Online Appendix
The Inner Workings of a Hub-and-Spoke Cartel in the Automotive Fuel Industry
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Appendix A   Synthetic Differences in Differences

We use Arkhangelsky et al. (2021) synthetic differences in differences (SDiD) approach to evaluate the markup charged during the cartel against what would have happened during the same period if there had been no coordination. The method allows for a data-driven selection of the control group that aligns pre-exposure trends in the outcome of not treated units with those for the treated units, and is especially suitable when there is a small number of treated units. Our implementation uses the statistical software R and the prebuild packages **synthdid** (https://synth-inference.github.io/synthdid/) and **Synth** (http://CRAN.R-project.org/package=Synth).

The outcome of interest Y_{FD} is the Federal District's fuel supply chain markup, and we want to estimate the difference between potential outcomes $\tau_{FD,t} = Y_{FD,t}^C - Y_{FD,t}^B$ for months t between 01/2011 and 03/2016, where C stands for a collusive firm conduct and B for a "normal" competitive conduct. The two main assumptions for our comparative case exercise are: (i) that markets located in state capitals did not have a similar collusive conduct as in the FD during that time; (ii) that the competitive conduct of firms in the FD after the cartel broke in 03/2016 is similar to the conduct from firms selling fuel at state capital markets. In this case, the markup trend observed at state capitals is informative about the counterfactual markups at the FD.

For a given set of month and market weights $\{\hat{\omega}_i\}_{i=1}^N$ and $\{\hat{\lambda}\}_{t=1}^T$, we can write the average causal effect $\hat{\tau}_{FD}$ of the cartel on markups as:

$$(\hat{\tau}_{FD}, \hat{\mu}, \hat{\alpha}, \hat{\beta}) = \underset{\tau_{FD},\mu,\alpha,\beta}{\operatorname{argmin}} \left\{ \sum_{i=1}^N \sum_{t=1}^T (Y_{i,t} - \mu - \alpha_i - \beta_t - D_{i,t}\tau_{FD})^2 \hat{\omega}_i \hat{\lambda}_t \right\}$$

where: $D_{i,t}$ is a dummy variable with unit value for the Federal District during the cartel period, and zero for state capital markets or the period after 03/2016; μ, α and β are a constant, fixed effect for market and fixed effect for month, respectively.

The main difference between the SDiD approach to the synthetic control (SC) of Abadie and Gardeazabal (2003) and the standard Differences in Differences (DiD) approach is over the choice of weights. While DiD approach sets the same weight for all control units and time periods, SDiD and SC perform a data-driven choice of weights. Arkhangelsky et al. (2021) propose to compute weights for SDiD and SC by roughly matching pre-treatment trends of exposed and unexposed units. This can be done my searching weights that minimize the squared difference between post-cartel markups in state capitals and in the Federal District. However, the SDiD differ from the SC by allowing for an intercept term on the minimization, i.e., weights on SDiD don't need to make

pre-trends perfectly match but only to make them parallel. The SDiD and SC results we show below are computed using this approach. [1] Another possibility is to include characteristics other than the pre-intervention outcomes in the choice of controls that could also be informative about markups, as in Abadie, Diamond and Hainmueller (2011). We refer to this approach as SC-X.

The weights implied by each method are shown in table 1. One point we make is that weights can vary greatly with adding predictors other than the pre-intervention outcome. It is probably due to the SC-X not being able to achieve a great fit for all predictors, as can be seen in table 2. Another evident point is the large weight dispersion in the SDiD choice. This pattern is imposed in the method by using a regularization parameter. According to Arkhangelsky et al. (2021), regularization is desired as we are able to achieve "parallel trends" without inducing excessive variance in the estimator from sparse weights and have gains in precision. From table 3 we can see that, except for the DiD, the estimated average causal effect is robust across methods.

Table 1: Weights

	DiD	SC	SC-X	SDiD
AL-MACEIO	0.056	0	0	0.041
BA-SALVADOR	0.056	0	0	0.055
CE-FORTALEZA	0.056	0	0	0.055
ES-VITORIA	0.056	0.126	0.520	0.065
GO-GOIANIA	0.056	0	0	0.056
MG-BELO HORIZONTE	0.056	0	0.278	0.063
MS-CAMPO GRANDE	0.056	0	0	0.041
MT-CUIABA	0.056	0.245	0	0.070
PB-JOAO PESSOA	0.056	0	0	0.046
PE-RECIFE	0.056	0.020	0	0.062
PI-TERESINA	0.056	0.163	0	0.061
PR-CURITIBA	0.056	0.066	0	0.065
RJ-RIO DE JANEIRO	0.056	0.380	0	0.069
RN-NATAL	0.056	0	0	0.039
RS-PORTO ALEGRE	0.056	0	0	0.046
SC-FLORIANOPOLIS	0.056	0	0.201	0.050
SE-ARACAJU	0.056	0	0	0.053
SP-SAO PAULO	0.056	0	0	0.061

Appendix B Logit Demand

We use a simple discrete choice formulation to model fuel demand. In any given month t, consumer i chooses a brand of gasoline (e.g. BR, Ipiranga, Raizen, unbranded) or the outside option of not purchasing fuel (option 0). The conditional indirect utility consumer i obtains with alternative b is:

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[1] We refer to Arkhangelsky et al. (2021) for the exact formula to compute weights.

Table 2: SC-X Predictors' Balance

	Treated	Synthetic	Sample Mean
Car Fleet/Population	0.413	0.413	0.329
Car Fleet/Number of Stations	3,979	3,331	2,334
Median Tank sSize	30	29.997	27.765
Avg. Number of Oppo. (3km)	15.832	20.426	30.391
Percent Bifuel Cars	0.518	0.512	0.461
Post-Cartel Markup	0.154	0.155	0.151

Table 3: Average Causal Effect

	DiD	SC	SC-X	SDiD
Average Causal Effect (Lerner Index - p.p.)	4.2	4.6	4.8	5.0
Placebo's Standard Error (Lerner Index - p.p.)	1.9	1.9	1.9	1.8
Average Causal Effect (price - 2015 cents per liter)	16.3	17.6	18.3	19.2
Overprice×Q (2015 million $ PPP)	467.8	505.3	526.8	529.5

$$u_{ibt} = \delta_{bt} + \epsilon_{ibt}$$

where $\delta_{bt} = \beta_b - \alpha p_{bt} + \lambda_t + \xi_{bt}$ is the mean utility for alternative b in period t and ϵ_{ibt} is an EVT1 idiosyncratic shock. To complete the specification, we normalize the mean utility of the outside option to be zero. Following Berry (1994) we invert the logit shares and obtain:

$$\log(s_{bt}/s_{0t}) = \beta_b - \alpha p_{bt} + \lambda_t + \xi_{bt} \tag{1}$$

To obtain market shares we assume that each automobile owner uses at most 114 liters of fuel per month. We obtain this number by multiplying the average fuel efficiency of automobiles in the Federal District by the average mileage driven. We obtain both numbers from the KBB. Then, we scale up the expected automobile consumption by the total number of registered automobiles in period t. Furthermore, the share s_{bt} for each brand is constructed based on the volume of gasoline sold by the network of exclusive dealing stations. Lastly, p_{bt} is the average retail price charged by the stations within the exclusive dealing network of each brand.

As in any differentiated products demand setting where firms exert market power, a systematically high unobserved demand component ξ_{bt} is associated with systematically high prices and shares. To account for this endogeneity issue, we rely on price variation induced by changes in the supply relation following the cartel's collapse. As shown in figure 2 in the text, prices are virtually the same across stations and distributors during the cartel. However, after the end of the cartel, price dispersion in the market increases. The idea behind the instrument is that after the end of the cartel, the local competition faced by the network of stations of each distributor affects equilibrium prices.

Formally, let UN_j be the number of independent stations within 1km of station j and $\mathcal{J}_b$ be the set of stations in the network of b. Our instrumental variable is $z_{bt} = \mathbf{1}(t > Jan\_2016) \times \sum_{j \in \mathcal{J}_b} UN_j$. This instrument is valid if the ξ_b is mean independent of the network of unbranded stations.

Table 4 reports the estimated parameters of equation 1. Column 1 reports the OLS estimates, and column 2 reports the TSLS using z_{bt} as the excluded instrument. The first stage F-statistic for instrument relevance is above the standard value indicating weak instruments. As expected, when accounting for the endogeneity caused by ξ_{bt}, the estimate of the price coefficient increases. This increase translates into a more elastic demand. Whereas the OLS estimates imply a median distributor level elasticity of 5, TSLS estimates imply a median distributor level elasticity of 14. Furthermore, considering the higher level of aggregation, the median distributor level elasticity of 14 is in line with what is found by other papers about fuel markets in Brazil (Soares, 2016; Chaves and Duarte, 2021).

Table 4: Demand for fuel at the FD

	$\log(s_{bt}/s_{0t})$	
	(1)	(2)
Retail Price	-2.07**	-5.57**
	(0.87)	(2.69)
Observations	384	384
R-squared	0.87	0.78
Brand FE	Yes	Yes
IV	No	Yes
Ejj	5.312	14.31
F1st	-	11.35

*** p<0.01, ** p<0.05, * p<0.1. Prices used are the retail prices. Data covers 2010-2017. Ejj is the median distributor own price elasticity. Standard errors are robust to heteroskedasticity and autocorrelation.

Appendix C   Proposition Proof & Model extension

Initial conditions

Set of collusive strategy profiles for given $(N; w_l; w_h)$: Symmetric grim-trigger strategy with Nash reversion with equilibrium path prices (p_l, p_h) s.t. $\pi_l \geq \pi_h \geq 0$.

Equilibrium condition: The incentive constraint during low cost of a SPNE is

$$\frac{\pi_l}{1-\delta^2} + \delta\frac{\pi_h}{1-\delta^2} \geq N\pi_l \iff$$

$$K(p,w) \equiv \frac{\pi_h}{\pi_l} \geq \left(N - \frac{1}{1-\delta^2}\right)\left(\frac{1-\delta^2}{\delta}\right) \equiv f(\delta, N) \tag{IC}$$

where $K(p,w)$ is a function of the wholesale prices and the retail prices played in the equilibrium path. Note that if $\delta \geq \sqrt{\frac{N-1}{N}}$ then any profile in the set is a SPNE. Moreover, if $\delta \geq \frac{N-1}{N}$, then any strategy profile in the subset where $\pi_l = \pi_h$ is a SPNE.

Proof of Proposition 1

We what follows, we develop a proof for a proposition equivalent to the one stated in the text:

Proposition 1. *Let $\bar{w} = [0.5w_l + 0.5w_h, w_h)$. For given N and $\{w_h, w_l, \bar{w}\}$, $\exists!\hat{\delta} \in (\frac{N-1}{N}, 1)$ such that $\frac{\pi^m(\bar{w})}{1-\delta} > V_{IC}^m(w_l, w_h, \delta)$ if $\delta \in (\frac{N-1}{N}, \hat{\delta})$. Furthermore, $\hat{\delta}$ increases as $w_h - w_l$ increases while $\bar{w}$ remains fixed and $\hat{\delta}$ decreases in $\bar{w}$.*

Proof. To prove the proposition, we first characterize, for a given number of players and collusive prices, the interval of discount factors that satisfy the incentive constraint:

Claim 1. *For given $N > 1$ and $K(p,w) \in (0,1]$, $\exists!\tilde{\delta} \in \left[\frac{N-1}{N}, \sqrt{\frac{N-1}{N}}\right]$ s.t. the IC is satisfy if and only if $\delta \geq \tilde{\delta}(N, K(p,w))$. In addition, $\frac{\partial\tilde{\delta}}{\partial N} > 0$ and $\frac{\partial\tilde{\delta}}{\partial K} < 0$.*

From the IC, $\lim_{\delta\to\sqrt{N-1/N}} f(\delta, N) = 0$, $\lim_{\delta\to 0} f(\delta, N) = +\infty$, f continuous and strictly decreasing in δ, and $0 \leq K(p,w) \leq 1$. Therefore, a unique $\tilde{\delta} \leq \sqrt{\frac{N-1}{N}}$ that satisfy $K(p,w) = f(\tilde{\delta}, N)$ exist. We can solve for it:

$$\tilde{\delta} = \frac{\sqrt{K^2 + 4N(N-1)} - K}{2N} \tag{2}$$

Using the implicity function theorem we can show:

$$\frac{\partial\tilde{\delta}}{\partial N} = \frac{(1-\tilde{\delta}^2)\tilde{\delta}}{N\tilde{\delta}^2 + N - 1} > 0 \quad \text{and} \quad \frac{\partial\tilde{\delta}}{\partial K} = \frac{-\tilde{\delta}^2}{N\tilde{\delta}^2 + N - 1} < 0$$

Moreover, since $K(p,w) \leq 1$, $\lim_{K\to 1}\tilde{\delta} = \frac{N-1}{N}$ and $\frac{\partial\tilde{\delta}}{\partial K} < 0$, then $\tilde{\delta} \geq \frac{N-1}{N}$ for any $K \in [0,1]$.

In other words, for given N and (w_l, w_h), any strategy profile is a SPNE if its correspondent $\tilde{\delta}$ is such that $\delta > \tilde{\delta}$.

Now, for a given triple $\{N, \delta, (w_l, w_h)\}$ s.t. $\delta \in [(N-1)/N, \sqrt{(N-1)/N})$, we can easily characterize the efficient equilibrium strategy profile: agents play the monopolist price during high cost periods,

and the minimum between the monopolist price and the maximum price that satisfy the incentive constraint during low cost periods.[2] Profits (π_l^*, π_h^*) in this case are:

$$\pi_h^*(w_h) = \pi_h^m(w_h) \quad \pi_l^*(w_l, w_h, \delta) = \min\{\pi_l^m(w_l), \frac{\pi_h^m(w_h)}{f(\delta, N)}\}$$

To easy notation, let $\tilde{\delta}^m$ the critical $\tilde{\delta}$ evaluated at N and $K(\{p_l^m(w_l), p_h^m(w_h)\}, \{w_l, w_h\})$, and define $V_l^*(\delta) \equiv \frac{\pi_l^*(w_l, w_h, \delta)}{1-\delta^2} + \delta \frac{\pi_h^*(w_h)}{1-\delta^2}$ as the cartel profit flow starting from a low cost period in the equilibrium path with alternating wholesale prices. We can rewrite the proposition as follows:

Claim 2. *Let $\bar{w} \in [0.5w_l + 0.5w_h, w_h)$. $\exists! \hat{\delta} \in ((N-1)/N, \tilde{\delta}^m)$ s.t. $\frac{\pi^m(\bar{w})}{1-\delta} > V_l^*(\delta)$ if $\delta \leq \hat{\delta}(\bar{w}, w_h, N)$. In addition, $\hat{\delta}$ increases as $w_h - w_l$ increase while $\bar{w}$ is hold fixed, and $\hat{\delta}$ is decreasing in $\bar{w}$.*

By claim 1, we know that $\delta \leq \tilde{\delta}^m \Rightarrow \pi_l^*(w_l, w_h, \delta) = \pi_h^m(w_h)/f(\delta, N)$. Hence, $F(\delta) \equiv \frac{\pi^m(\bar{w})}{1-\delta} - V_l^*(\delta) = \frac{\pi^m(\bar{w})}{1-\delta} - \frac{\pi^m(w_h)A(\delta, N)}{1-\delta}$ where $A(\delta, N) \equiv \frac{1}{1+\delta}(\frac{1}{f(\delta, N)} + \delta)$. Note that:

$$\pi_l^*\left(w_l, w_h, \frac{N-1}{N}\right) = \pi^m(w_h) \Rightarrow \frac{\pi^m(\bar{w})}{1 - \frac{N-1}{N}} > \frac{\pi^m(w_h)}{1 - \frac{N-1}{N}} = V_l^*(\frac{N-1}{N}) \Rightarrow$$
$$F\left(\frac{N-1}{N}\right) > 0$$

$$\pi_l^*\left(w_l, w_h, \tilde{\delta}^m\right) = \pi^m(w_l) \Rightarrow \frac{\pi^m(\bar{w})}{1 - \tilde{\delta}^m} \leq \frac{\pi^m(0.5(w_l + w_h))}{1 - \tilde{\delta}^m} < \frac{0.5(\pi^m(w_h) + \pi^m(w_l))}{1 - \tilde{\delta}^m} < V_l^*(\tilde{\delta}^m) \Rightarrow$$
$$F\left(\tilde{\delta}^m\right) < 0$$

and F is continuous on δ. Hence, F has at least one root. Let $\hat{\delta}$ a root of F. Note that,

$$\frac{dF(\delta)}{d\delta} = \frac{1}{(1-\delta)^2}\left(\pi^m(\bar{w}) - \pi^m(w_h)A(\delta, N)\right) - \frac{1}{1-\delta}\pi^m(w_h)\frac{\partial A(\delta, N)}{\partial \delta} \tag{3}$$

where $\frac{\partial A(\delta, N)}{\partial \delta} > 0$ for any $\delta \in (\frac{N-1}{N}, \tilde{\delta}^m)$. Since the first-element of (3) is zero when evaluated at $\hat{\delta}$, then $\frac{dF(\hat{\delta})}{d\delta} < 0 \Rightarrow$ F has a single root.[3]

We can implicitly solve for $\hat{\delta}(\bar{w}, w_h, N)$:

$$\hat{K}(\bar{w}, w_h) \equiv \frac{\pi^m(\bar{w})}{\pi^m(w_h)} = \frac{1}{(1+\hat{\delta})}\left(\frac{1}{f(N, \hat{\delta})} + \hat{\delta}\right) = \frac{\hat{\delta}}{1+\hat{\delta}}\left(\frac{N}{N - \frac{1}{1-\hat{\delta}^2}}\right)$$

and easily show that $\frac{\partial \hat{\delta}}{\partial \hat{K}} > 0$. Therefore, as $w_h - w_l$ increase while $\bar{w}$ is hold fixed, $\hat{K}$ increase and,

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[2]Efficient in the sense that maximizes the cartel's profit flow.

[3]If there where more than one, $\hat{\delta}$ and $\hat{\delta}'$, with $\frac{dF(\hat{\delta})}{d\delta} < 0$ and $\frac{dF(\hat{\delta}')}{d\delta} < 0$, then because F is continuous there must exist a third root such that $\frac{dF(\delta'')}{d\delta} > 0 \Rightarrow\!\!\Leftarrow$

consequentially, $\hat{\delta}$ increases; as $\bar{w}$ increases, $\hat{K}$ decrease, and $\hat{\delta}$ decrease.

$\square$

Hub-and-spoke collusion with alternating costs

In the spirit of Asker and Bar-Isaac (2014), we add to the previous game an initial stage of upstream competition between a potential hub and a fringe distributor and discuss the possibility of an exclusion equilibrium in this setting. The two distributors sell a homogeneous product to downstream retailers. The marginal cost of the distributors evolves according to a deterministic alternating sequence $(c_H, c_L, c_H, c_L, ...)$, with $c_L < c_H$. Players choose actions in each period according to the following: (i) distributors simultaneously choose wholesale prices; (ii) after observing wholesale prices, gas stations simultaneously make buying decisions; (iii) after observing buying decisions, gas stations simultaneously set retail prices.

If players price according to the Nash-Bertrand solution and retailers buy from the cheapest distributor, then in the competitive equilibrium the single-period payoff is zero for both retailers and distributors. Furthermore, if the strategy profile is such that retailers collude on the efficient collusive price while buying from the cheapest distributor, then the equilibrium conditions are analogous to those presented in the paper, with wholesale prices perfectly reflecting the marginal cost sequence. We call this collusive equilibrium a *horizontal cartel*.

We can also draw the conditions for an equilibrium profile strategy with an upstream exclusion component and constant wholesale prices. Retailers coordinate on the monopolist retail price and on only buying from the hub distributor. The hub distributor coordinates to charge retailers a constant wholesale price equal to $\hat{w} \in [\frac{1}{1+\delta}c_h + \frac{\delta}{1+\delta}c_l, c_h)$. Cartel members keep playing on the equilibrium path while no deviation is observed either in price or in buying decisions. The fringe distributor sets wholesale prices equal to the marginal cost for every period. We call this collusive equilibrium the *vertical cartel*.

In the vertical cartel the hub has no incentive to deviate since the average profit is greater than or equal to zero, and any deviation triggers an immediate response of retailers, which leads to zero profits. Downstream firms' incentives, however, imply the following constraint:

$$\frac{\pi(p^m(\hat{w}), \hat{w})}{1-\delta} \geq \max\{N\pi(p^m(\hat{w}), \hat{w}), \ \pi^{BR}(\hat{w}, c_l)\}$$

Now we must consider two deviation possibilities: a price deviation as before, which implies profit $N\pi(p^m(\hat{w}), \hat{w})$; and a buying deviation, which implies profit $\pi^{BR}(\hat{w}, c_l)$ from facing all other stations setting price equal to $\hat{w}$ while having a cost advantage of $\hat{w} - c_l$.

Extending the result of Proposition 1, we can show that the range of time-discount factors in which retailers are better off in a vertical cartel than in a horizontal cartel is $[\frac{N-a(\hat{w})}{N}, \hat{\delta}_{(c_l, c_h)}]$, where $a(\hat{w}) = \min\{N\pi(p^m(\hat{w}), \hat{w})/\pi^{BR}(\hat{w}, c_l), 1\}$ and $\hat{\delta}$ is the critical discount factor that guarantees

higher profit flow under a constant wholesale price sequence, as defined above in Claim 2. The possibility of buying from other distributors will generate a constraint on the amount of rent that the hub will be able to extract from retailers through $\hat{w}$.

Appendix D Horizontal Strategies used by the Cartel

We build on the documents and the data to provide a detailed characterization of the strategies used by retailers to solve the coordination, enforcement, and entry problems.

Leadership

According to the documents and the plea bargain deal, any change in the retail prices proceeded as follows:

1. The operations manager from the Cascol group was informed by distributors' sales representatives on any significant change in the next week wholesale price;

2. Based on this information, Cascol decided on the new retail price to be charged by its stations and other members of the cartel;[4]

3. Prior to the start of the following week, Cascol notified the cartel members of the new prices;

4. The members were responsible for transmitting the information to the stations in their vicinity. The new retail prices were posted on the beginning of the next week;

5. Cascol's employees drove around the city to make sure that the other stations were following the accorded price.

The modus operandi of the cartel indicates that Cascol is responsible for coordinating price changes. The presence of a leader is important when we consider that heterogeneous retailers would have preferences for different collusive prices. As such, Cascol acts to reduce the negotiation and bargaining costs between stations during the decisions of the new price..[5] It also deals with most of the monitoring costs involved in the coordination, an aspect difficult to be taken by owners of smaller networks.[6] Even so, because of the large size of the market, Cascol relied on the help of geographically disperse members for the transmission and monitoring of information.

Horizontal transfers

Coordination among asymmetric firms requires them to implement implicit or explicit transfers between participants (Jacquemin and Slade, 1989). The mechanism used by the cartel members to

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[4]Usually a few other members of the cartel were consulted by Cascol on what the next retail price should be. But it is clear from the documents that no decision on the retail price was made without the consent from Cascol managers.

[5]Byrne and De Roos (2019) show the importance of leadership in price coordination for a collusion in the Australian gasoline retail market.

[6]Quote 3 in Appendix E exemplify the benefits of having Cascol as a leader.

implement implicit horizontal transfers is highlighted in the depositions. According to the cartel members, a group of retailers was allowed to charge 2 to 3 cents below the price proposed by Cascol.[7]

The histogram (a) in Figure 1 captures the transfer mechanism used by the stations to stabilize the cartel. The light bars display the distribution of retail prices minus the minimum retail price in the week, from 2011 to 2015. From the histogram, it is evident that most prices were chosen to be 2 to 3 cents above the minimum price in any given week. Histogram (b) in Figure 1 shows the distribution of wholesale prices minus the minimum wholesale price in the week. Notice that both the spectrum and the decay in frequency are different from the ones in histogram (a). These patterns rule out cost explanations for the retail pricing patterns.

Furthermore, we investigate whether this pattern is in place after the antitrust authority intervened in the market. To this end, the dark bars display the analogous distribution for prices during the years of 2016, 2017 and 2018. Notice that after the intervention, the distribution of retail price differences from the minimum does not have a peak on the value agreed by the cartel and has a much larger support.

Motivated by the evidence presented in figure 1, we investigated the identity of the stations that charged the minimum price in any given week. The retail chains of these stations are characterized by operating only unbranded stations or having business other than fuel sales as their main activity (car rental, for example). Their distinct characteristics probably imply differences in marginal cost and consequentially higher gains if deviating from the agreed price. Some of these chains are also named in the depositions as those that were allowed to set retail prices below the one proposed by the cartel. Interestingly, transfers to low-cost chains are also observed in the gasoline cartel studied in Clark and Houde (2013).

Political machinations and Entry

Table 5 displays the number of stations and the number of new entrants from 2007 to 2018. We observe a steady increase in the number of stations from 2007 until 2011. The entry rate declines in 2012 and there is almost no change in the number of stations until 2016. In 2017, after the cartel was dismantled, the number of stations starts to grow again.

Despite the rents generated by the cartel, the entry patterns highlighted in table 5 show that the period in which the cartel was operational is also the period in which almost no entry is observed. The conversations captured by the wiretaps, and the documents obtained by the police suggest one possible explanation for the entry patterns:[8] the incumbent retailers' use of political connections with members of the local government to block entry.[9]

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[7]Quote 1

[8]Another explanation is the macroeconomic conditions at the time. Brazil entered into a recession in 2015, and we can observe a lower growth in the total number of gas stations also in some state capitals.
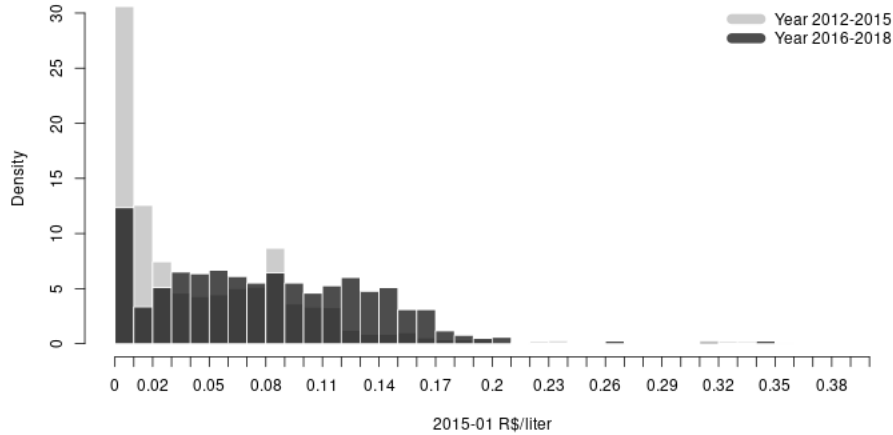
[9]Magnolfi and Roncoroni (2016) is an example on how political connections can affect market structure and

Figure 1: Difference of Gas Prices to the Weekly Minimum Price

(a) Retail Price
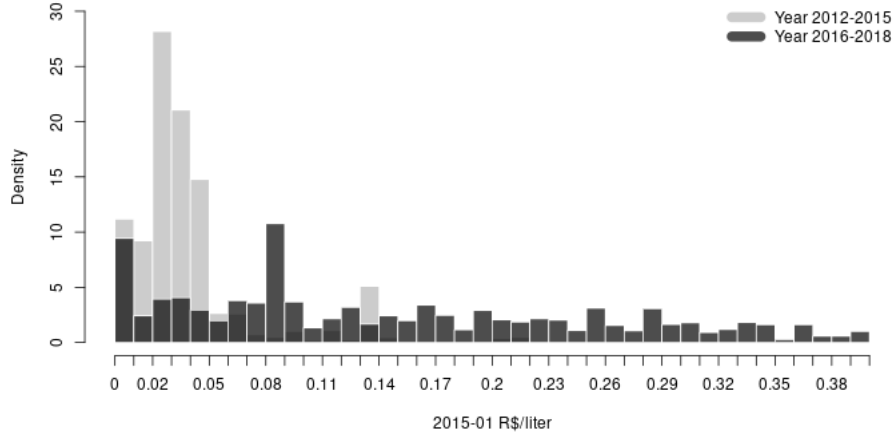
(b) Wholesale Price

There are strict zoning laws that regulate land use in the Federal District, especially in Brasilia, and the local government owns most of the current land that could be used to open new stations. On January 29th of 2015, the local government offered for sale a land tract located in the downtown area. The tract of land was listed as an area suitable for the installation of a gas station. On February 6th, two members of the cartel exchanged text messages regarding the sale of this land tract.[10] During the text exchange, one of the cartel members told the other that he contacted the Governor to dissuade him from selling the land tract. According to the cartel member, the Governor accepted the suggestion right away.[11] This prompt response from local authorities is

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perpetuate incumbents dominant position.

[10]Telephone Report number 16.

[11]The conversations between the cartel members are hearsay and it is not a legal proof that the Governor was

Table 5: Number of stations and entry in the Federal District

Year	2007	2008	2009	2010	2011	2012
Number of Stations	253	262	277	283	289	303
New Stations from Entrants	14	11	12	6	7	4
Car Fleet per Station	2,738	2,866	2,902	3,056	3,218	3,248
Year	2013	2014	2015	2016	2017	2018
Number of Stations	307	308	307	304	309	324
New Stations from Entrants	4	5	2	2	7	17
Car Fleet per Station	3,411	3,594	3,753	3,908	3,940	3,861

The number of stations refers to the total number registered as active in the ANP documents during December of that year. A station is allocated to a group by its initial 8 digits of the cnpj, or when it has a group brand name as part of the register name. We define an entrant as a group that did not have stations in the FD during the previous year.

not surprising , as information on political campaigns shows that Cascol is a major donor to local politicians.[12]

Appendix E   Police documents' quotes

Quote 1 - *General Manager and owner of Cascol, plea bargain*
 "Even though the unbranded stations belonging to Jarjour, Alemão Canhedo and Marco Crioulo, paid a lower price for fuel, they were also part of the price fixing agreement. **As part of the agreement, they were able to set a price two cents below the price set by other stations.**"

Quote 2 - *General Manager and owner of Cascol, plea bargain*
 "BR and Ipiranga goal during the 'price wars' was that the station that initiated the war couldn't sustain a price below the price set by the cartel members. This way, the station that initiated the war would have to realign their prices with the price set by cartel members and would not destabilize the agreement. Therefore, the high profitability of fuel distribution would not be affected. Fuel distributors did not give the station that initiated the price war the 10 cents discount they gave to other stations in order for them to face the 'price war'. That during 'price war' events, both BR and Ipiranga would subsidize retailers so they could force the 'rebel retailer' to raise prices again (...)."

Quote 3 - *General Manager and owner of Cascol, plea bargain*
 "(...) After a while, the price fixing became automatic, with price changes happening when there was an increase in the price set by distributors, or a change in other external factors, like a change in taxes. During this period, there was no need for retailers to meet in order to fix prices, the price adjustments were made

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involved in any wrong doing. But, in fact, the land was removed from the sale process without justification. The documents also indicate that members of the cartel kept track of legislative bills that could affect incumbent gas stations and had frequent meetings with aldermen.

[12]During the 2014 elections Cascol donated more than two hundred thousand reais to local politicians. This figure makes Cascol one of the largest individual campaign donors.

through phone calls or small meetings involving the cartel leaders - e.g. the meeting of the deponent with Cláudio Simm and José Carlos, or the contact exchange between Cláudio Simm and José Carlos - or when provoked other retailer. Usually, the message was transmitted by phone to other retailers in some sort of communication chain. Cascol employees were not part of the meetings in which prices were defined. Their only task was to spread the news, in other words, they were only messengers. This is so, that sometimes they even brought back price suggestions from other retailers (...)" (affidavit 01, 2017.01.1.024068-6).

Quote 4 - *Cascol employee, plea bargain*
"(...) small increases made by fuel distributors are not easy to be passed on the fuel pump, among the many reasons, one is that Gasol (Cascol) could increase their own price, but not necessarily the competitors would accept to do the same. For example, someone could not accept an increase of 2 cents and then generate a disequilibrium between retailers in the market between (...)" (affidavit 05, 2017.01.1.024070-8).

Quote 5 - *Police report referring to wiretap evidence*
"With the goal to impose barriers to competition, in particular the competition gasoline faces from ethanol, the defendant Cláudio Simm talked to a third party that the "cartel" was worried about how a state government plan to reduce the tax rate levied on ethanol would induce consumers to purchase ethanol and cannibalize gasoline sales. He told the third party that his concerns should reach the Federal District Secretary of Treasury."

Quote 6 - *Police report referring to wiretap evidence*
According to the case files, in October 19th 2018, Antônio Matias (Cascol) talks to a BR employee about wholesale prices. Antônio Matias complains about the difference in wholesale prices set by BR and Ipiranga for both gasoline and ethanol. In this conversation, Antônio Matias states that he got in touch with Ipiranga and asked them to increase prices, allegedly to eliminate the aforementioned wholesale price difference.

Quote 7 - *Police report referring to wiretap evidence*
In a conversation with a local retailer, Márcio Barreiros, a BR employee under the supervision of the defendant Adão do Nascimento, when asked why BR was setting such high prices for ethanol, replied that BR set ethanol prices 'following' gasoline and that BR was not interested in selling ethanol.

Quote 8 - *Police report referring to wiretap evidence*

"(...) Considering that with the diffusion of bifuel cars, ethanol became a substitute to gasoline, it was necessary to control the price of ethanol to avoid consumers to substitute gasoline for ethanol. Apparently, the cartel alternative found by the cartel was to raise the price of ethanol to a point that it would not be worthwhile for consumers. The price of ethanol is detrimental to the cartel because of its variation throughout the year." (Police report, 2183/2688, vols. 9 to 11, IPL 0889/2010).

Quote 9 - *Police report referring to seized document*

Regarding the prices suggested by Shell and documented in photographs, it should be registered that in 02/02/2015, Raízen displayed to its stations a suggested price of R$ 3,54. This was the target price implemented by members of the criminal organization.

Quote 10 - *Wiretap - Dialogue between Station Owner (Rivanaldo) and Manager(Ricardo) regarding the motivations for starting a price war.*

Ricardo: Come on, aren't the other stations complaining?

Rivanaldo: They are, but I told them I need that price difference, right?

Ricardo: How much is it?

Rivanaldo: But they don't want, I only want 2 cents, just like Alemão had for a long time.

Ricardo: Two?

Rivanaldo: Yes, and they don't want, so I told those s... to f... off.

Quote 11 - *Police report referring to seized documents evidence*

Regarding the Instituto Braslia Ambienta [IBRAMl, the accused José Carlos Ulhôa Fonseca sent an email, on 07/09/2014, at 4:51 pm, to the accused Antônio José Matias de Sousa, informing him that he had adopted measures with IBRAM, as well as before regional administrations, with the objective of hindering the construction of a certain undertaking real estate for the installation of a gas station.

Quote 12 - *General Manager and owner of Cascol, plea bargain*

It is common knowledge among resellers that one company [distributor] does not enter the area of the other, that is, a reseller of a given brand cannot switch to another brand, and it is necessary that, to change brands, he remains for a certain time as unbranded.

Quote 13 - *General Manager and owner of Cascol, plea bargain*

It is common throughout the month for there to be variations in the price charged by the distributor. These small variations, in the opinion of the deponent, when not announced by the government or not duly justified by the company [distributors],..., cannot be passed on to the consumer, since there is no justification to show the customer, and the resale of fuels is highly targeted by public authorities.

Quote 14 - *General Manager and owner of Cascol, plea bargain*

That the most interest in holding the collusive prices between retailers in the Federal District were the distribution firms, since the collusion generated high profits because retailers would pay for rent and fuel, and would not delay other payments due to the distributors.

Quote 15 - *Cascol employee, plea bargain*

When there was a retreat in these small increases on the part of companies [distributors], this fact certainly resulted from complaints from resellers, mainly from Cascol.

Quote 16 - *Police report*

From the contacts maintained between the retailers Antônio Matias and Cláudio Simm with the representatives of the distribution companies BR and Ipiranga, with the aim of equalizing the difference of ethanol prices that existed between them, the two distributors agreed with the request of these resellers: BR reduced

its price, and Ipiranga increased it, in order to reduce the difference in prices between them, balancing the costs for resale.

Appendix F   Tables and Graphs

Table 6: Cities' Summary Statistics

| | Federal District | State Capitals (n=18) | | |
		p10	median	p90
Population (millions)	2.75	0.53	1.17	3.93
Car Fleet/Population	0.37	0.18	0.28	0.42
Population Growth (%)	1.88	0.45	0.81	1.65
Car Fleet gGrowth (%)	5.54	3.34	4.91	6.49
Income (R$ 2015-01)	4,312.75	2,035.56	2,552.07	3,182.75
Urban Area (km sq)	626.50	134.68	284.94	888.06

Statistics refer to the years between 2007 and 2018. In comparison with state capitals, the Federal District is marked by a large potential demand for fuel. This is the case when we consider variables that affect the level of demand (e.g. population, car fleet per-capita and income), or variables that account for demand growth (e.g population growth and car fleet growth).

Table 7: Gasoline Retail Price Seasonality

Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.22	3.17	-0.79	-4.44	-3.46	-7.7	-6.05	-8.29	-4.83	0.7	0.25
(1.22)	(1.28)	(1.44)	(1.49)	(1.52)	(1.38)	(1.33)	(1.37)	(1.29)	(1.48)	(0.96)

Coefficients from a regression of the gasoline monthly average retail price on a polynomial of degree three in time, dummies for markets, and dummies for months of the year. Observations for 2012/01-2019/02 in the FD and state capitals. Months with negative and significant coefficients match with the sugar cane harvest season months.
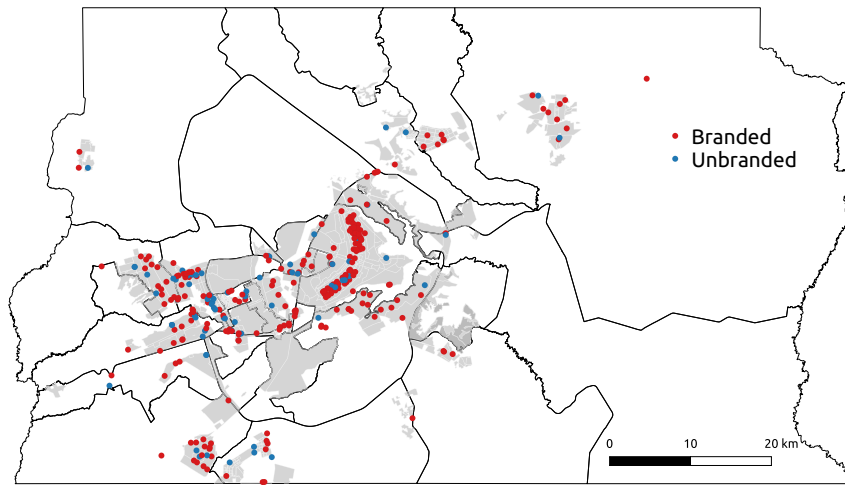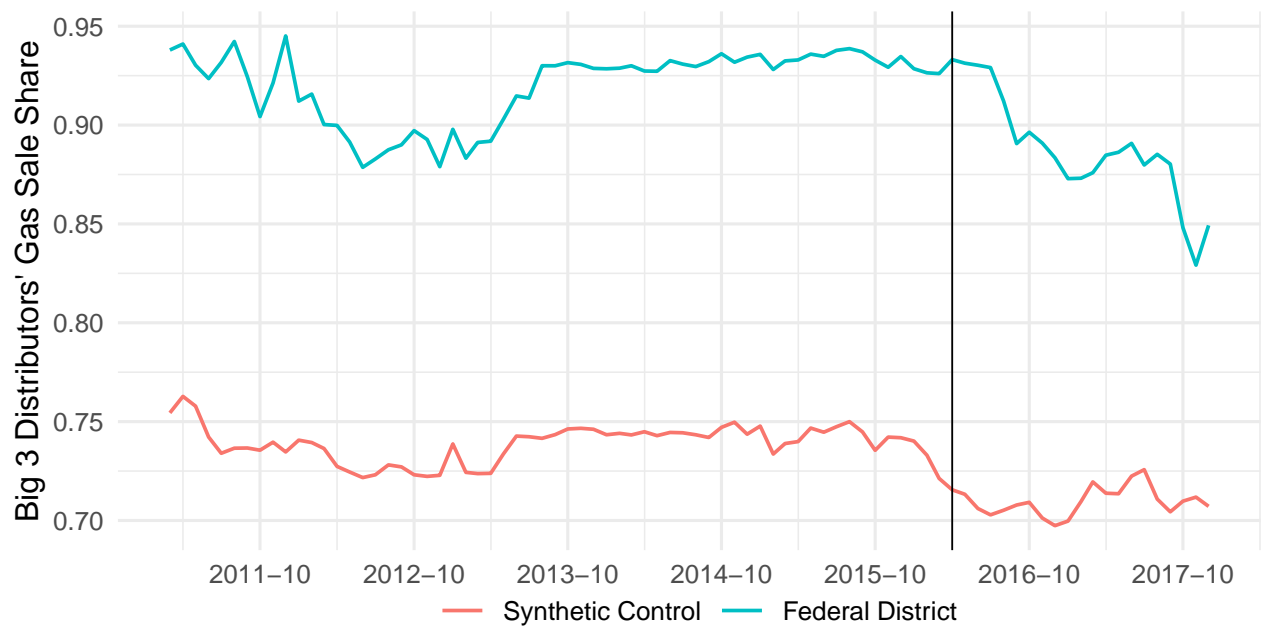
Figure 2: Federal District Map

Figure 3: Big 3 Distributors' Market Share Evolution at State Capitals

Market share for the synthetic control is constructed using sales data at the state capital level.
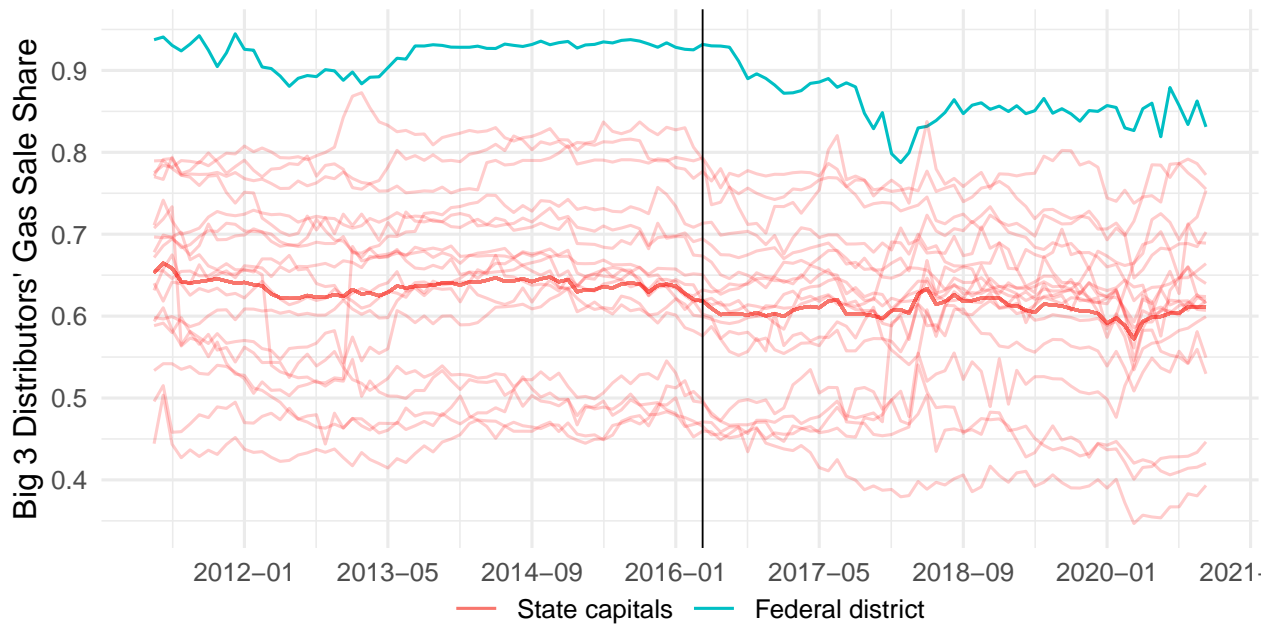
15

Figure 4: Big 3 Distributors' Market Share Evolution at States

Market share for the synthetic control is constructed using sales data at the state level. Bold red line is the average across states.
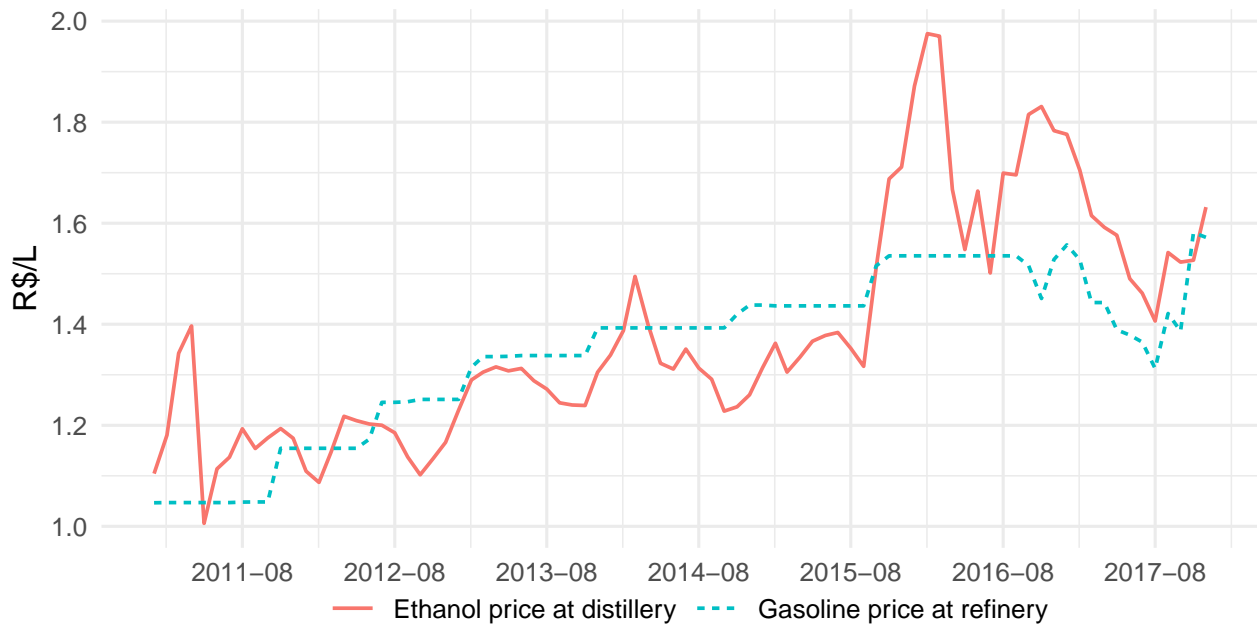

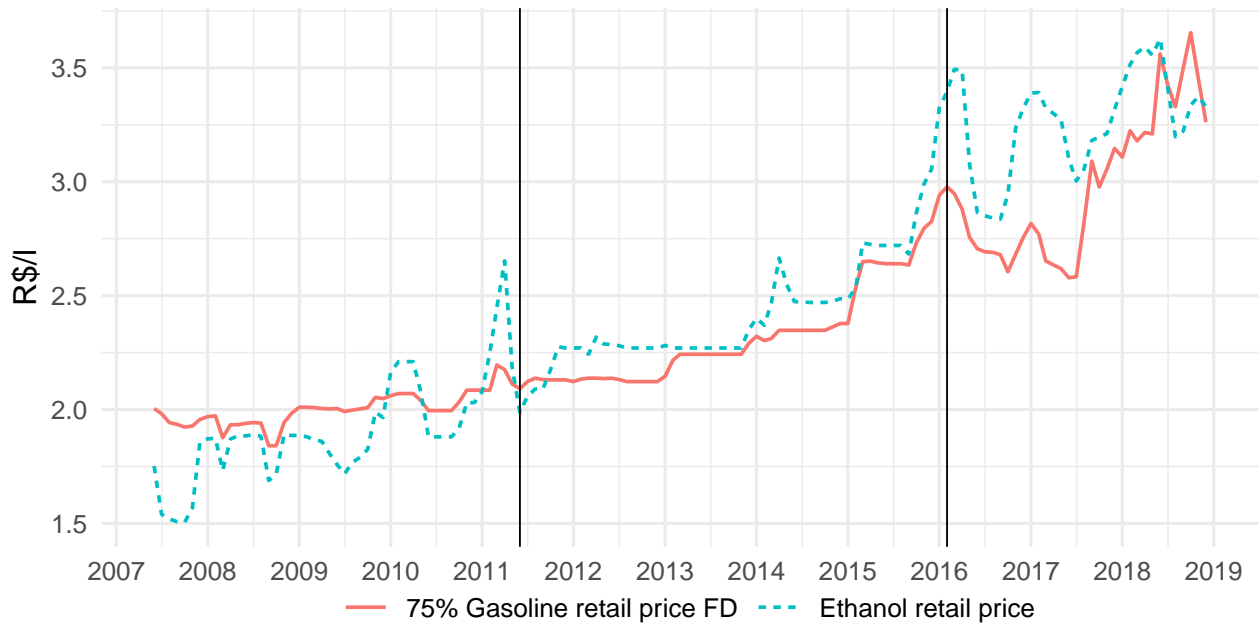
Figure 5: Ethanol vs Gasoline Cost Volatility

Figure 6: Ethanol retail price vs 75% Gas retail price

Nominal R$ price values. The 75% threshold should be understood as a rule-of-thumb for the fuel decision. The reference threshold can vary depending on engine performance, although it does not vary by much.
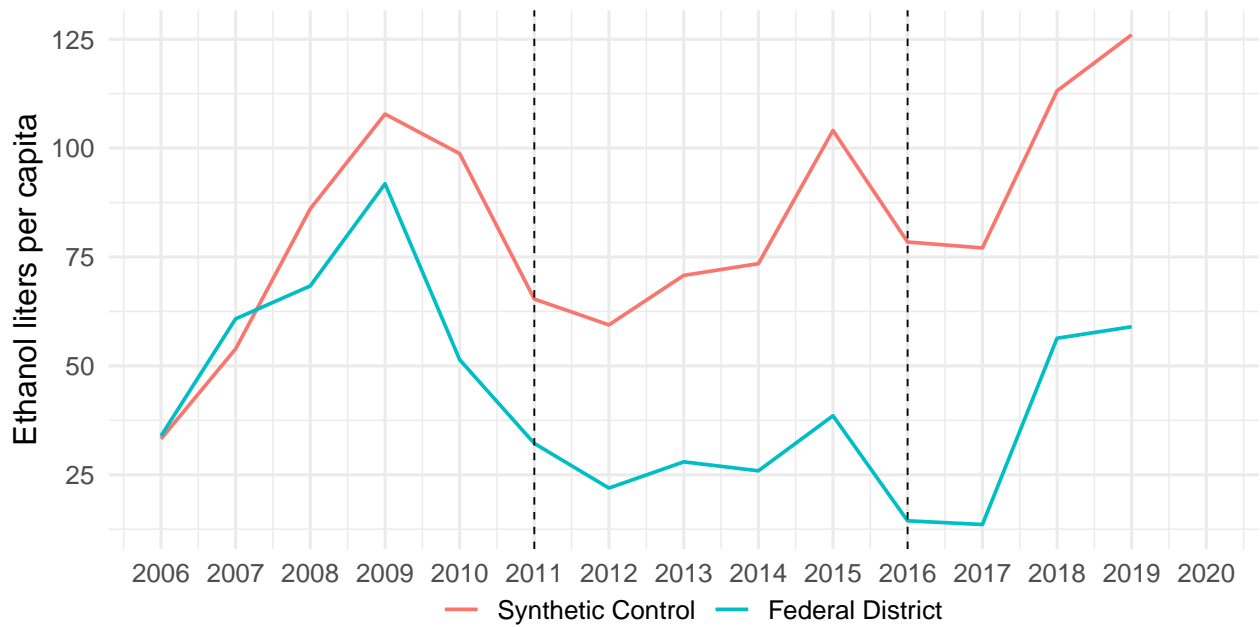

Figure 7: Ethanol Sales per capita

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