricing behaviour in irish and uk petrol and diesel markets. *The Energy Journal*, (pp. 1–26).

Bettendorf, L., Van der Geest, S. A., & Varkevisser, M. (2003). Price asymmetry in the dutch retail gasoline market. *Energy Economics*, *25*, 669–689.

Borenstein, S., Cameron, A. C., & Gilbert, R. (1997). Do gasoline prices respond asymmetrically to crude oil price changes? *The Quarterly journal of economics*, *112*, 305–339.

de Castro Albert, F. M., Zelati, P. E. C., & de Araújo, D. L. A. (2014). Is the brazilian real a commodity currency? large sample empirical evidence. *Independent Journal of Management & Production*, *5*, 1–24.

Da Silva, A. S., Vasconcelos, C. R. F., Vasconcelos, S. P., & de Mattos, R. S. (2014). Symmetric transmission of prices in the retail gasoline market in brazil. *Energy Economics*, *43*, 11–21.

De Salles, A. A. (2014). Some evidence on the asymmetry between gasoline and crude oil prices in selected countries. *International Journal of Energy Economics and Policy*, *4*, 670–678.

Deltas, G. (2008). Retail gasoline price dynamics and local market power. *The Journal of Industrial Economics*, *56*, 613–628.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, (pp. 251–276).

Fasoula, E., & Schweikert, K. (2018). *Price regulations and price adjustment dynamics: Evidence from the Austrian retail fuel market*. Technical Report Hohenheim Discussion Papers in Business, Economics and Social Sciences.

Frey, G., & Manera, M. (2007). Econometric models of asymmetric price transmission. *Journal of Economic surveys*, *21*, 349–415.

Honarvar, A. (2009). Theoretical explanations for asymmetric relationships between gasoline and crude oil prices with focus on the us market. *OPEC Energy Review*, *33*, 205–224.

Kpodar, K., & Abdallah, C. (2017). Dynamic fuel price pass-through: Evidence from a new global retail fuel price database. *Energy Economics*, *66*, 303–312.

Lourenço, L. d. S., & Vasconcelos, C. R. F. (2018). Nonlinear exchange rate pass-through in latin america. *Economics Bulletin*, *38*, 1566–1582.

Lourenço, L. d. S., & Vasconcelos, C. R. F. (2019). Impacts of exchange rate non-linearity on brazilian foreign trade. *International Economics and Economic Policy*, (pp. 1–21).

Meyer, J., & Von Cramon-Taubadel, S. (2004). Asymmetric price transmission: a survey. *Journal of agricultural economics*, *55*, 581–611.

Meyler, A. (2009). The pass through of oil prices into euro area consumer liquid fuel prices in an environment of high and volatile oil prices. *Energy Economics*, *31*, 867–881.

Narayan, P. K. (2005). The saving and investment nexus for china: evidence from cointegration tests. *Applied economics*, *37*, 1979–1990.

Nieh, C.-C., & Wang, Y.-S. (2005). Ardl approach to the exchange rate overshooting in taiwan. *Review of Quantitative Finance and Accounting*, *25*, 55–71.

Nusair, S. A. (2017). The j-curve phenomenon in european transition economies: A nonlinear ardl approach. *International Review of Applied Economics*, *31*, 1–27.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*, 289–326.

Phillips, P. C., & Ouliaris, S. (1990). Asymptotic properties of residual based tests for cointegration. *Econometrica: Journal of the Econometric Society*, (pp. 165–193).

Radchenko, S., & Tsurumi, H. (2006). Limited information bayesian analysis of a simultaneous equation with an autocorrelated error term and its application to the us gasoline market. *Journal of econometrics*, *133*, 31–49.

Rodrigues, N., Losekann, L., & Silveira Filho, G. (2018). Demand of automotive fuels in brazil: Underlying energy demand trend and asymmetric price response. *Energy Economics*, *74*, 644–655.

Serigati, F. C. (2014). Petrobras: a vilã poderia ser a solução. *AgroANALYSIS*, *34*, 25–28.

Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ardl framework. In *Festschrift in Honor of Peter Schmidt* (pp. 281–314). Nova York: Springer.

Silva, C. M. d. S. (2003). Estratégia de preços da petrobras no mercado de combustíveis brasileiro pós-liberalização e instrumentos de amortecimento de variações internacionais. *Trabalho de dissertação de Mestrado. Rio de Janeiro: UFRJ*, .

Uchôa, C. F. A. (2008). Testando a assimetria nos preços da gasolina brasileira. *Revista Brasileira de Economia*, *62*, 103–117.

Verheyen, F. (2012). Bilateral exports from euro zone countries to the us—does exchange rate variability play a role? *International Review of Economics & Finance*, *24*, 97–108.

Wlazlowski, S. (2001). Petrol and crude oil prices: asymmetric price transmission, .

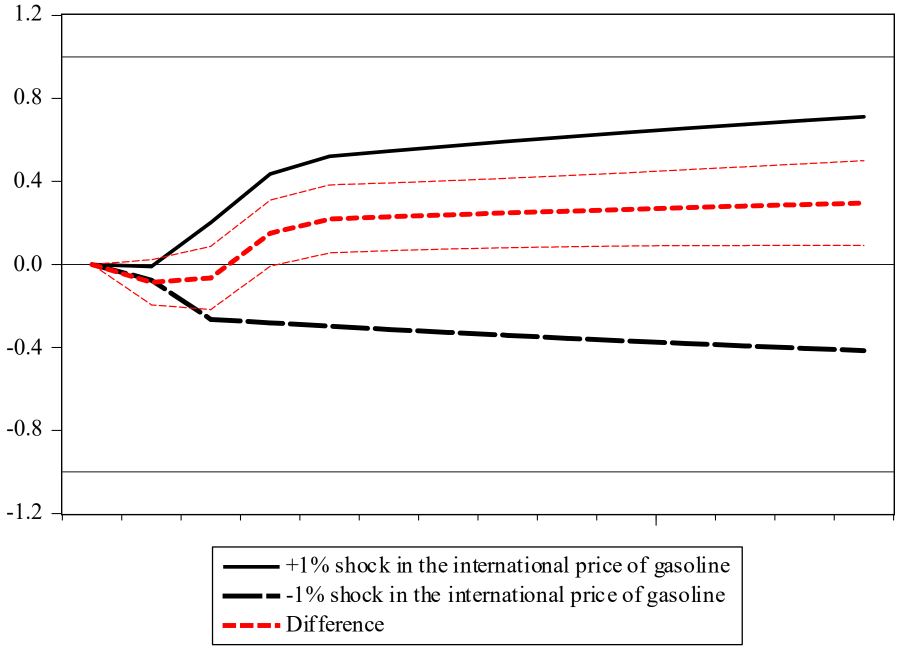
Appendix A - Diagnostics

(a) - Gasoline

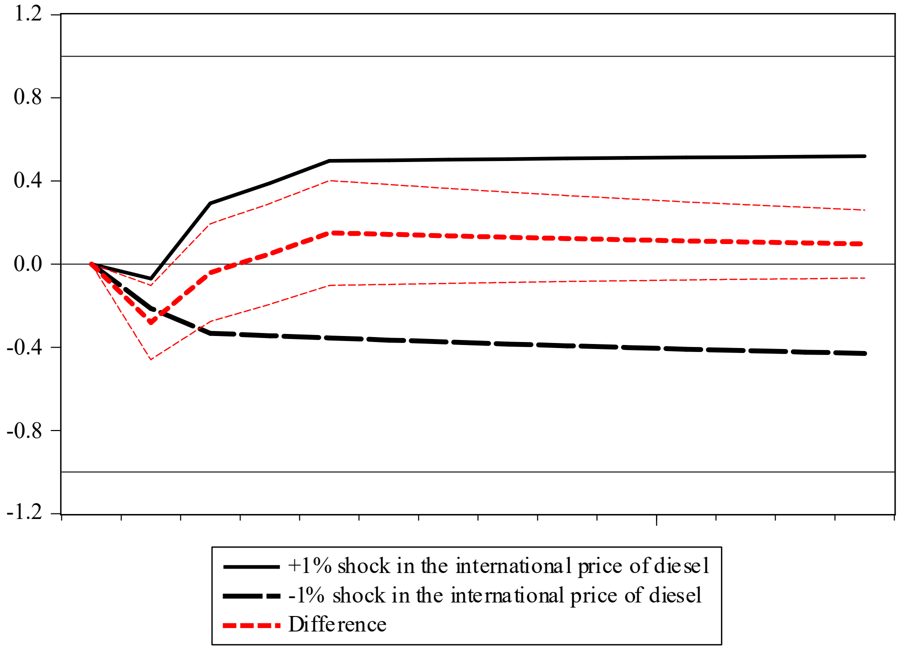
Model	*Performance*		*Heteroskedasticity*		*Serial Correlation*			*Stability*
	Adj. R^2	**Akaike**	**BPG**	**ARCH**	**Q-Stat Lag 1**	**Q-Stat Lag 2**	**Breusch-Godfrey LM Test**	**CUSUM CUSUMQ**
1.A	0.1065	-6.3681	2.4653 (0.0116)	0.0870 (0.9975)	1.4904 (0.222)	2.0137 (0.365)	0.6744 (0.6705)	Stable Unstable
1.B	0.1137	-6.3762	2.2996 (0.015)	0.0971 (0.9966)	0.9943 (0.319)	1.6599 (0.436)	0.6384 (0.6994)	Stable Unstable
1.C	0.2093	-6.4484	1.3759 (0.1465)	0.1172 (0.9943)	0.6081 (0.435)	0.7166 (0.699)	0.9869 (0.4364)	Stable Unstable
1.D	0.1956	-6.4522	1.6713 (0.0574)	0.1479 (0.9893)	0.0306 (0.861)	0.1025 (0.95)	0.4438 (0.8485)	Stable Unstable
2.A	0.2436	-5.9830	3.0725 (0.0026)	2.2542 (0.1071)	0.7165 (0.397)	0.7173 (0.699)	0.4243 (0.6547)	Stable Unstable
2.B	0.3038	-6.0738	1.0240 (0.4148)	1.2972 (0.2752)	0.0577 (0.81)	0.2895 (0.865)	0.1804 (0.8351)	Stable Unstable
2.C	0.2483	-5.9894	2.7226 (0.0049)	2.3344 (0.099)	0.5940 (0.441)	0.6222 (0.733)	0.3445 (0.7089)	Unstable Stable
2.D	0.3057	-6.0766	0.9713 (0.459)	1.3942 (0.25)	0.0941 (0.759)	0.4068 (0.816)	0.2604 (0.771)	Unstable Stable
3.A	0.3250	-6.0704	1.8705 (0.0196)	3.8249 (0.0012)	0.0106 (0.918)	0.8908 (0.641)	1.4085 (0.2127)	Stable Unstable
3.B	0.3431	-6.0976	1.9696 (0.0111)	3.6987 (0.0016)	0.0121 (0.912)	0.8979 (0.638)	1.3215 (0.2489)	Stable Unstable
3.C	0.3472	-6.0960	2.0528 (0.0057)	4.4207 (0.0003)	0.1289 (0.72)	1.6650 (0.435)	2.0415 (0.0617)	Stable Unstable
3.D	0.3650	-6.1236	2.1474 (0.003)	3.8070 (0.0012)	0.0828 (0.774)	1.3676 (0.505)	1.7021 (0.1221)	Stable Unstable
Total.A	0.1981	-6.0628	1.9059 (0.0416)	1.4895 (0.2037)	0.4594 (0.498)	0.5672 (0.753)	1.2817 (0.2758)	Stable Stable
Total.B	0.2112	-6.0793	1.8067 (0.0495)	1.8544 (0.1168)	0.3039 (0.581)	0.5462 (0.761)	1.8996 (0.0924)	Stable Stable
Total.C	0.2038	-6.0731	1.8522 (0.049)	1.7927 (0.1473)	0.3404 (0.56)	0.5626 (0.755)	1.7411 (0.1573)	Stable Stable
Total.D	0.2258	-6.0875	1.8670 (0.016)	1.4642 (0.188)	0.0195 (0.889)	0.2425 (0.886)	2.1152 (0.0498)	Stable Stable
(b) - Diesel								
1.A	0.1489	-5.6420	1.5782 (0.0854)	0.2027 (0.9755)	0.1307 (0.718)	0.1811 (0.913)	0.2254 (0.968)	Stable Stable
1.B	0.1507	-5.6440	1.4639 (0.1198)	0.1960 (0.9776)	0.0916 (0.762)	0.1751 (0.916)	0.2019 (0.9758)	Stable Stable
1.C	0.1724	-5.6594	1.3154 (0.1853)	0.1919 (0.9787)	0.0199 (0.888)	0.4037 (0.817)	0.4594 (0.8373)	Stable Stable
1.D	0.1724	-5.6595	1.2409 (0.2323)	0.1923 (0.9786)	0.0224 (0.881)	0.3825 (0.826)	0.4589 (0.8377)	Stable Stable
2.A	0.6559	-6.7988	0.5380 (0.8271)	0.4217 (0.6565)	4.5532 (0.033)	4.7044 (0.095)	2.9145 (0.0564)	Stable Unstable
2.B	0.6773	-6.8656	1.0424 (0.409)	0.2952 (0.7447)	1.9766 (0.16)	2.0307 (0.362)	1.2848 (0.2789)	Stable Unstable
2.C	0.6563	-6.8026	1.1933 (0.297)	0.1716 (0.8424)	3.5543 (0.059)	3.5756 (0.167)	2.3050 (0.1023)	Stable Unstable
2.D	0.6832	-6.8842	0.9164 (0.5255)	0.3023 (0.7394)	2.1368 (0.144)	2.1701 (0.338)	1.4211 (0.2438)	Stable Unstable
3*.A	0.1598	-5.1706	1.6452 (0.1519)	0.0019 (0.9981)	0.2114 (0.646)	0.4879 (0.784)	0.2407 (0.7864)	Stable Unstable
3*.B	0.1600	-5.1709	1.3819 (0.226)	0.0019 (0.9981)	0.2096 (0.647)	0.4905 (0.782)	0.2401 (0.7869)	Stable Unstable
3*.C	0.2042	-5.1799	1.5868 (0.0964)	0.0316 (0.9999)	0.0030 (0.956)	0.0428 (0.979)	0.4080 (0.8726)	Stable Unstable
3*.D	0.2062	-5.1824	1.4836 (0.1256)	0.0304 (0.9999)	0.0040 (0.949)	0.0366 (0.982)	0.4308 (0.8572)	Stable Unstable
4.A	0.3114	-6.6065	2.0571 (0.0309)	0.3003 (0.9116)	0.2335 (0.629)	0.3901 (0.823)	0.7538 (0.5854)	Stable Unstable
4.B	0.3578	-6.6763	1.5123 (0.1331)	0.2587 (0.9546)	0.1406 (0.708)	0.2689 (0.874)	0.9151 (0.488)	Stable Unstable
4.C	0.3117	-6.6070	1.8763 (0.047)	0.3006 (0.9114)	0.2288 (0.632)	0.3875 (0.824)	0.7410 (0.5947)	Stable Unstable
4.D	0.3590	-6.6783	1.3816 (0.1828)	0.2547 (0.9563)	0.1332 (0.715)	0.2613 (0.878)	0.9192 (0.4852)	Stable Unstable
Total.A	0.1225	-5.6062	1.1616 (0.317)	0.1474 (0.9641)	0.0436 (0.835)	0.0831 (0.959)	0.1688 (0.9542)	Stable Unstable
Total.B	0.1225	-5.6062	1.2325 (0.2665)	0.1474 (0.9641)	0.0432 (0.835)	0.0829 (0.959)	0.1689 (0.9542)	Stable Unstable
Total.C	0.1226	-5.6063	1.2445 (0.259)	0.1486 (0.9636)	0.0467 (0.829)	0.0805 (0.961)	0.1610 (0.958)	Stable Unstable
Total.D	0.1226	-5.6063	1.3391 (0.1983)	0.1487 (0.9636)	0.0458 (0.831)	0.0801 (0.961)	0.1609 (0.958)	Stable Unstable

Appendix B - Dynamic Multiplier

(a) - Gasoline (total sample)



(b) - Diesel (total sample)



The cumulative dynamic multipliers associated with a 1% change in the threshold variable show the convergence from the contemporaneous impact (i.e. in $t = 1$) all the way through the cumulative impact. At each point in time, the initial short-run effect is pulled towards the long-run equilibrium at the speed of adjustment θ in equation 08. At time H, the dynamics converge to the long-run elasticities:

$$m_h^{(+)} = \sum_{j=0}^{h} \frac{\partial p_{t+j}}{\partial p_t^{int(+)}}, \quad m_h^{(-)} = \sum_{j=0}^{h} \frac{\partial p_{t+j}}{\partial p_t^{int(-)}}, \quad h = 0, 1, .., H$$