

Pricing and Informality: Evidence from Energy Theft in Brazil

Davi Resende - FGV/EPGE

Gabriel Richter - Stone

Marcelo Sant'Anna - FGV/EPGE

Andre Trindade - Nova SBE

June 6, 2024

Toulouse Conference on the Economics of Energy and Climate

Introduction

- Informality has a sizeable presence in the world economy.
 - The volume of international trade in counterfeit and pirated products amounted to as much as USD 464 billion in 2019 (source: OECD)
 - Labor force employed in the informal sector is 35 percent in Chile and 80 percent in Peru (Perry et al., 2007)
- Recent literature has studied this phenomenon, mostly focused on its impact on trade, labor markets and firm dynamics (Ulyssea 2018, Dix-Carneiro et al 2021).
- Less attention has been given to how informality affects firms' micro decisions, e.g. **pricing**.

Introduction

- Informal consumer markets can have an impact on firms' profits in two ways:
 1. Reduce the direct revenue (less paying customers).
 2. Increase costs for the firm, potentially passed-on to consumers
- Examples:
 - Spotify/Netflix users sharing accounts with friends/family
 - Counterfeit goods
 - Software piracy
 - Theft (e.g. using and not paying for water, electricity, public transportation)

Introduction

- Informal consumer markets can have an impact on firms' profits in two ways:
 1. Reduce the direct revenue (less paying customers).
 2. Increase costs for the firm, potentially passed-on to consumers
- Examples:
 - Spotify/Netflix users sharing accounts with friends/family
 - Counterfeit goods
 - Software piracy
 - Theft (e.g. using and not paying for water, electricity, public transportation)

Our paper focuses on the latter.

A toy model of pricing with informality

Firm problem is:

$$\pi(p) = pd(p)s(p) - cd(p)s(p) - c\bar{d}(1 - s(p)).$$

where:

- p : price paid by formal consumers.
- $s(p)$: share of formal consumers as a function of price.
- $d(p)$: residual demand conditional on being formal.
- c : constant marginal cost.
- \bar{d} : demand of informal consumers (does not depend on price).

A toy model of pricing with informality

Then, the first order condition of the firm is

$$\underbrace{d(p)s(p) + (p - c)d'(p)s(p)}_{\text{trad. FOC}} + \underbrace{ps'(p)d(p)}_{\text{evasion adj.}} - \underbrace{cs'(p)(d(p) - \bar{d})}_{\text{theft adj.}} = 0$$

Note that:

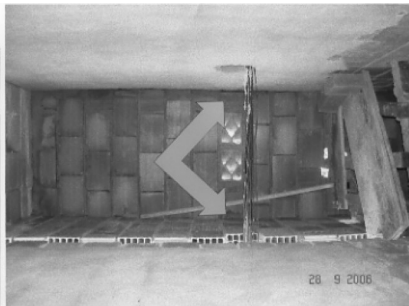
- The first part of the FOC is exactly the same as faced by a traditional monopolist facing demand $d(p)$
- The second term highlighted is an adjustment for the lost revenue from switchers between formal and informal status.
- The third term reflects the additional cost that informal consumers impose on formal.

Setting

We study this question in the context of electricity theft in Brazil.



Setting



Setting



Setting

- The utility firm that sells electricity in the state of Rio de Janeiro faces a large fraction of consumers that steal energy (in 2021 theft represented 54% of distributed energy).
- Consumers create illegal connections between the formal electric grid and their homes to steal energy.
- The utility firm has costs with informality as it still needs to generate power to serve the consumers with the illegal connections. A fraction of these costs is then passed on to formal consumers through higher tariffs.

Research Questions

1. How does the possibility of theft in this market affect optimal pricing decisions by firms?
2. What are the welfare effects from informality?
3. Can price discrimination be a useful tool to mitigate inefficiencies in this setting?

This paper

What do we do in this paper?

- Provide evidence of a causal link between pricing and the consumer decision to become informal.
- Estimate a structural model of consumer decisions using detailed micro data from the sector.
 - In this model consumers decide if they want to be formal or informal and then, conditional on that first decision, decide how much to consume.
- Leverage the structural model to simulate different pricing and informality scenarios for the firm in this market.

Empirical Challenges

Our data allows us to overcome the two empirical challenges to study markets with informality.

1. Informality is a long term and forward looking decision. Day-to-day (or month-to-month) price variation is not useful (without imposing strong assumptions on how consumers form expectations).
 - We leverage a natural experiment from 2011 where the electricity prices increased exogenously and *permanently* to a subset of consumers.
2. Quantity demanded in the informal sector is typically not observed
 - We leverage detailed observations of total electricity theft at a granular geographic level - the feeder - which allows us to understand how the informality varies along socio-demographic dimensions.

Findings

1. A **10%** permanent increase in the price level will result in an increase in the share of informal consumers of **1.6 p.p.**.
2. The aggregate demand curve for electricity becomes significantly more elastic when accounting for the informality margin (**-0.72** vs **-0.21** without informality).
3. Price discrimination (e.g. discount tariffs for low income households) can be an important tool for the firm as they reduce the share of informality with smaller inframarginal losses on formal consumers.

Roadmap

1. Literature
2. Institutional Details
3. Data and Patterns
4. Empirical Model
5. Counterfactual Results

Literature

- Informality in consumer markets: Qian (2014), Qian, Gong & Chen (2014), Lu, Wang & Bendle (2019), Li, Liao & Xie (2021)
- Consumer Demand for Electricity: Dubin and McFadden (1984), Reiss and White (2005), McRae (2015), McRae and Meeks (2016), Costa and Gerard (2018), Cahana, Fabra, Reguant & Wang (2022), among others.
- Demand Estimation for Illicit Products: Jacobi and Sovinsky (2016), Galenianos and Gavazza (2017)
- Electricity theft: Smith (2004), Min and Golden (2014)

Institutional Details

Why should we care?

Table 1 — Electricity Losses Worldwide by Income Group

Quartile	Lowest	Lower middle	Upper middle	Highest
Elec. Losses (%)	22.8	16.2	9.6	6.1

Source: World Bank (2020)

- Electricity theft is prevalent in much of the developing world
- It is forecasted that by 2035 the energy demand in the developing world will be twice that of the developed world (Wolfram et al., 2012)

Institutional details

- Brazil is one of ten largest countries in electricity consumption worldwide
- Potential effects from informality in this market:
 - Less reliable grids
 - Energy waste
 - Higher tariffs
 - Personal injuries

Institutional details

Social tariff and 2011 rule change

- Some customers have access to a *social tariff*, which gives them discounted rates over the regular tariff.

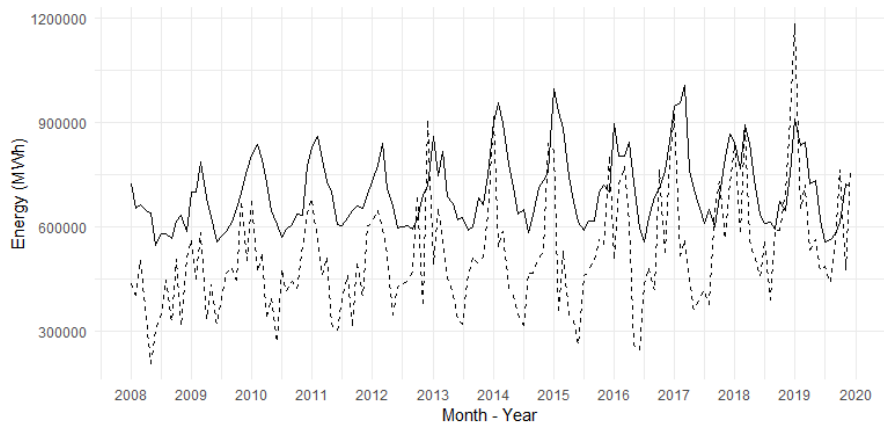
Consumption bracket	Discount
Up to 30 kWh/month	65%
From 31 to 100 kWh/month	40%
From 101 to 220 kWh/month	10%
Above 220 kWh/month	No discount

- The rules to have access to the *social tariff* changed.
 - In 2010 and before, every household with consumption below 80 kWh/month had automatic access. Above that limit, low income proof was required.
 - From 2011 onwards, everyone has to submit proof of low income in order to qualify for the social tariff.

Data

- (formal) **Household level data** (2017-2022)
 - Monthly consumption
 - Tariff type (regular vs social)
 - Installed capacity
- **Electricity theft** data (aka non-technical losses)
 - Feeder-month level (1,876 feeders)
 - Computed as electricity distributed minus billing minus technical losses
- **Prices** (2010-2019)
 - Monthly. Source: ANEEL
 - Prices are a function of qt consumed and status (social vs regular)
- **Demographics** (for all households)
 - (1) Income; (2) Household size, (3) Crime status
 - Different Sources: 2010 and 2022 Census, Fogo Cruzado Institute
- **Time Series Data**
 - Consumption, Nbr of formal households, and NTL (2010-2020)

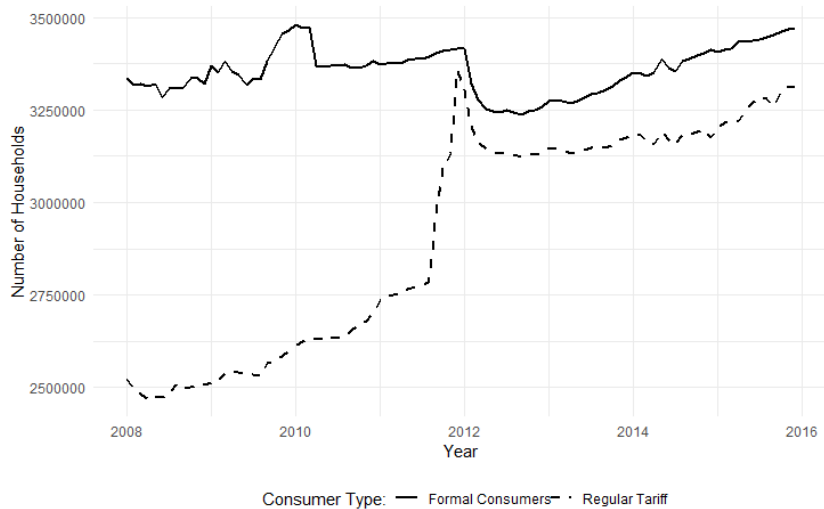
Data



Energy consumed by: — Household Consumption - - - Non Technical Loss

Descriptive evidence

Consumers respond to higher prices by migrating to the informal sector



Structural model

Overview

- Households i choice problem has two parts:
 1. **Discrete**: formal consumption ($j = 0$) or informal/theft ($j = 1$)
 2. **Continuous**: how much to consume based on the previous decision (i.e., the intensive margin)

Structural model

Intensive Margin

- Utility function is quasi-linear on consumption of electricity q and a numeraire good:

$$v_{it}(q, p) = \theta_{it} q^{\frac{\xi-1}{\xi}} - pq$$

- Which implies a demand curve with constant elasticity ξ and allowing for individual demand shifters

$$\log(q_{it}) = \gamma_i + \gamma_t + \xi \log(p_{it}) + \nu_{it}$$

- Where p_{it} is the average individual price.
- Under informality the price is zero and the quantity consumed is given by a capacity constraint \bar{q}_{it} .

Structural model

Extensive Margin

- The utility of being formal ($j = 0$) or informal ($j = 1$):

$$u_{ijt} = \beta\psi_{ijt} + \gamma X_{ijt} + \eta_j + \varepsilon_{ijt}$$

- Where:
 - ε_{ijt} has the usual e.v. distribution
 - ψ_{ijt} is the monetary expected consumer surplus conditional on formality status
 - X_{ijt} are covariates that affect one's propensity to be formal (e.g. income, living in a crime dominated area, etc)
 - η_j is a fixed utility shifter
- This specification yields typical logit conditional choice probabilities:

$$P_{i0t} = \frac{\exp(\beta(\psi_{i0t} - \psi_{i1t}) + \gamma X_{ijt} + \eta_0)}{1 + \exp(\beta(\psi_{i0t} - \psi_{i1t}) + \gamma X_{ijt} + \eta_0)}$$

Estimation

We estimate the model in two steps.

- **First**, we use monthly consumption data at the household level to estimate the parameters of the demand for electricity, conditional on being formal. This means that we estimate by OLS the following regression:

$$\log(q_{it}) = \gamma_i + \gamma_{m(t)} + \gamma_{y(t)} + \xi \log(p_{it}) + \nu_{it} \quad (1)$$

- We can now use the model to compute:
 - The \$ (net) utility of formal consumption for different price points, i.e., ψ_{i0t}
 - The utility of consumption under informality ($\psi_{i1t}(\bar{q})$), where \bar{q} is recovered directly from our theft data at the feeder level.

Estimation

- **Second**, we estimate the parameters behind the decision to be formal or informal (β, γ, η_0) , using the expression:

$$\mathbb{P}_{it}(\text{formal}) = \int_{i \in I} \frac{\exp(\beta(\psi_0 - \psi_{1,i}) + \gamma X_{ijt} + \eta_0)}{1 + \exp(\beta(\psi_0 - \psi_{1,i}) + \gamma X_{ijt} + \eta_0)} dF(i) \quad (2)$$

- Specifically, parameters are chosen to match the following moments, directly observed in our data:
 - **[A]** The observed total change in the number of formal consumers before and after the 2011 natural experiment - *identifies* β
 - **[B]** Cross-feeder variation in the share of formal consumers - *identifies* γ

Results

Table: Estimation: 1st Step

	(1)	(2)	(3)	(4)
ξ	-0.1782	-0.186	-0.198	-0.160
	(0.12)	(0.012)	(0.002)	(0.002)
capacity				1.329
				(0.002)
Constant	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Social Tariff FE	Yes	Yes	Yes	Yes
Feeder FE	No	Yes	No	No
Building FE	No	No	Yes	Yes
Observations	230,200,302	230,200,302	230,200,302	230,200,302
R-squared	0.009	0.083	0.218	0.540

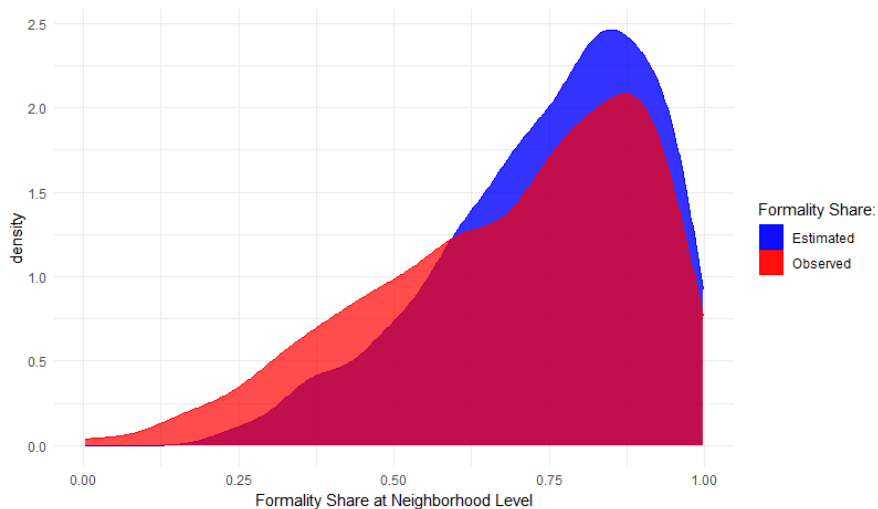
Results

Table: Extensive Margin Results

	(1)	(2)	(3)	(4)
β	0.0289	0.0289	0.0289	0.0289
η	4.704	3.914	-5.849	-10.294
γ (log income)			(3.852)	(1.558)
			0.730	1.745
			(0.277)	(0.160)
γ (avg hh size)			0.415	-0.033
			(0.579)	(0.185)
γ (traffic)			-1.872	-0.801
			(0.373)	(0.167)
γ (militia)			-0.840	-0.453
			(0.374)	(0.165)
Capacity in 1st stage	No	Yes	No	No
Spatial heterogeneity	N/A	N/A	Circuit	Neighborhood
Observations			897	690
F-stat			13.758	38.84
R_squared			0.072	0.221

Results

Model Fit



Results

Elasticities

Table: Elasticity Estimates

	No informality (1)	With informality (2)	Ratio (3)=(2)/(1)
Elasticity	0.21	0.72	3.4x

¹ In the “No Informality” scenario, we force all consumers to be formal (i.e., we drop the possibility of informality). In the “With informality” scenario that possibility is allowed.

Results

Counterfactuals

Table: Counterfactual Results - PRELIMINARY

	Baseline	CF1 Price Down 10%	CF2 Price Up 10%	CF3 No Crime Same Price
Qt formal/hhd (kWh)	201.7	205.9	197.9	201.7
Share formal	0.808	0.824	0.791	0.826
Regular Price (R\$ / kWh)	0.405	0.365	0.446	0.405
ψ_0	-83.53	-78.19	-88.50	-95.97
Revenue (in MM R\$)	196.0	191.0	200.5	203.0

Conclusion

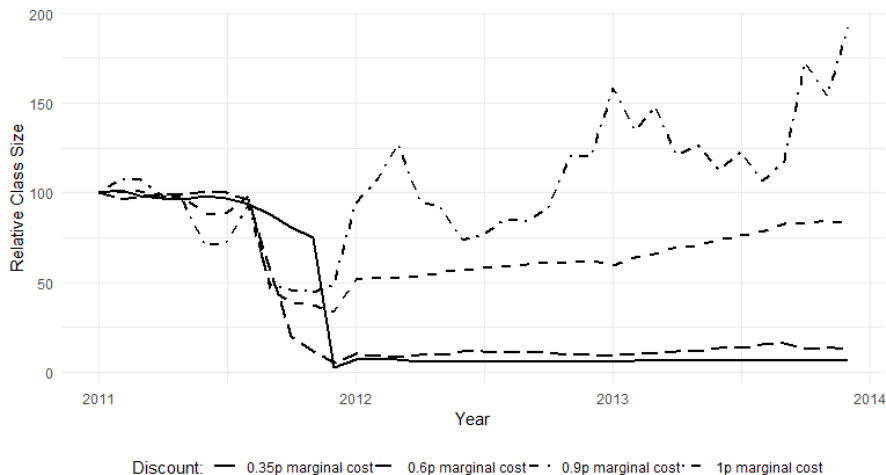
In this paper, we...

- Study how informal consumer markets affect firms' pricing decisions.
- Provide evidence of a formal link between pricing and consumer decisions to be formal or not.
- Set up a structural model where consumers optimally choose the informality margin and consumption, which we estimate with rich data from the electricity sector.
- Find that pricing decisions substantially change in the presence of informality (demand becomes 3.4x more elastic)
- Suggest how price discrimination strategies can be optimal for firms.

THANK YOU !!

APPENDIX

Consumers respond to higher prices by migrating to the informal sector



APPENDIX

Consumption distribution

