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Passing through the supply chain: Implications for market power[☆]

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ABSTRACT

In this paper, we study the connection between pass-through and market power in the Brazilian Liquefied Petroleum Gas (LPG) industry. We use a state tax shock and apply a difference-in-differences strategy to estimate pass-through – at different levels of the supply chain – and an instrumented difference-in-differences strategy to estimate demand, and then feed a theoretical model to make inferences about a conduct parameter – that measures market power. We find an incomplete pass-through at the distribution level and for the supply chain as a whole, and a more-than-complete one at the retail level. Furthermore, we estimate price-elasticity of demand to be greater than one. When we feed a theoretical model of pass-through under imperfect competition with these estimates, we obtain a high conduct parameter at the whole supply chain level and an even higher one at the retail level alone. These results show that considering only the whole supply chain pass-through may lead to hasty conclusions about market power. Besides contributing to the empirical literature that connects pass-through with market power, we contribute to on-going national discussions regarding competitiveness in the LPG industry.

1. Introduction

The concept of pass-through[2] is very important in economics and its study embraces a wide range of topics in industrial organization. Theory shows that pass-through is determined not only by supply and demand, but also by market power (Bulow and Pfleiderer, 1983; Seade, 1985; Delipalla and Keen, 1992; Anderson et al., 2001; Weyl and Fabinger, 2013). Many empirical studies, therefore, have sought to make a connection between pass-through and the existence of market power, so to elucidate potential welfare implications. In the energy sector, pass-through receives special attention (Fell, 2010; Fabra and Reguant, 2014; Stolper, 2016; Duso and Szucs, 2017; Genakos and Pagliero, 2019) due to the market power

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[1] All errors are our own.

[2] The pass-through rate can be defined as "the rise in price to consumers for each infinitesimal unit of specific tax imposed" (Weyl and Fabinger, 2013).

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that producers and distributors usually hold and manifest through markups over marginal costs, leading to welfare decreases (Borenstein et al., 1997).

In this paper, we study the connection between pass-through and market power in the Brazilian Liquefied Petroleum Gas (LPG) market. We estimate pass-through at different levels of the supply chain – including the distribution and retail levels, and the supply chain as a whole –, estimate demand, and calibrate a theoretical model to make inferences regarding a conduct parameter – an elasticity-adjusted Lerner index that measures market power – at both the retail and the whole supply chain levels.

In Brazil, the interest in the LPG market is due to the enormous reach and use of this type of gas as fuel for cooking, which is present in 100% of the country's municipalities and used by over 90% of households. Its price represents a substantial share of the monthly spending of the lowest income population (Sindigas, 2019; 2021). Therefore, cost changes along the supply chain of LPG directly affect the welfare of most Brazilian families, especially the lowest income ones.

The Brazilian LPG industry comprises production, distribution, and retail activities. The distribution price faced by retailers is made up of the producer's price, social contributions and social security related taxes, a state tax, and the distributor's gross margin; and the retail price paid by consumers is the sum of the distribution price with the retailer's gross margin (Petrobras, 2019). At the production level, there is one big player that holds monopoly power; at the distribution level, the market is concentrated in the hands of five big players; and, at the retail level, the market is made up of numerous players. Distributors are allowed to sell LPG either to final consumers directly or to retailers, who then reach consumers (Araujo-Jr., 2009). Given this industry structure, the National Petroleum Agency (ANP) and the National Competition Regulator (CADE) have faced cases of coordination among distributors to impose retail prices and retaliate retailers that oppose their conditions. Even though several cases have been investigated, no sound evidence against competition in the retail market has been documented to date.

In January 2017, the Brazilian state of Minas Gerais suffered a sudden shock in the LPG state tax. This shock is the basis of our empirical strategies used to estimate pass-through and demand. To estimate pass-through, we use a Difference-in-Differences strategy, in which we compare municipalities located in Minas Gerais to municipalities located in bordering federative units, before *versus* after the tax shock. In order to estimate demand, we use an Instrumented Difference-in-Differences strategy, in which exogeneity from the tax shock is used to isolate the "good" variation in price.

Empirical results show that pass-through in the distribution segment and the industry as a whole is incomplete, estimated at about 0.61 and 0.76, respectively. Pass-through in the retail segment, however, is more-than-complete, estimated at about 1.24. As for demand estimation results, we find price-elasticity estimates to range from 1.06 to 1.14, using our preferred log-log specification. And, when we allow for a more flexible functional form, using a quadratic specification, we find evidence of a convex demand curvature. Results for the tax shock effect on prices are robust to several checks.

When we feed the theoretical model of pass-through under imperfect competition with these estimates, we find that – for a supply elasticity ranging from 0.1 to 0.5 – the conduct parameter of the supply chain as a whole ranges from 0.61 to 1.02 and the retail conduct parameter ranges from 0.78 to 1.07. Moreover, in both cases, the conduct parameter decreases as supply elasticity increases. If we take supply elasticity to the extreme – that is, if we consider an infinitely elastic supply –, the conduct parameter of the whole supply chain approaches zero, but the retail conduct parameter remains higher – at about 0.2. Therefore, we find evidence of market power in the retail segment for any degree of supply elasticity. Furthermore, results show that if we only consider the whole supply chain pass-through, we underestimate the conduct parameter in the retail market.

The theoretical literature that entails both pass-through and market power started being built long ago. Jenkin (1872) defined pass-through under perfect competition and showed that, in this case, pass-through depends on the relative elasticity of demand and supply. Bulow and Pfleiderer (1983) and Seade (1985) theoretically addressed pass-through in the monopoly case. These authors made the connection between the elasticity of marginal surplus and the curvature of demand, and showed how it affects pass-through when there is no competition in the market. Delipalla and Keen (1992) and Anderson et al. (2001) advanced the work on pass-through under imperfect competition for specific models, adding a constant conduct parameter to the equation. More recently, Weyl and Fabinger (2013) generalized pass-through under imperfect competition for any symmetric model of complete information, allowing the conduct parameter to vary with quantity.

The empirical literature that connects pass-through and market power comprises two types of studies, one that uses structural model approaches and another that uses reduced form approaches. As discussed in Duso and Szucs (2017), studies that use structural models validate that markup adjustments can determine incomplete pass-through and focus on disentangling the mechanisms involved in this relationship – see, for instance, Bettendorf and Verboven (2000), Goldberg and Verboven (2001), Devereux and Engel (2002), Nakamura and Zerom (2010), Hellerstein and Villas-Boas (2010), Bonnet et al. (2013). In studies that use reduced form approaches, researchers have been engaged in documenting how pass-through changes with different degrees of competition and (to some extent) explaining their pass-through estimates with market power arguments (Stolper, 2016; Duso and Szucs, 2017; Cabral et al., 2018; Francois and Manchin, 2019; Genakos and Pagliero, 2019). Many of these studies have focused either on the supply chain of an industry as a whole or on a specific segment of the chain. We emphasize the importance of looking at different segments of the supply chain, so that the overall chain pass-through and conduct parameter do not mask what happens at a specific level.

More related to our work, Pless and Benthem (2019) estimate both pass-through (to the final consumer) and demand to make inferences regarding market power in the Californian solar energy industry. The authors aim at presenting an empirical test for their theoretical argument that a more-than-complete pass-through, combined with a sufficiently convex demand, is enough to say that a market is imperfectly competitive – if certain uncommon conditions can be ruled out. Although they use empirical estimates along with theory to say something about market power, they do not calibrate a theoretical model to calculate the conduct parameter – as we do in this paper.

Our paper is unique for we estimate pass-through along the supply chain to make inferences about a conduct parameter at both the whole supply chain and the retail levels. Moreover, we provide an additional empirical test for what Pless and Benthem (2019) argue in their paper, by showing that over-shifting in the retail segment and a convex demand imply the existence of market power for any level of supply elasticity. Thereupon, we believe to be contributing to both the applied literature that connects pass-through and market power through reduced form approaches and the on-going policy discussions regarding the competitiveness of the Brazilian LPG retail market in which ANP and CADE have been involved.

The rest of the paper is organized as follows. In Section 2, we provide background information on the Brazilian LPG market. In Section 3, we provide the theoretical setup, including the model that we calibrate and how we go about calibration. In Section 4, we present our data and the state tax shock experienced by Minas Gerais. In Sections 5 and 6, we present our empirical analyses of pass-through and demand, respectively. Section 7 is dedicated to the calibration of the theoretical model and consequent results. Finally, in Section 8, we present a brief discussion about our results and conclusions.

2. Background: The Brazilian LPG market

In Brazil, LPG is mainly used as fuel for cooking. It reaches 100% of municipalities and over 90% of households. No other energy source in the country can be compared to LPG in terms of importance, coverage, and reliability (Sindigas, 2019; 2021). The price of the 13-kilogram (kg) cylinder of LPG – the type mostly used by Brazilian households – represents a relevant share of the budget of low-income families – 3.4–5.0% of the minimum wage in the period of 2010–2020 (Sindigas, 2021) – and, for this reason, market power issues in this market can have important welfare implications.

LPG is a mixture of two petroleum gases, propane and butane. The production process of LPG begins with the extraction of oil and natural gas from the fields. Oil and natural gas are then moved to the refineries – or production centers – where the cracking process occurs and LPG is obtained. In Brazil, this activity is carried out by the monopolist Petrobras, which runs 23 production centers, ten in the Southeast, six in the Northeast, five in the South, and two in the state of Amazonas (Araujo-Jr., 2009). Next, the gas is directed by ducts to storage terminals, almost always, in areas close to the production centers.[3] LPG is then sent by ducts to 175 distribution plants (ANP, 2020a), where it is packaged in cylinders. Finally, distribution companies either distribute – mainly by road – LPG cylinders to retailers or deliver the product directly to final consumers,[4] acting as retailers themselves (Araujo-Jr., 2009; ANP, 2020b). Retailers are responsible for representing and promoting distributors' brands, as well as providing after-sale technical assistance to consumers (CADE, 2011).

As for how the LPG price is formed in Brazil, we can list 5 components: [i] refineries' price, determined by Petrobras; [ii] social contributions and social security related taxes (PIS/PASEP and COFINS); [iii] state tax (ICMS); [iv] distributor's gross margin; and [v] retailer's gross margin. Distributors buy LPG for the sum of the refineries' price with social contributions, social security related taxes, and the state tax. Distributors then add their gross margin and sell the product to retailers. Finally, retailers add their gross margin on top of the price practiced by distributors and sell LPG cylinders to the final consumer. It is worth noting that gross margins include both the costs incurred by distributors and retailers – such as transportation costs – and their net margins (Petrobras, 2019).

Transportation logistics has a decisive influence on the formation of the final price of the gas cylinder and on the competitive conditions in force in the LPG sector. According to Araujo-Jr. (2009), due to the precarious transportation infrastructure in various regions of the country, the price paid by the final consumer is a direct function of the distance between the municipality of his/her residence and the nearest base of LPG supply. The author also says that due to the regional distribution of supply bases and bottling units, changes in transportation costs tend to affect retail activities more intensively than distribution activities.

With regards to geographic dimension, each state (or federative unit) is defined as a distinct distribution market of LPG. The distribution market is known to be very concentrated. Although there are 20 authorized distribution companies in the country, over 90% of the country's LPG market share is held by only 5 distributors. At state level, the market is even more concentrated. In some cases, there is only one distributor serving a whole state (Araujo-Jr., 2009; Sindigas, 2021). At retail level, markets are more local – although no precise geographic delimitation is defined – and made of numerous players (Araujo-Jr., 2009).[5] In this paper, we define each municipality as a distinct retail market of LPG.

The National Petroleum Agency (ANP) and the National Competition Regulator (CADE) have been involved in on-going discussions regarding competition in the LPG market. The ANP and CADE seek to ensure that the retail market is competitive, despite the established concentration in the distribution market.

Several antitrust cases in the LPG market have been investigated by CADE. Each of them tells a unique story, but some patterns can be observed in all of the cases, including: [i] price coordination between distributor and retailers; [ii] geographical market segmentation among distributors; [iii] exclusive dealing agreements between distributor and retailers; and [iv]

[3] In 2009, there were 32 storage terminals of LPG in Brazil (Araujo-Jr., 2009).

[4] Retailers are responsible for 96% of all sales of 13-kg LPG cylinders to the final consumer, while distributors are responsible for only 4% of them (LCA, 2015).

[5] There are over 61 thousand retailers spread over 97% of Brazilian municipalities (Sindigas, 2021).

distributor selling LPG to clandestine retailers as a way of punishing sellers who deviate from the collusion. At the heart of all these cases is an issue of vertical restrictions among distributors and retailers to increase market power.[6]

Regulatory changes concerning the vertical integration of distributors into the retail market have been in the center of the debate in this industry.[7] Vertical integration was allowed without restrictions until 2016, when ANP enacted a law imposing conditions to it; then, in 2019, this law was reverted and integration was once again allowed without restrictions. It is important to note that the aforementioned cartel case investigations happened both in the period of 2016–2019 and prior to it.

The main argument of the regulator in favor of vertical integration is the low concentration of retailers and the high concentration of distributors, which may imply high competitiveness. In fact, despite the investigations and discussions, sound evidence of market power in the retail segment has not been presented to date.

3. Theoretical setup: Pass-through and market power

The generalization of pass-through theory under imperfect competition is essentially a combination of the perfect competition and monopoly cases. Therefore, we present these two extreme cases first.

Jenkin (1872) shows that, under perfect competition, pass-through of a tax is determined by the relative elasticity of demand and supply. In special, the more inelastic side of the market carries the burden of the tax. Consider the classic case in which demand is downward sloping and supply is upward sloping. Consider also that all firms are identical, consumers and producers take price as given, and they choose quantities to maximize welfare. Let p denote the price paid by consumers and t denote a per-unit tax paid by producers. Hence, in equilibrium, aggregate demand equals aggregate supply, $D(p) = S(p-t)$.

We are interested in pass-through, that is, in how consumer price changes with a marginal increase in tax. Thus, our interest lies in $\rho = \frac{dp}{dt}$. Under this setup, Jenkin (1872) shows that, by the implicit function theorem, $D(p) = S(p-t)$ implies that:

$$\rho = \frac{1}{1+\frac{\epsilon_D}{\epsilon_S}} \tag{1}$$

where ϵ_D is the elasticity of the aggregate demand and ϵ_S is the elasticity of the aggregate supply.

As discussed in Pless and Benthem (2019), Bulow and Pfleiderer (1983), Seade (1985) and Weyl and Fabinger (2013) show that, in the monopoly case, pass-through can be obtained by "solving the monopolist's maximization problem and finding the rate at which price changes with marginal cost". Consider that the monopolist has a concave profit function, and that the cost, $c(q)$, and demand functions are infinitely differentiable. Let $p(q)q$ represent the monopolist's revenue and t denote a per-unit tax. Hence, the monopolist chooses quantity so that $mr(q) = mc(q) + t$, where $mr(q)$ is the marginal revenue and $mc(q)$ is the marginal cost. With this setup, one can derive $\rho = \frac{dp}{dt}$ to reach the following equation:

$$\rho = \frac{1}{1+\frac{\epsilon_D - 1}{\epsilon_S}+\frac{1}{\epsilon_{ms}}} \tag{2}$$

where ϵ_{ms} is the elasticity of the inverse marginal consumer surplus function, that is $\epsilon_{ms} = \frac{ms}{ms'q}$.[8]

As highlighted by Seade (1985), the new term, ϵ_{ms}, measures the curvature of the (logarithm of) demand. He defines $E \equiv 1 - \frac{1}{\epsilon_{ms}}$, so that $\frac{1}{\epsilon_{ms}} = (1-E)$. Eq. (2), then, becomes:

$$\rho = \frac{1}{1+\frac{\epsilon_D - 1}{\epsilon_S}+(1-E)} \tag{3}$$

It is important to note that, when $\frac{1}{\epsilon_{ms}} > 0$, demand is log-concave. And, when $\frac{1}{\epsilon_{ms}} < 0$, demand is log-convex. Furthermore, a particular case of a log-convex demand is the isoelastic demand, where $\epsilon_{ms} = -\epsilon_D$. In this case, for a downward sloping demand, we have that $E = 1 + \frac{1}{|\epsilon_D|}$, which will be very useful later in this paper.

At last, consider a context of imperfect competition, in which there are n firms, each producing a single product, and a demand system assumed to be fully symmetric. Consider that all firms have the same cost function and that, for any firm i, the cost of producing quantity q_i is denoted by $c(q_i)$. The price that clears the market depends on the quantity produced and sold by each of the firms. If we let the quantity produced and sold by each firm be equal to the same number q, the market-clearing price can be written as $p(q)$, which is independent of i. The derivative of price, $p'(q)$, then, captures changes in the price of any of the goods given a simultaneous marginal symmetric increase of all quantities. Now, consider also that $\epsilon_D = -(p/qp')$ is the elasticity of market demand and $\theta = [(p - mc - t)/p]\epsilon_D$ is a conduct parameter – defined as the elasticity-adjusted Lerner index as in Genesove and Mullin (1998)'s variation of Bresnahan (1989). The conduct parameter, θ, measures market power and assumes values between 0 and 1. In the case of perfect competition, $\theta = 0$, whereas in the case of monopoly, $\theta = 1$.

[6] See, for instance, Administrative Processes Number 08012.006043/2008-37, 08012.001286/2012-652, 08700.003067/2009-67, 08700.001275/2017-31, and 08700.000379/2020-24.

[7] See ANP Resolution Number 49 and 51 from 2016.

[8] Note that marginal surplus is defined as $ms \equiv -p'q$.

With this imperfect competition scenario, we have that quantity is chosen so that $p(q) - \theta ms(q) = mc(q) + t$, where ms is the marginal consumer surplus per firm. Under this setup, one can derive $\rho = \frac{dp}{dt}$ to reach the following equation:

$$\rho = \frac{1}{1+\frac{\theta}{\epsilon_\theta}+\frac{\epsilon_D-\theta}{\epsilon_S}+\theta(1-E)} \tag{4}$$

where $\epsilon_\theta = \frac{\theta}{q(d\theta/dq)}$; that is, ϵ_θ summarizes how conduct changes with quantity.

Equation (4), presented by Weyl and Fabinger (2013),[9] generalizes the analyses of both Delipalla and Keen (1992) and Anderson et al. (2001). In fact, as Weyl and Fabinger (2013) argue, this equation generalizes pass-through for "any commonly used complete information symmetric model".

Now, note that ϵ_θ is a new term, not present in Eq. (3). We, however, follow other studies in the literature and adopt a constant conduct model.[10] Hence, $\frac{1}{\epsilon_\theta} = 0$ and Eq. (4) can be written as:

$$\rho = \frac{1}{1+\frac{\epsilon_D-\theta}{\epsilon_S}+\theta(1-E)} \tag{5}$$

As one can note, in the case represented by Eq. (5), the relative importance of the demand curvature and the relative elasticities of demand and supply is determined by θ, the conduct parameter (Weyl and Fabinger, 2013). In the case of a perfectly competitive market, where $\theta = 0$, Eq. (5) reduces to Eq. (1), and we go back to Jenkin (1872)'s result. In the case that $\theta = 1$, Eq. (5) becomes Eq. (3), which summarizes pass-through in the monopoly case.

Assuming a log-convex demand – i.e., $E > 1$ –, under imperfect competition, pass-through can only be less than 1 (incomplete) if the relative elasticities of demand and supply, $\frac{\epsilon_D}{\epsilon_S}$, is sufficiently large. If demand is inelastic and has a log-convex shape, pass-through is always greater than 1 (more-than-complete).

We follow the literature in assuming that $\frac{1}{\epsilon_\theta} = 0$ and take Eq. (5) as the theoretical model that summarizes pass-through in both the Brazilian LPG retail market and the supply chain as a whole. We find this model to adequately represent our context of interest because it allows for both perfect and imperfect competition and is highly generalizable.

Our objective, in this paper, is to calibrate this model and solve for the conduct parameter, so that we can make inferences about market power. Therefore, we isolate θ to make the analysis more straight forward:

$$\theta = \frac{\left(\frac{1}{\rho}-1-\frac{\epsilon_D}{\epsilon_S}\right)}{\left(1-E-\frac{1}{\epsilon_S}\right)} \tag{6}$$

To feed the right side of Eq. (6), we estimate the pass-through, ρ, and the demand elasticity, ϵ_D. For the demand estimation, our main specification has a log-log form,[11] so in solving for θ we assume an isoelastic demand, which allows us to calculate E through the simple formula $E = 1 + \frac{1}{|\epsilon_D|}$. We are, then, left with ϵ_S to be able to solve for θ.

Estimating supply elasticity is beyond the scope of this paper; therefore, we use Arora (2014)'s results as a benchmark.[12] The author finds supply elasticity in the natural gas industry of the United States to range from 0.1 to 0.5. We, then, calculate θ for different values of supply elasticity within this range. More details on model calibration are presented in Section 7.

Because, in this paper, we are interested in different stages of the supply chain, it is worth noting that, although this model is highly generalizable, it considers only one layer of symmetrically differentiated sellers. When using our estimates to calibrate the model and find the conduct parameter, then, we consider either retailers as sellers that represent the whole supply chain or retailers as sellers that represent the retail segment separately. We, therefore, provide an analysis of market power for the supply chain as a whole and another analysis for the retail segment alone.

4. Data

To perform our empirical analyses, we use publicly available data from the National Economic Council (CONFAZ), the Brazilian National Petroleum Agency (ANP), and the Brazilian Institute of Geography and Statistics (IBGE). From CONFAZ, which makes available data published on the Federal Register, we obtained data on the Weighted Average Price to the Final Consumer (PMPF) per kg of LPG[13] – these data are published every other week. From ANP, we obtained monthly data on LPG state tax rate (2016–2017),[14] monthly data on nominal distribution price and nominal retail price of the 13-kg

[9] Note that Weyl and Fabinger (2013) use the notation $\frac{1}{\epsilon_{ms}}$ where we use $(1-E)$.

[10] See, for instance, the early papers about the identification of market power, Bresnahan (1982) and Lau (1982), and the large literature that followed. In the context of assessing the effects of mergers, see also the recent work of Bjornerstedt and Verboven (2014) and Miller and Weinberg (2017), who assume that, under an imperfect competition setting, firms maximize their own profits plus rivals' profits times a fixed weight.

[11] Although we also estimate demand using a quadratic specification, so to allow for a more flexible form.

[12] Arora (2014) estimates supply elasticity in the natural gas industry of the United States. Because LPG and natural gas have similar processing and transportation methods, we believe that the author's results make for a good benchmark.

[13] CONFAZ. Data available at: https://www.confaz.fazenda.gov.br/legislacao/atos-pmpf.

[14] These data are available only upon request through *Lei de Acesso Informa*Ⅎ*o*.

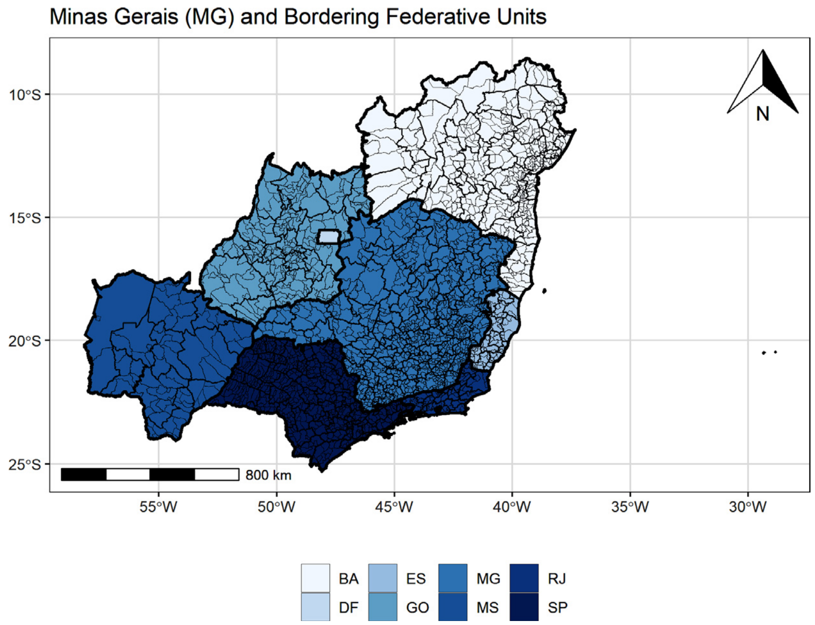

Fig. 1. Map of Minas Gerais and its bordering federative units. *Notes*. This figure presents a map of Minas Gerais and its bordering federative units. The thickest black lines represent federative unit divisions; the black lines of intermediate-thickness represent microregion divisions; and the thinest black lines represent municipality divisions. In the legend, names of federative units are abbreviated as follows: Bahia is BA, Federal District is DF, Espirito Santo is ES, Goias is GO, Minas Gerais is MG, Mato Grosso do Sul is MS, Rio de Janeiro is RJ, and Sao Paulo is SP.

LPG cylinder – and also of diesel[15] – per municipality[16] for a sample of municipalities taken from each state (2016–2017), and quarterly data on quantity sold of 13-kg LPG cylinders per municipality (2016–2017).[17] Finally, from IBGE, we obtained consumer price index data,[18] municipality names and codes,[19] and maps (in shape file format) – to define bordering and non-bordering municipalities.[20] All of these data were obtained for municipalities located in Minas Gerais and its bordering federative units, which include: Sao Paulo, Rio de Janeiro, Espirito Santo, Bahia, Goias, Mato Grosso do Sul, and the Federal District – see Fig. 1 for illustration in a map.

To calculate the state tax nominal value applicable to a 13-kg LPG cylinder, we used two variables: the Weighted Average Price to the Final Consumer (PMPF) per kg of LPG and the state tax rate. These two variables multiplied by each other result in the state tax nominal value per kg of LPG; and, by multiplying this result by 13, we obtain the state tax nominal value for the 13-kg cylinder.[21] Additionally, to transform nominal values of the state tax, distribution price, and retail price into real values, we used the consumer price index (IPCA[22]) obtained from IBGE, fixing 2015 as the base year.

As for how we defined whether a municipality is considered bordering or non-bordering, we used a three-step approach. Firstly, we used IBGE shape files to define the centroid point coordinates of each municipality. Secondly, we calculated the municipality centroid distance from the border of its federative unit. And, thirdly, we defined a municipality as *bordering* if its centroid is located less than 40 km away from the border of its federative unit (conversely, we defined a municipality as *non-bordering* if its centroid is located at least 40 km away from the border of its federative unit). We flexibilize this definition of bordering and non-bordering municipalities in Section 5.3, in order to perform robustness checks for pass-through estimations.

We built a municipality-by-quarter panel dataset that contains real values of state tax, distribution price and retail price of 13-kg LPG cylinders, real values of diesel prices,[23] quantity sold of 13-kg LPG cylinders, a variable that indicates whether the municipality is bordering, and the distance from the centroid of each municipality to the border. The final dataset is

[15] We use diesel prices to perform robustness checks for the estimations of pass-through.

[16] ANP. Data publicly available at: http://www.anp.gov.br/precos-e-defesa/234-precos/levantamento-de-precos/868-serie-historica-do-levantamento-de-precos-e-de-margens-de-comercializacao-de-combustiveis.

[17] These data are available only upon request through *Lei de Acesso Informa A o*.

[18] IBGE. Data publicly available at: https://ww2.ibge.gov.br/home/estatistica/indicadores/precos/inpc-ipca/defaultseriesHist.shtm.

[19] IBGE. Data publicly available at: https://concla.ibge.gov.br/classificacoes/por-tema/codigo-de-areas/codigo-de-areas.

[20] IBGE. Data publicly available at: https://mapas.ibge.gov.br/bases-e-referenciais/bases-cartograficas/malhas-digitais.

[21] Calculations were based on Pavarina (2018).

[22] An inflation index vastly used in Brazil.

[23] We transformed monthly data of state tax and prices into quarterly data by taking the average within each quarter.

Table 1
Summary Statistics.

	Q3-2016 to Q4-2016					Q1-2017 to Q2-2017				
	Mean	SD	Min.	Max.	N	Mean	SD	Min.	Max.	N
All municipalities										
Distribution Price of LPG	32.40	4.27	22.71	48.79	553	33.51	4.28	25.22	51.34	560
Retail Price of LPG	46.16	4.59	32.57	62.06	562	47.00	5.00	34.15	63.45	560
State Tax of LPG	5.63	0.45	5.18	7.41	564	6.45	1.45	5.13	9.02	564
Quantity of LPG	2.02	4.64	0.04	63.55	564	1.90	4.31	0.02	58.45	564
Retail Price of Diesel S500	2.60	0.10	2.40	2.96	563	2.60	0.11	2.33	3.02	564
Retail Price of Diesel S10	2.71	0.10	2.50	3.10	564	2.71	0.12	2.44	3.22	564
Bordering	0.24	0.43	0.00	1.00	564	0.24	0.43	0.00	1.00	564
Distance to Border (km)	88.18	60.60	2.46	311.14	564	88.18	60.60	2.46	311.14	564
Non-bordering municipalities of Minas Gerais										
Distribution Price of LPG	33.39	3.88	26.77	48.79	102	35.99	3.72	28.34	51.34	104
Retail Price of LPG	48.98	4.10	38.01	58.73	104	51.71	4.43	43.60	63.45	104
State Tax of LPG	5.77	0.02	5.75	5.79	104	9.02	0.01	9.01	9.02	104
Quantity of LPG	1.66	2.06	0.04	13.43	104	1.54	1.99	0.02	12.79	104
Retail Price of Diesel S500	2.62	0.06	2.45	2.81	103	2.61	0.08	2.40	2.83	104
Retail Price of Diesel S10	2.72	0.06	2.58	2.85	104	2.71	0.08	2.56	2.89	104
Distance to Border (km)	140.47	74.58	41.07	311.14	104	140.47	74.58	41.07	311.14	104
Non-bordering municipalities of control federative units										
Distribution Price of LPG	31.99	4.24	22.71	44.84	315	32.62	4.10	25.22	45.81	322
Retail Price of LPG	45.33	4.44	34.34	62.06	322	45.71	4.25	34.62	61.51	322
State Tax of LPG	5.57	0.52	5.18	7.41	324	5.67	0.47	5.13	7.29	324
Quantity of LPG	2.45	5.83	0.09	63.55	324	2.30	5.39	0.08	58.45	324
Retail Price of Diesel S500	2.59	0.10	2.42	2.96	324	2.59	0.11	2.34	3.02	324
Retail Price of Diesel S10	2.70	0.11	2.50	3.10	324	2.70	0.12	2.44	3.22	324
Distance to Border (km)	99.23	41.58	43.15	252.21	324	99.23	41.58	43.15	252.21	324

Notes. This table shows summary statistics for main variables contained in our municipality-by-quarter dataset for periods before and after the state tax shock in Minas Gerais. The top panel includes all municipalities. The middle panel includes non-bordering municipalities located in Minas Gerais. The bottom panel includes non-bordering municipalities located in control federative units. The variable *quantity of LPG* represents the quantity of LPG sold divided by 1,000,000 (1 million).

restricted to the periods used in our empirical analyses: from the third quarter of 2016 up to the second quarter of 2017. Summary statistics of main variables are presented in Table 1.

4.1. The state tax shock in minas gerais

Our data reveal that the LPG state tax in Minas Gerais and the average of its bordering federative units combined – Bahia, the Federal District, Espirito Santo, Goias, Mato Grosso do Sul, Rio de Janeiro, and Sao Paulo – were kept almost constant during the year of 2016. In fact, throughout 2016, Minas Gerais practiced an average state tax of 5.77 Brazilian Reals (BRL) and its bordering federative units combined practiced an average tax of 5.56 BRL. However, from the last quarter of 2016 to the first quarter of 2017, the state tax in Minas Gerais jumped from 5.75 BRL to 9.01 BRL.

The graph in Fig. 2 shows this sudden change in LPG state tax in Minas Gerais in the first quarter of 2017. In addition, it shows that the state tax in Minas Gerais and its bordering federative units was kept somewhat constant during 2016 and the trends in state tax for the two groups remained parallel after the shock – but with a greater gap between them.

If we consider a Difference-in-Differences approach – where Minas Gerais is the treated unit and its bordering federative units compose the set of controls – and if we restrict our sample to non-bordering municipalities and a period that goes from Q3-2016 up to Q4-2017 (2 quarters before and 2 quarters after the state tax shock),[24] we find that the shock was of a 3.1287 BRL magnitude.[25] This shock is the basis of our empirical strategy, used to estimate both the pass-through and demand.

5. Empirical analysis: Pass-through

5.1. Empirical strategy

Our empirical strategy to estimate pass-through is based on the sudden increase in the state tax of Minas Gerais in the first quarter of 2017. We use a Difference-in-Differences strategy to identify the effect of a 3.1287 BRL increase in the state tax of Minas Gerais on LPG's distribution price and retail price. We compare prices practiced in municipalities located in Minas Gerais (treated units) with prices practiced in municipalities located in Minas Gerais' bordering federative units

[24] The exact same sample restrictions used in our pass-through estimations and our price-elasticity of demand estimations.

[25] To obtain this value, we estimate regression Eq. (7) using *state tax* as the outcome variable and look at the coefficient on *treat*.

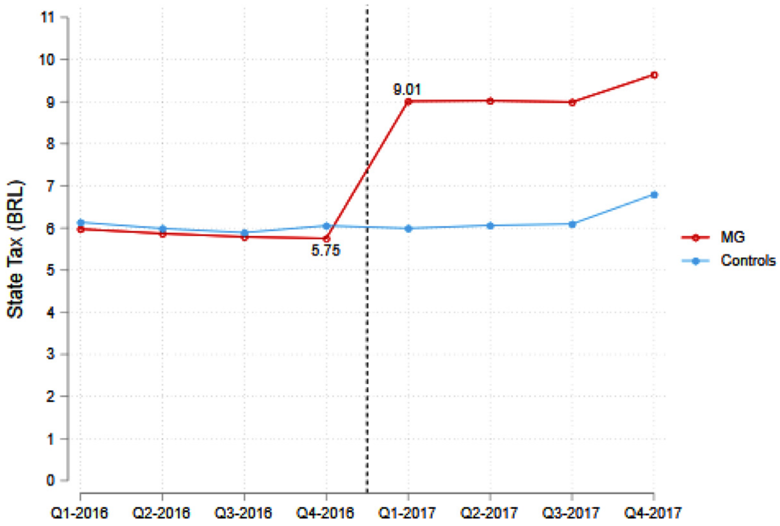

Fig. 2. Trends in State Tax Over Time. *Notes*. This figure shows trends in state tax over time. In the legend, MG stands for Minas Gerais and the set of controls includes Minas Gerais' bordering federative units.

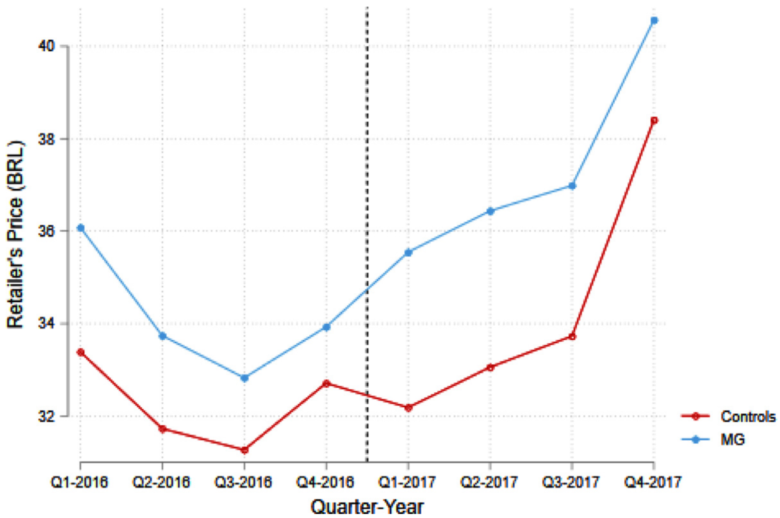

Fig. 3. Trends in Distribution Price Over Time: Non-bordering Municipalities. *Notes*. This figure shows trends in distribution price over time for non-bordering municipalities. In the legend, MG stands for Minas Gerais and the set of controls includes Minas Gerais' bordering federative units.

(control units), before and after the state tax shock, restricting our analyses to quarters that go from Q3-2016 up to Q2-2017.[26]

We rely on the usual identification assumption of a Difference-in-Differences model: the parallel trends assumption. In other words, we assume that outcome variable trends would have been parallel after the state tax shock, had it not occurred. In practice, the Difference-in-Differences strategy allows us to control both for all time-invariant characteristics of treated and control units, and for all variables that change over time equally for the two groups. However, for our results to be considered valid, it must be true that there are no factors that both affect LPG prices and change over time differently for the treated and untreated units.

We find evidence that the parallel trends assumption likely does not hold for municipalities located close to the border of their federative units. In Figs. 5 and 6, we present the trends in LPG prices over time for bordering municipalities. These figures show that trends do not look parallel before the shock, suggesting that it is unlikely that these trends would have

[26] We restrict all of our empirical analyses to the period that comprises the quarters from Q3-2016 up to Q2-2017 – and not to a longer window around the state tax shock – because we understand that, the farther we get from the period of the shock, the more likely we are to find factors that both affect our outcome variables of interest and change over time differently for treated and untreated units. Furthermore, in demand estimations, in which the change in state tax is used as an exogenous shock to isolate the good variation in price, a shorter period around the shock guarantees higher relevance of the first stage in the two-stage model.

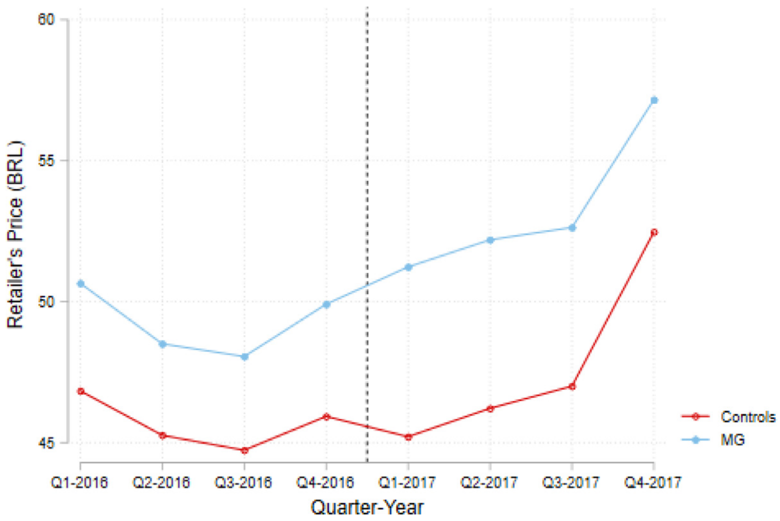

Fig. 4. Trends in Retail Price Over Time: Non-bordering Municipalities. *Notes*. This figure shows trends in retail price over time for non-bordering municipalities. In the legend, MG stands for Minas Gerais and the set of controls includes Minas Gerais' bordering federative units.

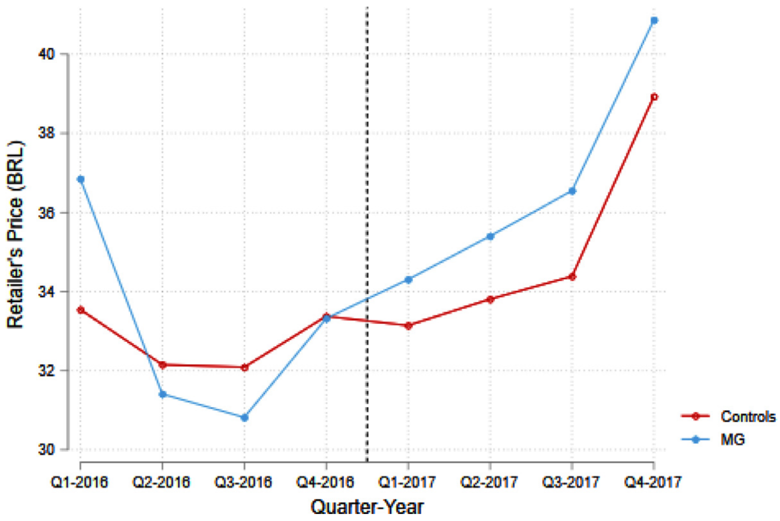

Fig. 5. Trends in Distribution Price Over Time: Bordering Municipalities. *Notes*. This figure shows trends in distribution price over time for bordering municipalities. In the legend, MG stands for Minas Gerais and the set of controls includes Minas Gerais' bordering federative units.

looked parallel after the shock, had it not occurred. In consistency with what was shown by Pavarina (2018), people who live in municipalities located close to the border may cross it to buy cheaper gas when prices are lower in a neighboring municipality of another federative unit. If this is the case, then the internal validity of our results is threatened.

In order to prevent the border-crossing phenomenon from undermining the validity of our pass-through estimates, we include in our model an interaction term that allows us to assess the effect of the shock for non-bordering municipalities separately. As shown in Figs. 3 and 4, the trends in prices look much closer to parallel before the shock when we restrict the sample to municipalities that have their centroids located at least 40 km away from the border.

We define the following equation as our main regression specification used to assess the effect of the state tax shock on the distribution price and the retail price of LPG:

$$Y_{iq} = \alpha + \beta treat_{iq} + \gamma treat_{iq} * bordering_i + \delta_i + \phi_q + u_{iq} \tag{7}$$

where: Y_{iq} is distribution (retail) price in municipality i and quarter q; $treat_{iq}$ is a binary variable that takes the value of 1 if municipality i is treated in quarter q (that is, if i is located in Minas Gerais and the observation corresponds to Q1-2017 or later), and zero otherwise; $bordering_i$ is a binary variable that takes the value of 1 if municipality i is located up to 40 km away from the border of its federative unit, and zero otherwise; δ_i represents municipality fixed effects; ϕ_q represents quarter/year fixed effects; and u_{iq} is the robust error term for municipality i and quarter q, clustered at the federative unit level. The parameter of interest is β, which gives the average pass-through in non-bordering municipalities of Minas Gerais.

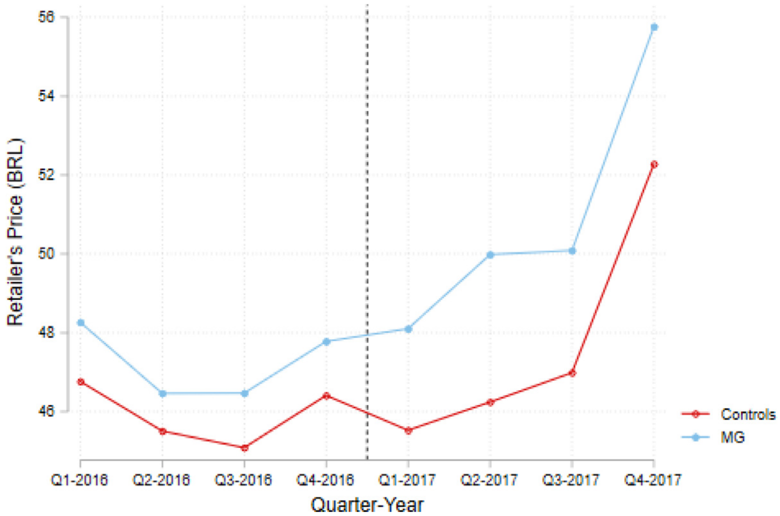

Fig. 6. Trends in Retail Price Over Time: Bordering Municipalities. *Notes*. This figure shows trends in retail price over time for bordering municipalities. In the legend, MG stands for Minas Gerais and the set of controls includes Minas Gerais' bordering federative units.

Table 2
Pass-through Estimates.

	Exogeneity from *treat*		**Exogeneity from *tax***	
	(1) Distribution Price	(2) Retail Price	(3) Distribution Price	(4) Retail Price
Treat	1.9352*** (0.0000)	2.3902*** (0.0000)		
Tax			0.6132*** (0.0000)	0.7607*** (0.0000)
Constant	30.8997*** (0.0000)	43.4400*** (0.0000)	27.7872*** (0.0000)	39.5727*** (0.0000)
R^2	0.9003	0.9062	0.9001	0.9064
Adj. R^2	0.8659	0.8742	0.8657	0.8745
N	1,113	1,122	1,113	1,122
Distribution / Retail Pass-through	0.6185	1.2352	0.6132	1.2405
Whole Supply Chain Pass-through		0.7640		0.7607

Notes. Results presented in columns 1 and 2 were generated by estimations in which the exogenous variation comes from *treat*; and results presented in columns 3 and 4 were generated by estimations in which the exogenous variation comes from *tax*. All regressions include municipality and quarter/year fixed effects. Analytic sample is restricted to periods from Q3-2016 to Q2-2017. Robust standard errors are clustered at the federative unit level. *P*-values are presented in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level. The second-to-last line of the table presents the pass-through in the distribution and retail markets that results from each model's estimates. The last line of the table presents the pass-through for the supply chain as a whole that results from each model's estimates.

We also estimate Eq. (7) using *tax* as the exogenous variable in place of *treat*. Although the use of *treat* allows us to perform interesting robustness checks, we find this alternative estimation useful, for the resulting coefficients on *tax* gives us the pass-through rate directly. When the outcome variable is the distribution price, the coefficient on *tax* gives the pass-through in the distribution market; and when the outcome variable is the retail price, the coefficient on *tax* gives the pass-through for the supply chain as a whole directly. To find the pass-through in the retail market, we always have to divide the estimated effect of *treat* (*tax*) on retail price by the estimated effect of *treat* (*tax*) on distribution price.

5.2. Results

Pass-through results are presented in Table 2. Columns 1 and 2 of the table present results obtained from estimations of Eq. (7) using *treat* as the exogenous variable, whereas columns 3 and 4 present results obtained from estimations of Eq. (7) using *tax* as the exogenous variable.

Results presented in column 1 show that the 3.1287 BRL increase in state tax generates an increase in distribution price of 1.9352 BRL on average, and this effect is significant at the 1% level. If we divide the size of this effect by the size of the shock, we obtain that the pass-through rate in the distribution market is equal to 0.6185. Results presented in column 2 show that the state tax shock generates an increase in retail price of 2.3902 BRL on average, and this effect is also significant at the 1% level. By dividing the shock effect on retail price by the shock effect on distribution price, we find that the pass-through in the retail market is equal to 1.2352. Now, by dividing the shock effect on retail price by the shock size, we find that the pass-through for the supply chain as a whole is equal to 0.7640.

Results obtained from estimations of Eq. (7) using *tax* as the exogenous variable are very similar to those obtained using *treat*. Results presented in column 3 directly show that the pass-through in the distribution market is estimated at 0.6132; and results presented in column 4 directly show that the pass-through for the whole supply chain is estimated at 0.7607. When we divide the coefficient on *tax* presented in column 4 by the coefficient on *tax* presented in column 3, we find that the pass-through in the retail market is estimated at 1.2405.

Overall, results reveal an incomplete pass-through in the distribution market and the supply chain as a whole, and a more-than-complete one in the retail market.

5.3. Robustness checks

To assess the robustness of our pass-through results, we perform several tests, including: [i] using an alternative specification with an interaction between *treat* and *distance* to the border (in kilometers), instead of an interaction between *treat* and the binary *bordering* variable; [ii] controlling for diesel prices;[27] [iii] sensitivity tests to different definitions of non-bordering; [iv] leave-one-out tests; and [v] placebo tests. Results of these tests are presented in appendix Section Appendix A. They show that our pass-through estimates and related main conclusions are robust to all checks.

6. Empirical analysis: Demand

6.1. Empirical strategy

Our empirical strategy to estimate demand is also based on the state tax shock of Minas Gerais. We use the exogenous variation in state tax to isolate the “good” variation in price in an Instrumented Difference-in-Differences (DDIV) design. As in pass-through estimations, we rely on the parallel trends assumption for exogeneity.[28] Additionally, we assume that state tax affects quantity only through price (exclusion restriction).

We use two different specifications, a quadratic one and a log-log one. The quadratic specification is flexible enough to allow for “different degrees of convexity or concavity” (Pless and Benthem, 2019); therefore, results obtained from it can be used to verify whether demand is convex.[29] With the confirmation that demand is convex, we then adopt a constant elasticity form and estimate a log-log specification, which directly gives the price-elasticity of demand estimates used to calibrate the model presented in Section 3. Again, we include interactions with *bordering*, since municipalities located close to the border may present a distinct behavior compared to that of their inner counterparts.

Our log-log specification can be expressed as follows:

$$ln(quantity)_{iq} = \beta_0 + \beta_1 \widehat{ln(price)}_{iq} + \beta_2 \widehat{ln(price)_{iq} * bordering_i} + \delta_i + \gamma_q + u_{iq} \tag{8}$$

$$ln(price)_{iq} = \alpha_0 + \alpha_1 treat_{iq} + \alpha_2 treat_{iq} * bordering_i + \delta_i + \gamma_q + v_{iq} \tag{9}$$

$$ln(price)_{iq} * bordering_i = \nu_0 + \nu_1 treat_{iq} + \nu_2 treat_{iq} * bordering_i + \delta_i + \gamma_q + w_{iq} \tag{10}$$

where: Eqs. (9) and (10) refer to the first stage and Eq. (8) refers to the second stage; $treat_{iq}$ can be replaced alternatively by $ln(tax)_{iq}$; $ln(price)_{iq}$ is the log of retail price in municipality i and quarter q; $ln(quantity)_{iq}$ is the log of quantity demanded in municipality i and quarter q; and u_{iq}, v_{iq}, and w_{iq} are robust error terms clustered at the federative unit level. β_1 is the parameter of interest and it gives the effect of the log of price on the log of quantity. The analytic sample comprises periods from the third quarter of 2016 up to the second quarter of 2017.

In our quadratic specification, we use *tax*, tax^2, $tax{*}bordering$, and $tax^2{*}bordering$ as instruments for *price*, $price^2$, $price{*}bordering$, and $price^2{*}bordering$.

6.2. Results

Second-stage results of demand estimations are presented in Table 3.[30] Column 1 of the table presents results obtained from estimations using exogeneity from *treat*, whereas columns 2 and 3 present results obtained from estimations using exogeneity from *tax*.

[27] Since transportation logistics has an important influence on the price of 13-kg LPG cylinders, we find it important to test for whether potential variations in transportation costs affect our results. To do so, we re-estimate our main specification, represented by regression Eq. (7), but now including diesel prices as controls.

[28] Since first stages of demand estimations are based on the effect of the tax shock on retail price, we consider that tests presented in Section 5.3 serve as robustness exercises for both pass-through estimations and demand estimations.

[29] We follow Pless and Benthem (2019) and verify whether demand estimates, in combination with pass-through results, can alone be used to make inferences about market power.

[30] For first-stage results, see Appendix B.

Table 3
Demand Estimates.

	Exogeneity from ***treat***	Exogeneity from ***tax***	
	(1) Log Quantity	(2) Log Quantity	(3) Quantity
Price			−1.1697***
			(0.0055)
Price^2			0.0112***
			(0.0057)
Log Price	−1.0586***	−1.1441***	
	(0.0004)	(0.0038)	
Constant	4.512***	4.8429***	31.4068***
	(0.0001)	(0.0012)	(0.0032)
R^2	0.9720	0.9758	0.9932
Adj. R^2	0.9624	0.9675	0.9908
N	1,122	1,122	1,122
Elasticity	−1.0586	−1.1441	−2.0308

Notes. Results presented in column 1 were generated by estimations in which the exogenous variation comes from the instrument *treat*; and results presented in columns 2 and 3 were generated by estimations in which the exogenous variation comes from the instrument *tax*. Columns 1 and 2 show results of log-log specifications, and column 3 shows results of the quadratic specification. All regressions include municipality and quarter/year fixed effects. Analytic sample is restricted to periods from Q3-2016 to Q2-2017. Robust standard errors are clustered at the federative unit level. *P*-values are presented in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level. The last line of the table presents the elasticity that results from each model's estimates; to calculate the elasticity for the quadratic model, we used the average retail price practiced in non-bordering municipalities of Minas Gerais from Q3-2016 to Q2-2017. The variable *quantity* represents the quantity of LPG sold divided by 1,000,000 (1 million).

Our quadratic model shows a negative coefficient on the level term and a positive coefficient on the quadratic term – both statistically significant at the 1% level –, suggesting that demand has a convex form. Results of the log-log models confirm that price and quantity are inversely related and show that price-elasticity of demand is, on average, greater than unity, 1.0586–1.1441 in absolute terms, with statistically significant coefficients at the 1% level.

7. Model calibration

7.1. Inputs

We, now, look at the inputs that will feed the theoretical model presented in Section 3, so that we can make inferences regarding market power in the retail segment and the supply chain as a whole. Recall that we have:

$$\theta = \frac{\left(\frac{1}{\rho} - 1 - \frac{\epsilon_D}{\epsilon_S}\right)}{\left(1 - E - \frac{1}{\epsilon_S}\right)} \tag{11}$$

In Eq. (11), ρ can be replaced by our pass-through estimates presented in Section 5. For the retail segment, we have that $\rho = 1.2352$, when we use exogenous variation in *treat*, and $\rho = 1.2405$, when we use exogenous variation in *tax*. For the supply chain as a whole, we have that $\rho = 0.7617$, when we use exogenous variation in *treat*, and $\rho = 0.7607$, when we use exogenous variation in *tax*.

The demand elasticity, ϵ_D, can be replaced by our estimates presented in Section 6. We have that $\epsilon_D = |-1.0586|$, when we use exogenous variation in *treat*, and $\epsilon_D = |-1.1441|$, when we use exogenous variation in *tax*. Considering a constant elasticity demand, we then calculate $E = 1 + \frac{1}{|\epsilon_D|}$ and obtain $E = 1.9446$ and $E = 1.8740$, for the cases in which exogeneity comes from *treat* and *tax*, respectively.

Finally, since we do not estimate the supply elasticity, we use a benchmark from the literature to feed the model. Arora (2014) reports supply price-elasticities ranging from 0.1 to 0.5 in the natural gas industry of the United States. Given that LPG and natural gas have similar processing methods, we use supply elasticities varying within this same range to solve for the retail conduct and the industry conduct.

7.2. Results

With the inputs presented in Section 7.1, we calibrate the theoretical model and solve for the retail conduct parameter and the whole supply chain conduct parameter. Results, presented in Table 4, reveal a high market power in the retail segment and the supply chain as a whole, for all values of supply elasticity that fall within the interval $[0.1, 0.5]$. The retail conduct parameter ranges from about 0.8 to unity and the conduct parameter of the supply chain as a whole ranges from about 0.6 to unity. Although the parameter decreases as supply elasticity increases, market power is still very high when supply elasticity is at the interval's upper bound. If we push supply elasticity to the extreme and consider that marginal

Table 4
Results of Model Calibration for Different Values of Supply Elasticity.

	Exogeneity from *treat*		**Exogeneity from *tax***	
Supply Elasticity	(1) Retail Conduct Parameter	(2) Whole Supply Chain Conduct Parameter	(3) Retail Conduct Parameter	(4) Whole Supply Chain Conduct Parameter
0.1	0.9846	0.9390	1.0699	1.0232
0.2	0.9224	0.8384	1.0068	0.9203
0.3	0.8694	0.7526	0.9525	0.8316
0.4	0.8236	0.6786	0.9051	0.7544
0.5	0.7837	0.6141	0.8636	0.6867

Notes. The table presents results for the conduct parameter in the retail market and the supply chain as a whole, calculated for different values of supply elasticity. Estimated inputs used in calculations include the retail pass-through, the pass-through of the whole supply chain, and the demand elasticity. For columns 1 and 2, inputs were generated by estimations in which the exogenous variation comes from *treat*. For columns 3 and 4, inputs were generated by estimations in which the exogenous variation comes from *tax*.

cost is constant, then the retail conduct parameter is still greater than zero – at about 0.2 –, but the whole supply chain conduct parameter goes to zero.

We, therefore, note that some degree of market power exists in the retail market for any level of supply elasticity. This result is consistent with Pless and Benthem (2019), who show that, if one can rule out certain (unlikely) conditions – such as giffen behavior, salience, subsidy manipulation, decreasing marginal costs, and nominal pricing rigidities –, then over-shifting indicates the existence of market power when demand is sufficiently convex.

More importantly, using the pass-through rate of the whole supply chain leads to an underestimation of market power in the industry. As shown, the retail pass-through rate is 1.24, while the whole supply chain pass-through is 0.76. When we feed these values into the model, we obtain different conduct parameter values, with values for the retail segment greater than those for the chain as a whole. The difference is larger for higher supply elasticities, reaching roughly 30% when supply elasticity is 0.5.

In the context of the Brazilian LPG industry, our results configure new evidence that may indicate the existence of coordination to control retail prices. The confirmation of market power existence at the retail level raises a red flag to ANP and CADE, pointing to the need to look at the industry structure more carefully in order to prevent welfare losses from final consumers.

8. Discussion and conclusions

Empirical studies have sought to make a connection between pass-through and the existence of market power. In particular, pass-through has received special attention in energy industries, for market power raises important welfare concerns in this sector. In this paper, we study the connection between pass-through and market power in the Brazilian Liquefied Petroleum Gas (LPG) industry.

We use a state tax shock to estimate pass-through – at different levels of the supply chain – and demand, and then feed a theoretical model to make inferences about a conduct parameter that measures market power. Results show an incomplete pass-through (of about 0.76) for the supply chain as a whole and at the distribution level (of about 0.61), and a more-than-complete pass-through at the retail level (of about 1.24). Furthermore, results show that demand is somewhat elastic with a price-elasticity estimated at 1.06–1.14. When we feed these estimates into a pass-through model that allows for imperfect competition, we find that – for supply elasticity ranging from 0.1 to 0.5 – the conduct parameter is high at both the industry and the retail levels, equal to or higher than 0.61 and 0.78 respectively. Moreover, we find that the conduct parameter decreases as supply elasticity increases; and, even if we take supply elasticity to infinity, market power still exists at the retail level.

These results show that only using the pass-through rate of the supply chain as a whole, without observing pass-through at distinct segments, may lead to hasty conclusions about the market power in an industry. In our case, we would underestimate it. By observing both the distribution and retail segments, we are able to say that retailers exercise market power at a high degree.

Besides contributing to the empirical literature that connects pass-through with market power, we also contribute to on-going national discussions regarding competitiveness in the LPG industry by providing evidence-based policy recommendations.

National regulatory agencies have investigated several antitrust cases in which one can observe: [i] price coordination between distributor and retailers; [ii] geographical market segmentation among distributors; [iii] exclusive dealing agreements between distributor and retailers; and [iv] distributor selling LPG to clandestine retailers as a way of punishing sellers who deviate from the collusion. A central issue in these cases lies in vertical restrictions imposed by distributors to increase market power.

Table A.1
Pass-through Estimates: Alternative Specifications.

	Exogeneity from *treat*		**Exogeneity from *tax***	
	(1) Distribution Price	(2) Retail Price	(3) Distribution Price	(4) Retail Price
Treat	2.7693***	2.6836***		
	(0.0000)	(0.0000)		
Treat*Distance	−0.0059***	−0.0021***		
	(0.0000)	(0.0000)		
Tax			0.8636***	0.8393***
			(0.0000)	(0.0000)
Tax*Distance			−0.0018***	−0.0006***
			(0.0000)	(0.0019)
Constant	30.8993***	43.4400***	27.3330***	39.4310***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
R^2	0.9008	0.9066	0.9007	0.9067
Adj. R^2	0.8663	0.8744	0.8661	0.8746
N	1,113	1,122	1,113	1,122
Distribution / Retail Pass-through	0.6191	1.2340	0.6147	1.2374
Whole Supply Chain Pass-through		0.7640		0.7606

Notes. Results presented in columns 1 and 2 were generated by estimations in which the exogenous variation comes from *treat*; and results presented in columns 3 and 4 were generated by estimations in which the exogenous variation comes from *tax*. Pass-through rates were calculated considering the distance to the border of the average non-bordering municipality of Minas Gerais, 140.4695 km. All regressions include municipality and quarter/year fixed effects. Analytic sample is restricted to periods from Q3-2016 to Q2-2017. Robust standard errors are clustered at the federative unit level. *P*-values are presented in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level. The second-to-last line of the table presents the pass-through in the distribution and retail markets that results from each model's estimates. The last line of the table presents the industry pass-through that results from each model's estimates. To calculate these pass-through values, we used the average distance to the border from the centroid of non-bordering municipalities located in Minas Gerais.

Despite the on-going debate, the regulatory agencies have always allowed vertical integration in the industry – although certain restrictions were imposed between 2016 and 2019. The main argument pro vertical integration is the low concentration found in the retail market – against high concentration at the distribution level – and the expected high competitiveness that this market structure may imply. However, the evidence of market power in the retail market that we bring forward corroborates the claims made in the antitrust cases, and against the argument supporting free vertical integration of distributors into the retail market.

We, therefore, conclude by recommending both a higher surveillance on the retail market concerning price collusion and, more importantly, a tighter regulation on vertical integration, as it appears to be the main source of anti-competitive conduct in this market.

Appendix A. Robustness tests for pass-through estimates

To assess the robustness of our pass-through results, we perform several tests, including: [i] using an alternative specification with an interaction between *treat* and *distance* to the border (in kilometers), instead of an interaction between *treat* and the binary *bordering* variable; [ii] controlling for diesel prices; [iii] sensitivity tests to different definitions of non-bordering; [iv] leave-one-out tests; and [v] placebo tests.[31]

Firstly, we worry about inference in our Difference-in-Differences design, because the tax shock treatment happens at the federative unit level and we only have one treated unit and few untreated units. This problem of having only few treated and untreated units has been recognized in the literature by a few researchers, including Brewer et al. (2018) and Ferman and Pinto (2019). By interacting *treat* with *distance* to the border, we add more variation in treatment at the municipality level and, potentially, improve the robustness of results. Results for this alternative specification are presented in Table A.1. As one can note, resulting pass-through estimates for the average non-bordering municipality of Minas Gerais are very similar to those found using our main specification.

Then, we worry about variations in transportation costs, since they make an important component of LPG prices. If transportation costs varied differently over time for the treated and untreated municipalities during the period we consider in our analyses, the internal validity of our results would be compromised. Because the transportation of LPG, after the packaging process, is mainly performed by roads, and because the most used fuel type in truck transportation in Brazil is diesel, we re-estimate our main specification with the inclusion of diesel prices as control variables. Results of these estimations are presented in Table A.2. As one can note, the coefficients on *treat* are very similar with and without diesel price controls. We, therefore, have evidence that transportation costs do not harm the internal validity of our results.

[31] The parallel trends assumption is confirmed with event study analysis using monthly data and marginally rejected using quarterly data, due to the aggregate nature of the latter.

Table A.2
Pass-through Estimates: Controlling for Diesel Prices.

	Exogeneity from *treat*		Exogeneity from *tax*	
	(1) Distribution Price	(2) Retail Price	(3) Distribution Price	(4) Retail Price
Treat	1.9276***	2.4291***		
	(0.0000)	(0.0000)		
Tax			0.6101***	0.7727***
			(0.0000)	(0.0000)
Constant	39.8046**	34.3127*	36.4786**	30.0787
	(0.0301)	(0.093)	(0.0401)	(0.1375)
R^2	0.9008	0.9068	0.9006	0.907
Adj. R^2	0.8662	0.8746	0.866	0.8749
N	1,112	1,121	1,112	1,121
Distribution / Retail Pass-through	0.6161	1.2602	0.6101	1.2666
Whole Supply Chain Pass-through		0.7764		0.7727

Notes. Results presented in columns 1 and 2 were generated by estimations in which the exogenous variation comes from *treat*; and results presented in columns 3 and 4 were generated by estimations in which the exogenous variation comes from *tax*. All regressions include municipality and quarter/year fixed effects. Analytic sample is restricted to periods from Q3-2016 to Q2-2017. Robust standard errors are clustered at the federative unit level. *P*-values are presented in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level. The second-to-last line of the table presents the pass-through in the distribution and retail markets that results from each model's estimates. The last line of the table presents the industry pass-through that results from each model's estimates.

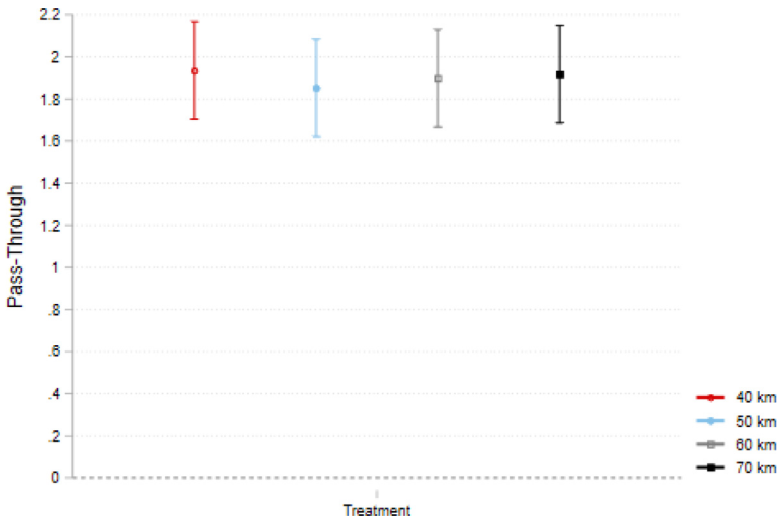

Fig. A.1. Sensitivity to alternative definitions of "non-bordering" municipalities: Distribution Price. *Notes*. This figure shows plots of state tax shock effects on distribution price and corresponding 95% confidence intervals. Robust standard errors are clustered at the federative unit level.

Now, because our decision on defining non-bordering municipalities as those for which the centroid is located at least 40 km away from the border is rather arbitrary, we also test if results change significantly for alternative definitions. In particular, we check if results remain similar when non-bordering municipalities are considered to be those for which the centroid is located at least 50, 60, and 70 km away from the border.[31] Results for tests of the sensitivity to the definition of non-bordering are presented graphically in Figs. A.1 and A.2. As one can note, the coefficient on *treat* changes very little when different definitions are adopted, strengthening further our confidence in our pass-through results.

Worried about a specific untreated federative unit being the driver of the effects rather than the actual state tax shock, we also perform leave-one-out tests. We estimate our main regression specification – Eq. (7) – seven times, each time excluding (or leaving out) the control municipalities that belong to one of Minas Gerais' bordering federative units from the sample. Results of these leave-one-out tests are presented in Figs. A.3 and A.4. As one can note, point estimates change very little when each set of control municipalities is dropped off of the sample, leading us to conclude that none of Minas Gerais' bordering federative units is particularly driving our effects of interest.

[31] In these alternative cases, we are even less likely to be exposed to the border-crossing phenomenon – but, as a trade-off, we lose observations and precision.

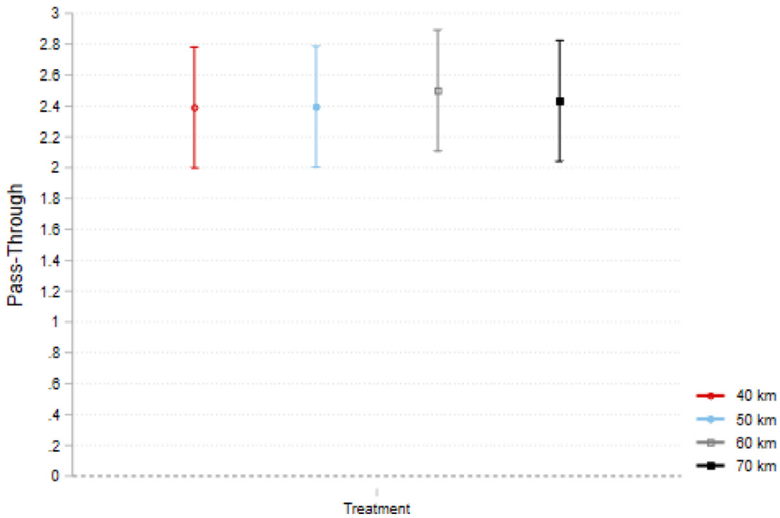

Fig. A.2. Sensitivity to alternative definitions of “non-bordering” municipalities: Retail Price. *Notes*. This figure shows plots of state tax shock effects on retail price and corresponding 95% confidence intervals. Robust standard errors are clustered at the federative unit level.

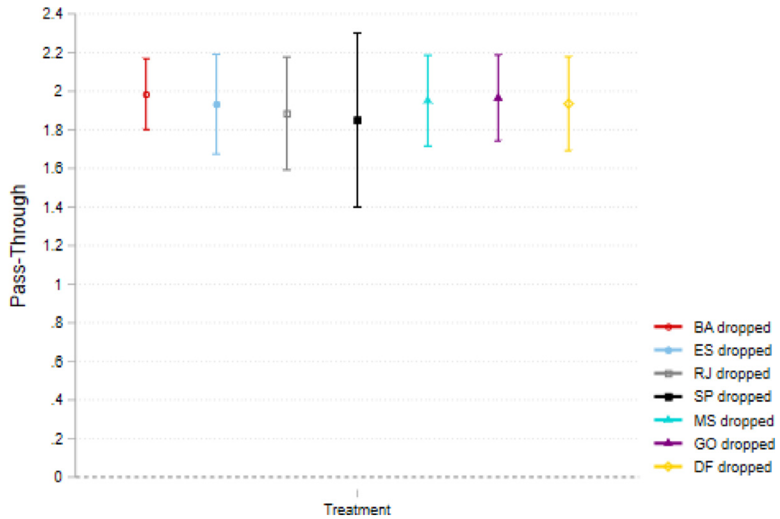

Fig. A.3. Leave-one-out test: Distribution Price. *Notes*. This figure shows plots of state tax shock effects on distribution price and corresponding 95% confidence intervals. Robust standard errors are clustered at the federative unit level. In the legend, names of federative units are abbreviated as follows: Bahia is BA, Federal District is DF, Espirito Santo is ES, Goias is GO, Mato Grosso do Sul is MS, Rio de Janeiro is RJ, and Sao Paulo is SP.

Finally, we also worry about having one of Minas Gerais’ bordering federative units presenting effects of Minas Gerais’ state tax shock, without actually suffering the shock. To check whether that is the case, we perform placebo tests. We drop municipalities located in Minas Gerais from our sample and estimate our main regression specification – Eq. (7) – seven times, each time classifying the municipalities of one of Minas Gerais’ bordering federative units as the treated ones. Results are presented in Figs. A.5 and A.6. No positive effects with a magnitude anywhere close to effects found for Minas Gerais are observed for when we attribute treatment to any of the control federative units.

In sum, the results of tests presented in this section show that our pass-through estimates and related main conclusions are robust to several checks.

Appendix B. First-stage results of demand estimations

Tables B.1 –B.3

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.ijindorg.2021.102796.

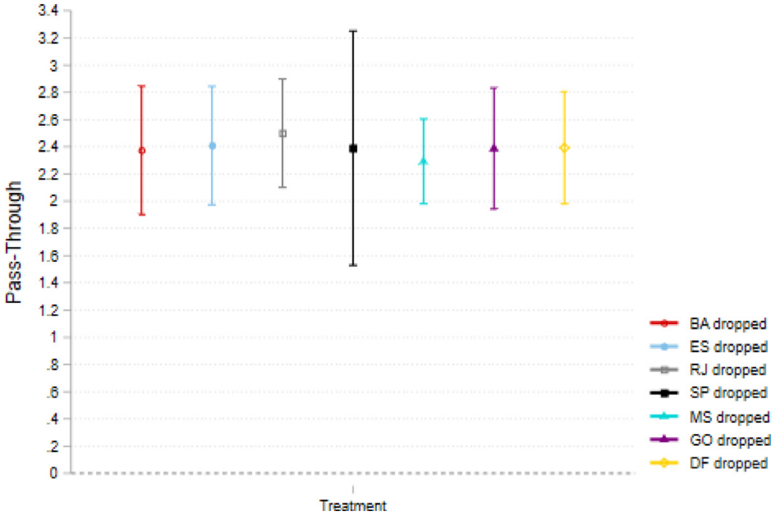

Fig. A.4. Leave-one-out test: Retail Price. *Notes*. This figure shows plots of state tax shock effects on retail price and corresponding 95% confidence intervals. Robust standard errors are clustered at the federative unit level. In the legend, names of federative units are abbreviated as follows: Bahia is BA, Federal District is DF, Espirito Santo is ES, Goias is GO, Mato Grosso do Sul is MS, Rio de Janeiro is RJ, and Sao Paulo is SP.

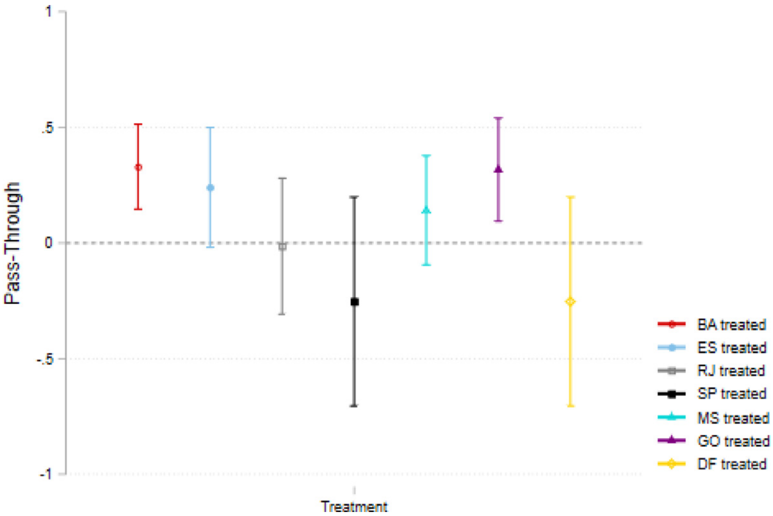

Fig. A.5. Placebo test: Distribution Price. *Notes*. This figure shows plots of state tax shock effects on distribution price and corresponding 95% confidence intervals. Robust standard errors are clustered at the federative unit level. In the legend, names of federative units are abbreviated as follows: Bahia is BA, Federal District is DF, Espirito Santo is ES, Goias is GO, Mato Grosso do Sul is MS, Rio de Janeiro is RJ, and Sao Paulo is SP.

Table B.1
First-stage Results of Demand Estimations: Log-log Specification with Exogenous Variation from *Treat*.

	(1) Log Price	(2) Log Price*Bordering
Treat	0.0464***	−0.0012
	(0.0058)	(0.5725)
Treat*Bordering	−0.0162***	0.038***
	(0.0000)	(0.0000)
Constant	3.7719***	−0.0040
	(0.0000)	(0.1598)
R^2	0.9086	0.9999
Adj. R^2	0.8775	0.9999
N	1,122	1,122

Notes. All regressions include municipality and quarter/year fixed effects. Analytic sample is restricted to periods from Q3-2016 to Q2-2017. Robust standard errors are clustered at the federative unit level. *P*-values are presented in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

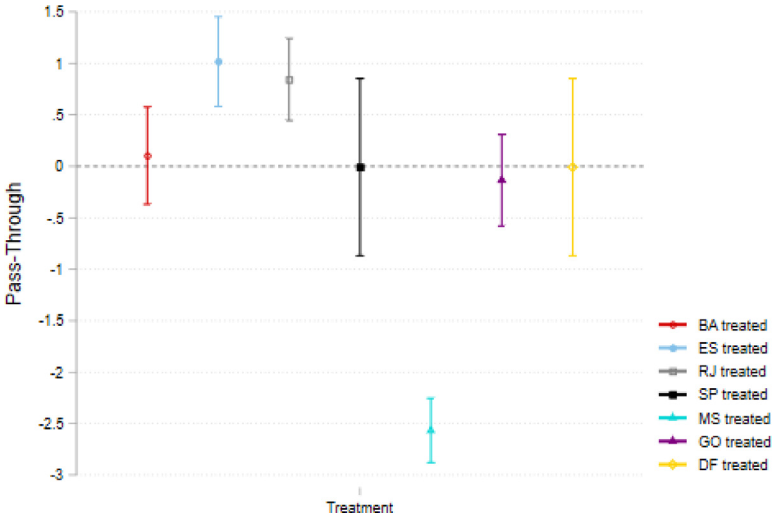

Fig. A.6. Placebo test: Retail Price. *Notes*. This figure shows plots of state tax shock effects on retail price and corresponding 95% confidence intervals. Robust standard errors are clustered at the federative unit level. In the legend, names of federative units are abbreviated as follows: Bahia is BA, Federal District is DF, Espirito Santo is ES, Goias is GO, Mato Grosso do Sul is MS, Rio de Janeiro is RJ, and Sao Paulo is SP.

Table B.2
First-stage Results of Demand Estimations: Log-log Specification with Exogenous Variation from *Tax*.

	(1) Log Price	(2) Log Price*Bordering
Log Tax	0.1088***	−0.0033
	(0.0001)	(0.6207)
Log Tax*Bordering	−0.0313**	0.1059**
	(0.0114)	(0.0233)
Constant	3.5949***	0.0022
	(0.0000)	(0.8295)
R^2	0.9089	0.9999
Adj. R^2	0.8778	0.9999
N	1,122	1,122

Notes. All regressions include municipality and quarter/year fixed effects. Analytic sample is restricted to periods from Q3-2016 to Q2-2017. Robust standard errors are clustered at the federative unit level. *P*-values are presented in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table B.3
First-stage Results of Demand Estimations: Quadratic Specification with Exogenous Variation from *Tax*.

	(1) Price	(2) $Price^2$	(3) Price*Bordering	(4) $Price^2$*Bordering
Tax	1.3316	−1.8084**	21.7379	−183.8588*
	(0.7816)	(0.0968)	(0.9641)	(0.0994)
Tax*Bordering	1.9787	14.7156***	225.0214	1349.427***
	(0.1378)	(0.0000)	(0.2687)	(0.0000)
Tax^2	−0.0379	0.1231*	3.863	12.4894*
	(0.9061)	(0.0890)	(0.9049)	(0.0923)
Tax^2*Bordering	-0.1501	-0.9547***	−16.8747	−87.1405***
	(0.1043)	(0.0000)	(0.2260)	(0.0000)
Constant	37.6675**	5.9955	1676.016	609.8132
	(0.0497)	(0.1016)	(0.3205)	(0.1040)
R^2	0.9064	0.9989	0.9018	0.9956
Adj. R^2	0.8742	0.9986	0.868	0.9941
N	1,122	1,122	1,122	1,122

Notes. All regressions include municipality and quarter/year fixed effects. Analytic sample is restricted to periods from Q3-2016 to Q2-2017. Robust standard errors are clustered at the federative unit level. *P*-values are presented in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

CRediT authorship contribution statement

Carolina Melo: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision. **Rodrigo Moita:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision. **Stefanie Sunao:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision.

References

Anderson, S.P., de Palma, A., Keide, B., 2001. Tax incidence in differentiated product oligopoly. J. Public Econ. 81 (2), 173–192.

ANP, 2020a. Bases de distribuiÄo. Data retrieved from Central de Sistemas ANP (CSA), http://app.anp.gov.br/anp-cpl-web/public/simp/consulta-base-distribuicao/consulta.xhtml.

ANP, 2020b. GLP. Data retrieved from DistribuiÄo e Revenda: Distribuidor: GLP, http://www.anp.gov.br/distribuicao-e-revenda/distribuidor/glp.

Araujo Jr., J.T.d., 2009. Regulação do setor de GLP No Brasil. In: Regulação do setor de GLP no Brasil. SindiGas, pp. 196–203.

Arora, V., 2014. Estimates of the Price Elasticities of Natural Gas Supply and Demand in the United States. Paper 54232. Munich Personal RePEc Archive. https://mpra.ub.uni-muenchen.de/id/eprint/54232

Bettendorf, L., Verboven, F., 2000. Incomplete transmission of coffee bean prices: evidence from the Netherlands. Eur. Rev. Agric. Econ. 27 (1), 1–16 http://gateway.newisiknowledge.com/gateway/Gateway.cgi?GWVersion=2&SrcAuth=CCC&SrcApp=PRODUCT_NAME&SrcURL=WOS_RETURN_URL&CKEY=BETT0001000027EL&DestLinkType=FullRecord&DestApp=CCC&SrcDesc=RETURN_ALT_TEXT&SrcAppSID=APP_SID.

Bjornerstedt, J., Verboven, F., 2014. Merger simulation with nested logit demand. Stata J. 14 (3), 511–540 30.

Bonnet, C., Dubois, P., Villas Boas, S.B., Klapper, D., 2013. Empirical evidence on the role of nonlinear wholesale pricing and vertical restraints on cost pass-through. Rev. Econ. Stat. 95 (2), 500–515. doi:10.1162/REST_a_00267.

Borenstein, S., Cameron, A.C., Gilbert, R., 1997. Do gasoline prices respond asymmetrically to crude oil price changes? Q. J. Econ. 112 (1), 305–339.

Bresnahan, T.F., 1982. The oligopoly solution concept is identified. Econ. Lett. 10 (1–2), 87–92.

Bresnahan, T.F., 1989. Empirical studies of industries with market power. In: Handbook of Industrial Organization, vol. 2. Elsevier, pp. 1011–1057. doi:10.1016/S1573-448X(89)02005-4. chapter 17

Brewer, M., Crossley, T.F., Joyce, R., 2018. Inference with difference-in-differences revisited. J. Econom. Methods 7 (1). doi:10.1515/jem-2017-0005.

Bulow, J.I., Pfleiderer, P., 1983. A note on the effect of cost changes on prices. J. Polit. Economy 1 (91), 182185.

Cabral, M., Geruso, M., Mahoney, N., 2018. Do larger health insurance subsidies benefit patients or producers? Evidence from medicare advantage. Am. Econ. Rev. 108 (8), 2048–2087. doi:10.1257/aer.20151362.

CADE, 2011. Ato de Concentração n◦ 08700.002155/2017-49. Conselho Administração do Direito Economico: CADE, https://sei.cade.gov.br/sei/modulos/pesquisa/md_pesq_documento_consulta_externa.php?DZ2uWeaYicbuRZEFhBt-n3BfPLlu9u7akQAh8mpB9yPH5mxC0ukYqmhWds_WM1m5pOl6QFy_jBTF4SRzPiOAEGYZ01s7L50wf4cylyvNTEOgxNFk20feRslsRMJmBON.

Delipalla, S., Keen, M., 1992. The comparison between ad valorem and specific taxation under imperfect competition. J. Public Econ. 49 (3), 351–367.

Devereux, M.B., Engel, C., 2002. Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect. J. Monet. Econ. 49 (5), 913–940. doi:10.1016/S0304-3932(02)00130-7.

Duso, T., Szucs, F., 2017. Market power and heterogeneous pass-through in german electricity retail. Eur. Econ. Rev. 98, 354–372. doi:10.1016/j.euroecorev.2017.07.010.

Fabra, N., Reguant, M., 2014. Pass-through of emissions costs in electricity markets. Am. Econ. Rev. 104 (9), 2872–2899.

Fell, H., 2010. EU-ETS and nordic electricity: a CVAR analysis. Energy J. 31 (2).

Ferman, B., Pinto, C., 2019. Inference in differences-in-differences with few treated groups and heteroskedasticity. Rev. Econ. Stat. 3 (101), 452–467. doi:10.1162/rest_a_00759.

Francois, J., Manchin, M., 2019. Market power in distribution and pass-through for consumers and producers. Rev. Int. Econ. 27 (1), 290–312. doi:10.1111/roie.12376.

Genakos, C., Pagliero, M., 2019. Competition and Pass-Through: Evidence from Isolated Markets. LSE - CEP Discussion Paper No 1638.

Genesove, D., Mullin, W.P., 1998. Testing static oligopoly models: conduct and cost in the sugar industry, 18901914. RAND J. Econ. 2 (29), 355–377.

Goldberg, P.K., Verboven, F., 2001. The evolution of price dispersion in the european car market. Rev. Econ. Stud. 68 (4), 811–848 http://www.jstor.org/stable/2695910.

Hellerstein, R., Villas-Boas, S.B., 2010. Outsourcing and pass-through. J. Int. Econ. 81 (2), 170–183. doi:10.1016/j.jinteco.2010.03.004.

Jenkin, F., 1872. On the principles which regulate the incidence of taxes. Proc. R. Soc. Edinb. (7) 618631.

Lau, L.J., 1982. On identifying the degree of competitiveness from industry price and output data. Econ. Lett. 10 (1–2), 93–99.

LCA, 2015. Lgica econỹmica e efeitos esperados de distintos arranjos para a comercializaÄo de GLP envasado no Brasil. In: RegulaÄo do setor de GLP no Brasil. SindiGas, pp. 80–99.

Miller, N.H., Weinberg, M.C., 2017. Understanding the price effects of the millercoors joint venture. Econometrica 85 (6), 1763–1791. http://www.jstor.org/stable/44955182

Nakamura, E., Zerom, D., 2010. Accounting for incomplete pass-through. Rev. Econ. Stud. 77 (3), 1192–1230 http://www.jstor.org/stable/40835861.

Pavarina, L., 2018. Master's Thesis at Insper Institute of Education and Research.

Petrobras, 2019. Gás liquefeito de petróleo. http://www.petrobras.com.br/pt/produtos-e-servicos/composicao-de-precos-de-venda-ao-consumidor/gas-liquefeito-de-petroleo-glp/.

Pless, J., Benthem, A.V., 2019. Pass-through as a test for market power: an application to solar subsidies. Am. Econ. J..

Seade, J., 1985. Profitable cost increases and the shifting of taxation: equilibrium responses of markets in oligopolyhttps://ageconsearch.umn.edu/record/269225/files/twerp_260.pdf.

Sindigas, 2019. Panorama do Setor de GLP em Movimento, MarÄo 2019 - 33a Edição. http://www.sindigas.org.br/novosite/?page_id=19576.

Sindigas, 2021. Panorama do Setor de GLP em Movimento, Janeiro 2021 - 44a Edição. http://www.sindigas.org.br/novosite/?page_id=19576.

Stolper, S., 2016. Local pass-through and the regressivity of taxes: evidence from automotive fuel markets. In: Proceedings. Annual Conference on Taxation and Minutes of the Annual Meeting of the National Tax Association, vol. 109, pp. 1–9.

Weyl, E.G., Fabinger, M., 2013. Pass-through as an economic tool: principles of incidence under imperfect competition. J. Polit. Economy 121 (3), 528–583.