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Asymmetry in Gasoline Price Transmission: How do Fuel Pricing Strategy and the Ethanol Addition Mandate Affect Consumers?

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ABSTRACT

This work aims at verifying the existence of asymmetries in gasoline price transmission between refining, distribution, and gas stations. The analysis covers two moments: before (2006-2016) and after (2016-2020) the new fuel pricing strategy adopted in the refining sector. Before 2016, gasoline prices in refineries were stable due to price intervention. After that, prices fluctuated in convergence with the international market. In this paper, we also consider ethanol prices. Due to an addition mandate, ethanol prices influence gasoline price' dynamics. Our hypothesis is that there are "rocket" and "feather" patterns. This means that positive changes in costs are rapidly and fully transmitted to prices, while negative cost changes tend to be transmitted gradually. As a consequence, there is a cost for consumers. We use Dynamic Ordinary Least Squares estimators and Error Correction Models to test the presence of asymmetries and Cumulative Response Functions to measure consumer cost. Results confirm an asymmetric price transmission and indicate that the new pricing strategy has changed the readjustment dynamic. Although we detect asymmetries in both periods, the new pricing strategy proved to be better for consumers, as social costs decreased after its adoption.

Keywords: Asymmetry in Price Transmission, Gasoline Prices, Ethanol Prices, Error Correction Model, Dynamic Ordinary Least Squares
JEL Classifications: C54; D40; L11; Q48

1. INTRODUCTION

In October 2016, Petrobras (the Brazilian State-owned oil company) announced a new pricing strategy in its refineries. Since then, the company has aimed at a short-term convergence with international prices. As a consequence of the fluctuation in the international market, fuel prices in Brazil have been very volatile. In 2017, it was not rare to see readjustments on oil product prices on a daily basis. Thereafter, the combination of rising international oil prices and Brazilian Real devaluation resulted in higher final prices of oil products.

Due to the fact that Petrobras has more than 98% of market-share in the refining sector, its pricing strategy affects all activities in the gasoline productive chain, including consumers. In May 2018, truck drivers, dissatisfied with this situation, went on strike and blocked important highways in protest. This impacted the Brazilian economy negatively and raised attention to the process of price transmissions of oil products. The negative perception of the new pricing strategy has been reinforced by the fact that oil product prices had remained stable for a long period before the adoption of the short-term international alignment in Petrobras refineries.

The economic literature of price transmission indicates that fuel prices are subject to asymmetric dynamics. In other words, a positive variation on wholesale prices tends to be rapidly and fully transmitted to retail prices. On the other hand, when wholesale prices decrease, retail price response tends to be slower and incomplete. Bacon (1991) compared this pattern to "rockets" and "feathers." Whenever "rockets" and "feathers" effects occur, there are welfare losses for consumers.

Many researchers point out that the main cause of asymmetric price transmission is imperfect competition (Bedrossian and Moschos, 1988; Meyer and von Cramon-Taubadel, 2004; Uchôa, 2016; Rodrigues and Losekann, 2018). However, there is a singularity in the Brazilian case that may be a potential source of asymmetry: the ethanol addition mandate (Rodrigues and Losekann, 2018). Currently, the gasoline sold in Brazilian gas stations is a mixture of 73% gasoline and 27% ethanol. In this context, ethanol prices affect gasoline price dynamics. It is important to highlight that the ethanol is produced mostly in São Paulo State, located in the Southeast region. Considering Brazilian continental dimensions, prices tend to be higher in regions far from the producing center due to transportation costs.

This paper investigates the gasoline price transmission in the Brazilian gasoline market. We analyze the price transmission between refineries and distribution (considering the ethanol addition mandate), and between distribution and gas stations in two different periods: 2006-2016 and 2016-2020. The first period was characterized by a certain stability in fuel prices and medium-term international convergence. Besides, the Brazilian Government intervened directly in oil product prices to contain inflationary pressures between 2010 and 2014. In the second period, fuel prices fluctuated according to the international market.

Our hypothesis is the presence of asymmetries in price transmission, especially "rockets" and "feathers" effects. As a method, we use Dynamic Ordinary Least Squares estimators (Stock and Watson, 1993) and Error Correction Models. Also, we estimate the consumers' welfare losses in both periods using Cumulative Response Functions. In terms of contribution to the literature, this paper analyses the role of the ethanol addition mandate and the effects of Petrobras' pricing strategy on gasoline price transmission.

This work is structured as follows: in section 2, there is a literature synthesis of asymmetric price transmission and a research gap we aim to fill. In section 3, we briefly describe the Brazilian gasoline market with emphasis on competition, and highlight the role of ethanol prices. The methodology and dataset are presented in section 4. In section 5, we discuss the results. Finally, in the last section, there are some concluding remarks and policy implications.

2. LITERATURE SYNTHESIS AND RESEARCH GAP

According to neoclassical theory, the interactions of supply and demand result in an equilibrium price. Suppliers and consumers have access to all the information they need, so the market allocation is Pareto-efficient. In this theoretical background, cost shocks are completely and instantaneously transmitted to prices. In other words, price transmission is symmetrical (Tappata, 2009).

However, symmetry in price transmission rarely occurs. Peltzman (2000) concluded that prices increase more rapidly than decrease in 2 out of 3 markets, which indicates asymmetrical adjustment. Silva et al. (2011) define asymmetry in price transmission as the differences between positive and negative adjustments in output prices when input prices change. This phenomenon is often verified in commodities due to the homogeneity of the product.

Meyer and von Cramon-Taubadel (2004) suggest that asymmetries can be classified according to their magnitude and speed. An asymmetry of magnitude occurs when prices in the wholesale change in and retail prices respond, also in t_0, but completely. If wholesale prices vary in t_0 and retail prices respond in the same magnitude, but in the following period (t_1), there is an asymmetry of speed. A combination of magnitude and speed is also possible. Suppose that wholesale prices change in t_0 and retail prices respond in t_1 but not completely. In this case, we have an asymmetry of magnitude and speed at the same time.

Asymmetries of magnitude and/or speed can also be classified as positive or negative. If output prices increase more completely and/or rapidly than they decrease, the asymmetry is positive. On the other hand, if output prices increase in a less intense and/or rapid way than they decrease, the asymmetry is negative. Bacon (1991) compares positive asymmetries to "rockets" and "feathers." Bremmer and Kesserling (2016) state that negative asymmetries can be compared to "balloons" and "rocks."

Most of the researchers, however, focus on the effects of positive asymmetries. In the "feather" effect, consumers do not take advantage of price decreases; in the "rocket," they may pay for higher prices. In both cases, there are distributive distortions and part of the welfare is transferred from consumers to suppliers. There seems to be a consensus that imperfect competition is the main source of positive asymmetries. However, some approaches stand out, such as market power, collusion and profitability (Bedrossian and Moschos, 1988; Uchôa, 2016), search costs (Uchôa, 2016; Rodrigues and Losekann, 2018) and other kinds of strategy (Valadkhani et al., 2021).

Uchôa (2016) points out that collusion can generate asymmetries in price transmission. In this case, firms maximize profit jointly and obtain monopoly results, in which prices are higher than marginal costs. Bedrossian and Moschos (1988) suggest that if a firm has the largest share of the market or higher profitability compared to its competitors, it has margins to not readjust its prices instantaneously.

Rodrigues and Losekann (2018) argue that homogenous products, such as gasoline, make price coordination easier. In markets with lower price dispersion, the consumer would spend significant time searching for lower prices. Thus, search costs tend to give temporary market power to gas stations. Uchôa (2016) emphasizes that search costs are only useful to consumers in cases where the price differential generates significant savings.

According to Valadkhani et al. (2021), retailers know how to hide an anti-competitive pricing behavior by adopting location-specific and time-varying tactics. In this context, the lack of transparency could lead to a mismatch between the resale price and the cost of unleaded petrol. This behavior is more recurrent if a gas station has fewer competitors nearby.

The first empirical works on asymmetry in price transmission were developed in the early 1990s, when all economies suffered the impacts of the Gulf War. The instability of petroleum prices caused fluctuations in oil product prices, motivating the research on price transmission. However, because of the importance of petroleum and oil products on economics, this topic is still a matter of attention.

The most used methodology is error correction models (Bacon, 1991; Manning, 1991; Kirchgässner and Kübler, 1992; Borenstein et al., 1997; Godby et al., 2000; Bachmeier and Griffin, 2003; Galeotti et al., 2003; Grasso and Manera, 2007; Balmaceda and Soruco, 2008; Silva et al., 2011; Canêdo-Pinheiro, 2012; Polemis and Fotis, 2014; Chen et al., 2017). However, there are other methods that can detect asymmetries in price transmission, such as non-linear autoregressive distributed lag (Chattopadhyay and Mitra, 2015; Chou and Tseng, 2016; Ogbuabor et al., 2020; Bakhat et al., 2022); asymmetric mixed data sampling (Valadkhani and Smyth, 2018) and threshold autoregressive (Uchôa, 2016).

Even though the asymmetric price transmission literature is rich, there are some research gaps in the Brazilian case we aim to fill. First, we analyze price transmission in two distinct moments. Second, our approach considers ethanol prices. Because of an addition mandate, the Brazilian case is peculiar. Third, we compare consumer cost before and after international alignment. All three issues are relevant in terms of policy implications.

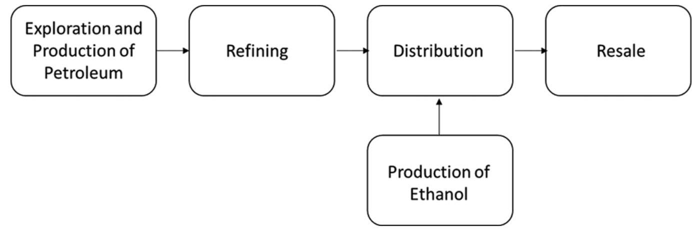
3. THE BRAZILIAN GASOLINE MARKET

The Brazilian gasoline market has five main activities: exploration and production of petroleum, refining, distribution, production of ethanol and resale (gas stations). Figure 1 shows how the Brazilian gasoline market is structured.

The most relevant agent in the Brazilian gasoline market is Petrobras, which is a State-owned oil company. Historically, Petrobras has been the only company allowed to develop activities in the production of petroleum and refining. Nevertheless, during the 1990s, petroleum and oil products sectors were restructured. In 1995, the monopoly in the production of petroleum was relaxed. Since then, concessions to the private sector have been made and other agents have been able to produce petroleum in Brazil. Another relevant institutional landmark was the creation of the National Petroleum Agency (ANP) in 1997. The ANP regulates all petroleum and oil activities and is also responsible for promoting competition in these sectors.

The efforts made by ANP to stimulate competition in the production of petroleum have shown to be positive. Although Petrobras is the main agent in this activity, there are now approximately 53 agents in the exploration and production of petroleum in Brazil. On the other hand, ANP has not succeeded in promoting competition in refining. More than two decades after the liberalization of refining activities, Petrobras is still a monopoly with more than 98% of market-share (ANP, 2020a). Thus, Petrobras' pricing strategy influences not only all other activities but also final consumers.

Figure 1: Brazilian gasoline market



Source: Authors' elaboration

The distribution sector has never been a legal monopoly. However, prices in this activity had been regulated by the government until 2001, when they finally were liberalized. Nowadays, there are more than 130 agents in the distribution activity, but the three largest companies (BR, Ipiranga and Raízen) have more than 60% of market-share in gasoline sales. (ANP, 2020a).

Another relevant topic concerning this sector is that distributors produce a mixture composed of 27% ethanol and 73% gasoline. This addition mandate affects the gasoline price dynamics because ethanol production is concentrated in the Southeast region, mainly in the state of São Paulo. Therefore, gasoline generally is more expensive in regions that are distant from the state. In these locations, readjustments in ethanol prices tend to be transmitted to gasoline prices in greater magnitude because of transportation costs.

In terms of competition, resale is the less concentrated sector. As of 2020, there are approximately 40,000 gas stations in Brazil and almost 44% are unbranded (ANP, 2020a). Nevertheless, price coordination is easier in this activity due to the homogeneity of the product. Besides, many gas stations are connected to distributors due to exclusivity contracts. Hence, both price coordination and exclusivity contracts consist of relevant obstacles to competition.

In brief, gasoline prices are initially determined according to the pricing strategy adopted in the refineries. Thereafter, these prices are transmitted along all other activities, incorporating the margins of each sector, ethanol prices and taxes.

4. DATA AND METHODOLOGY

4.1. Data

The dataset used in this work was collected from the National Agency of Petroleum (ANP) and the Center for Advanced Studies in Applied Economics of São Paulo University (CEPEA). The average gasoline prices in Brazil in all activities (refining, distribution and resale) are available on the ANP website, while ethanol prices in the state of São Paulo[1] come from CEPEA. The sample contains price series from January 2006 to February 2020[2], on a weekly basis. All series are in Brazilian Reais per liter (R$/liter).

1 Almost 60% of ethanol in Brazil is produced in São Paulo Station. In this context, it is a good proxy for national prices.

2 Due to the covid-19 pandemic, we have chosen not to include information from March 2020 onwards in the database. The sharp drop in demand for gasoline, as a consequence of social isolation, made prices show an atypical pattern in this period.

Figure 2 presents the weekly movement of gasoline prices in refinery, distribution and resale activities, as well as ethanol prices. If a graphic analysis is made, it is possible to verify that after October 2016 the dynamic of gasoline prices in the refinery changed. As stated before, from January 2006 to October 2016, prices of gasoline in refineries were stable. However, after the adoption of the new pricing strategy by Petrobras, gasoline prices in refineries became volatile because of the short-term international alignment. Besides the volatility, the Brazilian currency devaluated between 2016 and 2019, which reinforced the tendency for higher prices at resale.

In Table 1 we have some descriptive statistics of the sample. Comparing the average prices in both periods, an expressive increase after the international alignment can be observed: 53.1% for the refinery, 5.3% in distribution, and 49.3% in resale. Except for the ethanol price changes, the average positive readjustments of gasoline prices in all activities are higher in absolute values than the average negative ones. This may be indicative of the presence of "rocket" and "feather" effects in both periods, reinforcing our main hypothesis.

In Figure 3, we consider a period of six months before and after Petrobras' new pricing strategy, adopted in October 2016. It is clear that the readjustment pattern changed. In the previous period, both prices and readjustments seem to be stable in wholesale (refineries) and retail (resale). However, before 2016, not only prices were volatile, but readjustments were as well.

4.2. Methodology

The methodology used in this work is divided into two stages. In the first stage, we analyze the presence of asymmetries in price transmissions in Brazil in two periods: before (from January 2006 to October 2016) and after (from November 2016 to February 2020) the adoption of Petrobras' new pricing strategy. The analysis covers the price transmission between gasoline prices in refining and ethanol prices to gasoline prices in distribution, and between gasoline prices in distribution to resale. In this part, we combine Dynamic Ordinary Least Squares Estimator (DOLS) and Error Correction Models.

In the second stage, we estimate two Cumulative Response Functions (one negative and the other positive) to calculate the cost of asymmetry incurred by Brazilian consumers in both periods. In other words, we estimate the loss of welfare due to the asymmetric price adjustment between the distributors and resale (gas stations).

4.2.1. Dynamic ordinary least squares estimator and error correction models

The first step is to determine the relation between the variables of our dataset. In the wholesale sector, the price of gasoline in distribution depends on the price of gasoline in refinery and on the price of ethanol. On the other hand, in the retail sector, the price of gasoline in resale closely follows the price of gasoline in distribution. We use Dynamic Ordinary Least Squares estimators, developed by Stock and Watson (1993), to obtain the long-run relationship between variables. We chose the DOLS estimator because it is efficient and asymptotically consistent for cointegrated variables. The DOLS estimator is preferable to the OLS estimator because it mitigates bias in small samples (Stock and Watson, 2008). Furthermore, it follows an asymptotical normal distribution and eliminates the feedback in the cointegrating system (Polemis and Fotis, 2014). Hence, we have:

$$Dist_t = \alpha + \gamma_1 Ref_t + \gamma_2 Eth_t + \tau Time + \varepsilon_t \quad (1)$$

$$GS_t = \alpha + \gamma Dist_t + \tau Time + \varepsilon_t \quad (2)$$

where: *Dist* is the average price of gasoline in distribution; *Ref* is the average price of gasoline in the refining sector; *Eth* is the average price of ethanol in the state of São Paulo; *GS* is the average price of gasoline in gas stations (resale) and *Time* is a time trend.

Following the standard literature (for more details, see Section 2), we estimate Error Correction Models for analyzing price transmission. Since our objective is to test the presence of asymmetries, we consider dynamic models by applying the first difference and lagged variables. We also decompose all variables to accommodate positive and negative shocks:

Figure 2: Gasoline and ethanol prices. Source: Authors' elaboration using data from ANP (2020b), ANP (2020c), and CEPEA (2020)

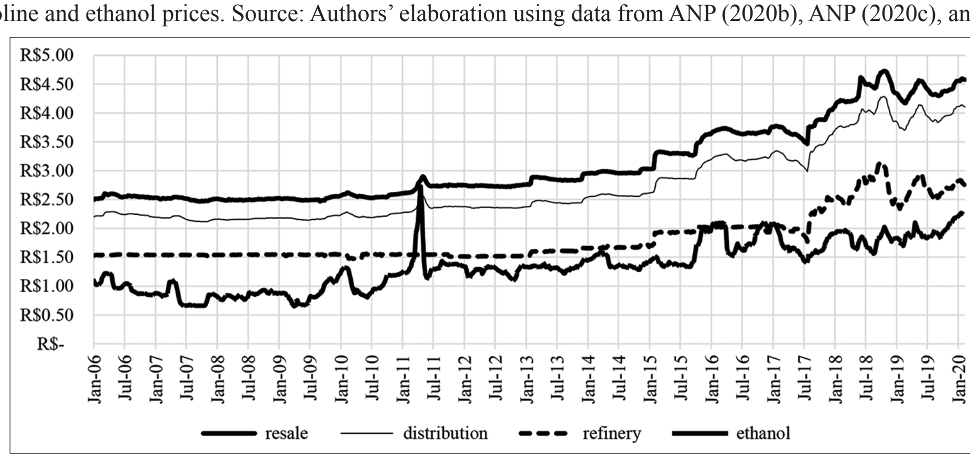
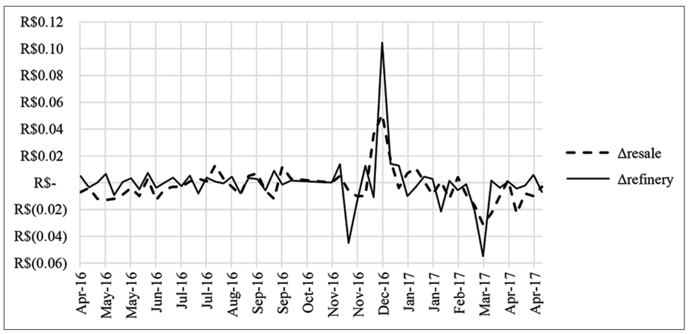


Table 1: Descriptive statistics

Descriptive Statistic	Stability (2006–2016)				International alignment (2016–2020)			
	Ref	Dist	Res	Eth	Ref	Dist	Res	Eth
Average price	1.627	2.424	2.795	1.198	2.491	3.720	4.172	1.838
Standard deviation	0.163	0.311	0.352	0.343	0.345	0.348	0.350	0.191
Minimum	1.471	2.117	2.468	0.651	1.768	2.987	3.464	1.413
Maximum	2.034	3.289	3.734	2.726	3.153	4.284	4.725	2.268
Number of positive changes	289	279	264	299	89	95	84	87
Average positive change	0.0056	0.0074	0.0093	0.0255	0.0385	0.0254	0.0281	0.0304
Number of negative changes	272	228	251	258	81	72	83	83
Average negative change	−0.0041	−0.0047	−0.0052	−0.0261	−0.0329	−0.0214	−0.0176	−0.0300
Number of observations	562	562	562	562	171	171	171	171

Ref: Refinery, Dist: Distribution, Res: Resale, Eth: Ethanol. Source: Authors' elaboration using data from ANP (2020b), ANP (2020c) and CEPEA (2020)

Figure 3: Readjustments in Refinery and Resale. Source: Authors' elaboration using data from ANP (2020b), and ANP (2020c)



$$\Delta Dist_t = \alpha + \sum_{i=1}^{I+} \theta_i^+ \Delta Dist_{t-i}^+ + \sum_{i=1}^{I-} \theta_i^- \Delta Dist_{t-i}^- + \sum_{j=0}^{j+} \beta_j^+ \Delta Ref_{t-j}^+ + \sum_{j=0}^{j-} \beta_j^- \Delta Ref_{t-j}^- + \sum_{k=0}^{k+} \beta_k^+ \Delta Eth_{t-k}^+ + \sum_{k=0}^{k-} \beta_k^- \Delta Eth_{t-k}^- + \lambda^+ ECM_{t-1}^+ + \lambda^- ECM_{t-1}^- + \varepsilon_t \quad (3)$$

$$\Delta GS_t = \alpha + \sum_{i=1}^{I+} \theta_i^+ \Delta GS_{t-i}^+ + \sum_{i=1}^{I-} \theta_i^- \Delta GS_{t-i}^- + \sum_{j=0}^{j+} \beta_j^+ \Delta Dist_{t-j}^+ + \sum_{j=0}^{j-} \beta_j^- \Delta Dist_{t-j}^- + \lambda^+ ECM_{t-1}^+ + \lambda^- ECM_{t-1}^- + \varepsilon_t \quad (4)$$

where: Δ is the first difference operator; i, j and k are the numbers of lags; and ECM is the error correction term, which corresponds to the lagged residual of Equations (1) and (2). The decomposition of the variables has the following notation: $\Delta variable_t^+ = variable_t - variable_{t-1} = \max\{\Delta variable_t^+, 0\}$ and; $\Delta variable_t^- = variable_t - variable_{t-1} = \min\{\Delta variable_t^-, 0\}$

Then, we test some hypotheses for (3) and (4) to verify the presence of asymmetries in price transmission:

$$H_0 : \beta_0^+ = \beta_0^- \quad (5)$$

$$H_0 : \sum \beta^+ = \sum \beta^- \quad (6)$$

$$H_0 : \lambda^+ = \lambda^- \quad (7)$$

By rejecting all the null hypotheses, we detect asymmetries in price transmission. In (5), we test for contemporaneous asymmetry of magnitude; in (6), cumulative asymmetry of magnitude and in (7), asymmetry of speed. One can observe "rocket" and "feather" effects if $\sum \beta_0^+ > \sum \beta_0^-$ and/or $\sum \beta_0^+ > \sum \beta_0^-$.

4.2.2. Cumulative response functions

The presence of asymmetries in price transmission results in costs to consumers. To calculate these costs, we estimate positive and negative Cumulative Response Functions (CRF) for Equation (4). A CRF measures the estimated accumulated variation in the gas station price in period $t + j$, after a shock of R\$1.00 in the distribution price in period t (Balmaceda and Soruco, 2008). If the shock is positive, we account for it in CRF^+. Similarly, a negative shock is accounted for in CRF^-. Therein, the consumer cost is:

$$Consumer\ Cost_{t+j} = \sum_{j=0}^{j} (CRF_{t+j}^+ - CRF_{t+j}^-) \quad (8)$$

where:

$$CRF_{t+j}^+ = CRF_{t+j-1}^+ + \hat{\beta}_{t+j}^+ + \sum_{i=1}^{I} \hat{\theta}_i^+ \Delta GS_{t+j-i}^+ + \lambda^+ \left(CRF_{t+j-1}^+ - \hat{\gamma}\right);$$

and

$$CRF_{t+j}^- = CRF_{t+j-1}^- + \hat{\beta}_{t+j}^- + \sum_{i=1}^{I} \hat{\theta}_i^- \Delta GS_{t+j-i}^- + \lambda^- (CRF_{t+j-1}^- - \hat{\gamma})$$

The CRFs consist of a sum of four terms: (i) the adjustment throughout the previous period (CRF_{t+j-1}); (ii) the contemporaneous impact ($\hat{\beta}_{t+j}$); (iii) the dynamic effect of past changes in the price of the product ($\sum_{i=1}^{I} \theta_i \Delta GS_{t+j-i}$); and (iv) the effect of being away from the long-term equilibrium path [$\lambda(CRF_{t+j-1} - \hat{\gamma})$]. For further details about the decomposition in positive and negative, see Borenstein et al. (1997).

5. RESULTS

5.1. Stationarity and Cointegration

A preliminary step is to check the stationarity and cointegration of the price series (Results in Appendix). We consider ADF, Phillips Perron, KPSS, and DFGLS tests at a level of 5% significance. All variables from both periods are not stationary in level[3], but are

3 Ethanol prices between 2006 and 2016 are stationary in level, according to the DF-GLS Test. However, they are not stationary considering all other tests. Hence, we consider ethanol prices as I(1).

stationary in the first difference, except for ethanol prices, in level between 2006 and 2016.

To verify cointegration, we test the stationarity of the residuals of Equations (1) and (2). If the residuals are stationary, then the variables are cointegrated and have a long-run relationship (Engle and Granger, 1987). At a significance level of 5%, we verified cointegration in all cases.

5.2. Price Transmission from Refinery and Ethanol to Distribution

In a cointegrated series, cost shocks can temporarily deflect prices from a long-term equilibrium. Thus, we test asymmetries in price transmissions in the short-term. Table 2 shows the results of the Errors Correction Models for Distribution.

Interpreting the results of Errors Correction Models is not the purpose of this work, but some points should be considered. First, the coefficient for ΔRef_t^+ is higher than ΔRef_t^- in both periods, which seems to indicate "rocket" and "feather" patterns in terms of magnitude. Second, the ECM_{t-1} coefficients are negative. If prices are above (below) the long-term equilibrium, they are expected to decrease (increase). In other words, the ECM_{t-1} coefficients measure how quickly deviations from the long-term equilibrium are corrected.

Then, the estimated coefficients are used in hypothesis tests. In Table 3 the results for the Asymmetry Tests for Distribution can be seen.

Comparing both periods, it is clear that the adoption of the new pricing strategy changed the price transmission pattern. Between 2006 and 2016, we found evidence of contemporaneous and cumulative asymmetries of magnitude from the refinery, considering 10% of significance. In the same period, ethanol prices were transmitted symmetrically in , as we could not reject the null hypothesis. Nonetheless, there is a cumulative asymmetry of magnitude from ethanol to gasoline in distribution prices. Lastly, asymmetry of speed was not detected.

In the second period (2016-2020), we could not find evidence for contemporaneous asymmetry of magnitude from ethanol prices to distribution. In contrast to the previous period, cumulative asymmetry of magnitude from ethanol seemed to dissipate. Turning now to refinery transmission, we detected a contemporaneous asymmetry of magnitude. After three weeks, the cumulative adjustment proved to be symmetrical. Finally, there is no evidence for the presence of asymmetry of speed.

Although the number of asymmetries decreased from the first period to the second, there is still the presence of "feather" and "rocket" effects. In both periods, the positive estimated coefficients were higher than the negative ones.

5.3. Price Transmission from Distribution to Gas Stations

In this subsection, we investigate the price transmission between distribution and gas stations. Table 4 presents the results of Errors Correction Models for Resale.

Table 2: Results of errors correction models for distribution

Coefficient	2006–2016	2016–2020
Constant	−0.00051 (0.0005)	0.00133 (0.0036)
$\Delta Dist_{t-1}^+$	0.108** (0.048)	−0.083 (0.102)
$\Delta Dist_{t-1}^-$	−0.0203 (0.103)	−0.218 (0.161)
$\Delta Dist_{t-2}^+$	0.112** (0.044)	0.019 (0.097)
$\Delta Dist_{t-2}^-$	0.242*** (0.093)	0.166 (0.141)
$\Delta Dist_{t-3}^+$	0.016 (0.033)	−0.039 (0.095)
$\Delta Dist_{t-3}^-$	0.067 (0.080)	0.003 (0.144)
ΔRef_t^+	0.255*** (0.024)	0.535*** (0.045)
ΔRef_t^-	0.134** (0.053)	0.328*** (0.061)
ΔRef_{t-1}^+	0.496*** (0.027)	0.072 (0.067)
ΔRef_{t-1}^-	0.092* (0.054)	0.213** (0.084)
ΔRef_{t-2}^+	0.005 (0.036)	0.095 (0.064)
ΔRef_{t-2}^-	0.195*** (0.054)	−0.021 (0.084)
ΔRef_{t-3}^+	0.036 (0.032)	0.045 (0.066)
ΔRef_{t-3}^-	0.061 (0.054)	0.075 (0.085)
ΔEth_t^+	0.003 (0.009)	0.024 (0.054)
ΔEth_t^-	−0.001 (0.009)	0.021 (0.060)
ΔEth_{t-1}^+	0.058*** (0.010)	0.172*** (0.059)
ΔEth_{t-1}^-	0.036*** (0.011)	0.078 (0.061)
ΔEth_{t-2}^+	0.070*** (0.011)	0.040 (0.063)
ΔEth_{t-2}^-	0.042*** (0.011)	0.078 (0.060)
ΔEth_{t-3}^+	0.025** (0.012)	0.059 (0.061)
ΔEth_{t-3}^-	0.046*** (0.011)	0.079 (0.060)
ECM_{t-1}^+	−0.025* (0.013)	−0.164*** (0.061)
ECM_{t-1}^-	−0.026* (0.014)	−0.049 (0.069)
Obs	557	166
DW Statistic	2.0102	2.0019
R^2	0.776	0.820

***P<0.01, **P<0.05, *P<0.10. Standard errors in parenthesis, Source: Authors' elaboration

The estimated coefficients for $\Delta Dist_t^+$ and $\Delta Dist_t^-$ are clearly different. As the positive coefficients are higher than the negative ones, there is some evidence for "rocket" and "feather" patterns before and after the international alignment. Also, only the ECM_{t-1}^+ coefficients are positive in both periods. This indicates that positive deviations from the long-term equilibrium are corrected faster than the negative deviations.

As in the previous subsection, we used the estimated coefficients of Errors Correction Models to test the price transmission from distribution to resale. The results are reported in Table 5.

Table 3: Asymmetry tests for distribution

Period	Magnitude–Contemporaneous		Magnitude–Cumulative		Speed	Total
	Refinery	Ethanol	Refinery	Ethanol		
	$\beta_j^+ = \beta_j^-, j=0$	$\beta_j^+ = \beta_j^-, j=0$	$\sum_{i=0}^{3}\beta_j^+ = \sum_{i=0}^{3}\beta_j^-$	$\sum_{k=0}^{3}\beta_k^+ = \sum_{k=0}^{3}\beta_k^-$	$\lambda^+ = \lambda^-$	
2006-2016	F=3.99 (0.05)	F=0.06 (0.81)	F=7.01 (0.01)	F=3.18 (0.08)	F=0.00 (0.97)	3
2016-2020	F=6.32 (0.01)	F=0.00 (0.97)	F=0.67 (0.41)	F=0.06 (0.81)	F=1.09 (0.30)	1

Source: Authors' elaboration

Table 4: Results of errors corrections models for resale

Coefficient	2006-2016	2016-2020
Constant	0.00054 (0.0006)	−0.0061 (0.0048)
ΔGS_{t-1}^{+}	−0.603*** (0.055)	−0.0353 (0.118)
ΔGS_{t-1}^{-}	0.195 (0.121)	0.00797 (0.299)
ΔGS_{t-2}^{+}	−0.189*** (0.056)	−0.129 (0.104)
ΔGS_{t-2}^{-}	−0.103 (0.123)	0.299 (0.298)
ΔGS_{t-3}^{+}	−0.041 (0.044)	0.121 (0.0993)
ΔGS_{t-3}^{-}	−0.154 (0.123)	−0.404 (0.280)
$\Delta Dist_{t}^{+}$	1.731*** (0.050)	1.096*** (0.105)
$\Delta Dist_{t}^{-}$	0.432*** (0.114)	0.528*** (0.159)
$\Delta Dist_{t-1}^{+}$	0.448*** (0.096)	0.160 (0.140)
$\Delta Dist_{t-1}^{-}$	−0.004 (0.152)	−0.355 (0.236)
$\Delta Dist_{t-2}^{+}$	−0.121 (0.085)	0.101 (0.129)
$\Delta Dist_{t-2}^{-}$	0.121 (0.153)	0.0258 (0.236)
$\Delta Dist_{t-3}^{+}$	−0.115* (0.062)	−0.0198 (0.108)
$\Delta Dist_{t-3}^{-}$	0.109 (0.133)	0.320 (0.236)
ECM_{t-1}^{+}	−0.131*** (0.043)	−0.478*** (0.134)
ECM_{t-1}^{-}	0.026 (0.048)	−0.163 (0.185)
Obs	557	166
DW Statistic	2.0183	2.0351
R^2	0.749	0.666

***P<0.01; , **P<0.05, *P<0.10. Standard errors in parenthesis. Source: Authors' elaboration

In the first period, the results proved to be the worst possible. We found evidence of all kinds of asymmetry. All positive estimated coefficients for distribution are higher than the negative, which indicates the presence of the "rocket" and "feather" pattern. In other words, when prices increase in distribution, resale prices increase faster and in greater magnitude. Furthermore, if distribution prices decrease, the adjustment in gas stations is not complete. Therefore, consumers do not take advantage of price reductions and pay more than they should when prices increase. We detected asymmetries in all three tests.

Between 2016 and 2020, both contemporaneous and cumulative asymmetries of magnitude were detected, which indicates the "rockets" and "feathers" effects in terms of magnitude. However, in terms of speed, gas station responses were symmetrical to positive and negative changes in distribution. Overall, the consumers' situation improved due to a reduction in the number of asymmetries. In this period, we detected asymmetries in 2 out of 3 tests.

These results suggest that the new pricing strategy did not impact resale as it did with the distribution sector. Probably this occurred because the pricing strategy has changed only in refineries. In distribution and resale, the pricing pattern was the same in both periods (2006-2016 and 2016-2020). However, there is still space for debating alternatives to mitigate the asymmetries in this stage and reduce consumer loss of welfare.

5.4. Consumer Cost

After detecting the presence of asymmetries in gasoline price transmission, we estimate the magnitude of its impacts on consumers. Figure 4 reports the positive and negative CRFs and Consumer Costs from both periods, with a 95% confidence interval.

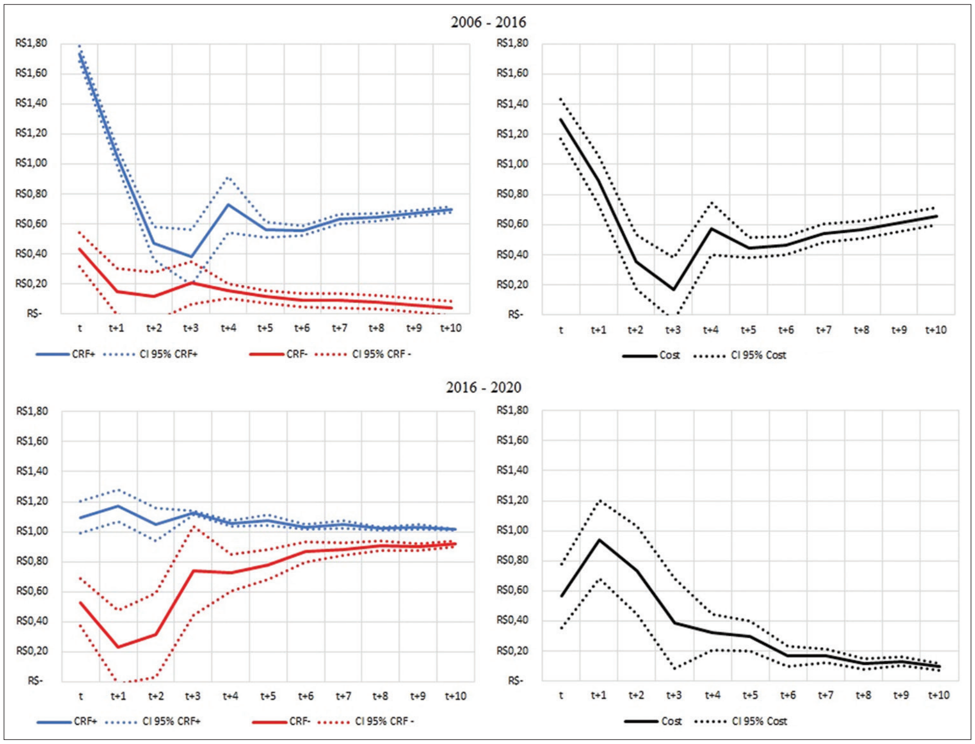
In the first period, when prices were stable, an increase of R$ 1.00 in distribution resulted in a R$ 1.73 increase in gas stations. In its turn, a decrease of R$ 1.00 in distribution led to a R$ 0.43 decrease in resale. Thus, the consumer cost at the moment of the cost shock () is R$ 1.30 (1.73–0.43). In this period, the "rocket" effect stands out.

On the other hand, when prices were aligned to the international market (2016-2020), an increase of R$ 1.00 in distribution led to a R$ 1.10 increase in gas stations. A R$ 1.00 decrease in this period resulted in a R$ 0.53 decrease in resale. Therefore, the contemporaneous consumer cost is R$ 0.57. In this case, the "feather" effect is more relevant.

Between 2006 and 2016, the consumer cost decreases in the first 3 weeks but begins to increase after that. Two facts are worth mentioning: first, a R$ 1.00 decrease results in little impact on gas station prices, as approximates to R$ 0.00 during a 10-week transmission. Second, in *t* and *t+1*, the CRF^+ is much higher than R$ 1.00, revealing significant welfare loss for consumers.

From 2016 to 2020, after peaking at R$ 0.94 in *t+1*, the consumer cost decreases. Notwithstanding, there is a convergence between CRF^- and CRF^+ after *t+3*. A convergence indicates that asymmetries dissipate and, consequently, consumer cost and welfare loss tend to zero. Therein, the international alignment has shown to be better for consumers, compared to stability. If prices in refineries follow the international market, it generates a focal point to all

Figure 4: Cumulative response functions (right) and consumer cost (left) with a 95% confidence interval



Source: Authors' elaboration

Table 5: Asymmetry tests for resale

Period	Magnitude – Contemporaneous	Magnitude – Cumulative	Speed	Total
	$\beta_j^{+}=\beta_j^{-}, j=0$	$\sum_{j=0}^{3}\beta_j^{+}=\sum_{j=0}^{3}$	$\lambda^{+}=\lambda^{-}$	
2006-2016	F=97.18 (0.00)	F=32.29 (0.00)	F=4.25 (0.04)	3
2016-2020	F=7.10 (0.01)	F=4.64 (0.03)	F=1.86 (0.17)	2

Source: Authors' elaboration

agents, which mitigates asymmetries and consequently reduces consumer cost.

6. CONCLUSIONS AND POLICY IMPLICATIONS

In this paper, we aimed at testing the presence of asymmetries in price transmission in the Brazilian gasoline market. Furthermore, we considered a Brazilian singularity (ethanol addition mandate) and compared two distinct pricing strategies in the refineries. We gathered evidence that corroborates the hypothesis of the "rocket" and "feather" effects in gasoline price transmission. Our findings support the results of Bacon (1991), Manning (1991), Kirchgässner and Kübler (1992), Borenstein et al. (1997), Galeoti et al. (2003), Grasso and Manera (2007), Balmaceda and Soruco (2008), Silva et al. (2011), Cânedo-Pinheiro (2012), Polemis and Fotis (2014), Chatopadhyay and Mitra (2015), Uchôa (2016), Chen et al. (2017), Valadkhani and Smyth (2018), Ogbuabor et al. (2020), and Valadkhani et al. (2021).

Nonetheless, the "rocket" and "feathers" effect vary in the Brazilian case. Between 2006 and 2016, gasoline prices in refineries were stable. Even with stability in the refining sector, distributors and gas stations did not follow this pattern. There was no economic reason for private agents keep their prices stable, especially in sectors in which firms have market power. Consequently, we detected asymmetries in 3 tests (out of 5) for distribution and 3 (out of 3) for resale. It is worth highlighting that one of the asymmetries found in distribution occurs due to ethanol price changes.

During the second period (2016-2020), we also detect "rocket" and "feather" patterns. However, the total number of asymmetries decreased. We found evidence of only one kind of asymmetry (out of 5 tests) in distribution. In its turn, our results showed the presence of two asymmetries (out of 3) for gas stations. Notwithstanding, ethanol price transmission was symmetrical. In this period, prices in refineries converged with gasoline prices in the international market.

In this context, the price fluctuation strategy, according to the international market, proved to be better for consumers. Not only the total number of asymmetries decreased, but consumer cost as well. As we estimated, positive and negative CRFs converge after some weeks, which means that asymmetries dissipate. It is more reasonable to suppose that, in concentrated markets such as distribution, stability in prices will not be followed by agents with a considerable market share. Therefore, the domestic convergence with the international mitigates asymmetrical transmission, if compared to pricing intervention.

The main cause of asymmetries in gasoline price transmission in Brazil is more than likely imperfect competition. Although the ANP has been stimulating the competition in the Brazilian gasoline market, more effort is still needed. Stimulating transparency could be a solution for the Brazilian case. There are apps for smartphones that disclose gas station prices in real-time in some countries, such as Chile, Germany, and South Korea (Jang, 2015; Dewenter and Heimeshoff, 2017; Luco, 2019). After a massive diffusion of these apps, the "rocket" and "feather" effects dissipated in Germany, and competition between gas stations increased in Chile and South Korea. This is an effective way to mitigate search costs, which is a source of asymmetry, and provide more transparency for consumers. However, this tool requires the anti-trust authority's attention, so that gas stations do not use it as a form of price coordination.

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APPENDICES

A. Stationarity Tests

A.1. ADF Tests

The null hypothesis is that the variable contains a unit root

Variable	Test statistic (P-value)	
	2006–2016	2016–2020
Ref	0.854 (0.992)	–1.407 (0.579)
Δ*Ref*	–23.662 (0.000)	–7.770 (0.000)
Dist	2.904 (1.000)	–0.928 (0.778)
Δ*Dist*	–11.803 (0.000)	–6.913 (0.000)
GS	1.892 (0.998)	–0.956 (0.769)
Δ*GS*	–17.764 (0.000)	–8.682 (0.000)
Eth	–1.207 (0.670)	–0.935 (0.776)
Δ*Eth*	–12.235 (0.000)	–8.538 (0.000)

A.2. Phillips Perron Tests

The null hypothesis is that the variable contains a unit root

Variable	Test statistic (P-value)	
	2006–2016	2016–2020
Ref	0.853 (0.992)	–1.673 (0.445)
Δ*Ref*	–23.663 (0.000)	–7.684 (0.000)
Dist	1.255 (0.996)	–1.194 (0.676)
Δ*Dist*	–11.971 (0.000)	–6.951 (0.000)
GS	1.148 (0.996)	–1.179 (0.682)
Δ*GS*	–18.021 (0.000)	–8.772 (0.000)
Eth	–2.303 (0.171)	–1.602 (0.482)
Δ*Eth*	–11.994 (0.000)	–8.541 (0.000)

A.3. KPSS Tests

The null hypothesis is that the variable is trend stationary

	Test Statistics (Critical value at 5%=0.146)									
	2006–2016					2016–2020				
Lag order	0	1	2	3	4	0	1	2	3	4
Ref	11.3	5.66	3.79	2.85	2.29	2.17	1.10	0.747	0.571	0.466
Δ*Ref*	0.057	0.058	0.058	0.058	0.057	0.091	0.062	0.053	0.048	0.046
Dist	9.91	4.97	3.33	2.51	2.01	2.29	1.15	0.777	0.590	0.478
Δ*Dist*	0.103	0.065	0.051	0.043	0.039	0.178	0.115	0.089	0.077	0.070
GS	10.2	5.13	3.44	2.59	2.08	2.39	1.21	0.813	0.617	0.501
Δ*GS*	0.060	0.047	0.042	0.039	0.037	0.138	0.099	0.083	0.075	0.070
Eth	1.51	0.77	0.53	0.41	0.33	1.11	0.569	0.390	0.301	0.248
Δ*Eth*	0.031	0.020	0.016	0.015	0.014	0.094	0.068	0.059	0.055	0.053

A.4. DFGLS Tests

The null hypothesis is that the variable contains a unit root

	Test Statistic (Critical value at 5%=–2.87)				Test Statistic (Critical value at 5%=–2.94)			
	2006–2016				2016–2020			
Lags	1	2	3	4	1	2	3	4
Ref	–0.547	–0.557	–0.583	–0.666	–2.384	–2.162	–2.335	–2.364
Δ*Ref*	–14.444	–11.211	–9.012	–8.564	–7.326	–5.968	–5.398	–4.897
Dist	–0.811	–0.910	–0.840	–0.884	–2.089	–2.390	–2.030	–2.370
Δ*Dist*	–8.151	–7.589	–6.723	–6.303	–5.334	–5.818	–4.602	–4.352
GS	–0.626	–0.692	–0.791	–0.837	–1.903	–2.125	–2.053	–2.055
Δ*GS*	–10.373	–8.145	–6.926	–5.978	–6.438	–5.984	–5.454	–4.919
Eth	–4.498	–3.712	–3.751	–3.520	–1.447	–1.424	–1.498	–1.384
Δ*Eth*	–12.293	–10.542	–9.990	–10.271	–7.161	–6.002	–5.801	–5.424

B. Cointegration Tests

The null hypothesis is that the residuals contain a unit root (ADF Test)

Variable	Test statistic (P-value)	
	2006–2016	2016–2020
Residuals of Equation (1)	–4.928 (0.000)	–2.861 (0.050)
Residuals of Equation (2)	–5.911 (0.000)	–5.320 (0.000)