Privatizing Local Refining Monopolies*

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Resumo: Em 2020, a Petrobras detinha mais de 98% da capacidade total de refino do Brasil. Uma das reformas para promover a concorrência nesse mercado envolveu o desinvestimento nesse setor pela Petrobras. Avaliamos os impactos dessa política com foco na privatização de duas refinarias: a Refinaria Landulpho Alves (2021) e a Refinaria Isaac Sabbá (2022). Para esse fim foi utilizado o método de diferenças-em-diferenças, revelando que consumidores nos estados da Bahia e do Amazonas, mais diretamente afetados pela privatização, experimentaram aumentos significativos nos preços dos combustíveis em comparação com o restante do país. Em média, o preço da gasolina ficou R$ 0,29 por litro mais caro, o do diesel R$ 0,14 por litro e o do etanol R$ 0,21 por litro. Além disso, foi estimado curvas de demanda com o objetivo de quantificar o impacto da privatização sobre o bem-estar. De janeiro de 2021 a outubro de 2023, consumidores no Amazonas e na Bahia sofreram uma perda de bem-estar de R$ 2,6 bilhões. Esses resultados são atribuídos ao posicionamento inicial das refinarias como monopólios locais dentro de um sistema nacional integrado, posteriormente privatizadas como se fossem firmas em concorrência.

Palavras-chave: Privatização, mercado de refino, bem-estar, eventy study, preços dos combustíveis.

Abstract: In 2020, Petrobras held more than 98% of Brazil's total refining capacity. One of the reforms promoting competition in this market involved Petrobras' divestment. We assess the impacts of this policy by focusing on the privatization of two refining plants: Refinaria Landulpho Alves (2021) and Refinaria Isaac Sabbá (2022). Using difference-in-differences research designs, our analysis reveals that consumers in the states of Bahia and Amazonas, who were most directly affected by the privatization, experienced significant increases in end-user fuel prices compared to the rest of the country. On average, gasoline prices were overpriced by 0.29 BRL per liter, diesel prices by 0.14 BRL per liter, and ethanol prices by 0.21 BRL per liter. Furthermore, by estimating demand curves and conducting back-of-the-envelope calculations, we quantify the welfare impact of privatization sales. From January 2021 to October 2023, consumers in Amazonas and Bahia experienced a welfare loss of 2.6 billion BRL. These outcomes are attributed to the initial positioning of refineries as local monopolies within an integrated national system, subsequently privatized as if they were competitive firms.

Keywords: Privatization, refining market, welfare, event study, fuel prices.

JEL Codes: R40, L12, L33.

Área 7 - Infra-estrutura, transporte, energia, mobilidade e comunicação

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1 Introduction

In Brazil, the oil refining market has long been dominated by Petrobras, which held exclusive rights to oil exploration and refining until 1997. Even after market opening, private companies showed little interest due to the challenges of competing with an established monopoly and Petrobras's politically influenced pricing below international levels. To promote competition, two recent policy reforms were enacted: in 2016, Petrobras introduced the import parity policy (IPP) to align domestic prices with international benchmarks and reduce political influence (Petrobras, 2016, 2023); and in 2019, Petrobras agreed with CADE[1] to divest half its refining capacity by selling eight refineries (CADE, 2019).

This study investigates the welfare implications of the second approach, a divestment plan in the refining sector in Brazil. Our specific focus lies on the welfare impacts arising from the privatization of the initial two refining facilities within this divestment plan: Refinaria Landulpho Alves (RLAM), privatized in late 2021, and Refinaria Isaac Sabbá (REMAN), privatized in late 2022. RLAM, the country's second-largest refinery, commanded a 12% share of the total refining market in 2022, the most significant privatization in Brazil's refining sector to date. RLAM is located in the state of Bahia, the biggest state in the Northeast region of Brazil. The second privatized plant, REMAN, is located in the state of Amazonas and contributes 1.7% to the refining market[2]. REMAN is the sole refinery in the entire North region of Brazil[3](ANP, 2023).

Our analytical framework has two parts. First, *we quantify price shifts* from privatization using event study and difference-in-differences models, comparing end-user fuel prices in Bahia and Amazonas (treated group) to those in other Brazilian regions (control group), while excluding other North and Northeast states to avoid spillover effects. Second, we assess the welfare implications by estimating gasoline, diesel, and ethanol demand in these states with city-month panel data, and calculate the welfare impact of RLAM and REMAN privatizations using back-of-the-envelope methods[4].

The primary motive behind privatization is the belief that private firms will outperform their state-owned counterparts (Brada, 1996; Megginson & Netter, 2001). Introducing competition and effective regulation is believed to yield welfare gains, particularly in improving the quality, availability, and affordability of goods and services. The shift towards profit maximization is expected to be offset by production efficiencies, thus avoiding any deadweight losses (Bradburd, 1995). Therefore, discussion surrounding privatization focuses on identifying the necessary conditions to achieve these desired outcomes, i.e., how it can be properly designed and implemented to benefit society at large (Estache et al., 2001).

The privatization of RLAM and REMAN offers a compelling case for studying privatizations of local oil refining monopolies. The Brazilian refining market was initially structured as a monopoly, with each geographical area being served by a single refinery, all of which was owned by Petrobras. Like most of the refineries in Brazil, RLAM and REMAN are local monopolies. The closest RLAM rival is located more than 805 kilometers away (500 miles), and the closest REMAN rival is located more than 2000 kilometers

[1]CADE refers to the "Conselho Administrativo de Defesa Econômica", Brazil's antitrust authority.

[2]Further details on the role of each refinery in the Brazilian refining market are provided in the next section, Background.

[3]Brazil is geographically divided into 27 states and 5 regions: North, Northeast, Midwest, Southeast, and South.

[4]Our scope is the liquid fuel market (gasoline, diesel, and ethanol fuels). However, a similar approach could be used for LPG or other energy goods.

away (more than 1200 miles)[5]. The initial intuition is that these privatizations should have followed a regulatory framework closely aligned with the privatization of natural monopoly public enterprises and monopolistic industries (Bradburd, 1995; Bortolotti & Siniscalco, 2004), but that was not the case.

Several features make our setting ideal for asserting a causal effect of privatizing local refining monopolies. First, we conduct surveys of gas station prices before and after privatization. Second, neither consumers nor gas station owners influence the privatization process; it is solely a government decision. Third, despite widespread dissemination of news regarding privatization, consumers cannot store fuel in anticipation of higher prices or hedge against fuel price fluctuations if they expect future lower prices.

Contrary to expectations of lower prices, our difference-in-differences analysis (Wooldridge, 2021) shows that consumers in Bahia and Amazonas faced higher fuel costs after privatization. Compared to the rest of Brazil (excluding the North and Northeast), end-user prices increased by 27 cents (gasoline), 15 cents (diesel), and 21 cents (ethanol) per liter; including all states, these premiums were only slightly lower. There was no trend toward declining overpricing, indicating a persistent effect. Back-of-the-envelope calculations estimate a welfare loss exceeding 2.6 billion BRL for these states from January 2022 to October 2023. Analysis of wholesale prices yielded similar results, suggesting that the price increases were driven by changes at the refinery level, not by gas station margins.

While oil workers' unions argue that privatization has not resulted in fair sale prices or lower fuel costs, policymakers often claim the opposite. Our study adds rigorous empirical evidence to this debate by providing the first causal analysis of refinery privatization in Brazil. Given the ongoing privatization plan, our findings serve as a warning that such reforms do not necessarily benefit consumers and highlight the need for better policy design. By estimating fuel demand at the city-month level, we offer a more precise welfare analysis that goes beyond simple calculations of overpricing, deepening the understanding of privatization's true effects.

This paper contributes to the political economy literature on privatization (Vickers & Yarrow, 1991; Spulber & Sabbaghi, 2012; Viscusi et al., 2018). In the oil sector, prior studies include evidence from Mexico's petrochemical privatization (Laguna, 2004) and international comparisons favoring private firms (Wolf, 2009). In Brazil, research on electricity distribution shows improved company performance without harming consumers (Muller & Rego, 2021; Silvestre et al., 2010), though privatization also reduced wages for affected workers (Arnold, 2022) and, in Eastern Europe, lowered emissions (Meyer & Pac, 2013). However, micro-level evidence on price effects remains limited, as most studies analyze simultaneous or sector-wide privatizations. Our quasi-experimental design, based on staggered refinery sales, provides new causal evidence for this gap.

This paper is organized as follows. Section 2 provides an overview of Brazil's refining market and details the privatizations of RLAM and REMAN. Section 3 delves into the price effects of privatization. In Section 4, we estimate the demands for gasoline, diesel, and ethanol, specifically in Bahia and Amazonas, and leverage the findings from the previous sections to conduct a welfare analysis. Finally, Section 5 concludes the paper and provides some policy implications based on our results.

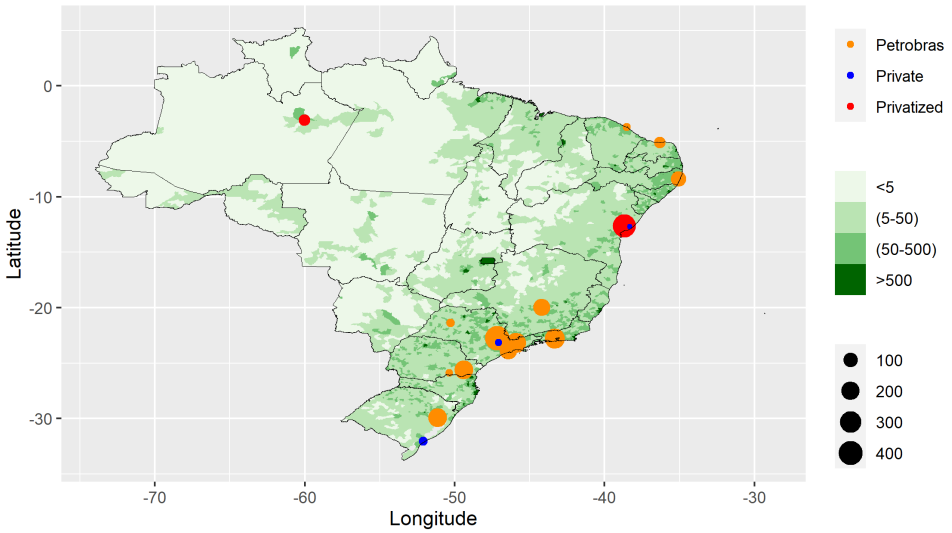
[5]See the map in Figure 1, in the next section.

2 Background

As of 2020, Petrobras held an impressive 98.6% of Brazil's total refining capacity (ANP, 2021). According to Bridgman et al. (2011), the dominant position of Petrobras does not necessarily imply inefficiency. The threat of competition after the end of the legal monopoly would spurred Petrobras to improve its efficiency, leading to a doubling of efficiency within a six-year period.

Given the high market concentration in Brazil's refinery market, frequent policy recommendations have called for increasing the number of market participants (Ordonez & Rosa, 2018; Rojas & Leite, 2018; Cabral, 2020; CNPE, 2019; MME, 2017). However, this transition risks simply replacing a national monopoly with new local monopolies, since the market was initially structured for maximum production scale and minimum distribution costs (Tavares et al., 2006, p.3030). This concern is particularly relevant for the North and Northeast regions. Figure 1 illustrates the geographic distribution of refineries and population density in 2021.

Figure 1: Refining Capacity and Population Density in Brazil (2022)

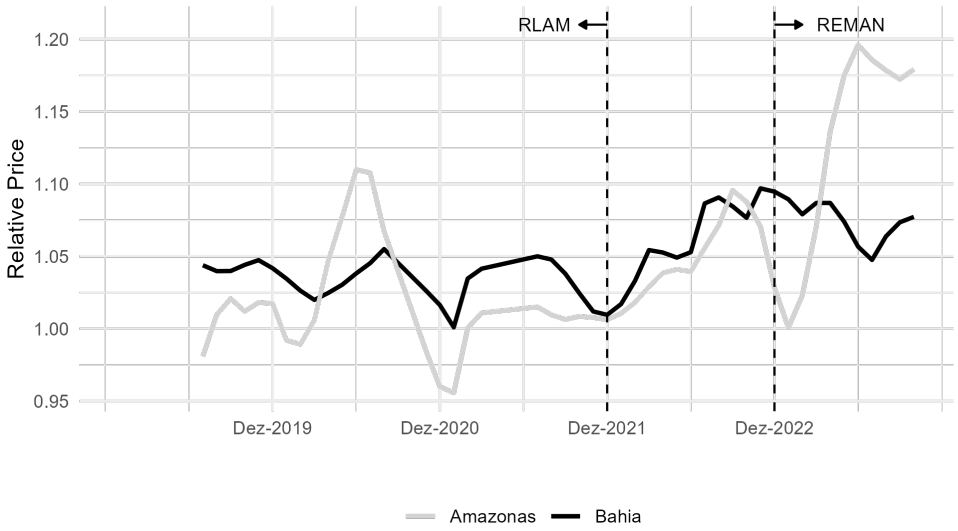


Source: Authors with data from ANP (2023) for refineries and IBGE (2023*a*) for population density. Notes: The sizes of the circles represent the refining capacity in thousands of barrels per day for each refinery. The red color corresponds to the Refinaria de Mataripe (formerly RLAM), which was acquired in 2021 by the Emirati group Mabudala Capital, and Refinaria Isaac Sabbá (REMAN), acquired in 2022 by Atem group. The blue color represents privately operated refineries, while the orange represents refineries owned by Petrobras. The intensity of green represents the population density by city in 2022 (people per square kilometer).

Two major reforms were implemented to reduce Petrobras's dominance and foster competition. First, the import parity policy (IPP), introduced in October 2016, aligned domestic fuel prices with international benchmarks and aimed to deter politically motivated pricing (Rojas & Leite, 2018, p.26; Petrobras, 2016, 2023). IPP ended in May 2023. Second, a 2019 agreement between Petrobras and CADE required Petrobras to divest half of its refining capacity by selling 8 of its 13 refineries. The first sale, RLAM to Mubadala Capital, was approved in July 2021 and completed in December 2021 (CADE, 2022; Griebeler da Motta & Pastore, 2022). The REMAN sale to Atem Group was signed in August 2021 and completed in December 2022.

RLAM accounts for 12% of Brazil's refining capacity and dominates the Bahia and

Figure 2: Relative Price of Gasoline in Bahia and Amazonas Pre and Post-Privatization



Source: Data from ANP (2023). Notes: The graph illustrates a relative price comparison calculated by dividing the average monthly prices in Bahia or Amazonas (treated cohorts) by the average price of the control group. The solid black line represents the average relative prices in Bahia, while the gray solid line represents the average relative prices in Amazonas. The vertical dashed lines mark the timing of privatization for RLAM and REMAN.

Northeast markets; other local refineries, such as Dax Oil, are negligible by comparison, and the combined capacity of Lubnor and Rnest is only one-third that of RLAM (ANP, 2022). REMAN, though responsible for just 1.7% of national capacity, is the only refinery in the North region, with no competitors within 2,000 kilometers. As the North and Northeast are among the country's least affluent regions—representing only 62% and 63% of Brazil's per capita income, respectively (IBGE (2023*b*))—the price impacts of privatization are especially significant for these populations.

Opponents of privatization would predict higher end-user prices, while proponents would expect lower prices. Therefore, thoroughly examining the data is necessary, and Figure 2 offers valuable insights. Following the privatization of RLAM and REMAN, relative prices in Bahia and Amazonas increased compared to the control group: before privatization, prices in Bahia were 3% higher than those of the control group, but surged to 7% above post-privatization; in Amazonas, the difference grew from 2% higher to a substantial 14% higher after privatization[6].

Although this initial evidence from relative prices is suggestive, it is important to ensure that the observed differences are not simply due to chance or other confounding factors. Notably, during our study period, there was a change in state tax just before the presidential election in late June 2022, which remained in effect until the end of our sample in October 2023, and this change varied across states. To address these potential confounders and accurately measure the effect of privatization on prices, the next section employs a difference-in-differences model.

[6]One might be interested in examining a canonical DiD graph that compares outcomes pre and post-treatment in the Appendix, specifically in the section on Parallel Trends.

3 Price Effects of Privatization

We begin by outlining our empirical strategy and detailing the difference-in-differences estimator and the dataset used. Next, we present our baseline results, estimating the average treatment effect of refining plant privatizations in Brazil, followed by results that account for time and cohort heterogeneity. In both analyses, we apply the modifications to the two-way fixed effects estimator as recommended by Wooldridge (2021), addressing potential issues arising from the staggered adoption of the treatment.

3.1 Empirical Strategy and Data on Price Effects of Privatization

To measure the price effects of privatization, we employed a commonly used quasi-experimental identification strategy, difference-in-differences (DiD) research designs. It serves as valuable alternative to randomized controlled trials (RCTs) in cases like the privatization of RLAM and REMAN, where RCTs may not be feasible (Cunningham, 2021). Exploiting natural variations and exogenous shocks, the DiD allows us to analyze the causal impact of privatization sales. Assuming that fuel consumers or gas station owners did not influence the privatization sale process, which is a reasonable assumption, we can consider the privatization as a quasi-experimental setting.

The difference-in-differences method relies on the assumption of an exogenous shock, where the treatment group experiences the intervention (privatization) while the control group does not. By comparing the changes in outcomes between these groups before and after the intervention, researchers can estimate the causal effect of the intervention. The mathematical expression representing it is defined by Equation 1.

$$P_{it}^{f} = \alpha + \beta_{Priv} T_{it} + \gamma X_{it}^{'} + \delta_i + \theta_t + \varepsilon_{it} \tag{1}$$

In the equation, P_{it}^{f} represents the price of fuel f (gasoline, diesel, or ethanol) in nominal terms at gas station i during time t. The variable T_{it} acts as the treatment indicator, indicating whether the policy is in effect. Consequently, T_{it} takes a value of 1 if the gas station is located in Bahia and time t is post-privatization of RLAM or if the gas station is in Amazonas and time t is post-privatization of REMAN. In all other cases, T_{it} equals 0.

$X_{it}^{\prime}$ is a matrix incorporating control variables, including the brand of each gas station and a dummy variable indicating whether the gas station is situated in the state capital. δ_i and θt denote specific gas station and time effects, respectively. To clarify what we are estimating, β_{Priv} signifies the estimated average treatment effect, quantifying the privatization's average price impact per liter of fuel on consumers in Bahia and Amazonas, measured in BRL. We performed three estimations of Equation 1, one for each fuel type (gasoline, ethanol, and diesel).

Equation 1 represents the standard specification commonly referred to as the classic TWFE (Two-Way Fixed Effects) or the naive difference-in-differences (DiD) specification. However, recent literature has highlighted potential issues with this approach, particularly in cases where treatment is adopted in a staggered manner (De Chaisemartin & D'haultfœuille, 2023; Roth et al., 2023; Athey & Imbens, 2022; Baker et al., 2022). In our case, the privatizations occurred at different points in time, indicating staggered adoption. To address this, we applied the two-way Mundlak (TWM) regression method proposed by Wooldridge (2021). This ordinary least squares (OLS) estimator accommodates stag-

gered entry by incorporating unit-specific and time-specific cross-sectional averages into Equation 1, resulting in Equation 2.

$$P_{it}^{f} = \alpha + \sum_{t} \sum_{i} \beta_{it} \cdot T_{it} \cdot t \cdot i + \gamma X^{'} it + \delta i + \theta_{t} + \varepsilon_{it} \tag{2}$$

This approach allows us to distinguish the varying effects of the treatment across time and between the two treated cohorts. The other variables remain consistent with those described in Equation 1.

Additionally, on June 23, 2022, four months before Brazil's presidential election, the incumbent president implemented a significant reduction in state taxes. However, this reduction was uneven across states, making it difficult to fully capture its effect using time-fixed effects alone. To address this, we introduced a control variable that takes the value of one before the tax change and reflects one minus the tax reduction after June 2022. We used the logarithm of this variable in our analysis.

Data used in this subsection comes from the *Sistema de Levantamento de Preços* of the *Agência Nacional do Petróleo, Gás Natural e Biocombustíveis* (ANP, 2023). The survey is released every week, and each observation has the social name of the gas station, CNPJ[7], full address (state, municipality, street, number, and zip code), gasoline, diesel, and ethanol end-user prices and gas station brand[8]. Data goes from Jan-2019 to Oct-2023. We transformed this database into monthly price observations.

In summary, our dataset comprises gas station-level fuel prices and other variables from January 2019 to October 2023. The treatment was applied to two states—Bahia (from December 2021) and Amazonas (from December 2022), with no reversal through the sample period. To avoid spillover effects, our main specification excludes gas stations from other North and Northeast states. Notably, privatization was exogenous to both gas stations and consumers.

Before presenting the results, it is important to address the assumption of parallel trends. The estimators used in this analysis rely on a more flexible version of this assumption, where parallel trends are conditioned on observed covariates (Roth et al., 2023). Detailed tests and information on parallel trends, along with summary statistics, are provided in the Appendix. For those who may not refer to the Appendix, in summary, there are no observable pre-trends in the three markets (gasoline, diesel, and ethanol). Both control and treated groups exhibited similar trajectories before the privatization events (see Figures 5, 6, and 7 in the Appendix).

3.2 Results on the Price Effects of Privatization

Privatizing RLAM and REMAN led to a relative price increase in all three markets examined. On average, there was an overprice of 28 cents in the gasoline market, 15 cents in the diesel market, and 22 cents in the ethanol market (all values in Brazilian Real) (see Panel A in Table 1). To better understand the results, average prices in Brazil before the first privatization were 6.44 BRL for gasoline, 6.40 BRL for diesel, and 5.44 BRL for ethanol. Consequently, the overprice percentages for gasoline, diesel, and ethanol

[7]CNPJ is the Brazilian acronym for "Cadastro Nacional da Pessoa Jurídica" or the National Register of Legal Entities, a unique identification number assigned by the Brazilian Federal Revenue Service to businesses for tax and regulatory purposes.

[8]In this subsection, we used data obtained from `basedosdados.org` that compiled database from ANP (2023).

were 4.2%, 2.3%, and 4%, respectively.

Table 1: Impact of RLAM and REMAN Privatization on Fuel Prices

	Panel A			*Panel B*		
	Gasoline	Diesel	Ethanol	Gasoline	Diesel	Ethanol
Treated	0.277***	0.155***	0.216***	0.240***	0.148***	0.184***
	(0.020)	(0.022)	(0.022)	(0.019)	(0.022)	(0.021)
Num.Obs.	684,584	621,007	543,272	870,937	711,316	759,664
Std.Errors	by: city	by: city	by: city	by: city	by: city	by: city
FE: city	✓	✓	✓	✓	✓	✓
FE: time	✓	✓	✓	✓	✓	✓
Gasoline tax as control	✓	×	✓	✓	×	✓
Control group (all states)	×	×	×	✓	✓	✓

Notes: Our preferred specification, Panel A, presents results with North and Northeast states excluded from the control group, whereas Panel B displays results including those states. Both panels used the Differences in Differences (DID) method from Wooldridge (2021). Robust standard errors are in parentheses, adjusted for clustering by city. The symbols *, **, and *** denote rejections of the null hypothesis at significance levels of 10%, 5%, and 1%, respectively. We used prices in level, so the variable *Treated* represents the marginal effect of privatization on prices. We excluded capital fixed effects from our analysis as city fixed effects fully capture them. The control for gasoline tax variation is represented by the logarithm of one minus the tax variation.

We expanded the control group to include all states for robustness checks (Panel B in Table 1). This alternative specification resulted in a slight reduction of 4 cents in overpricing within the gasoline market, dropping from 28 to 24 cents. In the ethanol and diesel markets, the changes were minimal. The ethanol market saw a decrease of 3 cents (from 21 to 18 cents). Overall, expanding the control group led to lower overpricing effects in the light fuel markets (ethanol and gasoline), indicating that the influence of RLAM and REMAN extends beyond Bahia and Amazonas, the most affected states, into neighboring regions in the Northeast and North. However, there was no change in the diesel market's overpricing from Panel A to Panel B.

One could argue that firms may exploit market turmoil to increase their margins. In this context, gas station owners might have raised their margins precisely during the timing of the privatizations. To address this, we performed a similar analysis using wholesale prices, which is one step back in the supply chain. The results of this analysis (Table 2) closely mirror our previous findings (Table 1): privatization led to higher wholesale prices in the most affected states. In summary, the increase in end-user prices cannot be attributed to changes in the behavior of gas station owners in the most affected states and is very likely due to changes in pricing strategies in privatized refineries. This occurs primarily in the fossil fuel markets, as the ethanol market did not show any significant effects.

Exploiting Heterogeneity of Privatization Effects Across Time and Cohorts Results

After presenting the average effects of privatization on fuel end-user prices, two key questions arise: (i) How do price effects vary across cohorts – did consumers in Bahia experience different overpricing compared to those in Amazonas? (ii) Are the effects persistent, or

are they merely short-term? We first differentiate the average treatment effects by cohort (see Table 2).

Table 2: Impact of RLAM and REMAN Privatization by Cohort

	Bahia			*Amazonas*		
	Gasoline	Diesel	Ethanol	Gasoline	Diesel	Ethanol
Treated	0.246***	0.146***	0.219***	0.552***	0.236	0.181***
	(0.021)	(0.019)	(0.023)	(0.033)	(0.150)	(0.033)
Num.Obs.	684,584	621,007	543,272	684,584	621,007	543,272
Std.Errors	by: city	by: city	by: city	by: city	by: city	by: city
FE: city	✓	✓	✓	✓	✓	✓
FE: time	✓	✓	✓	✓	✓	✓
Gasoline tax as control	✓	×	✓	✓	×	✓
Control group (all states)	×	×	×	×	×	×

The table presents results excluding the North and Northeast states from the control group. Panel Bahia represents the average treatment effects for the cohort of gas stations in Bahia, while Panel Amazonas corresponds to the cohort in Amazonas. Both panels are derived from the estimations in Table 1, with the key distinction being that this table calculates ATT by cohort. Robust standard errors, adjusted for clustering at the city level, are provided in parentheses. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Prices are in levels, meaning the variable *Treated* captures the marginal effect of privatization on prices. Capital fixed effects are excluded, as city fixed effects account for them entirely. The gasoline tax variation is controlled using the logarithm of one minus the tax variation.

In the gasoline market, seven months after RLAM privatization, consumers in Bahia had overpricing exceeding 50 cents per liter of gasoline. The overpricing faced by consumers in Amazonas is even more pronounced, reaching values close to 1 BRL after five months of REMAN privatization (refer to Figure 3).

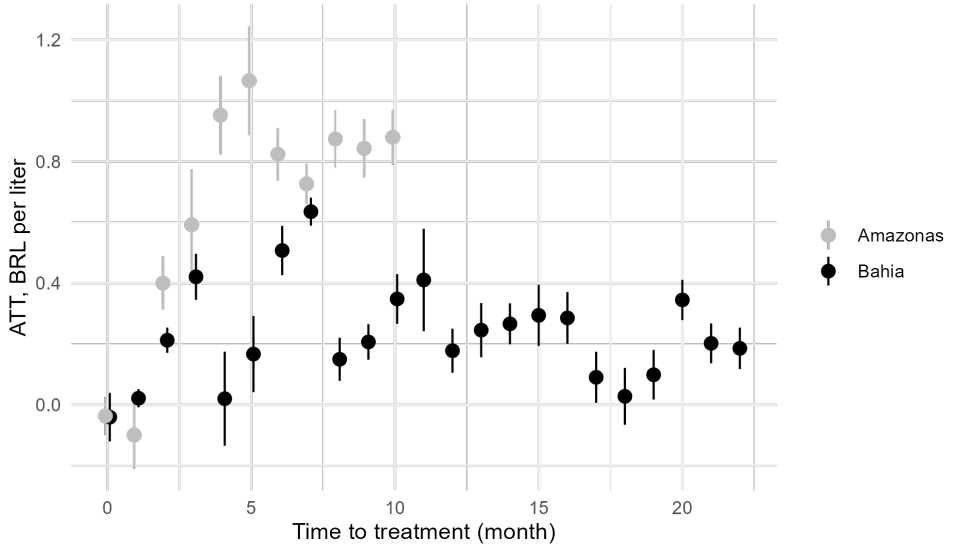
The diesel and ethanol markets exhibited closely aligned overpricing impacts between the two treated cohorts (see Figure 8 in the Appendix), with comparable effects faced by consumers in Bahia and Amazonas. Both markets experienced overpricing of approximately 50 cents five months after the privatization of their main oil refining.

A key concern regarding the overpricing observed in the three examined markets, and across both treated cohorts, is that in the final months of the treatment period, the trajectories show no clear trend toward zero effects (see Figures 3 and 8). This suggests that the overpricing resulting from privatization in Brazil's refining market may have a lasting impact.

4 Welfare analysis

Thus far, the analysis has demonstrated persistent overpricing in end-user fuels caused by RLAM and REMAN privatization sales. The absence of any signal indicating a temporary nature of this overpricing is particularly troubling. The next logical step is to gauge the welfare effects resulting from this policy. To assess this, we calculated fuel demand in the affected states, Bahia and Amazonas, and employed some back-of-the-envelope calculations.

Figure 3: Gasoline Overpricing Across Time and Cohorts (Wooldridge, 2021)



Notes: The points are the Average Treatment Effect (ATT) of privatization sales for consumers in Bahia and Amazonas over successive months post-privatization. Bars show the confidence intervals at the 95 percent level. We used the Two-Way Mundlak proposed by Wooldridge (2021). Amazonas have fewer observations due to the one-year lag in privatizing their refinery compared to Bahia's refinery.

4.1 Fuel demand in states of Bahia and Amazonas

Numerous studies have explored fuel demand in Brazil, with a predominant focus on the gasoline and ethanol markets, as seen in works such as De Freitas & Kaneko (2011), Santos (2013), Junior (2013), and Cardoso et al. (2019), among others. However, our contribution lies in scrutinizing the repercussions of price shifts within two specific states. Acknowledging the regional nuances in fuel demand parameters (Cardoso & Bittencourt, 2013), we conducted estimations to assess demand patterns specifically for Bahia and Amazonas. All the cited papers relied on more aggregated databases, encompassing either country-level or state-level observations. In contrast, our study benefited from a more granular dataset, providing city-level information every month.

There is a well-known simultaneity between price and quantity demanded. To address this issue, we used Two-Stage Least Squares (2SLS) to measure the fuel demand in Bahia and Amazonas municipalities. The first and second stages are given by:

$$First \quad Stage: \quad P_{it}^{f} = \theta + \hat{\phi} Z_{it}^{f} + \eta Inc_{it} + \kappa_t + \omega_i + \upsilon_{it} \tag{3}$$

$$Second \quad Stage: \quad Q_{it}^{f} = \alpha + P_{it}^{f} + \beta P_{it}^{a} + \gamma Inc_{it} + \lambda_t + \mu_i + \varepsilon_{it} \tag{4}$$

In Equation 3, the variables are defined as follows. Q_{it}^{f} denotes the logarithm of the quantity (in liters) of fuel f (gasoline, diesel, or ethanol) sold in municipality i and period t, while P_{it}^{f} denotes the logarithm of the price of fuel f. The variable $\hat{P}_{it}^{a}$ represents the price of the substitute fuel: for gasoline, ethanol is considered the substitute, and for ethanol, gasoline is the substitute; there is no substitutability for diesel. The instrumental variables Z_{it}^{f} are constructed following the Hausman instrument approach, utilizing contemporaneous prices of the same fuel in different geographic markets (Berry & Haile, 2021). Additionally, we include international prices of oil for gasoline and diesel, and

sugar prices for ethanol; to account for time and city variation, these international prices are multiplied by the distance to the nearest refinery. Inc_{it} represents municipal income. Finally, t and i are fixed effects for time and municipality, respectively, and ε_{it} and υ_{it} represent the idiosyncratic errors.

The demand estimation is based on a city-month database. Regarding the Hausman Instruments used, when referring to *other geographic markets*, we are specifically considering other regions within Brazil. For instance, when estimating diesel prices for a city in the North region, the instrumental variables consist of diesel prices from the other four regions in Brazil. As said, we also used international oil prices multiplied by the distance between the city and the nearest refinery. In the analysis of gasoline demand, we accounted for the endogeneity of both gasoline and ethanol prices. However, in the estimation of diesel and ethanol demand, only own-prices were treated as endogenous.

The findings, presented in Table 3, reveal that diesel demonstrates an own-price elasticity of approximately -0.5, while gasoline exhibits a price elasticity of -0.7. The cross-elasticities align with expectations, indicating positive effects on demand, with values of 0.3 for the gasoline market and 8.4 for the ethanol market. A noteworthy deviation from existing literature on fuel demand in Brazil is observed in the estimates for the ethanol market, where values are higher. This discrepancy can be attributed to the possibility that Bahia and Amazonas may not be significant ethanol consumers. Consequently, even minor price increases could lead to substantial reductions in consumption.

Table 3: Fuel Demand in Bahia and Amazonas: city-month, TWFE

	Gasoline	Diesel	Ethanol
Gasoline price (log)	−0.719**		8.392***
	(0.282)		(1.313)
Ethanol price (log)	0.316		−8.651***
	(0.287)		(1.344)
Diesel price (log)		−0.535***	
		(0.074)	
Income proxy (log)	0.515***	0.475***	0.830***
	(0.007)	(0.010)	(0.035)
Num.Obs.	3,588	3,835	3,588
R2	0.590	0.376	0.180
Instruments			
Gasoline prices (neighbors, log)	✓		
Diesel prices (neighbors, log)		✓	
Ethanol prices (neighbors, log)	✓		✓
Distance to the closest refinery (level)	✓	✓	
Global oil price (level)	✓	✓	
Global sugar price (level)	✓		✓
Endogenous prices	gasoline and ethanol	diesel	ethanol

Notes: Standard errors are in parentheses. The symbols *, **, and *** denote rejections of the null hypothesis at significance levels of 10%, 5%, and 1%, respectively. The model is specified in a log-log form, with the estimated parameters representing elasticities.

The diesel market exhibits an own-elasticity of approximately -0.5, and no cross-

elasticity is calculated. In Brazil, there is a legal separation between gasoline and ethanol, which are used for cars and motorcycles, while diesel is designated exclusively for heavy-duty vehicles such as buses and trucks. Therefore, given the type of vehicle, there is no direct substitute for diesel.

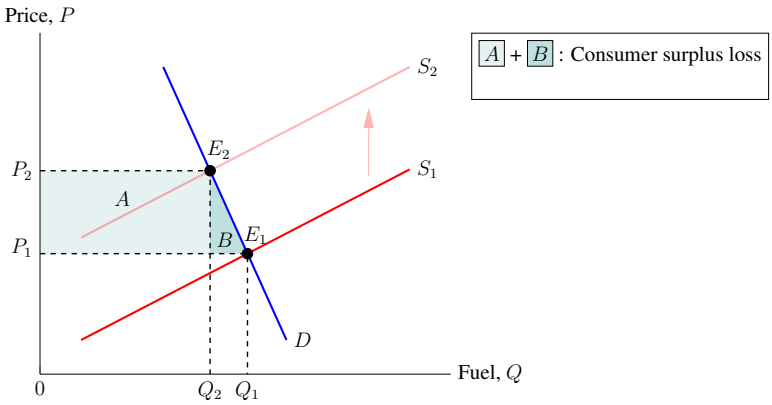
4.2 Welfare Effects in Bahia and Amazonas

A common welfare measure is the assessment of changes in consumer surplus (Hausman & Newey, 1995; Dargay & Goodwin, 1995). Figure 4 illustrates the supply shift after the privatization sales where the variation in consumer surplus is given by:

$$\Delta CS = A + B = (\Delta P.Q_2) + (\frac{\Delta P.\Delta Q}{2}) \tag{5}$$

The change in consumer surplus (ΔCS) captures the overall welfare impact for a specific market. Thus, we repeated this calculation for the three markets targeted here (gasoline, diesel, and ethanol) and for the two privatization sales (REMAN and RLAM). ΔP denotes the difference in fuel prices caused by each privatization sale in each fuel market. The quantity of fuel sold after each privatization is denoted by Q_2, and the change in quantity sold is ΔQ. This change in quantity is estimated using demand parameters and the time and cohort-specific price effects.

Figure 4: Consumer surplus loss



Notes: This figure has been created based on the code provided by Bandekar (2021). The S denotes the supply curve, while D represents the demand curve. The subscripts 1 and 2 indicate the pre and post-privatization scenarios, respectively. The E represents the equilibrium points. The vertical axis represents prices, and the horizontal axis represents quantities.

Table 4 illustrates a substantial decrease in welfare, totaling approximately 2.6 billion BRL for consumers in Bahia and Amazonas. The welfare impact in Bahia's market is almost 2 billion BRL, while it amounts to 0.6 billion BRL in Amazonas. Despite encountering similar overpricing in both markets, the significant difference is attributed to Bahia being a larger market and the first cohort treated. The post-treatment period in Bahia spans 22 months, whereas it covers only 10 months in Amazonas.

Table 4: Welfare Variation by Fuel Following Privatization Sales (in millions of BRL)

	RLAM – Bahia			*REMAN – Amazonas*			Total
	Gasoline	Diesel	Ethanol	Gasoline	Diesel	Ethanol	
Area A	1.009	816	110	378	221	41	2,575
Area B	13	16	27	13	3	3	75
A + B	1.022	832	137	391	224	44	2,650

Notes: The period of 22 months after RLAM privatization goes from January 2022 to October 2023. The period of 10 months after REMAN privatization goes from January 2023 to October 2023. Area A is the direct impact of privatization, $\Delta Price * Q_2$, while area B is the indirect impact, $\Delta Consumption * \Delta Price$, as defined in Figure 4.

The gasoline and diesel markets collectively account for 93% of the observed welfare loss among the three markets, with approximately 1.4 billion BRL for gasoline and 1 billion BRL for diesel. While overpricing in the ethanol market is noticeable, the lower levels of ethanol consumption in Bahia and Amazonas contribute to its comparatively smaller impact on the overall welfare loss.

The direct impact of overpricing, the value found by the amount of fuel sold multiplied by the overpricing, is 97% of the total effect. The indirect impact caused by changes in consumption by demand is only 3% of the total impact.

5 Conclusion and Policy Implications

In this paper, we examined the impact of the privatization of the Refinaria Landulpho Alves (RLAM) and Refinaria Isaac Sabbá (REMAN). We focused on end-user fuel prices, comparing prices in the gas stations of the two most affected states, Bahia (RLAM) and Amazonas (REMAN), to the rest of the country in a DiD approach. We also estimated fuel demands in Bahia and Amazonas and conducted a welfare analysis. Contrary to the belief that privatization always leads to lower prices, our findings show that consumers in most affected states experienced significant increases in end-user fuel prices following privatization sales. On average, gasoline prices were overpriced by 0.29 BRL per liter, diesel prices by 0.14 BRL per liter, and ethanol prices by 0.21 BRL per liter. It resulted in a welfare loss of 2.6 billion BRL for consumers in Bahia and Amazonas from January 2021 to October 2023. The diesel and gasoline markets primarily drove the decline in welfare.

We conducted initial robustness checks on our price impact estimations, altering the control group from excluding the North and Northeast gas stations to including all gas stations in the country. This adjustment led to minimal deviations, as detailed in Table 1. Additionally, we compared our chosen approach, inspired by Gardner et al. (2023) and Wooldridge (2021), with alternative estimators. For instance, our preferred method revealed a 27-cent overpricing in the gasoline market. Replicating the exact estimates using a two-way fixed-effects estimator resulted in a 28-cent overpricing, while employing the Callaway & Sant'Anna (2021) estimator yielded 23 cents of overpricing. Despite marginal differences across various estimators, the overarching narrative remains consistent.

We assert that the privatization sales have increased prices in Bahia and Amazonas due to a lack of regulation. The sale of refining plants treated them as competitive entities, but they are integral components of a national monopoly. Without additional stringent regulations, privatization sales have resulted in the formation of local monopolies. Given

that the privatization of these two firms is part of a larger plan involving eight plants, *the most crucial policy recommendation* is straightforward: either halt or reconsider the entire privatization initiative in the Brazilian refining market. As privatization can take several forms, the Brazilian government needs to think of new approaches because the used ones do not work.

Our findings provide a conservative estimate of the welfare loss resulting from those privatization sales for several reasons. First, we are not considering all products sold by the two privatized refining plants. They also sell liquefied petroleum gas, naphtha, and aviation kerosene. Hence, the welfare loss could be more significant if they also practice similar pricing policies in those markets. Second, there is a possible impact on neighboring markets, with higher end-user prices affecting consumers contiguous to the most affected states. Third, higher energy prices indirectly influence various other prices in the economy. Therefore, accounting for this indirect effect would lead to higher welfare losses. Consequently, *our second policy recommendation* advocates expanding the scope of our study to assess the broader impact of privatization sales on the Brazilian economy.

As our focus was on end-user prices, we cannot guarantee that the new owners of RLAM and REMAN absorbed the entire consumer welfare loss. It is possible, for example, that Petrobras was charging subsidized prices in those states, and current prices only reflect the end of those subsidies. What we can assert is that consumers in Bahia and Amazonas experienced a loss of welfare. It would be valuable to conduct a similar analysis as we did here, shedding light on refining and other intermediate prices to understand the situation comprehensively.

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Appendix

Summary Statistics

Table 5: Summary statistics for three data sets: gasoline, diesel and ethanol market – gas station level

Variable	N	Mean	St. Dev.	Min	Max
Panel A – Gasoline					
Price	2,441,683	4.900	0.886	2.870	8.990
Latitude	2,441,683	−20.679	6.144	−32.035	2.824
Longitude	2,441,683	−48.126	5.043	−72.676	−38.222
Capital	2,441,683	0.200	0.400	0	1
Treated	2,441,683	0.010	0.099	0	1
Month	2,441,683	5.767	3.163	1	12
Year	2,441,683	2,019.757	1.527	2018	2023
Panel B – Diesel					
Price	1,267,164	4.022	1.026	2.453	8.999
Latitude	1,267,164	−20.150	6.398	−32.035	2.824
Longitude	1,267,164	−48.676	5.511	−72.676	−38.222
Capital	1,267,164	0.121	0.326	0	1
Treated	1,267,164	0.009	0.092	0	1
Month	1,267,164	5.766	3.132	1	12
Year	1,267,164	2,019.546	1.426	2018	2023
Panel C – Ethanol					
Price	2,112,180	3.577	0.912	1.799	7.980
Latitude	2,112,180	−20.888	4.958	−32.035	2.824
Longitude	2,112,180	−47.606	4.573	−72.676	−38.222
Capital	2,112,180	0.196	0.397	0	1
Treated	2,112,180	0.009	0.097	0	1
Month	2,112,180	5.838	3.168	1	12
Year	2,112,180	2,019.661	1.443	2018	2023

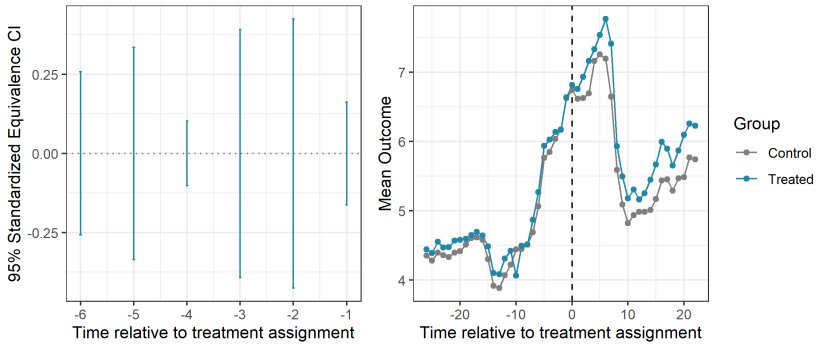
Notes: The data used in this table is from ANP (2023). The variable *Capital* indicates whether the gas station is located in a state capital. All prices are expressed in Brazilian Real (BRL) in nominal terms.

Parallel Trends

We employed estimators derived from Gardner et al. (2023) and Wooldridge (2021), both relying on the conditional parallel trends assumption. To validate this assumption, we conducted tests using the framework outlined by Egami & Yamauchi (2023). The outcomes for the gasoline, diesel, and ethanol markets are depicted in the following three figures, revealing an absence of pre-trends across all three markets. The following figures are estimates based on Equation 6.

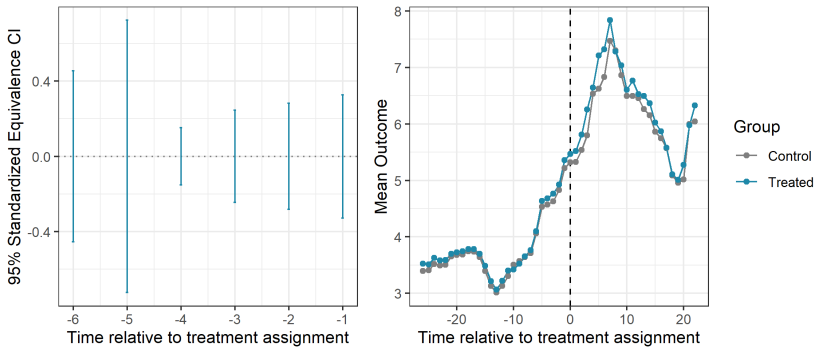
$$P_{it}^{f} = \alpha + \sum_{\tau=-q}^{-1} \beta_{\tau} T_{i\tau} + \sum_{\tau=0}^{m} \beta_{\tau} T_{i\tau} + \gamma X_{it}^{'} + \delta_i + \theta_t + \varepsilon_{it} \tag{6}$$

Figure 5: Gasoline: Pre-trends and pre- and post-privatization outcomes



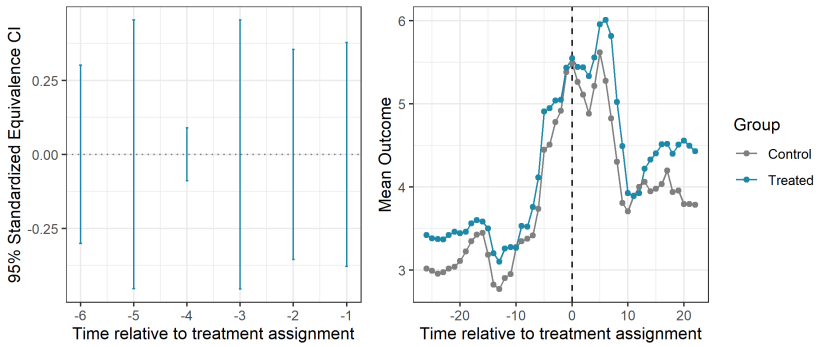
Notes: These graphs are constructed using codes from Egami & Yamauchi (2023). The left side displays confidence intervals for pre-trends until six months before privatization. On the right side, outcomes for the treated group (gas stations in Bahia and Amazonas) are compared with the control group (gas stations in all other states, excluding those in the North and Northeast regions). The mean outcome is in nominal BRL.

Figure 6: Diesel: Pre-trends and pre- and post-privatization outcomes



Notes: These graphs are constructed using codes from Egami & Yamauchi (2023). The left side displays confidence intervals for pre-trends until six months before privatization. On the right side, outcomes for the treated group (gas stations in Bahia and Amazonas) are compared with the control group (gas stations in all other states, excluding those in the North and Northeast regions). The mean outcome is in nominal BRL.

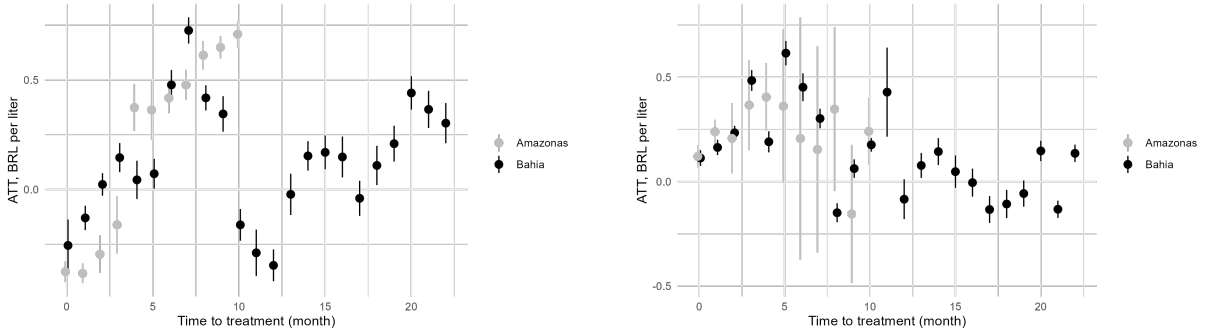
Figure 7: Ethanol: Pre-trends and pre- and post-privatization outcomes



Notes: These graphs are constructed using codes from Egami & Yamauchi (2023). The left side displays confidence intervals for pre-trends until six months before privatization. On the right side, outcomes for the treated group (gas stations in Bahia and Amazonas) are compared with the control group (gas stations in all other states, excluding those in the North and Northeast regions). The mean outcome is in nominal BRL.

Cohort-Specific Overpricing for Other Fuels

Figure 8: Overpricing across time and cohorts for Ethanol and Diesel



The points represent the Average Treatment Effect (ATT) of privatization sales for consumers in Bahia and Amazonas over successive months post-privatization for ethanol and diesel, respectively. Bars show the confidence intervals at the 95% level. We used the Wooldridge (2021) estimator. Amazonas have fewer observations due to the one-year lag in privatizing their refinery compared to Bahia's refinery.