YOU DO NOT ALWAYS GET WHAT YOU HOPE FOR: ORGANIZED CRIME AND MARKET LIBERALIZATION

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Market liberalization is expected to increase entry, reduce prices, and improve consumer welfare. We show that these effects can be reversed when organized criminal groups (OCGs) already operate illegally in the liberalized market. We study Mexico's 2015–2017 liberalization of the liquefied petroleum gas (LPG) retail market, where OCGs had previously developed the capacity to steal LPG from ducts and commercialize it in territories under their control. We formalize how liberalization can provide legal cover for criminal operations, expand the demand OCGs can capture, and increase the value of territorial control, generating more violent conflict, higher prices, and lower consumption. Empirically, we combine difference-in-differences and instrumental-variable designs that exploit the timing of the reform and the pre-reform location of actual and predicted LPG ducts. Liberalization increased LPG retail service station permits, LPG duct tapping, OCG conflict, and OCG-related homicides and disappearances in municipalities near ducts. Rather than falling, consumer prices increased, especially among retailers with low pass-through to international LPG prices, while households reduced LPG use and substituted toward alternative fuels. The results show that the welfare costs of criminal market power extend beyond violence to include higher prices, reduced energy use, and household energy substitution.

1. INTRODUCTION

The deregulation of markets is a central pillar of contemporary public policy worldwide. By dismantling statutory monopolies, market liberalization is expected to reduce consumer prices, increase quantities, and ultimately improve consumer welfare. Yet in settings where organized criminal groups (OCGs) already operate illegally in those markets, the effect of deregulation is less clear-cut. Market liberalization might allow OCGs to expand their operations by providing legal cover to their previously illegal operations, thereby increasing returns from operating in those markets. Market liberalization might then lead to increased violent competition between OCGs rather than an orderly increase in private-sector entry. Moreover, market liberalization might not lead to lower prices and higher quantities, as OCGs exercise territorial control and can sustain localized monopolies.

We formalize this logic in a simple model. The model compares municipalities where only legal suppliers operate to municipalities where OCGs already control part of the local market

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for a homogeneous good. Before liberalization, OCGs can only serve a limited captured segment of demand, while legal suppliers serve the remaining consumers. Liberalization increases the share of demand that OCGs can capture by allowing them to operate under legal cover, without eliminating their local market power. This has three implications. First, liberalization raises the value of controlling territories connected to the illegal supply chain, increasing the likelihood of conflict between OCGs. Second, because competition among legal suppliers coexists with OCG monopoly power over the captured segment, average prices can rise rather than fall, and price dispersion increases in OCG municipalities relative to non-OCG municipalities. Third, the higher prices induced by criminal market power reduce aggregate consumption of the good, especially among households that can more easily substitute toward alternatives.

We empirically test the model's predictions by exploiting the context of Mexico's 2015–2017 liberalization of the liquefied petroleum gas (LPG) retail market, the sixth worldwide after China, the United States, India, Russia, and Japan (Secretaría de Gobernación, 2022). Until 2013, Mexican Petroleum (PEMEX, *Petróleos Mexicanos*) held a legally mandated monopoly over LPG production, import, and wholesale distribution. Moreover, while the retail distribution sector was technically open to competition, it was effectively constrained: permit issuance was *de facto* extremely limited and prices were regulated by the Energy Regulatory Commission (CRE, *Comisión Reguladora de Energía*). The constitutional reform of December 2013 and the Hydrocarbon Law of 2014 dismantled PEMEX's monopoly and assigned regulatory authority to the Security, Energy, and Environment Agency (ASEA, *Agencia de Seguridad, Energía y Ambiente*). A central goal of the reform was to reduce prices by increasing competition in the retail part of the value chain. Effective LPG retail distribution permit issuance began in 2015 and accelerated in 2016, while regulated prices were fully liberalized in January 2017 (Comisión Reguladora de Energía, 2016).

Critically, OCGs have been operating in the LPG sector for around a decade. Following the Calderón administration's 2006 War on Drugs, there was significant OCG fragmentation and diversification into new economic activities, including fuel—oil and LPG—theft (Battiston, Daniele, Moglie, and Pinotti, 2024). By the early 2010s, OCGs had established territorial control near LPG ducts and developed the operational and logistical capacity to tap LPG ducts and commercialize stolen LPG. Therefore, LPG market liberalization provided legal cover for the OCGs to expand their operations in the territories under their control. Beyond facing a significantly lower likelihood of detection when commercializing stolen LPG, OCGs could start selling it legally, enabling them to capture new residential and non-residential consumers who can buy only from legal suppliers due to regulatory restrictions.

We use difference-in-differences (DiD) and instrumental variable (IV) DiD designs that exploit *two* sources of variation: the uniform timing of the 2015-2017 LPG retail market liberalization and the pre-reform geographic distribution of LPG gas ducts, as cross-sectional variation in the capacity of OCGs to engage in LPG duct tapping and commercialization of stolen LPG. Specifically, we compare outcomes in treated municipalities—those near LPG ducts—with those in control municipalities before and after 2015. As IV, we use municipalities near predicted LPG ducts, which are straight lines between the endpoints of actual LPG ducts. We rely on novel administrative data—compiled through freedom-of-information requests and regulatory open-data portals—and survey data to measure the effects of LPG retail market liberalization on retail LPG distribution permits, LPG duct tapping, OCG conflict, LPG prices, and LPG residential consumption and substitution across all Mexican municipalities.

Across the various empirical specifications, considering different treatment definitions and DiD and IV-DiD strategies, our results are as follows. *First*, annual LPG permits increased after the LPG market liberalization by 13-19% in treated municipalities, relative to control municipalities. This effect is driven by the 2016 acceleration in the granting of LPG retail

service station permits, a category that did not exist before the reform. These results validate the intuition behind the identification strategy: the reform allowed legal LPG retail market entry precisely where OCGs had pre-existing operational and logistical capacity to conduct LPG duct tapping and commercialize stolen LPG. *Second*, LPG duct taps increased on average by 3-5% in treated municipalities, relative to control. Aggregate LPG theft data also indicates a surge in theft immediately following the reform. Taken together, these results on LPG retail service station permits and LPG duct tapping reinforce the view that the LPG retail market liberalization provided legal cover for OCGs to expand their existing illegal operations in the sector.

Third, the higher returns from operating in the LPG retail market triggered violent competition among OCGs in treated municipalities as predicted by the model. The probability of peaceful OCG coexistence (*pax narca*) fell by 2-4 percentage points (pp), while OCG conflict increased by 4-6 pp in treated municipalities relative to controls. Moreover, there is a 16-24% increase in OCG-related homicides, and an 18-29% increase in OCG-related disappearances—individuals reported disappeared who remain missing or were found dead—in treated municipalities compared to control municipalities. Taken together, these results indicate that LPG market liberalization raised the returns to controlling LPG duct-tapping infrastructure and LPG retail distribution in controlled territories, making OCG contestation and deviations from previously peaceful criminal arrangements more likely.

Fourth, despite the significant increase in LPG retail permits, consumer prices rose rather than fell in treated municipalities compared to controls, as predicted by the simple model. The price of LPG distributed through tanker trucks increased by approximately 2-3% and residential cylinder prices by 1-2% in treated municipalities relative to controls, consistent with the model given the higher demand elasticity of the residential-cylinder market than the tanker-truck market. This differential price increase is driven by LPG retailers we predict are likely OCG-affiliated, given their low price elasticity to international LPG prices. Moreover, as the model also predicts, price dispersion is greater in treated than in control municipalities.

Finally, as the model predicts, households reduce their LPG demand and substitute toward alternatives. The likelihood that households use LPG drops by 4.6-7.4 percentage points in treated municipalities, compared to controls, while the likelihood that they use an alternative to LPG increases by 1.4-2.1 percentage points. These patterns are also reflected in household expenditures. Households reduce their LPG expenditures by 0.34-0.54 log points and increase their expenditures on the alternative by 0.10-0.16 log points in treated municipalities compared to control municipalities.

This pattern of increased violent competition, rising LPG prices, and falling LPG consumption in municipalities in the vicinity of LPG ducts, which received the most legal LPG retail entry, is inconsistent with competitive liberalization and consistent with a simple model where LPG market liberalization provided legal cover for OCGs to expand their illegal activities in the LPG sector—LPG duct tapping and LPG retail distribution to captured demand—in the municipalities under their control. The consumer welfare cost of criminal market power thus extends beyond the direct costs of violence to include higher energy prices and lower quantities demanded.

These results are robust to whether we define treated municipalities as those traversed by an LPG duct and their adjacent municipalities, or as those whose borders are within 25 km or 50 km of an LPG duct, and whether we use a DiD or IV-DiD specification. Results are robust to inference using the Conley (1999) standard errors that account for spatial correlation. The causal interpretation of these DiD results is supported by the absence of differential pre-trends between treated and control municipalities, consistent with parallel trends and the no-anticipation assumption. Moreover, the lack of differential pre-trends between predicted treated

and control municipalities supports the exclusion-restriction assumption behind the IV-DiD results.

The paper offers three principal contributions to the literature. *First*, we provide, to our knowledge, the first causal evidence that the pre-reform operation of OCGs in a market can fundamentally shape the effects of market liberalization. Standard accounts of liberalization emphasize entry, competition, lower prices, and higher consumer welfare. We show that these predictions can be reversed when criminal organizations are already embedded in the sector and exercise local territorial control. In this setting, liberalization does not simply open the market to competitive legal entry; it also provides formal cover for criminal organizations to expand operations that were previously illegal or more easily detectable. The closest paper to ours is Pereira and Pucci (2026), who provide indirect evidence that Brazil's gold-sector liberalization induced criminal group entry by showing that violence increased in municipalities with mines. We complement this evidence by studying a market in which OCGs were already operating before liberalization, and by showing directly that liberalization increased legal entry, expanded criminally connected activity, intensified OCG competition—especially by disrupting previously peaceful coexistence—and raised consumer prices while lowering demand.

Relatedly, our paper speaks to work on how changes in the legal status of markets affect violence. Chimeli and Soares (2017) show that the transition of the mahogany trade from legality to illegality increased violence in areas with natural occurrences of mahogany, highlighting the costs of prohibition. We show that a reform in the opposite direction—the liberalization of a previously restricted activity—can also increase violence when criminal groups are already positioned to appropriate the new rents. Thus, the relationship between regulation and violence is not simply about whether a market is legal or illegal, but about how changes in market rules interact with pre-existing criminal control over territory, infrastructure, and distribution.

Second, we add to the literature on the welfare and economic effects of criminal-group presence, infiltration, and territorial control. Existing work shows that criminal governance can affect social welfare through several channels. Brown, Montero, Schmidt-Padilla, and Sviatschi (2025) show that higher extortion rates were passed through to retailers and consumers, raising delivery fees and prices for pharmaceutical drugs, with a corresponding increase in hospital visits for chronic illnesses. Melnikov, Schmidt-Padilla, and Sviatschi (2025) shows that gang territorial control reduces income, assets, and job opportunities in gang-controlled neighborhoods in San Salvador, largely by restricting residents' mobility to protect gang borders, avoid police and rival groups, and facilitate extortion. Related work on criminal infiltration shows that Mafia influence lowers firm productivity in Italy (Mirenda, Mocetti, and Rizzica, 2022, Calamunci and Drago, 2020). Mafia infiltration can also distort firm behavior by providing an alternative source of finance to firms excluded from legal credit markets, allowing them to expand employment while serving the strategic interests of criminal organizations, including money laundering (DDSMM+, 2025). More broadly, Mafia presence is associated with losses in economic activity, as measured by lower GDP growth and electricity consumption (Pinotti, 2015), as well as lower public-good provision and political competition (Acemoglu, Feo, and Luca, 2020). We extend this literature by identifying a product-market channel through which territorial criminal control affects consumer welfare: OCGs can use territorial control and legal cover to sustain market power in a formally liberalized sector, raising prices, reducing LPG use, and inducing households to substitute toward alternative fuels.

Third, we contribute to the literature on the unintended effects of policies implemented in settings marked by organized crime. A growing body of work shows that policies directly targeting criminal groups can generate negative spillovers in places that are strategically valuable for criminal activity. We build on Battiston, Daniele, Moglie, and Pinotti (2024), who show that the Calderón administration's 2006 War on Drugs induced OCG fragmentation and economic

diversification, including into fuel theft from oil ducts, at a time when the sector was still dominated by PEMEX. Calderón's war on drugs has also been associated with increased violence in non-aligned municipalities located along roads leading to the United States (Dell, 2015). In Brazil, air interdiction in Amazon airspace displaced cocaine trafficking routes toward municipalities along river networks originating in the Andean region, inadvertently escalating ground violence (Pereira, Pucci, and Soares, 2024). Spillovers can also cross national borders: cocaine seizures in Colombia exacerbated conflict in Mexico (Mejía and Restrepo, 2016, Castillo, Mejía, and Restrepo, 2020), while OxyContin regulation in the United States promoted cartel expansion and increased violence in Mexican municipalities suitable for opium poppy cultivation (Sobrino, 2020). We show that such unintended effects are not limited to anti-crime or drug-enforcement policies. General economic reforms can also alter criminal rents and generate negative welfare effects when implemented in sectors and territories already penetrated by OCGs. In our setting, LPG market liberalization increased formal entry, but also renewed violent competition between OCGs, raised prices, and reduced household LPG consumption.

The paper proceeds as follows. Section 3 provides institutional background. Section 4 presents the identification strategy. Section 5 describes the data. Section 6 reports results alongside interpretation. Section 7 concludes.

2. THEORY

Consider a setup in which each municipality consists of two territories, indexed by $j \in \{a, b\}$. In each territory, demand for a homogeneous good is $q^j(p) = A^j - \beta p$, with $\beta > 0$ denoting the demand elasticity.

There are two regulatory regimes. Regime m denotes when only a monopoly can legally sell the good, and regime ℓ denotes market liberalization. The legal marginal cost is c_L.

There are two types of municipalities. In non-OCG municipalities, only legal suppliers operate. In OCG municipalities, an incumbent OCG A operates in both territories, and a second OCG B can pay a fixed contest cost κ, drawn from a uniform distribution on $[0, \bar{\kappa}]$, to contest for territory b, which it wins with probability $1/2$. The OCG marginal cost is c_G, with $0 < c_G < c_L$.

The key distinction between the two regimes is that liberalization effectively provides legal cover for OCGs, thereby expanding the share of local demand they can capture. Let $\alpha_m \in (0, 1)$ denote this share in the absence of market liberalization and let $\alpha_\ell \in (0, 1)$ denote the corresponding share under market liberalization, with $0 < \alpha_m < \alpha_\ell < 1$. In an OCG municipality, the captured and uncaptured demand segments in territory j are therefore $q^j_{O,r}(p) = \alpha_r A^j - \beta p$ and $q^j_{L,r}(p) = (1 - \alpha_r)A^j - \beta p$, for $r \in \{m, \ell\}$.

The legal supplier posts a territory-specific price before liberalization. After liberalization, legal suppliers compete and charge marginal cost c_L. In OCG territories, buyers can in principle bypass OCGs, but doing so entails a wedge $\tau > 0$. Throughout, we assume that τ is large enough that the OCG's interior monopoly price on its captured segment is feasible.

ASSUMPTION 1—Interior pricing: *For each territory j, demand is strong enough that all equilibrium quantities below are strictly positive (i.e., $A^j > \beta c_L$, $\alpha_m A^j > \beta c_G$, $\alpha_\ell A^j > \beta c_G$), and the bypass wedge τ is large enough that the OCG's unconstrained monopoly price on the captured segment lies below the relevant bypass cap in both regimes.*

2.1. *No market liberalization*

Without market liberalization, each territory has a legal monopoly wherever OCGs are absent. In OCG municipalities, the legal supplier serves the uncaptured segment, while OCGs

monopolize the captured segment. Since the legal supplier serves a smaller residual market than when OCGs are absent, its local monopoly price is lower. The OCG also prices monopolistically on the captured segment, but because its marginal cost is lower than that of the legal supplier, its price is also below the legal monopoly price observed in non-OCG municipalities. The flip side is that splitting the market into two separately monopolized segments creates an additional output distortion.

PROPOSITION 1—Equilibrium and outcomes without market liberalization: *Fix a territory j. In a non-OCG municipality, the territory-specific legal monopoly price and quantity are $p^j_{m,N} = \frac{A^j+\beta c_L}{2\beta}$ and $Q^j_{m,N} = \frac{A^j-\beta c_L}{2}$.*

In an OCG municipality, the legal supplier charges $p^{j,O}_{L,m} = \frac{(1-\alpha_m)A^j+\beta c_L}{2\beta}$ on the uncaptured segment and the OCG charges $p^j_{O,m} = \frac{\alpha_m A^j+\beta c_G}{2\beta}$ on the captured segment. The corresponding quantities are $q^{j,O}_{L,m} = \frac{(1-\alpha_m)A^j-\beta c_L}{2}$, $q^j_{O,m} = \frac{\alpha_m A^j-\beta c_G}{2}$, so aggregate territory quantity is $Q^j_{m,O} = \frac{A^j-\beta(c_L+c_G)}{2}$.

In an OCG municipality, the probability that OCG B contests territory b is $\Pr(\text{conflict} \mid m) = \min\left\{\frac{(\alpha_m A^b-\beta c_G)^2}{8\beta\bar{\kappa}}, 1\right\}$.

Next, we compare outcomes in OCG and non-OCG municipalities before market liberalization. Because the market is split into two separately monopolized segments, the relevant comparison is between a single monopoly over the whole market and two monopolies over smaller segments. That fragmentation lowers average prices but also quantities.

PROPOSITION 2—Cross-sectional comparison without market liberalization: *Fix a territory j. In the absence of market liberalization, both the legal-segment price and the OCG-segment price in an OCG municipality are below the legal monopoly price in a non-OCG municipality, $p^{j,O}_{L,m} < p^j_{m,N}$ and $p^j_{O,m} < p^j_{m,N}$. Hence, the quantity-weighted average price in an OCG municipality is lower than the price in a non-OCG municipality.*

At the same time, aggregate quantity is lower in OCG municipalities, $Q^j_{m,O} - Q^j_{m,N} = -\frac{\beta c_G}{2} < 0$. Thus, without market liberalization, OCG municipalities have lower average prices and lower aggregate quantities than non-OCG municipalities.

2.2. *Market liberalization*

With market liberalization, legal suppliers compete and therefore charge c_L in every municipality. In non-OCG municipalities, this fully determines equilibrium. In OCG municipalities, legal suppliers still serve the uncaptured segment at price c_L, but the OCG continues to price monopolistically on the captured segment. This means that the relevant comparison is now between a competitive legal benchmark in non-OCG municipalities and a mixed market in which competition coexists with local OCG market power in OCG municipalities.

PROPOSITION 3—Equilibrium and outcomes with market liberalization: *Fix a territory j. In a non-OCG municipality, the legal price and quantity are $p^j_{\ell,N} = c_L$ and $Q^j_{\ell,N} = A^j - \beta c_L$.*

In an OCG municipality, legal suppliers charge $p^{j,O}_{L,\ell} = c_L$ on the uncaptured segment, while OCGs charge $p^j_{O,\ell} = \frac{\alpha_\ell A^j+\beta c_G}{2\beta}$ on the captured segment. The corresponding quantities are $q^{j,O}_{L,\ell} = (1-\alpha_\ell)A^j - \beta c_L$ and $q^j_{O,\ell} = \frac{\alpha_\ell A^j-\beta c_G}{2}$, so aggregate territory quantity is $Q^j_{\ell,O} =$

$A^j\left(1-\frac{\alpha_\ell}{2}\right)-\beta\left(c_L+\frac{c_G}{2}\right)$. *In an OCG municipality, the probability that OCG* B *contests territory* b *is* $\Pr(\text{conflict}\mid \ell)=\min\left\{\frac{(\alpha_\ell A^b-\beta c_G)^2}{8\beta\bar{\kappa}},1\right\}$.

The cross-sectional comparison between OCG and non-OCG municipalities after liberalization is more intuitive. Quantities are always lower in OCG municipalities because part of the market remains monopolized by the OCG. Prices, however, are higher on average only if the post-reform market is sufficiently large, which is likely to hold and we assume. In that region, the price gap widens with α_ℓ and (focusing on the direct effect) narrows with the demand elasticity, β.

PROPOSITION 4—Cross-sectional price and quantity comparisons with market liberalization: *Fix a territory* j. *Aggregate quantity is always lower in OCG municipalities than in non-OCG municipalities,* $Q^j_{\ell,O}-Q^j_{\ell,N}=-\frac{\alpha_\ell A^j+\beta c_G}{2}<0$. *The average price difference between OCG and non-OCG municipalities,* $\bar{p}^j_{\ell,O}-c_L=\frac{(\alpha_\ell A^j-\beta c_G)\left(\alpha_\ell A^j-\beta(2c_L-c_G)\right)}{4\beta\left[A^j\left(1-\frac{\alpha_\ell}{2}\right)-\beta\left(c_L+\frac{c_G}{2}\right)\right]}$, *is positive if and only if* $\alpha_\ell A^j>\beta(2c_L-c_G)$, *and in that region, is increasing in* α_ℓ *and (focusing on the direct effect) decreasing in* β.

Because liberalization expands the demand segment that the OCG can profitably control, it also raises the value of territory control. This makes entry by OCG B more attractive and therefore raises the likelihood of conflict.

Price dispersion is mechanically higher in OCG municipalities under liberalization because legal suppliers charge c_L while OCGs charge territory-specific monopoly prices.

PROPOSITION 5—Cross-sectional price dispersion comparison under market liberalization: *Under market liberalization, unweighted price dispersion is zero in non-OCG municipalities because all sellers charge* c_L. *In an OCG municipality, the unweighted price dispersion is positive.*

PROPOSITION 6—Conflict is more likely under market liberalization: *Suppose* $\alpha_\ell>\alpha_m$. *Then conflict between OCG* A *and OCG* B *in territory* b *is more likely under market liberalization than under no market liberalization whenever* $A^b(\alpha_\ell+\alpha_m)>2\beta c_G$, *which holds under the interior assumptions maintained throughout. Hence,* $\Pr(\text{conflict}\mid \ell)>\Pr(\text{conflict}\mid m)$.

The positive quantity gap between non-OCG municipalities and OCGs widens with market liberalization, and even more so as the share of local demand OCGs can capture increases. At the same time, the legal-market price gap between OCG and non-OCG municipalities is more positive under market liberalization than without it, and more so the larger the share of local demand OCGs can capture under liberalization and less so the more elastic the demand is.[1]

PROPOSITION 7—Difference-in-differences quantity and price comparison: *The quantity gap between OCG and non-OCG municipalities is more negative under market liberalization than under no market liberalization. Specifically,* $\left(Q^j_{\ell,O}-Q^j_{\ell,N}\right)-\left(Q^j_{m,O}-Q^j_{m,N}\right)=-\frac{\alpha_\ell A^j}{2}<0$, *which is decreasing in* α_ℓ.

Moreover, assuming that $\alpha_\ell A^j>\beta(2c_L-c_G)$, *the legal price gap between OCG and non-OCG municipalities is more positive under market liberalization than under no market liberalization. Specifically,* $\left(\bar{p}^j_{\ell,O}-p^j_{\ell,N}\right)-\left(p^{j,O}_{L,m}-p^j_{m,N}\right)=\left(\bar{p}^j_{\ell,O}-c_L\right)+\frac{\alpha_m A^j}{2\beta}>0$, *which is increasing in* α_ℓ *and (focusing on the direct effect) decreasing in* β.

[1] We focus on prediction on overall quantities, but only legal prices due to measurement constraints on the latter.

3. INSTITUTIONAL BACKGROUND

3.1. *LPG Consumption and Substitution in Mexico*

Mexico ranked sixth worldwide in LPG consumption in 2018, after China, the United States, India, Russia, and Japan, according to the Energy Information Administration (Secretaría de Gobernación, 2022). The national domestic LPG demand was 282.5 thousand barrels per day in 2016, which translates to roughly 8.6 million tons annually. Residential demand accounts for approximately 60% of total LPG consumption, while commercial demand represents 14%, vehicular use 10%, industrial use 9%, and other uses the remaining 7% (Secretaría de Energía, 2017).

Two LPG supply modalities operate under distinct regulatory frameworks and distribution systems. The tanker truck mode delivers LPG in bulk via tanker trucks to stationary storage tanks installed at end-users' premises. It is billed per liter and primarily serves commercial, industrial, and suburban residential consumers. The cylinder modality distributes portable cylinders billed by kilogram, predominantly to lower-income residential households. The cylinders are distributed either through route-based cylinder exchange services or via fixed retail outlets.

Tanker truck demand, especially before the LPG market liberalization, has been structurally confined mainly to the legal sector, whereas cylinder demand has a greater scope to acquire LPG through informal channels (Alonso-Berbotto and Chainey, 2021, López-Vallejo and Pilar Fuerte-Celis, 2021). Since non-residential segments are primarily supplied by tanker trucks, they face stronger incentives to acquire LPG from legal suppliers due to the federal regulatory and fiscal framework. First, to deduct commercial purchases as business expenses or claim value-added tax as a credit, buyers require a digital tax receipt validated by the Tax Administration Service. Second, federal regulation of hazardous-materials transport requires tanker truck operators to obtain a permit from the Security, Energy, and Environment Agency (ASEA, *Agencia de Seguridad, Energía y Ambiente*), maintain insurance coverage, and comply with safety inspections (Agencia Nacional de Seguridad Industrial y de Protección al Medio Ambiente del Sector Hidrocarburos, 2016). Informal tanker truck operators do not hold the necessary permits and therefore cannot legally operate within this regulatory framework.

FIGURE 1.—Household cooking and heating energy sources before the LPG market liberalization

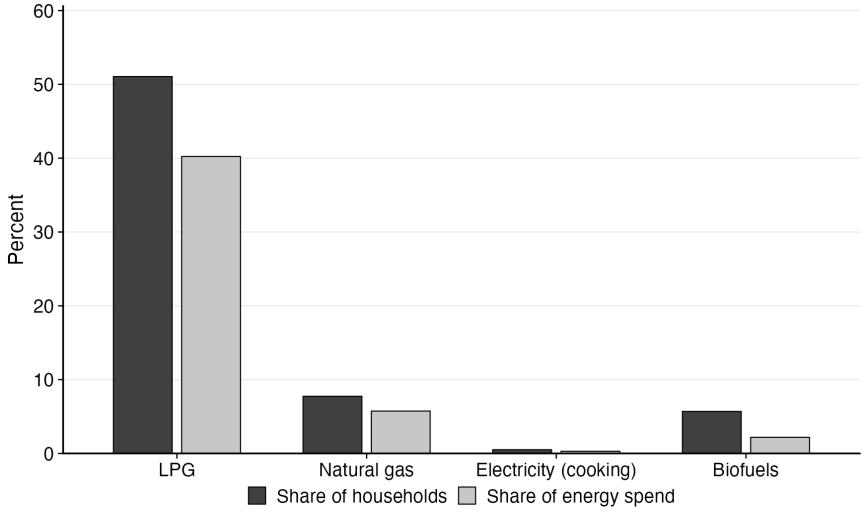


FIGURE 1.—*Note:* Share of households reporting positive quarterly expenditure on each energy cooking and heating source, and share of total household energy spending accounted for by each source, pooling the pre-LPG market liberalization ENIGH waves (2008–2014), survey-weighted. Source: authors' calculations from (Instituto Nacional de Estadística y Geografía, 2021).

While LPG is the dominant cooking and water-heating fuel for Mexican households, they often substitute it for alternative energy sources. Figure 1 uses the ENIGH data prior to the LPG liberalization reform (2008–2014) and shows that 51.1% of households reported positive LPG expenditures, of which 85.4% were LPG cylinder consumers and 14.6% LPG tanker truck consumers, and spent 40.2% of their energy budget on LPG. Very distant analogous figures are 7.7% and 5.7% for natural gas, 0.5% and 0.3% for electricity (cooking), and 5.7% and 2.2% for biofuels. Moreover, ENIGH data shows that 7.6% of the households that use 25.2% of the households that use LPG cylinders and LPG stationary tanks supplied by LPG tanker trucks report using an LPG substitute, suggesting that households that use cylinders are 3.32 times more likely to use an LPG substitute than those supplied via LPG tanker trucks.

3.2. *Mexico's LPG Market Liberalization*

Mexico enacted a progressive reform to liberalize the LPG market between 2013 and 2017, aiming to increase competition and lower prices. The constitutional reform of December 2013 and the Hydrocarbon Law (*Ley de Hidrocarburos*) of 2014 dismantled PEMEX's *de jure* monopoly over LPG production, import, and wholesale distribution, and assigned regulatory authority to the Comisión Reguladora de Energía and to the Security, Energy, and Environment Agency (ASEA, *Agencia de Seguridad, Energía y Ambiente*).

The reform also affected the retail distribution sector by dramatically increasing the number of permits. Before the reform, the retail distribution sector was technically open but effectively constrained: distribution permits were few, and prices were set by Energy Regulatory Commission (CRE, *Comisión Reguladora de Energía*)—maximum allowed prices were published monthly in the Official Gazette of the Federation (DOF, *Diario Oficial de la Federación*). Beginning in 2015, private firms could apply for CRE and ASEA retail and wholesale permits in four categories: distribution plants, service stations, storage facilities, and duct operations.

Figure 2a documents the resulting national LPG permit expansion. The CRE and ASEA suddenly started granting LPG permits in 2016: 3,400 of 4,409 total permits (77%) were granted that year. The main expansion was in the retail service station category, which authorizes consumer-facing LPG retail sale outlets where households and businesses purchase LPG directly, was effectively non-existent before the reform (2 pre-market liberalization grants out of 3,192 total), and jumped to 3,184 new permits in 2016.

The remaining permits (1,214) authorize LPG wholesale distribution and storage. These are primarily for distribution plants that receive LPG from the duct network, store it in large tanks, and distribute it to retailers. Critically, 998 of these 1,214 permits (82%) were granted before the reform, stretching back to 1960, when PEMEX progressively licensed private operators to co-run the wholesale distribution infrastructure within its network. Only 216 new distribution plant permits were issued post-reform, all in 2016.

In addition, regulated prices were fully liberalized in January 2017 (Comisión Reguladora de Energía, 2016), when regulated maximum prices were replaced by market-determined prices monitored by ASEA (Agencia de Seguridad, Energía y Ambiente, 2022).

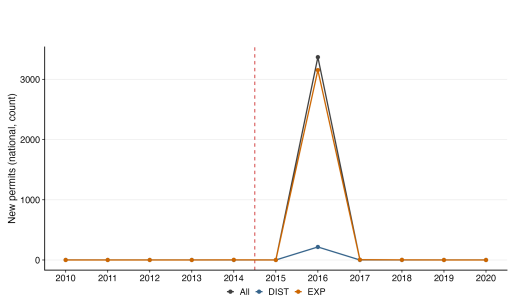
The 2014 Hydrocarbons Law authorized private participation in LPG wholesale transport, but Pemex retained ownership of the entire pre-existing LPG-bearing duct network PEMEX's duct network allows the distribution of oil and gas in Mexico through three operationally distinct ducts (Petróleos Mexicanos (PEMEX) Logística and Centro Nacional de Prevención de Desastres (CENAPRED), 2020). There are 8,386 kms of *polyducts* that transport all refined fuels—gasoline, diesel, and LPG—from refineries to distribution terminals. Dedicated *LPG ducts* transport only LPG and comprise 1,583 kms. Finally, there are 9,168 km of *gasoducts* that transport natural gas through entirely separate corridors and are largely unrelated to LPG distribution. This last category of ducts is operated by the legally distinct entity known as the National Natural Gas Control Center (CENAGAS, *Centro Nacional de Control del Gas Natural*).

3.3. *Criminal Activity along the LPG Duct Corridor*

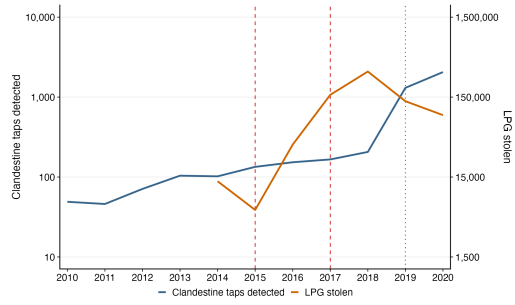
Well before the reform, the LPG duct infrastructure was already the site of systematic criminal exploitation. Following the Calderón administration's 2006 War on Drugs, OCGs fragmented and diversified into new economic activities, including fuel theft—oil and LPG—from PEMEX ducts (Battiston, Daniele, Moglie, and Pinotti, 2024). By the early 2010s, OCGs had built operational capacity for LPG duct tapping—territorial control, infrastructure knowledge, and physical access to the duct network.

Figure 2b shows that clandestine taps on the LPG duct network were commonly documented in Mexico since 2010 (Petróleos Mexicanos (PEMEX) Logística and Centro Nacional de Prevención de Desastres (CENAPRED), 2020, Petróleos Mexicanos, Transparency Unit, 2024). We observe a gradual, sustained rise in documented taps from 2010 to 2018, followed by a jump in 2019. In turn, the volume of LPG stolen for which we have data starting in 2014 experiences a sudden increase after the LPG liberalization reform in 2015.

There were 153 documented events in 2016 confirming pre-existing criminal extraction capacity before the permit market expanded. Documented taps grew 8% to 166 in 2017 and a further 24% to 206 in 2018 as formal market activity deepened. The figure also indicates a 533% increase to 1,305 documented events in 2019, which is associated with the military closure of gasoline polyducts to counter OCG oil theft by the AMLO administration. This prompted criminal organizations to shift their activities from gasoline theft to LPG theft, a natural substitution since both fuels use the same duct network (Lopez and Katovich, 2025).



(a) National LPG permits granted, by type



(b) National documented LPG duct taps and volume

FIGURE 2.—Market entry and illicit activity 2010-2020

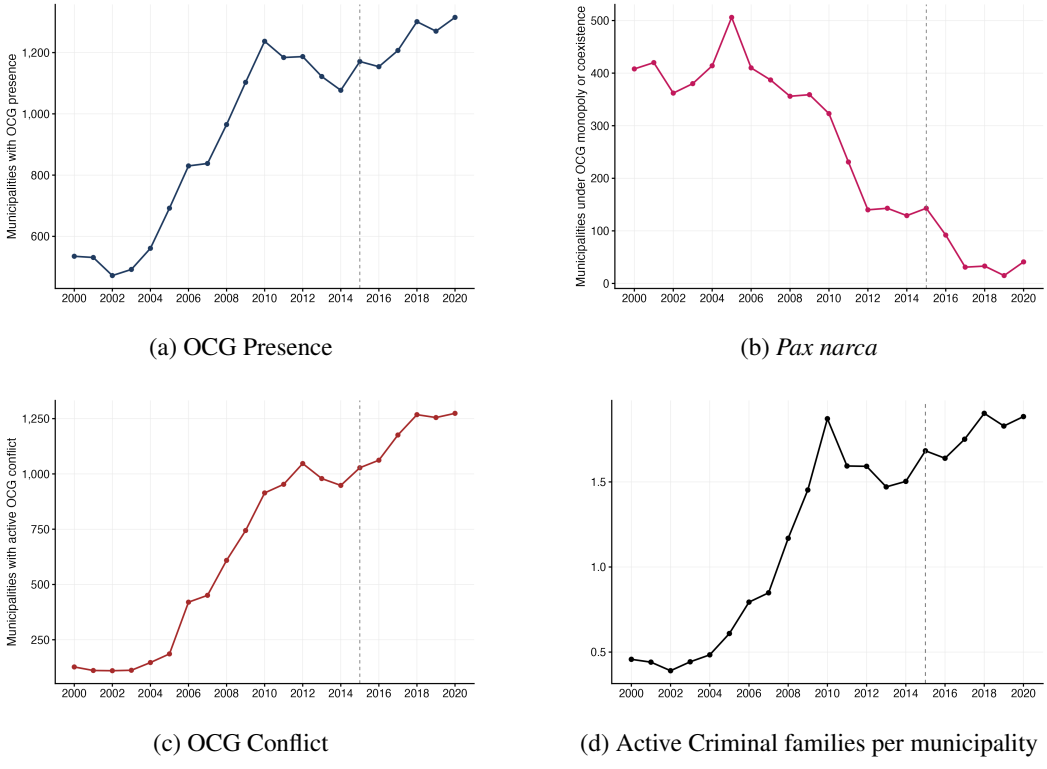
FIGURE 2.—*Note:* Left panel: national LPG permits granted by type; LPG wholesale distribution and storage plant permits in blue, LPG retail service station permits in orange, and their sum in black. Source: Secretaría de Energía and Comisión Reguladora de Energía (2022). Right panel: logged national documented clandestine taps on the LPG duct network plotted and national documented stolen LPG volume. The tap series runs from 2010 and the volume series from 2014. The red dashed lines mark 2015, when private permit issuance began, and 2017, when prices were freed; the gray dotted line marks 2019, when the gasoline ducts were closed. Source: Petróleos Mexicanos, Transparency Unit (2024).

3.4. *Organized Crime Groups: Origins, Expansion, Fragmentation, and Conflict*

The LPG liberalization reform was introduced amid widespread organized crime activity. The origins of Mexico's major criminal organizations lie in the international cocaine trade: as US enforcement dismantled Caribbean trafficking routes in the late 1970s and 1980s, Mexican groups evolved from couriers into major stakeholders, ultimately eclipsing their Colombian predecessors (Astorga and Shirk, 2010). By 1990, six criminal families, within which OCGs are organized, were active across approximately 14% of Mexican municipalities (347 of 2,466), concentrated in Baja California, Chihuahua, Jalisco, Sinaloa, and Tamaulipas.

The Calderón administration's 2006 War on Drugs triggered the most consequential reorganization of this landscape. The targeted removal of senior family leaders produced internal power struggles within families, which, in some instances, led to organizational splintering (Calderón, Robles, Díaz-Cayeros, and Magaloni, 2015, Phillips, 2015). New families—including the Beltrán Leyva Organization, CJNG, and Los Zetas—emerged from internal conflicts that fractured existing families. Greater partisan alternation also weakened long-standing politico-criminal protection networks, leaving organizations exposed to rival attacks and accelerating territorial conflict (Trejo and Ley, 2020). These conflicts within families and between families led them to expand both geographically and economically in search of new markets. OCGs diversified into extortion, human trafficking, illegal mining, kidnapping, and, critically for this paper, fuel theft (Battiston, Daniele, Moglie, and Pinotti, 2024).

FIGURE 3.—National OCG presence and conflict trends across all Mexican municipalities, 2000–2020.



(a) OCG Presence

(b) *Pax narca*

(c) OCG Conflict

(d) Active Criminal families per municipality

FIGURE 3.—*Note*: Vertical dashed line: January 2015 (LPG market liberalization start date). Sources: Sobrino (2020); Osorio (2015); Coscia and Ríos (2012); Armed Conflict Location and Event Data Project (2024).

Figure 3 documents this expansion, fragmentation, and conflict between criminal groups. By 2010, 13 criminal families were active across the country, and at least one OCG was present in 50% of Mexican municipalities (1,237 of 2,466), a pattern that remained largely stable over the following decade. In addition, peaceful coexistence between families and groups within families, which we denote *pax narca*, essentially collapsed after 2006. While there was *pax narca* in 49% (410 of 830) of the OCG-present municipalities in 2006, this dropped to 3% (41 of 1,315) by 2020. At the same time, active conflict between families or groups within families rose sharply after 2006 and reached 97% of OCG-present municipalities by 2020 (1,274 of 1,315).

Figure 4 shows that, as a consequence, OCG-related homicides and disappearances rose dramatically after 2006. OCG-related homicides tripled between 2007 and 2010, from 5,975 to 17,897, reaching a first peak of 19,599 in 2011. They then declined markedly through 2014, falling 37% to 12,356 in 2015. Disappearances similarly peaked and relatively plateaued until 2015, when they reached 4,232. This half-decade-long contraction in homicides and stability in disappearances reversed precisely in 2015, together with LPG market reform. OCG-related homicides rose 63% between 2015 and 2017, from 12,364 to 20,143, and disappearances rose 97% over the same two years, from 4,232 to 8,351, reaching 9,186 by 2020.

FIGURE 4.—National OCG-related homicides and disappearances, 2000–2020

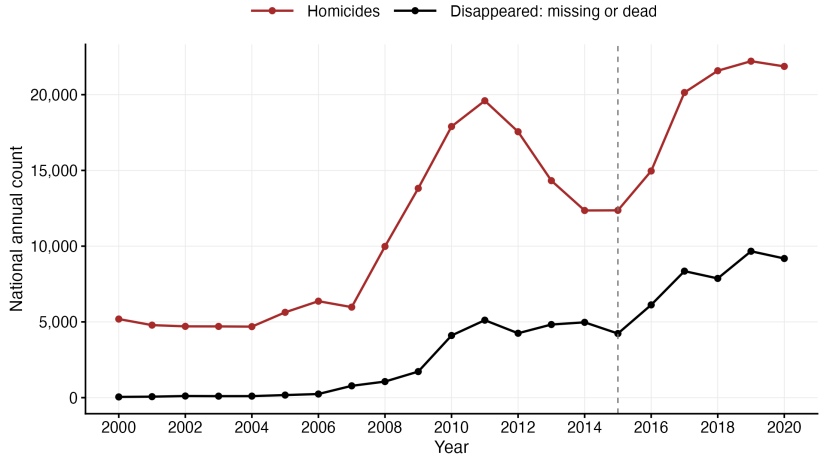


FIGURE 4.—*Note*: Vertical dashed line: January 2015 (LPG market liberalization start date). Sources: See Section 5 for details on OCG-related-homicides construction; The disappearance series counts persons reported disappeared who remain missing or were located deceased, are from Comisión Nacional de Búsqueda, Secretaría de Gobernación (2024)

4. EMPIRICAL STRATEGY

We estimate the effects of the 2015–2017 LPG retail reform using difference-in-differences and instrumental-variable designs that exploit two sources of variation: the uniform timing of the reform across all municipalities, and the pre-reform geographic, actual, or predicted location of the LPG duct network as cross-sectional variation in the likelihood of OCG operation in the LPG sector.

4.1. *Sample and Treatment Definition*

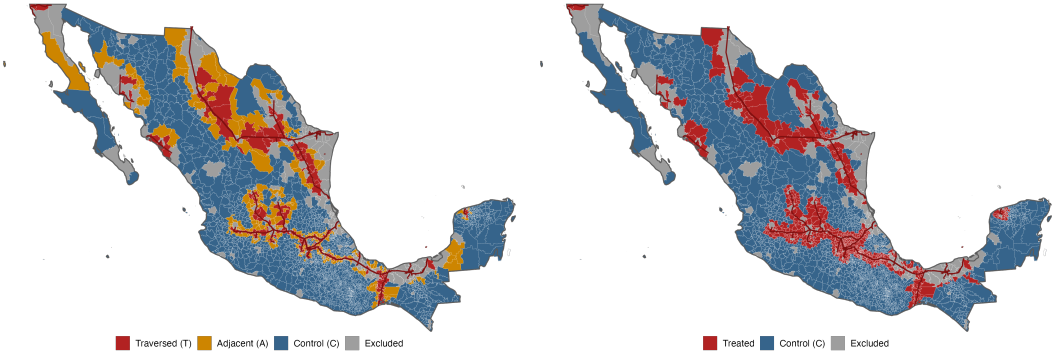
Our sample comprises the $2,287$ municipalities that, aside from differing in whether there is an LPG duct underneath, providing an opportunity for duct tapping, are comparable with regard to local economic and security conditions associated with the production, distribution, and storage of LPG gas.[2] Of the $2,469$ Mexican municipalities, we exclude 180 municipalities that contain any facility regulated by the CRE. These facilities include PEMEX refineries, gas-processing complexes, storage and dispatch terminals, compression stations, special-handling facilities, and border-crossing infrastructure. These municipalities are not only characterized by different local economic conditions and a heavier presence of security forces, but might also provide different incentives for LPG retailers to locate.

Figure 5 portrays the two treatment definitions we consider. First, on the left, 538 treated municipalities are those traversed by an LPG duct (red) or directly adjacent to them (orange), while $1,749$ control municipalities are non-LPG duct, non-adjacent municipalities (blue). Second, on the right, 689 treated municipalities are those whose borders are within 25 km of an

[2]These include those intersected by CENAGAS natural gas ducts, which transport a distinct commodity along entirely separate ducts and are operationally unrelated to PEMEX LPG ducts (Petróleos Mexicanos (PEMEX) Logística and Centro Nacional de Prevención de Desastres (CENAPRED), 2020).

LPG duct via the road network (red), while $1,598$ control municipalities are those further away (blue).

FIGURE 5.—Sample composition under the two treatment definitions



(a) Treatment: Traversed and adjacent

(b) Treatment: Boundary ≤ 25 km

Notes. Cross-section of the 2,289 Mexican municipalities used in the estimation sample under each treatment definition. Excluded municipalities (gray) are those that host at least one LPG infrastructure facility. For the definition on the left, a municipality is treated if traversed by an LPG duct (red) or adjacent (orange). For the definition on the right, a municipality is treated if its boundary lies within 25 km of an LPG duct. Control municipalities (blue) are those untreated. Solid dark-red lines are LPG ducts *Sources.* (Secretaría de Energía and Comisión Reguladora de Energía, 2022)

4.2. *Difference-in-Differences*

Our baseline difference-in-differences specification is as follows:

$$y_{i,t} = \beta D_i \cdot \text{Post}_t^a + \mu_i + \delta_t + \varepsilon_{i,t}, \tag{1}$$

where i indexes municipalities and t years (or year-months). $D_i \in \{0,1\}$ indicates a treatment municipality and Post_t^a indicates the time a after which the corresponding LPG market liberalization took place. This is 2015, when LPG service station permit issuance began, for all outcomes but those derived from LPG prices, which were liberalized in 2017. μ_i and δ_t are municipality and time fixed effects. We report standard errors either clustered at the municipal level, or that account for spatial correlation within 25 km (Conley, 1999).

We consider the following transformations of our outcome variables to address zeros and right-skewness. Binary variables are left as such. Continuous variables without zeros are subjected to the inverse hyperbolic sine (IHS) transformation. Variables with zeros are subjected to the following Chen and Roth (2024) transformation: $\ln(y)$ if $y > 0$ and $-\min\{Y > 0\}$ if $y = 0$, where $\min\{Y > 0\}$ is the smallest strictly positive observed value of y.

The coefficient β identifies the average treatment effect of LPG market liberalization on treated municipalities relative to control municipalities, under three identifying assumptions: parallel trends and no anticipation, no additional contemporaneous differential shocks, and the stable unit treatment value assumption (SUTVA).

The parallel-trends assumption—that, in the absence of the LPG market liberalization, treated and control municipalities would have followed parallel trends in all outcome variables—is fundamentally untestable. However, to provide support for the assumption, we test for parallel pre-trends by estimating event studies analogous to equation (1):

$$Y_{it} = \sum_{\substack{k=-T \\ k\neq -1}}^{+T} \delta_k \left(D_i \times \mathbf{1}[k = t - \tau] \right) + \alpha_i + \gamma_t + \varepsilon_{it}. \quad (2)$$

For all outcomes except those derived from LPG prices, we set $\tau = 2015$ and 2014 as the omitted reference period. For outcomes derived from LPG prices, we consider $\tau =$ January 2017 and thus December 2016 as the omitted reference period. Regardless, to test for parallel pre-trends and anticipation effects, we assess whether pre-LPG market liberalization coefficients are indistinguishable from zero.

Regarding the assumption of no additional differential contemporaneous shocks, the most significant potential threat is the December 2018 closure of gasoline ducts to counter fuel theft by OCGs. Several pieces of evidence lessen this concern. While Figure 2b shows that it triggered a sixfold increase in LPG duct tapping, the LPG volume stolen remained relatively stable. Moreover, the event studies reported in Section 6 indicate that treatment effects for all outcomes except LPG duct tapping already appear by 2015 and show no structural break starting in 2019. Moreover, to further address this possible concern associated with the endogenous location of treated municipalities, we implement a complementary instrumental variable strategy that we describe next.

Lastly, SUTVA requires that a control municipality's potential outcomes are unaffected by the treatment status of other municipalities. OCG activities span municipalities. For example, OCGs contesting access to LPG might establish their presence in adjacent municipalities to establish buffer zones, while also co-opting LPG retail distribution chains in those municipalities. To address this concern, our first treatment definition considers municipalities adjacent to those traversed by an LPG duct as also treated, while our second treatment definition treats municipalities sufficiently close to an LPG duct via the road network as treated. Regardless, any SUTVA violations are likely to bias estimates toward the null.

4.3. *Instrumental Variable*

A concern is that the location of the LPG ducts was chosen with regard to the same local economic and security conditions, which are correlated with time-varying unobservable variables that drive the outcomes of interest. While unlikely, since these facilities were built between the early twentieth century and the late 1970s (Secretaría de Energía, 2017, Petróleos Mexicanos (PEMEX) Logística and Centro Nacional de Prevención de Desastres (CENAPRED), 2020), we address this concern by implementing an instrumental-variable approach commonly used in the economic trade literature (Banerjee, Duflo, and Qian, 2020, Faber, 2014) that exploits the logic of duct building.

To construct the instruments for each treatment definition, we first identify the endpoints of each duct, including refineries, gas-processing complexes, storage and dispatch terminals, and border-crossing infrastructure. We then calculate straight lines from the two endpoints of each duct. For our first treatment definition, the instrument indicates the municipalities traversed by those straight lines, or the municipalities adjacent to them. For our second treatment definition, the instrument indicates municipalities within 25 km of those straight lines via the road network.[3] Excluding the municipalities at the endpoints, whether municipalities are crossed by or proximate to these lines is arguably exogenous to local economic and security conditions.

[3]Appendix Figure 12 shows the extent of overlap between the treatment and instrument for the two treatment definitions graphically.

The first stage, reduced form, and second stage specifications are respectively as follows:

$$D_i \cdot \text{Post}_t^a = \pi Z_i \cdot \text{Post}_t^a + \mu_i + \delta_t + \varepsilon_{i,t}, \tag{3}$$

$$Y_{i,t} = \rho Z_i \cdot \text{Post}_t^a + \mu_i + \delta_t + \varepsilon_{i,t}, \text{and} \tag{4}$$

$$Y_{i,t} = \beta \widehat{D_i \cdot \text{Post}_t^a} + \mu_i + \delta_t + \varepsilon_{i,t}, \tag{5}$$

where Z_i the corresponding straight-line instrument and $\widehat{D_i \cdot \text{Post}_t^a}$ is the instrumented potential endogenous variable.

The coefficient β identifies the local average treatment effect of LPG market liberalization on treated municipalities relative to control municipalities, under three identifying assumptions: relevance, exclusion restriction, and monotonicity. The relevance condition is very likely satisfied in our design, given the instrumental-variable construction, but can be formally assessed by demonstrating a sufficiently strong instrument. Appendix Table VI in Appendix Section C shows that the first stage ranges between 0.74 and 0.92, with F-statistics for the excluded instrument that largely exceed the usual threshold for a strong first stage, and thus that the assumption holds.

The exclusion restriction assumption requires that, conditional on the fixed effects, the instrument affects the outcome of interest through the treatment. While directly untestable, a natural indirect test for the assumption is to test for parallel pre-trends of the instruments by conducting the event study associated with the reduced form:

$$Y_{it} = \sum_{\substack{k=-T \\ k\neq -1}}^{+T} \delta_k \left(Z_i \times \mathbf{1}[k = t - \tau] \right) + \alpha_i + \gamma_t + \varepsilon_{it}. \tag{6}$$

Lastly, by construction of the instrument, the monotonicity assumption is satisfied because the proximity to a predicted LPG duct type can only increase the probability that an LPG duct is realized.

5. DATA

We rely on novel administrative data—compiled through freedom-of-information requests and regulatory open-data portals— and survey data to measure the effects of the LPG retail market liberalization reform on LPG retail distribution permits, LPG duct tapping, LPG volume stolen, OCG conflict, LPG prices, and LPG residential consumption and substitution across all municipalities.

LPG Permits The LPG permit data was obtained via a Freedom of Information request to the Ministry of Energy (SENER, *Secretaría de Energía*) and the Energy Regulatory Commission (CRE, *Comisión Reguladora de Energía*) (Secretaría de Energía and Comisión Reguladora de Energía, 2022). The registry covers 4,409 permits issued between 1960 and 2018, divided into two main categories: 1,214 for distribution plants and 3,192 for service stations. We geocoded 99.3% of the LPG permits (4,379 of 4,409) to the municipality level.

LPG Duct Taps and LPG volume stolen We obtained monthly LPG duct-tapping data from January 2007 to July 2024 and yearly LPG volume stolen from 2014 to 2024 via a freedom of information request to PEMEX (Petróleos Mexicanos, Transparency Unit, 2024). The data includes LPG duct taps reported by municipal and state police forces, and LPG volume stolen data reported by PEMEX. We use this duct tapping data to construct a variable indicating the

number of duct taps at the municipal-month level across all municipalities between 2010 and 2020. The yearly LPG volume stolen is only for descriptive purposes. While the LPG duct taps are likely far from the universe, their dynamics across treated and control municipalities are informative for our identification strategy.

Homicides Homicide data comes from the Statistics on Registered Deaths (*Estadísticas de Defunciones Registradas*), published by the National Institute of Statistics and Geography (INEGI, *Instituto Nacional de Estadística y Geografía*), records all deaths registered in Mexico using the classification of the 10th revision of the International Classification of Diseases, commonly known as ICD-10. We select the records classified as intentional assault. The information includes the date and municipality of occurrence, the incident location, the weapon used, and the victim's demographic variables.

In order to identify which homicides are OCG-related, we use data from the OCG-related homicide event database compiled by the Center for Economic Research and Teaching (CIDE, *Centro de Investigación y Docencia Económicas*) on all confirmed event-level inter-cartel and state-cartel homicides between 2006 and 2011. These data are based on national and regional Mexican news media, prosecutor releases, and specific event reports. Importantly, it includes data on the event location, date, and number of homicides.

We use this data to classify whether a homicide in the INEGI database is OCG-related and extrapolate this classification to the full sample. Specifically, we match the INEGI deaths to the CIDE homicides using the month and municipality of occurrence, and code the likelihood that an INEGI individual's intentional assault is a confirmed inter-cartel and state-cartel violent death. We use a random forest classifier to classify whether an INEGI individual's intentional assault is OCG-related between 2006 and 2011 using as predictors information about the victim's demographics, weapon used, and location characteristics.[4] We then extrapolate this classification to all INEGI individual intentional assaults between 2006 and 2020, which we then aggregate at the municipality-year level.

Disappearances Disappearances are available between 2010 and 2021 from the annual municipal aggregates of the National Registry of Missing and Unlocated Persons (RNPDNO, *Registro Nacional de Personas Desaparecidas y No Localizadas*) from the National Search Commission (*Comisión Nacional de Búsqueda*, SEGOB). The registry classifies every reported individual as still missing, located alive, or located deceased. We aggregate at the municipal-year level instances of reported individuals who remain missing or were located deceased, who are likely OCG-related disappearances.

OCG Variables The OCG dataset records OCG presence and peaceful coexistence or conflict between OCGs across all Mexican municipalities from 1990 to 2020. To build this data set, we rely on four complementary OCG data sources. The primary source is Sobrino (2020), who conducted targeted scraping of a large corpus of national and regional Mexican newspapers from Google News and machine-learning extraction of OCG municipal presence, covering 1990 to 2020. A BERT (Bidirectional Encoder Representations from Transformers) model fine-tuned on labeled news articles classifies the presence of 74 OCGs for all Mexican municipalities.

The second source is Osorio (2015)'s Organized Crime Violence Events Database (OCVED), which documents over 34,000 armed-confrontation events between OCGs in Mexico from 2000 to 2018. The events are geocoded to the municipal level and include actor classifications at two

[4]Consistent with the demographics of those working for OCGs and the nature of inter-cartel and state-cartel confrontations, whether the victim was a male aged 15–49, the weapon used was a firearm, and the incident took place in a public event are the main features that predict whether an INEGI individual's intentional assault is classified as an OCG-related homicide.

levels: primary organization and specific faction or armed wing, enabling both presence and conflict coding from a human-curated event record. The third source is Coscia and Ríos (2012), who constructed a dataset of the locations of the nine main OCGs across Mexico between 1990 and 2010, extracted from reliable sources such as online newspapers and blogs using unambiguous query terms on Google's search engine. The last source is the Armed Conflict Location and Event Data project (Armed Conflict Location and Event Data Project, 2024), which provides georeferenced conflict events—battles, violence against civilians, and riots involving armed groups. We extracted this data for 2018–2020 and aggregated it to the municipality-year level.

We consider the union of the four sources at the municipality-year level. Because the same organization may appear in multiple sources for the same municipality-year, we remove duplicates using a documented crosswalk that links 167 different OCGs to 13 *family* groupings: Cartel de Sinaloa (CDS), Beltrán Leyva Organization (BLO), Cartel del Golfo (CDG), Los Zetas, Cartel Jalisco Nueva Generación (CJNG), Michoacán families (Familia Michoacana, Caballeros Templarios, and Viagras), Cartel de Juárez, Cartel de Tijuana, Guerrero organizations, Huachicoleros, CDMX organizations, Cartel del Milenio, and Regional/local organizations. Each of the 167 crosswalk entries records the source identifier, the source's original organization name, the family assignment, the relationship type (core, faction, armed wing, successor, ally, or regional), the years active, and a primary-source citation supporting the classification.

A key innovation is the construction of year-specific 13×13 rivalry and alliance matrices that capture documented inter-OCG relationships. We code changes in rivalry based on primary sources. In particular, we consider five well-documented events as indicators of changes in alliances: the BLO–CDS split (21 January 2008, triggered by the arrest of Alfredo "El Mochomo" Beltrán Leyva; Treasury OFAC designation jy1952 describes this as an event that "ignited years of bloodshed"); the CDG–Los Zetas split (February 2010, confirmed by DEA threat assessments and CTC West Point, February 2012); CJNG emergence (September 2011, marked by the Veracruz "Matazetas" public debut); and the CJNG–CDS split (January 2014)(U.S. Drug Enforcement Administration, 2012). Prior datasets typically treat inter-OCG relationships as static, but accounting for their dynamics is essential to determine whether there was peaceful coexistence or conflict between OCGs. For instance, a municipality hosting both CDG and Zetas is coded as experiencing OCG conflict only from 2010 onward, but not during the period (1997–2009) when Zetas served as CDG's enforcement arm.

Each municipality-year is then assigned to one of three OCG categories. *Presence*: OCG presence documented in any source. *Pax narca*: at least one OCG present with no active conflict documented, or single-family territorial control (monopoly), or multi-family peaceful coexistence under documented alliance (e.g., as in CDG–Zetas before February 2010). *Conflict*: at least two OCGs present and a documented active rivalry between them. Conflict coding distinguishes two forms of inter-group violence. *Between-family conflict* is identified when two or more families documented as rivals in the year-specific rivalry matrix and are simultaneously present in the same municipality-year. *Within-family conflict* occurs when OCGs of the parent family engage in internal contestation. Crucially, conflict coding is computed at the national family and group levels, and then assigned to municipalities where the involved groups are documented as present.

Lastly, note that we consider two approaches to construct the OCG presence variables, depending on whether we perform imputation. An OCG may be recorded as active in a given municipality in year t and again in year $t + k$ $(k > 1)$, but not in the years in between $t+1, \ldots, t+k-1$. In cases where families exercise a monopoly of control over municipalities, these discontinuities likely reflect OCG detection failures rather than a genuine absence from the municipality, due to a lack of need to engage in violent conflict and pressure on local media to avoid reporting. Our baseline coding then assumes that such an OCG was present between

the years t and $t + k$, but Appendix **??** reports estimates without this imputation, which yield very similar results.

LPG Retail Prices LPG price data comes from three sources. Prices before the LPG market liberalization period (January 2014 through December 2016) were regulated at the state level, and the highest price allowed per state was published monthly in the Official Gazette of the Federation (DOF, *Diario Oficial de la Federación*) (Diario Oficial de la Federación, 2016). We attribute each state's highest price allowed in a given state-month uniformly to every municipality in the state for that month, since the highest prices allowed were effectively binding.

For the post-deregulation period (January 2017 onwards), prices come from two CRE registries obtained under freedom-of-information requests (Comisión Reguladora de Energía, 2022). The first registry contains daily prices per LPG kilogram reported by permit holders when complying with the reporting regulations. Given the limited enforcement, these data are spotty and likely from competitive permit holders rather than OCGs. We only have 970 permit holders reporting LPG price data across 521 municipalities, which is a very small subset of the 3,192 LPG retail service station permits. The second registry is constructed by CRE and is already aggregated at the municipality-month-delivery-mode level. These data include 83.7% of municipality-months in Mexico.

Household Energy Expenditure We measure the household-level use and expenditure on LPG and alternative energy sources, differentiating between clean alternatives (natural gas) and biofuels and other fossil fuels, from nine biennial waves of the National Household Income and Expenditure Survey (*Encuesta Nacional de Ingresos y Gastos de los Hogares*, ENIGH) covering the 2008–2024 period (Instituto Nacional de Estadística y Geografía, 2021).The pooled estimation sample comprises 323,696 households residing in 1,682 in-sample municipalities. For each household wave, we observe quarterly expenditure on LPG, natural gas, electricity, and other fuels, including biomass (firewood and charcoal) and other fossil fuels (diesel, kerosene, and candles). We construct household-level use of LPG, natural gas and electricity, and other fuels by considering positive spending in those categories. We also aggregate the total spending in those categories at the household level. Importantly, there is also information on whether the household can use LPG via a stationary tank refilled by a tanker truck or cylinders.

6. RESULTS

We begin by showing the effects of LPG market liberalization in treated municipalities relative to control municipalities on LPG permits and duct taps, which validate the intuition of the empirical identification design. We then examine how liberalization affected organized-crime dynamics through different measures of expansion and conflict. Finally, we study the consumer-welfare implications by analyzing LPG consumer prices, household LPG use, and substitution toward alternative fuels.

6.1. *LPG Permits and Duct Taps*

Table I reports average effects of the LPG market liberalization on new LPG permits and on illicit duct taps. Across all tables, each column reports the OLS two-way fixed-effect estimate (TWFE), the reduced-form (RF) TWFE on the corresponding straight-line corridor instrument, and the instrumental variable (IV) TWFE successively. Moreover, columns 1 to 3 define as treated municipalities those traversed by an LPG duct and their adjacent ones (Duct $\cup$ Adjacent), while columns 4 to 6 define as treated municipalities the ones with borders within 25 km from an LPG duct ($\leq$ 25 km). Cluster-robust standard errors at the municipality level appear in parentheses, while Conley (1999) standard errors that account for spatial correlation within 25 km appear in square brackets.

The first row of Panel A indicates that LPG market liberalization is associated with an annual increase of 13-19% in LPG permits in treated municipalities relative to control municipalities. The second and third rows indicate that this effect is driven by an annual 12-18% increase in LPG retail service station permits rather than by the smaller annual 1.5-2.5% increase in LPG wholesale distribution and storage permits. In turn, Panel B shows that the effect of liberalization on documented LPG duct taps increased significantly by 3-5% in treated municipalities relative to control municipalities. These results validate the intuition behind our identification design: the liberalization reform disproportionately led to formal LPG retail entry in municipalities near LPG ducts, where OCGs already had operational capacity to tap and commercialize LPG.

The estimates are robust to defining treated municipalities as those traversed by an LPG duct and their adjacent municipalities, or as those whose borders are within 25 km or 50 km of an LPG duct (see Appendix **??** for results with 50 km). They are also robust to inference using Conley (1999) standard errors that account for spatial correlation within 25 km.

TABLE I

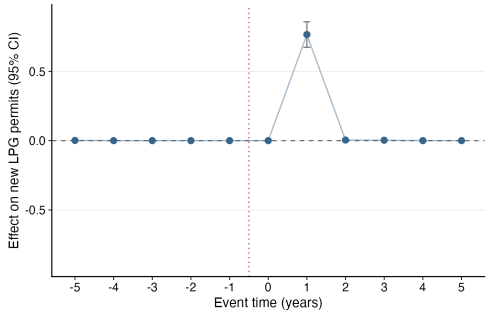
EFFECTS OF LPG MARKET LIBERALIZATION ACROSS TREATED AND CONTROL MUNICIPALITIES ON NEW LPG PERMITS AND LPG DUCT TAPS

	Duct ∪ Adjacent			Boundary ≤ 25 km		
Outcome	OLS	RF	IV	OLS	RF	IV
Panel A. New LPG Permits						
New permits (all categories) (Chen and Roth (2024))						N=25,124
	0.1429^{***}	0.1412^{***}	0.1899^{***}	0.1285^{***}	0.1262^{***}	0.1394^{***}
	(0.0090)	(0.0081)	(0.0112)	(0.0079)	(0.0080)	(0.0088)
	$[0.0148]^{***}$	$[0.0150]^{***}$	$[0.0206]^{***}$	$[0.0161]^{***}$	$[0.0161]^{***}$	$[0.0177]^{***}$
New LPG retail service station permits (Chen and Roth (2024))						N=25,124
	0.1382^{***}	0.1357^{***}	0.1825^{***}	0.1240^{***}	0.1223^{***}	0.1350^{***}
	(0.0088)	(0.0079)	(0.0109)	(0.0077)	(0.0078)	(0.0086)
	$[0.0144]^{***}$	$[0.0145]^{***}$	$[0.0197]^{***}$	$[0.0155]^{***}$	$[0.0154]^{***}$	$[0.0170]^{***}$
New LPG wholesale distribution and storage permits (Chen and Roth (2024))						N=25,124
	0.0175^{***}	0.0182^{***}	0.0245^{***}	0.0158^{***}	0.0149^{***}	0.0165^{***}
	(0.0029)	(0.0026)	(0.0035)	(0.0025)	(0.0025)	(0.0027)
	$[0.0035]^{***}$	$[0.0032]^{***}$	$[0.0045]^{***}$	$[0.0033]^{***}$	$[0.0032]^{***}$	$[0.0036]^{***}$
Panel B. LPG Taps						
LPG duct taps (Chen and Roth (2024))						N=329,616
	0.0362^{***}	0.0363^{***}	0.0488^{***}	0.0347^{***}	0.0348^{***}	0.0384^{***}
	(0.0086)	(0.0074)	(0.0100)	(0.0071)	(0.0071)	(0.0079)
	$[0.0152]^{**}$	$[0.0145]^{**}$	$[0.0192]^{**}$	$[0.0137]^{**}$	$[0.0138]^{**}$	$[0.0151]^{**}$

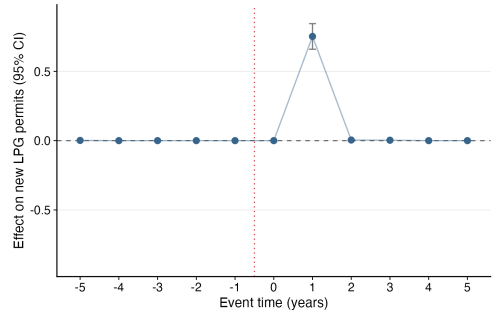
Notes: All specifications include municipality and time fixed effects. Observations in Panel A are at the municipality-year level, and in Panel B at the municipality-month level. OLS estimates are TWFE, RF estimates are reduced-form TWFE on the corresponding straight-line corridor instrument, and IV estimates are the corresponding instrumental variable TWFE. Columns 1 to 3 define as treated municipalities those traversed by an LPG duct and their adjacent ones (Duct ∪ Adjacent), while columns 4 to 6 define as treated municipalities the ones with borders within 25 km from an LPG duct (≤ 25 km). Variable transformation in parentheses. Standard errors clustered at the municipality level in parentheses, and standard errors that account for spatial correlation with 25 km in square brackets Conley (1999). * p<0.1, ** p<0.05, *** p<0.01.

The event study plots in Figure 6 provide support for the parallel-trend and exclusion-restriction assumptions on LPG permits and duct taps. Pre-reform OLS and RF coefficients are substantively small and statistically indistinguishable for all outcomes in Table I. Treatment effects on LPG permits peak in 2016, when the ASEA started granting service station permits and processing backlogged distribution permits. In contrast, effects on LPG duct taps are rather small immediately after the reform and only accelerate sharply in 2019, consistent with the documented OCG shift from oil theft to LPG theft after the government temporarily shut down oil ducts to counter fuel theft, commonly known in Mexico as *huachicol*.

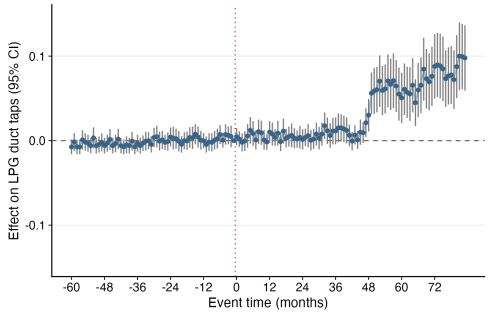
FIGURE 6.—Dynamic Effects of LPG market liberalization across treated and control municipalities on LPG permits and LPG duct taps



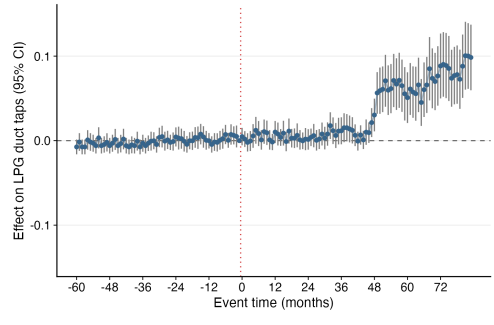
Panel A. New LPG Permits (all categories) · OLS



Panel A. New LPG Permits (all categories) · RF



Panel B. LPG Duct Taps · OLS



Panel B. LPG Duct Taps · RF

FIGURE 6.—*Note:* Event-study figures corresponding to the OLS (left) and reduced-form (right) specifications in Table I. Treated municipalities are defined as those whose borders are within 25 km of an LPG duct via the road network. Standard errors are cluster-robust at the municipality level. The event studies for the remaining specifications are reported in Appendix **??**. The reference period is 2014 in Panel A and December 2014 in Panel B.

6.2. *OCG Conflict*

Proposition 6 indicates that LPG market liberalization should increase OCG contestation, and consequently OCG-related conflict, in treated municipalities. The results in Table II support this prediction. Panels A and B show that the liberalization reform led to a 2-4 percentage points (pp) decline in peaceful OCG coexistence (*pax narca*) and an associated 4-6 pp increase in OCG conflict in treated municipalities relative to control municipalities.[5] In turn, reflecting this increased conflict between OCGs, Panels C and D show a 16-24% increase in OCG-related homicides, and 18-29% in OCG-related disappearances in treated municipalities relative to control municipalities.

The pattern is also stable across treatment definitions and when using spatially correlated standard errors. In addition, the event study plots in Figure 7 provide support for the parallel-trend and exclusion-restriction assumptions on OCG conflict-related outcomes. Moreover, we observe a sharp differential drop in peaceful coexistence and an increase in conflict between OCGs, as well as an associated increase in OCG-related homicides and disappearances, that stabilizes three years after the liberalization reform.

TABLE II

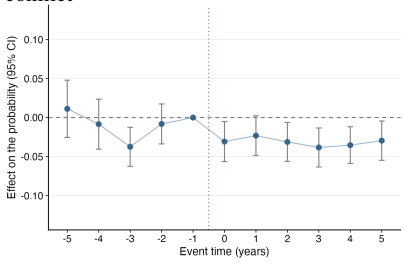
EFFECTS OF LPG MARKET LIBERALIZATION ACROSS TREATED AND CONTROL MUNICIPALITIES ON OCG CONFLICT

	Duct ∪ Adjacent			Boundary $\leq$25 km		
Outcome	OLS	RF	IV	OLS	RF	IV
Panel A. Peaceful OCG Control						N=25,124
Pax Narca (binary)	-0.0355^{***}	-0.0279^{***}	-0.0375^{***}	-0.0228^{***}	-0.0229^{***}	-0.0252^{***}
	(0.0096)	(0.0085)	(0.0114)	(0.0083)	(0.0084)	(0.0093)
	$[0.0133]^{***}$	$[0.0118]^{**}$	$[0.0158]^{**}$	$[0.0120]^{*}$	$[0.0119]^{*}$	$[0.0132]^{*}$
Panel B. OCG Conflict						N=25,124
OCG Conflict (binary)	0.0447^{***}	0.0407^{***}	0.0547^{***}	0.0505^{***}	0.0519^{***}	0.0573^{***}
	(0.0137)	(0.0123)	(0.0165)	(0.0119)	(0.0120)	(0.0133)
	$[0.0189]^{**}$	$[0.0172]^{**}$	$[0.0229]^{**}$	$[0.0159]^{***}$	$[0.0166]^{***}$	$[0.0184]^{***}$
Panel C. OCG-related Homicides						N=24,486
OCG-related Homicides	0.1619^{***}	0.1604^{***}	0.2157^{***}	0.2294^{***}	0.2203^{***}	0.2436^{***}
(Chen and Roth (2024))	(0.0418)	(0.0369)	(0.0497)	(0.0344)	(0.0349)	(0.0385)
	$[0.0645]^{**}$	$[0.0584]^{***}$	$[0.0778]^{***}$	$[0.0536]^{***}$	$[0.0563]^{***}$	$[0.0616]^{***}$
Panel D. Disappearances						N=25,102
Disappearances: still missing or found dead	0.1844^{***}	0.2121^{***}	0.2853^{***}	0.2188^{***}	0.1950^{***}	0.2153^{***}
(Chen and Roth (2024))	(0.0339)	(0.0303)	(0.0413)	(0.0292)	(0.0294)	(0.0324)
	$[0.0438]^{***}$	$[0.0414]^{***}$	$[0.0564]^{***}$	$[0.0453]^{***}$	$[0.0451]^{***}$	$[0.0496]^{***}$

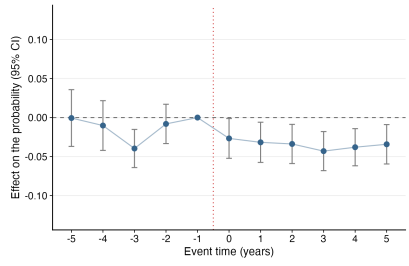
Notes: All specifications include municipality and year fixed effects. Observations are at the municipality-year level. OLS estimates are TWFE, RF estimates are reduced-form TWFE on the corresponding straight-line corridor instrument, and IV estimates are the corresponding instrumental variable TWFE. Columns 1 to 3 define as treated municipalities those traversed by an LPG duct and their adjacent ones (Duct ∪ Adjacent), while columns 4 to 6 define as treated municipalities the ones with borders within 25 km from an LPG duct ($\leq$ 25 km). Variable transformation in parentheses. Standard errors clustered at the municipality level in parentheses, and standard errors that account for spatial correlation with 25 km in square brackets Conley (1999). * p<0.1, ** p<0.05, *** p<0.01.

[5]The results in Appendix **??** also point to a 2.8-3.2 pp increase in OCG presence and a 8.6-13.0% increase in the number of families operating in the municipality, although the results on OCG presence are not robust to defining treated municipalities as those traversed by an LPG duct and their adjacent ones. These results are consistent with the model, which does not distinguish between OCGs already present in the municipality but not operating in the LPG market and those entering the municipality to enter the market.

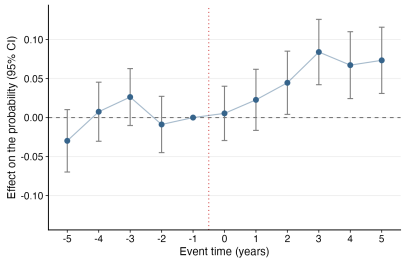
FIGURE 7.—Dynamic effects of LPG market liberalization across treated and control municipalities on OCG conflict



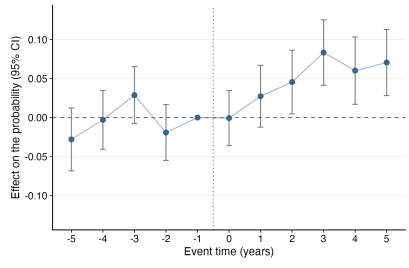
Panel A. Peaceful OCG Control · OLS



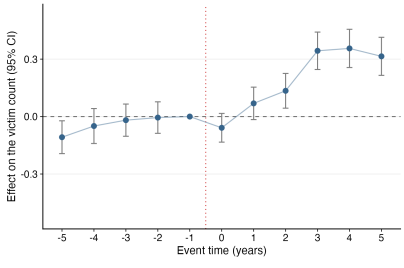
Panel A. Peaceful OCG Control · RF



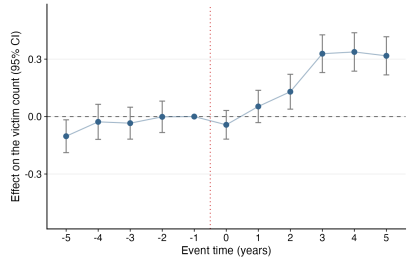
Panel B. OCG Conflict · OLS



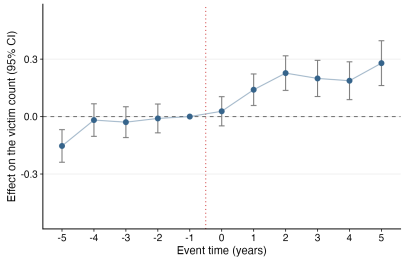
Panel B. OCG Conflict · RF



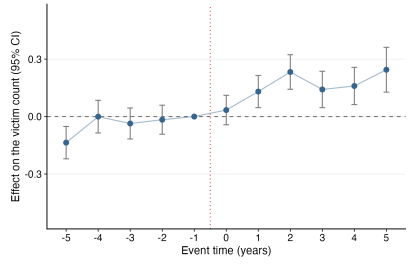
Panel C. OCG-related Homicides · OLS



Panel C. OCG-related Homicides · RF



Panel D. Disappearances: still missing or found dead · OLS



Panel D. Disappearances: still missing or found dead · RF

FIGURE 7.—*Note:* Event-study figures corresponding to the OLS (left) and reduced-form (right) specifications in Table II. Treated municipalities are defined as those whose borders are within 25 km of an LPG duct via the road network. Standard errors are cluster-robust at the municipality level. The event studies for the remaining specifications are reported in Appendix **??**. The reference period is 2014.

6.3. *LPG Retail Prices*

Proposition 7 indicates that LPG market liberalization should have led to a larger price increase in treated municipalities than in control municipalities.[6] Moreover, it does not unambiguously predict whether the effect should be greater for the LPG cylinder or tanker truck markets. On the one hand, it suggests that the effect should be greater for the LPG tanker truck market than the LPG cylinder market, given that the demand elasticity (in the model, β) is higher in the LPG cylinder market because it is driven by residential households who are more likely to substitute LPG consumption for alternative fuels. On the other hand, it suggests the opposite, given that LPG market liberalization allowed OCGs to access a larger LPG market (in the model, α_ℓ) through cylinder distribution to primarily residential informal demand, rather than through tanker truck distribution to much more formal non-residential demand.

The results in Table III support the main prediction of Proposition 7 regarding the average effect of the LPG market liberalization on the legal price gap between treated and control municipalities. Moreover, they suggest that the greater elasticity of demand dominates the larger capturable market size in explaining the heterogeneity in this effect between the LPG cylinder and tanker truck markets. Panel A shows that the LPG market liberalization led to a 2-3% increase in average monthly legal prices of LPG distributed through tanker trucks in treated municipalities compared to control municipalities, while Panel B shows an analogous, smaller 1-2% increase in average legal prices of LPG distributed through cylinders. Moreover, the estimated effect is between 41 and 89% higher in the LPG tanker truck market than in the LPG cylinder market for each estimator.

To further probe the mechanism behind the prediction of Proposition 7 regarding the effect of LPG market liberalization on the legal LPG price difference across treated and control municipalities, we explore heterogeneous treatment effects by examining the elasticity of LPG prices with respect to international LPG prices across retailers. Estimates from Panels A and B use LPG price data at the municipal-month level, already aggregated by the CRE. We also have spotty daily LPG price data at the retailer-municipality level for the limited subset of retailers that complied with CRE reporting requirements. The model implies that prices charged by non-OCG retailers should be more elastic to legal marginal costs than prices charged by OCG retailers.[7] We therefore classify retailers according to the elasticity of their prices with respect to the international LPG price, which is the main component of LPG marginal costs. We expect the positive effects of LPG market liberalization on legal prices to be driven by low-elasticity retailers. High-elasticity retailers operate in competitive markets and should, in theory, sell at marginal cost. Consequently, there should be no post-liberalization price difference among them across treated and control municipalities.

For comparison purposes, Panel C replicates the specification in Panels A and B, but with LPG price data at the retailer-municipality-month level, while Panel D reports heterogeneity by above- versus below-median retailer LPG price elasticity with respect to LPG international prices. Compared with the positive treatment effects in Panels A and B, the null effects in Panel C indicate that retailers who comply with reporting their LPG prices to the CRE are more likely to be non-OCG retailers. More importantly, as expected, the estimates in the second row of Panel D indicate that the positive effects of LPG market liberalization on LPG prices are driven by the least elastic LPG retailers. Consistent with the model, the LPG market liberalization

[6] Given the LPG prices were regulated prior to LPG market liberalization by the CRE, note also that Proposition 4 also indicates that the LPG prices should be higher in treated municipalities than in control municipalities under LPG market liberalization.

[7] In the model, the prices of non-OCG retailers, but not those of OCG retailers, vary with legal marginal costs.

led to a small, statistically insignificant effect on the prices of LPG retailers with high (above-median) elasticity in treated municipalities relative to control municipalities. Moreover, the LPG market reform had a more positive effect on the least elastic retailers (below median) than the most elastic retailers (above median) in treated municipalities than in control municipalities.

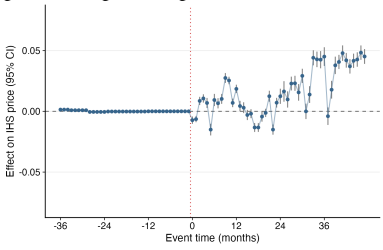
TABLE III

EFFECTS OF LPG MARKET LIBERALIZATION ACROSS TREATED AND CONTROL MUNICIPALITIES ON LPG RETAIL PRICES AND PRICE DISPERSION

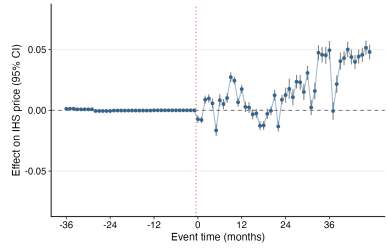
	Duct ∪ Adjacent			Boundary ≤ 25 km		
Outcome	OLS	RF	IV	OLS	RF	IV
Panel A. Mean Tanker Truck Retail Price						
Mean tanker truck retail price (IHS)						N=164,071
	0.0185^{***}	0.0209^{***}	0.0280^{***}	0.0166^{***}	0.0176^{***}	0.0192^{***}
	(0.0020)	(0.0019)	(0.0026)	(0.0018)	(0.0018)	(0.0020)
	$[0.0045]^{***}$	$[0.0046]^{***}$	$[0.0063]^{***}$	$[0.0048]^{***}$	$[0.0049]^{***}$	$[0.0053]^{***}$
Panel B. Mean Cylinder Retail Price						
Mean cylinder retail price (IHS)						N=155,953
	0.0128^{***}	0.0147^{***}	0.0198^{***}	0.0088^{***}	0.0097^{***}	0.0105^{***}
	(0.0020)	(0.0019)	(0.0026)	(0.0018)	(0.0018)	(0.0020)
	$[0.0043]^{***}$	$[0.0044]^{***}$	$[0.0060]^{***}$	$[0.0047]^{*}$	$[0.0047]^{**}$	$[0.0051]^{**}$
Panel C. Mean Permit-holder Price (IHS)						
Mean permit-holder price (IHS)						N=35,351
	-0.0062	0.0001	0.0001	-0.0039	-0.0022	-0.0024
	(0.0068)	(0.0062)	(0.0086)	(0.0062)	(0.0062)	(0.0066)
	[0.0082]	[0.0099]	[0.0136]	[0.0096]	[0.0097]	[0.0103]
Panel D. Mean Permit-holder Price by Above/Below-Media Elasticity with Respect to International Prices						
						N=35,351
Above median elasticity	-0.0132^{*}	-0.0081	-0.0099	-0.0112^{*}	-0.0096	-0.0100
	(0.0072)	(0.0067)	(0.0085)	(0.0066)	(0.0067)	(0.0071)
	[0.0089]	[0.0107]	[0.0136]	[0.0103]	[0.0107]	[0.0112]
Below − above median (differential)	0.0153^{**}	0.0165^{***}	0.0222^{***}	0.0148^{***}	0.0146^{***}	0.0148^{***}
	(0.0066)	(0.0056)	(0.0077)	(0.0056)	(0.0056)	(0.0057)
	$[0.0085]^{*}$	$[0.0076]^{**}$	$[0.0106]^{**}$	$[0.0076]^{*}$	$[0.0077]^{*}$	$[0.0078]^{*}$
Panel E. Monthly Inter-Permit-Holder SD						
Monthly inter-permit-holder SD (Chen and Roth (2024))						N=8,079
	0.5784^{**}	0.8298^{***}	1.1170^{***}	0.7830^{***}	0.8209^{***}	0.8643^{***}
	(0.2316)	(0.2583)	(0.3554)	(0.2652)	(0.2562)	(0.2719)
	$[0.2048]^{***}$	$[0.2671]^{***}$	$[0.3746]^{***}$	$[0.2734]^{***}$	$[0.2655]^{***}$	$[0.2818]^{***}$

Notes: All specifications include municipality and calendar month fixed effects. Observations are at the municipality-month level in Panels A, B, and E, and municipality-month-permit holder in Panels C and D. In Panel E, the sample is restricted to municipality-months with at least two permit holders reporting LPG retail prices. OLS estimates are TWFE, RF estimates are reduced-form TWFE on the corresponding straight-line corridor instrument, and IV estimates are the corresponding instrumental variable TWFE. Columns 1 to 3 define as treated municipalities those traversed by an LPG duct and their adjacent ones (Duct ∪ Adjacent), while columns 4 to 6 define as treated municipalities the ones with borders within 25 km from an LPG duct ($\leq$ 25 km). Variable transformation in parentheses. The number of observations differs since the permit-holder data is spottier. Standard errors clustered at the municipality level in parentheses, and standard errors that account for spatial correlation with 25 km in square brackets Conley (1999). * p$<$0.1, ** p$<$0.05, *** p$<$0.01.

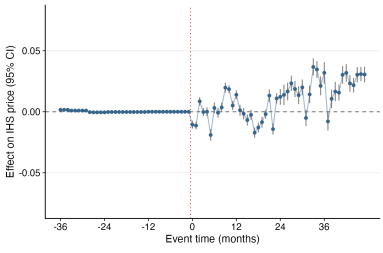
FIGURE 8.—Dynamic Effects of LPG market liberalization across treated and control municipalities on LPG retail prices and price dispersion



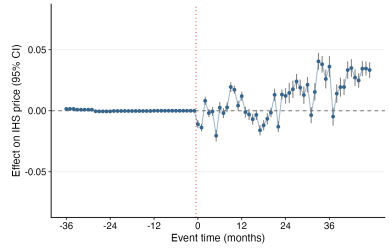
Panel A. Mean Tanker Truck Retail Price · OLS



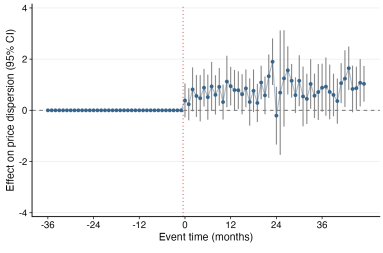
Panel A. Mean Tanker Truck Retail Price · RF



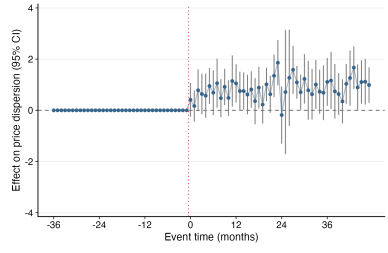
Panel B. Mean Cylinder Retail Price · OLS



Panel B. Mean Cylinder Retail Price · RF



Panel E. Monthly inter-permit-holder SD · OLS



Panel E. Monthly inter-permit-holder SD · RF

FIGURE 8.—*Note:* Event-study figures corresponding to the OLS (left) and reduced-form (right) specifications in Table III. Panel letters follow Table III; Panels C and D are not displayed. Treated municipalities are defined as those whose borders are within 25 km of an LPG duct via the road network. Standard errors are cluster-robust at the municipality level. The event studies for the remaining specifications are reported in Appendix **??**. The reference period is December 2016.

Lastly, we test the prediction of Proposition 5 regarding LPG price dispersion in treated municipalities compared to control municipalities under LPG market liberalization.[8] Panel E of Table III presents results of the LPG market liberalization on price dispersion, where the outcome is the municipal standard deviation of each retailer's monthly average LPG price. The results indicate that, consistent with Proposition 5, under LPG market liberalization, LPG price dispersion is greater in treated municipalities than in control municipalities.

The price estimates are similarly robust to treatment definition and to inference that accounts for spatial clustering. Importantly, while the event studies in Figure 8 appear to support parallel-trend and exclusion-restriction assumptions across different price outcomes, this is partly mechanical, given that prior to the liberalization reform, the prices were regulated and set at the state-month level. Also worth mentioning is that, while we see somewhat unstable dynamic treatment effects across all price outcomes, likely reflecting the spottiness of the reported LPG price data, the overall pattern of the treatment effects is clear.

These results suggest that, in contrast to standard competitive liberalization models, and consistent with the model in Section 2, LPG prices increased in both level and dispersion across retailers following LPG market liberalization in treated municipalities, compared to controls. However, the results also show that these effects are driven by retailers we predict are likely OCGs.

6.4. *Household Energy Use and Expenditures*

Proposition 7 indicates that LPG market liberalization should have led to a greater reduction in LPG consumption in treated municipalities than in control municipalities. The results in Tables IV and V, which analyze the differential effect of LPG market liberalization across treated and control municipalities on household energy use and expenditures, support this prediction. Panel A of Table IV indicates that LPG market liberalization led to a 4.6-7.4 percentage point reduction in the likelihood that households use LPG in treated municipalities compared to control municipalities. Panel B shows the counterpart: a 1.4-2.1 percentage point increase in the likelihood that households use a clean alternative to LPG; natural gas or electricity.

Table V is analogous to Table IV but focuses on energy expenditure as opposed to use. Panel A suggests that LPG market liberalization led to a 0.34-0.54 log point reduction in LPG spending in treated municipalities compared to control municipalities. Panel B shows that the counterpart of this effect is a 0.10-0.16 log point increase in spending on clean alternatives to LPG. Importantly, consistent with the model, these results are driven by households who consume LPG via cylinders rather than stationary tanks and thus represent more elastic demand.

These household estimates are similarly robust to treatment definition and to inference that accounts for spatial clustering. The event studies in Figures 9 and 10 support the parallel-trend and exclusion-restriction assumptions across the different outcomes, capturing LPG and energy-substitute use and expenditures. Altogether, these results suggest that, in contrast to standard competitive liberalization models, and consistent with the model in Section 2, household LPG use and spending fell following LPG market liberalization in treated municipalities compared to controls, while use of and spending on clean substitutes increased.

[8] We focus on this cross-sectional prediction as opposed to the differential effect of the LPG market liberalization across treated and control municipalities because prices were regulated and set at the state level prior to the LPG market liberalization.

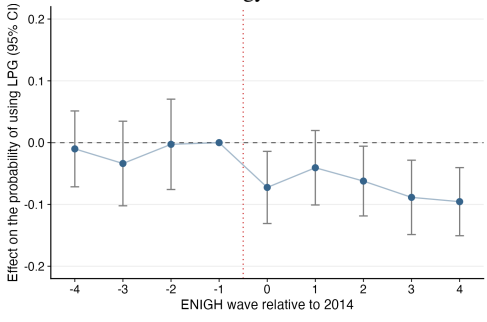
TABLE IV

EFFECTS OF LPG MARKET LIBERALIZATION ACROSS TREATED AND CONTROL MUNICIPALITIES ON HOUSEHOLD USE OF LPG AND ENERGY SUBSTITUTES

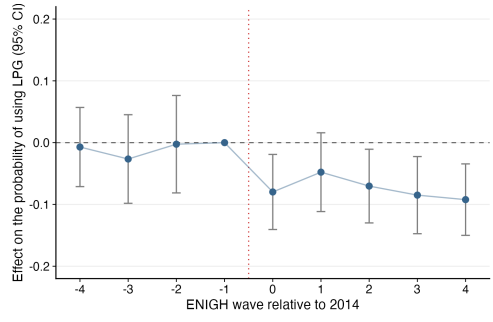
	Duct ∪ Adjacent			Boundary ≤ 25 km		
Outcome	OLS	RF	IV	OLS	RF	IV
Panel A. Household Uses LPG						
Uses LPG (binary)						N=323,696
All households	-0.0565^{***}	-0.0459^{***}	-0.0621^{***}	-0.0630^{***}	-0.0680^{***}	-0.0738^{***}
	(0.0154)	(0.0146)	(0.0197)	(0.0158)	(0.0156)	(0.0171)
Cylinder households	-0.0443^{***}	-0.0464^{***}	-0.0629^{***}	-0.0570^{***}	-0.0624^{***}	-0.0678^{***}
	(0.0148)	(0.0133)	(0.0181)	(0.0143)	(0.0140)	(0.0153)
Stationary tank households	-0.0122	0.0006	0.0008	-0.0059	-0.0055	-0.0060
	(0.0083)	(0.0075)	(0.0101)	(0.0064)	(0.0062)	(0.0067)
Panel B. Household Uses an Alternative to LPG						
Uses an alternative to LPG (binary)						N=323,696
All households	0.0136^{*}	0.0136^{**}	0.0184^{**}	0.0188^{***}	0.0197^{***}	0.0214^{***}
	(0.0079)	(0.0059)	(0.0081)	(0.0066)	(0.0064)	(0.0070)
Cylinder household	0.0112	0.0116^{**}	0.0157^{**}	0.0154^{**}	0.0161^{***}	0.0175^{***}
	(0.0071)	(0.0055)	(0.0075)	(0.0061)	(0.0060)	(0.0065)
Stationary tank household	0.0024	0.0020	0.0027	0.0034^{**}	0.0036^{**}	0.0039^{**}
	(0.0022)	(0.0015)	(0.0021)	(0.0015)	(0.0015)	(0.0017)

Notes: All specifications include municipality-of-residence and survey-wave fixed effects. Observations are at the municipality-of-residence-survey-respondent level and pool the nine biennial ENIGH waves from 2008 to 2024. Observations are weighted to recover nationally representative estimates. The dependent variable is an indicator for positive quarterly expenditure on the source. The substitute outcome is natural gas plus cooking-attributed electricity, the electricity bill retained for households reporting electricity as their main cooking fuel and zero otherwise. OLS estimates are TWFE, RF estimates are reduced-form TWFE on the corresponding straight-line corridor instrument, and IV estimates are the corresponding instrumental variable TWFE. Columns 1 to 3 define as treated municipalities those traversed by an LPG duct and their adjacent ones (Duct ∪ Adjacent), while columns 4 to 6 define as treated municipalities the ones with borders within 25 km from an LPG duct (≤ 25 km). Standard errors clustered at the municipality-of-residence level in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

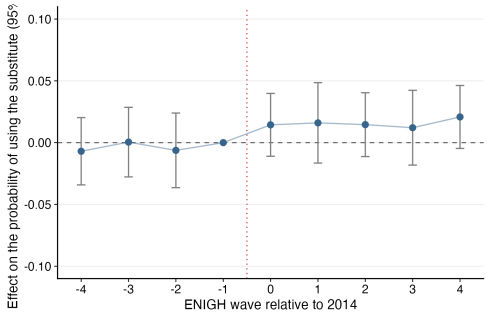
FIGURE 9.—Dynamic Effects of LPG market liberalization across treated and control municipalities on household use of LPG and clean energy substitutes



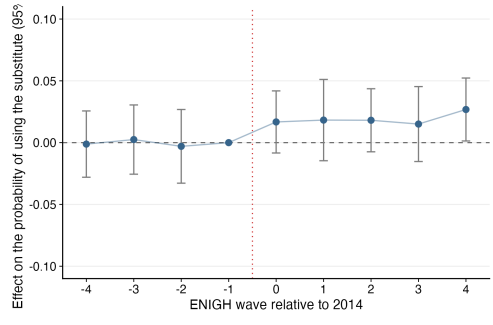
Panel A. Uses LPG · OLS



Panel A. Uses LPG · RF



Panel B. Uses clean alternative to LPG · OLS



Panel B. Uses clean alternative to LPG · RF

FIGURE 9.—*Note:* Event-study figures corresponding to the OLS (left) and reduced-form (right) specifications in Table IV. Treated municipalities are defined as those whose borders are within 25 km of an LPG duct via the road network. Standard errors are cluster-robust at the municipality level. The event studies for the remaining specifications are reported in Appendix **??**. The reference wave is 2014.

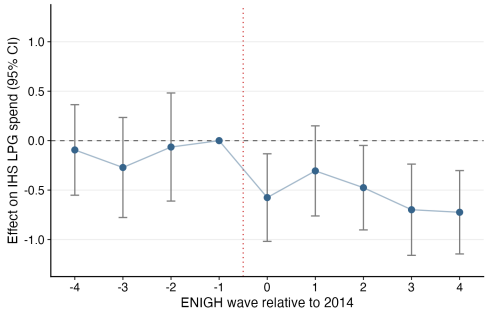
TABLE V

EFFECTS OF LPG MARKET LIBERALIZATION ACROSS TREATED AND CONTROL MUNICIPALITIES ON HOUSEHOLD SPENDING ON LPG AND CLEAN SUBSTITUTES

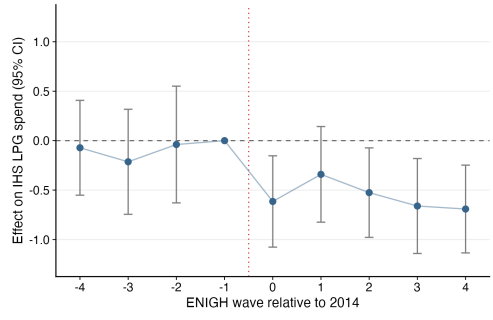
	Duct ∪ Adjacent			Boundary ≤ 25 km		
Outcome	OLS	RF	IV	OLS	RF	IV
Panel A. Spending in LPG						
Spending in LPG (IHS)						N=323,696
All households	-0.4265^{***}	-0.3433^{***}	-0.4646^{***}	-0.4697^{***}	-0.5016^{***}	-0.5448^{***}
	(0.1163)	(0.1093)	(0.1474)	(0.1181)	(0.1168)	(0.1272)
Cylinder household	-0.3348^{***}	-0.3553^{***}	-0.4808^{***}	-0.4341^{***}	-0.4711^{***}	-0.5117^{***}
	(0.1104)	(0.0979)	(0.1335)	(0.1053)	(0.1029)	(0.1122)
Stationary tank household	-0.0917	0.0120	0.0163	-0.0356	-0.0305	-0.0331
	(0.0667)	(0.0577)	(0.0782)	(0.0505)	(0.0484)	(0.0525)
Panel B. Spending on clean alternative to LPG						
Spending on an alternative to LPG (IHS)						N=323,696
All households	0.1013^{*}	0.1027^{**}	0.1390^{**}	0.1371^{***}	0.1446^{***}	0.1571^{***}
	(0.0581)	(0.0408)	(0.0558)	(0.0455)	(0.0444)	(0.0481)
Cylinder household	0.0836	0.0886^{**}	0.1198^{**}	0.1118^{***}	0.1186^{***}	0.1288^{***}
	(0.0516)	(0.0376)	(0.0515)	(0.0423)	(0.0412)	(0.0446)
Stationary tank household	0.0177	0.0141	0.0191	0.0253^{**}	0.0260^{**}	0.0283^{**}
	(0.0171)	(0.0113)	(0.0152)	(0.0110)	(0.0111)	(0.0120)

Notes: All specifications include municipality-of-residence and survey-wave fixed effects. Observations are at the municipality-of-residence-survey-respondent level and pool the nine biennial ENIGH waves from 2008 to 2024. Observations are weighted to recover nationally representative estimates. The dependent variable is the inverse hyperbolic sine transformation of the quarterly expenditure (MXN) on the energy source. The substitute outcome is natural gas plus cooking-attributed electricity. OLS estimates are TWFE, RF estimates are reduced-form TWFE on the corresponding straight-line corridor instrument, and IV estimates are the corresponding instrumental variable TWFE. Columns 1 to 3 define as treated municipalities those traversed by an LPG duct and their adjacent ones (Duct ∪ Adjacent), while columns 4 to 6 define as treated municipalities the ones with borders within 25 km from an LPG duct ($\leq$ 25 km). Standard errors clustered at the municipality-of-residence level in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

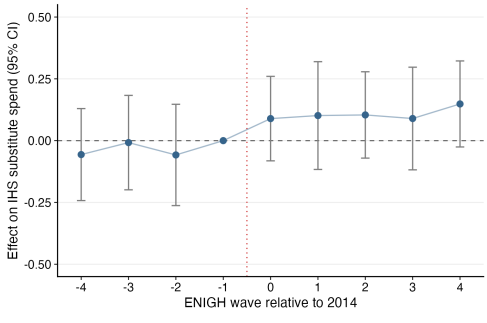
FIGURE 10.—Dynamic effects of LPG market liberalization across treated and control municipalities on household spending on LPG and clean substitutes



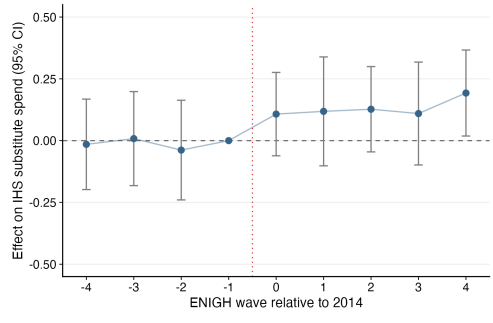
Panel A. Spending in LPG · OLS



Panel A. Spending in LPG · RF



Panel B. Spending on clean alternative to LPG · OLS



Panel B. Spending on clean alternative to LPG · RF

FIGURE 10.—*Note:* Event-study figures corresponding to the OLS (left) and reduced-form (right) specifications in Table V. Treated municipalities are defined as those whose borders are within 25 km of an LPG duct via the road network. Standard errors are cluster-robust at the municipality level. The event studies for the remaining specifications are reported in Appendix **??**. The reference wave is 2014.

7. CONCLUSION

Mexico's 2015–2017 LPG retail market liberalization generated large and robust effects in municipalities close to LPG ducts, where OCGs already had operational capacity to tap and commercialize stolen LPG. Formal LPG service station permits expanded disproportionately in these municipalities, and documented LPG duct taps and stolen volume also increased. These patterns are consistent with the model's core mechanism: liberalization provided legal cover, increasing the returns to operating in markets where OCGs already had territorial control and sector-specific capabilities.

The reform therefore did not generate the standard competitive-liberalization pattern. Instead, treated municipalities experienced less peaceful OCG coexistence, more OCG conflict, and higher OCG-related homicides and disappearances. Consumer outcomes also moved in the opposite direction from what a simple competitive benchmark would predict. LPG prices rose, especially for the less elastic tanker-truck LPG distribution, price dispersion increased, and the price effects were concentrated among retailers whose prices are least elastic to international LPG prices, consistent with OCG not acquiring LPG through legal mechanisms. Households responded by reducing LPG use and LPG spending and by increasing the use of substitute fuels, with these effects driven primarily by more elastic households that consume LPG in cylinders rather than through stationary tanks.

More broadly, the results underscore that market reforms in sectors already penetrated by organized crime can formalize criminal market power rather than discipline it. Liberalization may expand legal entry and still reduce consumer welfare when criminal groups can use permits and territorial control to capture local demand. This does not imply that liberalization should be avoided, but it does imply that, in such settings, market-liberalizing reforms require complementary regulatory and enforcement capacity to address permit-holder behavior, local market concentration, and the territorial conditions that enable criminal groups to convert legal cover into market power.

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APPENDIX A: MODEL PROOFS

A.1. *Proof of Proposition 1*

In a non-OCG municipality without market liberalization, the legal supplier solves $\max_p (p - c_L)(A^j - \beta p)$, which yields $p^j_{m,N} = \frac{A^j + \beta c_L}{2\beta}$, $Q^j_{m,N} = \frac{A^j - \beta c_L}{2}$, and $\Pi^j_{m,N} = \frac{(A^j - \beta c_L)^2}{4\beta}$. In an OCG municipality, the legal supplier solves $\max_p (p - c_L)\big((1-\alpha_m)A^j - \beta p\big)$, which implies $p^{j,O}_{L,m} = \frac{(1-\alpha_m)A^j + \beta c_L}{2\beta}$ and $q^{j,O}_{L,m} = \frac{(1-\alpha_m)A^j - \beta c_L}{2}$. The OCG solves $\max_p (p - c_G)(\alpha_m A^j - \beta p)$, which implies $p^j_{O,m} = \frac{\alpha_m A^j + \beta c_G}{2\beta}$, $q^j_{O,m} = \frac{\alpha_m A^j - \beta c_G}{2}$, and $\Pi^j_{O,m} = \frac{(\alpha_m A^j - \beta c_G)^2}{4\beta}$. Adding segment quantities yields $Q^j_{m,O} = \frac{A^j - \beta(c_L + c_G)}{2}$. Entrant B contests if $\frac{1}{2}\Pi^b_{O,m} - \kappa \geq 0$. Since $\kappa \sim U[0, \bar{\kappa}]$, $\Pr(\text{conflict} \mid m) = \min\left\{\frac{\Pi^b_{O,m}}{2\bar{\kappa}}, 1\right\}$. □

A.2. *Proof of Proposition 2*

First, $p^{j,O}_{L,m} - p^j_{m,N} = -\frac{\alpha_m A^j}{2\beta} < 0$, and second, $p^j_{O,m} - p^j_{m,N} = \frac{(\alpha_m - 1)A^j + \beta(c_G - c_L)}{2\beta} < 0$, because $\alpha_m < 1$ and $c_G < c_L$. Since both component prices are below $p^j_{m,N}$, the quantity-weighted average price in the OCG municipality is also below $p^j_{m,N}$.

For quantities, $Q^j_{m,O} - Q^j_{m,N} = \frac{A^j - \beta(c_L + c_G)}{2} - \frac{A^j - \beta c_L}{2} = -\frac{\beta c_G}{2} < 0$. □

A.3. *Proof of Proposition 3*

In a non-OCG municipality under market liberalization, perfect competition implies $p^j_{\ell,N} = c_L$ and $Q^j_{\ell,N} = A^j - \beta c_L$. In an OCG municipality, legal sellers charge c_L on the uncaptured segment, so $q^{j,O}_{L,\ell} = (1 - \alpha_\ell)A^j - \beta c_L$. The OCG solves $\max_p (p - c_G)(\alpha_\ell A^j - \beta p)$, which yields $p^j_{O,\ell} = \frac{\alpha_\ell A^j + \beta c_G}{2\beta}$, $q^j_{O,\ell} = \frac{\alpha_\ell A^j - \beta c_G}{2}$, and $\Pi^j_{O,\ell} = \frac{(\alpha_\ell A^j - \beta c_G)^2}{4\beta}$. Hence $Q^j_{\ell,O} = (1-\alpha_\ell)A^j - \beta c_L + \frac{\alpha_\ell A^j - \beta c_G}{2} = A^j\left(1 - \frac{\alpha_\ell}{2}\right) - \beta\left(c_L + \frac{c_G}{2}\right)$. The conflict probability follows exactly as in Proposition 1. □

A.4. *Proof of Proposition 4*

The average price in an OCG municipality is $\bar{p}^j_{\ell,O} = \frac{c_L q^{j,O}_{L,\ell} + p^j_{O,\ell} q^j_{O,\ell}}{Q^j_{\ell,O}} = c_L + \frac{q^j_{O,\ell}}{Q^j_{\ell,O}}(p^j_{O,\ell} - c_L)$. Using $q^j_{O,\ell} = \frac{\alpha_\ell A^j - \beta c_G}{2}$, $p^j_{O,\ell} - c_L = \frac{\alpha_\ell A^j - \beta(2c_L - c_G)}{2\beta}$, and $Q^j_{\ell,O} = A^j\left(1 - \frac{\alpha_\ell}{2}\right) - \beta\left(c_L + \frac{c_G}{2}\right)$, we obtain $\bar{p}^j_{\ell,O} - c_L = \frac{(\alpha_\ell A^j - \beta c_G)\left(\alpha_\ell A^j - \beta(2c_L - c_G)\right)}{4\beta\left[A^j\left(1 - \frac{\alpha_\ell}{2}\right) - \beta\left(c_L + \frac{c_G}{2}\right)\right]}$. Under Assumption 1, the denominator is positive and $\alpha_\ell A^j - \beta c_G > 0$. Hence $\bar{p}^j_{\ell,O} > c_L \iff \alpha_\ell A^j > \beta(2c_L - c_G)$.

To show how it varies with α_ℓ, differentiate $\bar{p}^j_{\ell,O} - c_L = \frac{q^j_{O,\ell}}{Q^j_{\ell,O}}\left(p^j_{O,\ell} - c_L\right)$ with respect to α_ℓ. Since $\frac{\partial q^j_{O,\ell}}{\partial \alpha_\ell} = \frac{A^j}{2}$, $\frac{\partial (p^j_{O,\ell} - c_L)}{\partial \alpha_\ell} = \frac{A^j}{2\beta}$, and $\frac{\partial Q^j_{\ell,O}}{\partial \alpha_\ell} = -\frac{A^j}{2}$, it follows that $\frac{\partial (\bar{p}^j_{\ell,O} - c_L)}{\partial \alpha_\ell} = \frac{A^j}{2Q^j_{\ell,O}}\left(p^j_{O,\ell} - c_L\right) + \frac{A^j q^j_{O,\ell}}{2\beta Q^j_{\ell,O}} + \frac{A^j q^j_{O,\ell}\left(p^j_{O,\ell} - c_L\right)}{2(Q^j_{\ell,O})^2}$. Under Assumption 1, $q^j_{O,\ell} > 0$ and $Q^j_{\ell,O} > 0$. Therefore, whenever $p^j_{O,\ell} \geq c_L$, all three terms on the right-hand side are nonnegative, with strict inequality in the interior. Hence the price gap is increasing in α_ℓ on the region where

$\bar{p}^j_{\ell,O} \geq c_L$. Finally, $Q^j_{\ell,O} - Q^j_{\ell,N} = A^j\left(1 - \frac{\alpha_\ell}{2}\right) - \beta\left(c_L + \frac{c_G}{2}\right) - (A^j - \beta c_L) = -\frac{\alpha_\ell A^j + \beta c_G}{2} < 0$.

To show the direct effect of β on prices, we abstract from the effect of β on equilibrium quantities and quantity shares, and write $\bar{p}^j_{\ell,O} - c_L = \frac{q^j_{O,\ell}}{Q^j_{\ell,O}}\left(p^j_{O,\ell} - c_L\right)$. Holding fixed the weight $q^j_{O,\ell}/Q^j_{\ell,O}$, the sign of the comparative static is the sign of $\frac{\partial(p^j_{O,\ell} - c_L)}{\partial\beta}$. Since $p^j_{O,\ell} - c_L = \frac{\alpha_\ell A^j - \beta(2c_L - c_G)}{2\beta}$, it follows that $\frac{\partial(p^j_{O,\ell} - c_L)}{\partial\beta} = -\frac{\alpha_\ell A^j}{2\beta^2} < 0$. Therefore, the direct effect of a higher β is to reduce the price gap. □

A.5. *Proof of Proposition 6*

Because both conflict probabilities are increasing in the relevant OCG profit, it is enough to compare $\Pi^b_{O,\ell}$ and $\Pi^b_{O,m}$: $\Pi^b_{O,\ell} - \Pi^b_{O,m} = \frac{(\alpha_\ell A^b - \beta c_G)^2 - (\alpha_m A^b - \beta c_G)^2}{4\beta}$. Factoring gives $\Pi^b_{O,\ell} - \Pi^b_{O,m} = \frac{A^b(\alpha_\ell - \alpha_m)\left(A^b(\alpha_\ell + \alpha_m) - 2\beta c_G\right)}{4\beta}$. Since $\alpha_\ell > \alpha_m$, this difference is positive whenever $A^b(\alpha_\ell + \alpha_m) > 2\beta c_G$. Under the interior assumptions, this condition holds. Hence $\Pr(\text{conflict} \mid \ell) > \Pr(\text{conflict} \mid m)$. □

A.6. *Proof of Proposition 5*

In a non-OCG municipality under market liberalization, all sellers charge c_L, so $D_{\ell,N} = 0$. In an OCG municipality, the three posted prices are c_L, $p^a_{O,\ell}$, and $p^b_{O,\ell}$. The variance of three equally weighted prices is $D_{\ell,O} = \frac{(c_L - p^a_{O,\ell})^2 + (c_L - p^b_{O,\ell})^2 + (p^a_{O,\ell} - p^b_{O,\ell})^2}{9}$. This is weakly positive, and it is zero only if $p^a_{O,\ell} = p^b_{O,\ell} = c_L$. □

A.7. *Proof of Proposition 7*

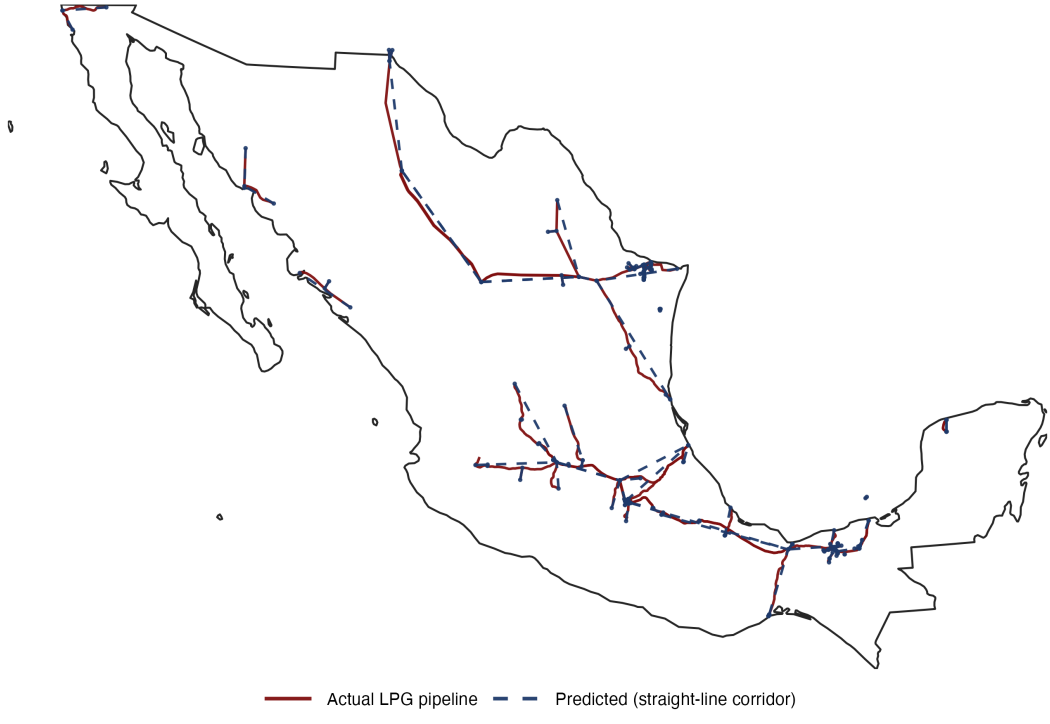
Using the quantity gaps from Propositions 2 and 4, $\left(Q^j_{\ell,O} - Q^j_{\ell,N}\right) - \left(Q^j_{m,O} - Q^j_{m,N}\right) = -\frac{\alpha_\ell A^j + \beta c_G}{2} + \frac{\beta c_G}{2} = -\frac{\alpha_\ell A^j}{2} < 0$. Thus, the quantity disadvantage of OCG municipalities becomes larger under market liberalization, and more so the larger the α_ℓ.

Using the price gaps from Propositions 2 and 4, $\left(\bar{p}^j_{\ell,O} - p^j_{\ell,N}\right) - \left(p^{j,O}_{L,m} - p^j_{m,N}\right) = \left(\bar{p}^j_{\ell,O} - c_L\right) + \frac{\alpha_m A^j}{2\beta}$. If $\alpha_\ell A^j > \beta(2c_L - c_G)$, Proposition 4 implies $\bar{p}^j_{\ell,O} \geq c_L$, and thus the right-hand side is strictly positive. From Proposition 4, $\bar{p}^j_{\ell,O} - c_L$ is increasing in α_ℓ and (focusing on the direct effect) decreasing in β, and $\frac{\alpha_m A^j}{2\beta}$ is also decreasing in β. Hence, the increase in the legal price gap generated by market liberalization is larger when α_ℓ is higher and (focusing on the direct effect) smaller when β is higher. □

APPENDIX B: GRAPHICAL INTUITION OF THE INSTRUMENTAL VARIABLE IDENTIFICATION STRATEGY

Figure 11 presents the actual LPG duct network against the predicted one using a straight-line approximation between the endpoints of each LPG duct.

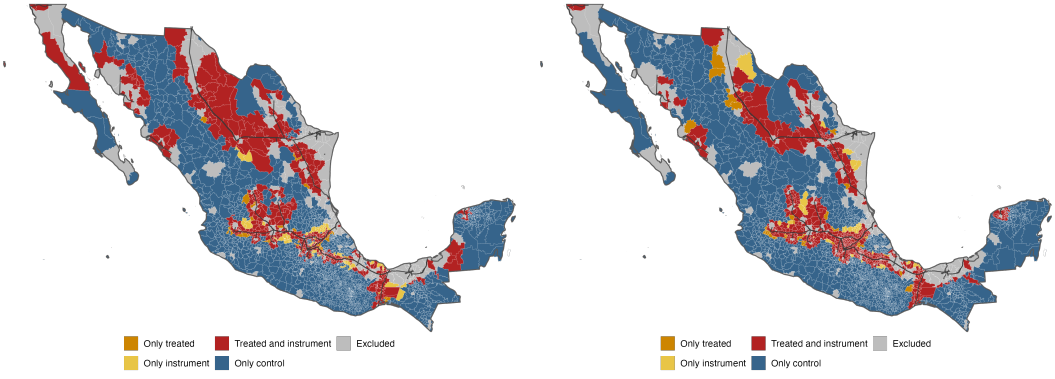
FIGURE 11.—LPG duct actual and predicted network



Notes. Actual LPG duct network in continuous red, and predicted in dashed blue. Straight lines between LPG duct endpoints are used to predict LPG ducts. *Sources.* Secretaría de Energía and Comisión Reguladora de Energía (2022)

Figure 12 presents the instrumental variable variation under the two definitions of treated municipalities.

FIGURE 12.—Instrumental Variable Variation



(a) Treatment: Traversed and adjacent

(b) Treatment: Boundary ≤ 25 km

FIGURE 12.—*Note.* Cross-section of the 2,289 Mexican municipalities used in the estimation sample under each treatment definition. Excluded municipalities (gray) are those that host at least one LPG infrastructure facility. A municipality can be treated and indicated by the instrument, i.e., complier (red), or only treated, i.e., always taker (orange), or only indicated by the instrument, i.e., never taker (yellow), or control (blue). Solid dark-red lines are LPG ducts. *Sources.* (Secretaría de Energía and Comisión Reguladora de Energía, 2022)

APPENDIX C: FIRST STAGE

TABLE VI

FIRST STAGE ACROSS ESTIMATION SAMPLES

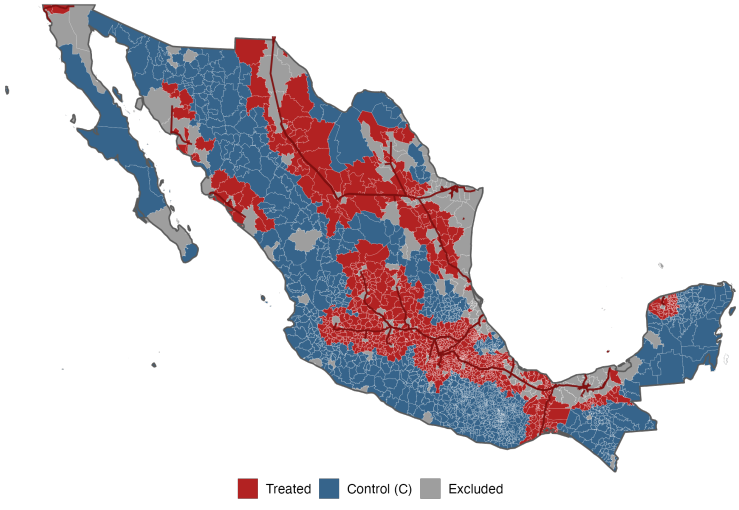
Estimation sample	(1) Tab. I Panel A Permits	(2) Tab. I Panel B Taps	(3) Tab. II Panels A–D Violence/OCG	(4) Tab. III Panels A–B Prices	(5) Tab. III Panels D–E Permit price	(6) Tab. III Panel C Dispersion	(7) Tab. IV–V all panels ENIGH
Panel A. Duct ∪ Adjacent							
First stage	0.7435	0.7439	0.7435	0.7439	0.8331	0.7439	0.7463
(SE)	(0.0169)	(0.0169)	(0.0169)	(0.0169)	(0.0262)	(0.0169)	(0.0392)
Partial F:	1,930.3	1,937.7	1,930.3	1,937.7	1,008.2	1,937.7	362.5
Panel B. Boundary ≤ 25 km							
First stage	0.9057	0.9059	0.9057	0.9059	0.7833	0.9059	0.9220
(SE)	(0.0103)	(0.0103)	(0.0103)	(0.0103)	(0.0297)	(0.0103)	(0.0213)
Partial F:	7,738.8	7,766.6	7,738.8	7,766.6	694.2	7,766.6	1,870.3

Notes: Each cell reports the first-stage coefficient π from equation (3), its municipality-clustered standard error.

APPENDIX D: LESS THAN 50 KM ROBUSTNESS: SAMPLE COMPOSITION AND GRAPHICAL INTUITION OF THE IDENTIFICATION STRATEGY

Figure 13 show the sample composition, and Figure 14 the graphical intuition of the instrumental variable identification strategy when treated municipalities are those whose borders are within 50 km of an LPG duct via the road network.

FIGURE 13.—Sample Composition Under Alternative Treatment Definition (Less than 50 km)



Notes. Cross-section of the 2,289 Mexican municipalities used in the estimation sample sample. Excluded municipalities (gray) are those that host at least one LPG infrastructure facility. A municipality is treated (red) if its boundary lies within 50 km of an LPG duct. Control municipalities (blue) are those untreated. Solid dark-red lines are LPG ducts *Sources.* (Secretaría de Energía and Comisión Reguladora de Energía, 2022)

FIGURE 14.—Instrumental Variable Variation Under Alternative Treatment Definition (Less than 50 km)

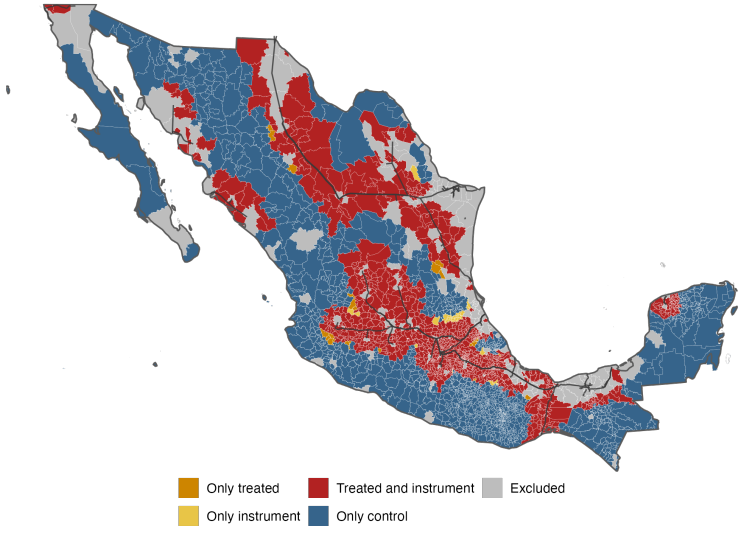


FIGURE 14.—*Note.* Cross-section of the 2,289 Mexican municipalities used in the estimation sample when treated municipalities are those whose borders are within 50 km of an LPG duct via the road network. Excluded municipalities (gray) are those that host at least one LPG infrastructure facility. A municipality can be treated and indicated by the instrument, i.e., complier (red), or only treated, i.e., always taker (orange), or only indicated by the instrument, i.e., never taker (yellow), or control (blue). Solid dark-red lines are LPG ducts. *Sources.* (Secretaría de Energía and Comisión Reguladora de Energía, 2022)