Subsidy

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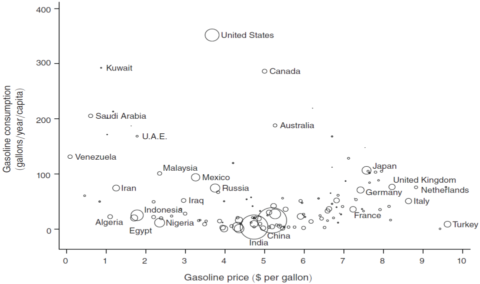
Table of Content

Introduction

- By 2015, global oil consumption: 90 million barrels per day
- Many countries provide subsidies for gasoline and diesel.
- World Bank data: road-sector subsidies for gasoline and diesel totaled $110 billion in 2012
- Result: total annual deadweight loss $44 billion, because of over consumption

Fuel Prices

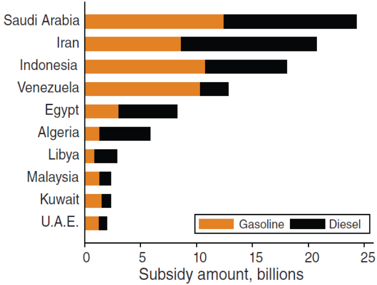
- Road-sector gasoline consumption per capita and gasoline prices (circles size: population)



- Price from \$0.09 in Venezuela to \$9.0 in Turkey & Norway
- Gasoline taxes per gallon \$0.49 in US, to \$4.00 in Germany & Netherlands

Fuel Prices

- Countries with the largest fuel subsidies



- Subsidy per gallon × road consumption of each fuel
- 24 & 35 countries subsidize gasoline & diesel.
- Total subsidies $110 billion
- Top ten countries represent 90 % of total global subsidies

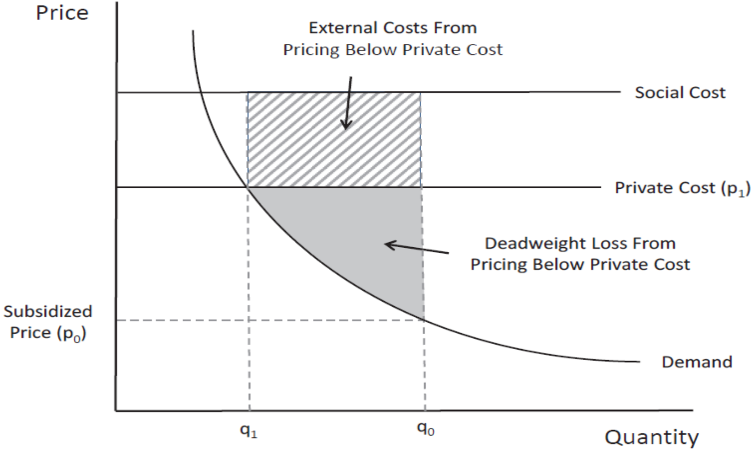
Deadweight Loss

- The more longrun elastic are demand and supply, the larger the deadweight loss from pricing below cost
- Supply is assumed to be perfectly elastic.
- For transportation demand elasticity -0.6
- Demand: a constant elasticity $q = Ap^{\varepsilon}$
- p_0 & p_1 subsidized and market price,
- Givern $p_0, q_0, \varepsilon = -0.6$ easy to calculate A for each country
- As in next figure

$$DWL = (p_1 - p_0)q_0 - \int_{p_0}^{p_1} Ap^{\varepsilon} dp$$

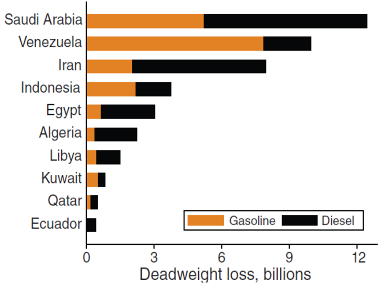
$$DWL = (p_1 - p_0)q_0 - \frac{A}{1+\varepsilon}[p_1^{1+\varepsilon} - p_0^{1+\varepsilon}]$$

The Economic Cost of Fuel Subsidies



Deadweight Loss

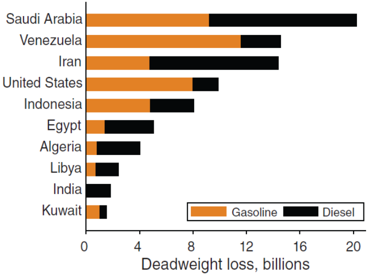
- Deadweight Loss from fuel subsidy



- Total global deadweight loss from fuel subsidies $44 billion.
- Deadweight loss increases with square of subsidy amount

Incorporating External Costs

- Externality: emissions , traffic congestion, and accidents.



- IMF calculation: $1.11 per gallon.
- No subsidies decrease consumption by 29 billion gallons
- At $1.11, external costs worth $32 billion annually
- Total economic cost of fuel subsidies is $76 billion annually

Table of Content

Question and Motivation

- Electricity subsidized to increase affordability for low-income HH
- Subsidies would create sufficient demand in poor neighborhoods to encourage private investment in their infrastructure.
- Precarious distribution networks supplying users who never pay (discourage investment)
- This paper empirical explanation: the subsidies discourage investment in infrastructure and trap households and firms in a nonpaying, low-quality equilibrium.

Introduction

- Latin American: vast differences in quality of infrastructure
- Middle- and upper-income same as developed countries
- Informal settlements on outskirts of cities: dangerous and unreliable infrastructure
- Electricity supply here, a bare wire strung up by residents to the nearest power line.
- Why: quality is low, but free, so resistance to pay for infrastructure upgrades
- Inadequate infrastructure major barrier to economic advancement for affected households
- Utility firms tolerate nonpayment: receive government financial support
- Government provides payments to retain the political support, avoid civil unrest

Introduction

- Firms receive transfers greater than cost of providing service.
- High profits from low-quality service
- A subsidy program for short-term consumption instead displaces long-term investment.
- How an upgrade affects informal consumption
  1. installation of a meter means that the household is billed
  2. improve quality household's utility
  3. firm can disconnect nonpayment
- Model
  - Estimate electricity demand of metered HH in Colombia
  - Use model, predict the consumption of unmetered households
  - Have data on outages
  - Predict consumption after a hypothetical upgrade of the distribution network
    - reduces number, length of outages and increases household's marginal price to the regulated price schedule.

Introduction

- Estimate the change in the firm's profit as a result of the upgrade
- Results: more profitable not to upgrade its network, maintain low-quality service to informal settlement, even with 100% increase in price
- Consumption is lower after the upgrade
- Firm subsidy, payment is wipe out
- Upgrade unprofitable for most counties
- Analyze alternative subsidy programs under political concerns.
- Optimally: all counties upgrade at a total cost to the government 34 % less than the current program.
- If firms cannot be made worse off: upgraded at a total cost to the government 23 % less than the existing program.
- Related to literature on infrastructure
- No welfare analyses but set goal of government for informal settlements is the provision of a metered connection as a result

Institutional Setting

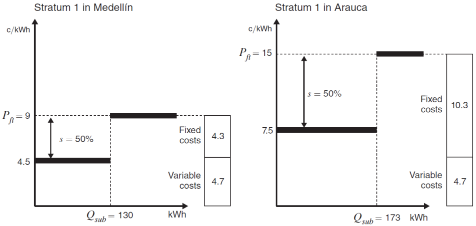
- Colombia: 34 utility firms, natural monopoly.
- Energy and Gas Regulatory Commission (CREG) sets price P_{ft} .
- Regulated price for transmission, distribution, and retailing charges, revised once every five years.
- Generation charge is calculated based on the average price of wholesale electricity purchases—both spot and contract—over the previous 12 months.
- Marginal cost of utilities c_{ft}: wholesale generation price, transmission charges is fixed cost
- Regulator sets a target rate for line losses in P_{ft} wholesale costs are scaled up by this target amount

Institutional Setting

- A targeted program of quantity-based subsidies that mean most users do not pay P_{ft} .
- Universal geographical classification of all neighborhoods into six socioeconomic strata (estratos).
- Households classified in Strata 1, 2, 3 receive a subsidy of approximately 50 %, 40 %, 15 % for the first Q_{sub} units of consumption, and then pay P_{ft} for all additional units.
- Strata 5 and 6 (less than 5 % of all users) pay 120 % of P_{ft} for their entire consumption
- Strata 4 pay P_{ft} for their entire consumption.

Institutional Setting

- Figure shows Stratum 1 price schedule, in a low base price region (Medellín) a high base price region (Arauca).



- Maximum amount of subsidy is more than twice as large in Arauca as in Medellín ($12.98 versus $5.85) why?

1. Subsidy is calculated as a fraction (50 %) of P_{ft} , P_{ft} 6 cents/kWh higher in Arauca than in Medellín
2. Q_{sub} is 173 kWh in Arauca compared to 130 kWh in Medellín

Institutional Setting

- Variable costs are similar in both regions
- Subsidy covers 138 % of variable costs in Arauca but only 62 % of variable costs in Medellín
- Areas with a high base price, the Stratum 1 subsidy is sufficient to cover variable costs and contribute to fixed costs and profit, even if the household does not pay their bill.
- Ministry of Mines and Energy operates a redistribution fund for subsidies and government fund the deficit (46%)
- Government policies for informal connections:
  1. Informal settlements brought into Stratum 1
  2. Social Energy Fund (FOES) provide additional subsidies
  3. Government upgrade of local distribution networks

Household Demand for Electricity

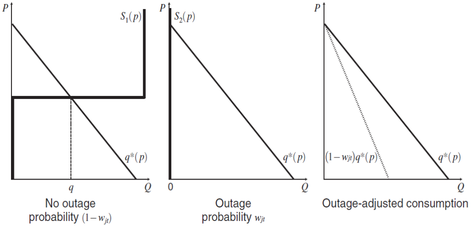
- Demand model based on Reiss and White (2005), with the addition of supply outages
- Demand for electricity is derived from services of devices
- HH decides how many hours of television to watch
- appliance i, HH j, month t, with no supply interruptions

$$q^*_{ijt}(p_{jt}, y_{jt}, .) = \alpha_i + \gamma_i y_{jt} + \beta_i p_{jt} + \delta_i' z_{jt} + \eta_{ijt}$$

- y_{jt} income, notice $p_{jt} = P_{jt}(q_{jt})$ (non-linearity in price)
- z_{jt} vector of hh characteristics,

Interruption

- Effect of supply interruption on appliance-level consumption



- $q^*(p)$ appliance level demand without interruptions
- Fraction $(1-\omega_{jt})$ is uninterrupted
- $S_1(p)$HH can consume up to the capacity of its connection
- Fraction ω_{jt}, supply to interrupted $S_2(p)$), consumption zero
- Random outage: consumption $(1-\omega_{jt})q^*(p)$

Interruption Reschedule

- Reschedule consumption during a supply interruption.
- Depend on appliance: TV vs.refrigerator
- Extent to reschedule usage of an appliance θ_i
- $\theta_i = 0$ possibility of full rescheduled
- Consumption in a month:

$$q_{ijt}(p_{jt}, y_{jt}, .) = (1 - \theta_i \omega_{jt}) q^*_{ijt}(p_{jt}, y_{jt}, .)$$

Consumption

- Total electricity consumption

$$q_{jt} = \begin{cases} \sum_{i=1}^{M} A_{ijt} q_{ijt}(p^L_{jt}, y_{jt}, .) + \varepsilon_{jt} & if \sum_{i=1}^{M} A_{ijt} q_{ijt}(p^L_{jt}, y_{jt}, .) < Q_{sub} \\ \sum_{i=1}^{M} A_{ijt} q_{ijt}(p^H_{jt}, y^H_{jt}, .) + \varepsilon_{jt} & if \sum_{i=1}^{M} A_{ijt} q_{ijt}(p^H_{jt}, y^H_{jt}, .) > Q_{sub} \\ Q_{sub} + \varepsilon_j t & otherwise \end{cases}$$

- A_{ijt} if j owns appliance i
- M all types of appliance, including base-load
- No-linearity in price model by discrete-continuous choice
- If pay p^L_{jt} for first Q_{sub} but consume more, transfer to income

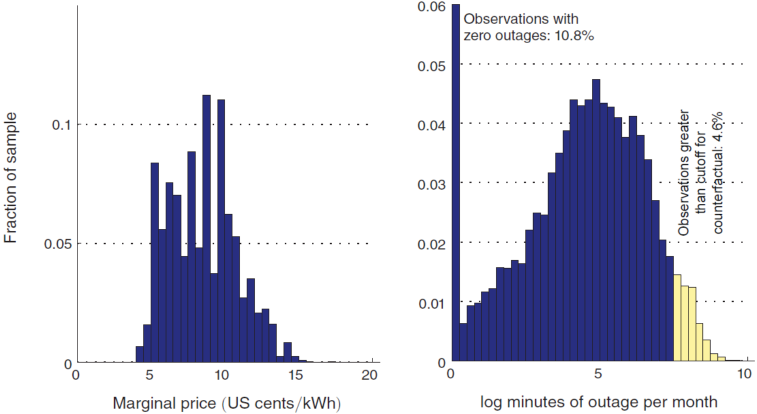
$$y^H_{jt} = y_{jt} + Q_{sub}(p^H_{jt} - p^L_{jt})$$

- ε_{jt} measurement error, optimization error, or perception error

Data

- Monthly electricity billing data is matched at a household level to cross-sectional census data on appliance holdings and dwelling characteristics
- Combined with network information on monthly transformer-level outages.
- Data of all transformers (last stage step down voltage):location, capacity, number of users, number and length of outages , five categories (planned, unplanned, minor, force majeure, others)
- Identification: price variation across households (due to different regulation)+(due to consumption quantity)

Distribution of Marginal Prices and Outages in Estimation Sample



Empirical Strategy

- Five appliances : refrigerator, washing machine, television, computer, fan
- Baseload: blender, oven, microwave, water heater, electric shower, stereo, and air conditioner
- Six heterogeneous preference for each appliance: $H_{jt} = (\eta_{1jt}, \cdots, \eta_{6jt})' \sim$ multivariate normal with mean $(0, \cdots, 0)'$, variance Σ
- Assume covariance between the baseload consumption error term and the individual appliance error terms is zero.
- Vector $A_{jt} = [A_{1jt}, \cdots, A_{6jt}]'$ zeros and ones (if j own i), so $\eta_{jt} \sim N(0, \sigma^2_{\eta_{jt}})$ where $\sigma^2_{\eta_{jt}} \equiv A'_{jt}\Sigma A_{jt}$

Likelihood Computation

- Every possible combination of the five appliances occurs at least once in the data
- Possible to estimate variances for 32 groups
- $\varepsilon_{jt} \sim N(0, \sigma_{\varepsilon}^2)$, independent of H_{jt}
- Define $\nu_{jt} = \eta_{jt} + \varepsilon_{jt}$, probability of q_{jt}

$$
\begin{aligned}
Pr(q_{jt}) \quad = \quad & Pr(\nu_{jt} = q_{jt} - \overline{q}_{jt}(p_{jt}^{L}, y_{jt}, .), \eta_{jt} < Q_{sub} - \overline{q}_{jt}(p_{jt}^{L}, y_{jy}, .)) \\
& + Pr(\nu_{jt} = q_{jt} - \overline{q}_{jt}(p_{jt}^{H}, y_{jt}^{H}, .), \eta_{jt} > Q_{sub} - \overline{q}_{jt}(p_{jt}^{H}, y_{jy}^{H}, .)) \\
& + Pr(\varepsilon_{jt} = q_{jt} - Q_{sub}, Q_{sub} - \overline{q}_{jt}(p_{jt}^{L}, y_{jt}, .) < \eta_{jt} < Q_{sub} - \overline{q}_{jt}(p_{jt}^{H}, y_{jy}^{H}, .))
\end{aligned}
$$

- If $\nu_{jt} \sim N(0, \sigma_{\nu_{jt}}^2)$, $\eta_{jt}|\nu_{jt} \sim N(\frac{\rho_{jt}\sigma_{\eta_{jt}}}{\sigma_{\nu_{jt}}}\nu_{jt}, \sigma_{\eta_{jt}}^2(1-\rho_{jt}^2))$
- Correlation $\rho_{jt} \equiv corr(\nu, \eta) = \frac{\sigma_{\eta_{jt}}}{\sigma_{\nu_{jt}}}$
- Notice ϕ is standard normal distribution
- $h(\nu_{jt}, \eta_{jt})$ is joint distribution

Likelihood Computation

$$
\begin{aligned}
& Pr(\nu_{jt} = q_{jt} - \overline{q}_{jt}(p^L_{jt}, y_{jt}, .), \eta_{jt} < Q_{sub} - \overline{q}_{jt}(p^L_{jt}, y_{jy}, .)) \\
= & \int_{-\infty}^{Q_{sub} - \overline{q}_{jt}(p^L_{jt}, y_{jt}, .)} h(\nu_{jt} = q_{jt} - \overline{q}_{jt}(p^L_{jt}, y_{jt}, .), \eta_{jt}) d\eta_{jt} \\
= & \frac{1}{\sigma_{\nu_{jt}}} \phi \left(\frac{q_{jt} - \overline{q_{jt}}(p^L_{jt}, y_{jt}, .)}{\sigma_{\nu_{jt}}} \right) \\
& \Phi \left(\frac{Q_{sub} - \overline{q}_{jt}(p^L_{jt}, y_{jt}, .) - \frac{\rho \sigma_{\eta_{jt}}}{\sigma_{\nu_{jt}}} (q_{jt} - \overline{q}_{jt}(p^L_{jt}, y_{jt}, .)}{\sigma_{\eta_{jt}} \sqrt{1 - \rho^2_{jt}}} \right)
\end{aligned}
$$

- Calculate two other likelihood in your homework.

Empirical Strategy

- θ_i may differ across appliances (because of reschedul)
- However, estimating separate θ_i for each appliance is not empirically tractable
- z_{jt}: no. of household members, no. of rooms (both also interacted with price and income), dummy apartment, daily temperature, linear & quadratic number & length of outages
- Balanced panel of household billing data for the six months before and six months after each household's census interview
- Drop outliers.
  - HH with a small business in their home
  - HH: consumption $> 1,000kWh$
  - HH with estimated consumption rather than metered usage
  - HH with a fine $> \$20$
  - 1% outliers residuals of reg. of consumption on all variables
- Sample size: 869,304 observations from 72,442 households

Description of Variables Used in Analysis

Variable name	Description
Consumption	Monthly metered electricity consumption, normalized to a standard billing cycle length by multiplying by $30/n$ where n is the number of days in the billing cycle.
Electricity price	Price schedule for metered households has three components: low price p_{jt}^{L}, high price p_{jt}^{H}, and subsidized quantity Q_{sub}. The high price is calculated by dividing the billed amount before subsidies by consumption. The subsidized quantity is based on the table in Resolution 355 of 2004 by the Unidad de Planeación Minero-Energética; the exact cutoff between high and low altitude areas is determined for each firm by examining discontinuities in the implied subsidies. The subsidy percentage (and therefore the low price) is determined by dividing the subsidy amount in pesos by the minimum of consumption quantity and subsidized quantity.
Income	Monthly household expenditure in millions of Colombian pesos (1 million Colombian pesos = 422 United States dollars). Calculated as the midpoint of one of nine bins for a census question on the required level of monthly income for the household to adequately cover its basic expenses.
Outage hours	Reported total number of hours of outages for a month at the transformer serving the household, allocated pro rata to observations using the number of days in the month in each billing cycle.
Appliance variables	For each of 12 appliances, this is an indicator variable equal to 1 if the household reports ownership of that appliance.
Household members	Total number of people in the household.
Rooms	Total number of rooms in the dwelling, excluding kitchen, bathroom, and garage.
Apartment	Indicator variable equal to 1 if the dwelling is an apartment.

Maximum Likelihood Parameter Estimates

Variable[a,b]	Base[c]	Fridge	Washer	Fan	Computer	Televisior
Constant[d]	139.268	−14.764	63.669	−105.631	27.159	4.147
	(35.714)	(13.903)	(10.511)	(10.533)	(9.606)	(14.508)
β_i (Price)	0.0003	−0.0960	−0.4586	−0.0055	−0.2125	0.0003
	(0.262)	(0.098)	(0.035)	(0.030)	(0.032)	(0.099)
γ_i (Income)	−1.679	−2.803	−1.504	5.056	0.903	−1.515
	(2.398)	(1.816)	(1.110)	(1.074)	(1.121)	(2.003)
θ_i (Outage fraction)	0.789	0.789	0.789	0.789	0.789	0.789
	(0.135)	(0.135)	(0.135)	(0.135)	(0.135)	(0.135)
Hh members	2.283	2.741	5.622	−0.972	6.827	1.650
	(0.593)	(0.423)	(0.484)	(0.360)	(0.657)	(0.458)
Rooms	−5.983	6.073	7.129	3.049	2.271	1.952
	(1.263)	(0.746)	(0.654)	(0.580)	(0.806)	(0.861)
Apartment (0/1)	35.184	−17.428	−19.433	1.457	−13.749	−4.442
	(3.902)	(3.060)	(2.231)	(2.289)	(2.445)	(3.435)
Temperature	−0.988	1.366	−0.189	3.548	−0.080	−0.216
	(0.270)	(0.228)	(0.225)	(0.354)	(0.261)	(0.277)
Average outages	−1.243	0.476	1.051	1.083	1.148	−0.720
	(0.275)	(0.327)	(0.390)	(0.267)	(0.442)	(0.334)
Average outages sq	0.026	−0.020	−0.026	−0.023	−0.011	0.019
	(0.005)	(0.009)	(0.011)	(0.007)	(0.011)	(0.008)
Average outage hrs	−0.822	1.063	−0.200	0.587	−0.125	0.213
	(0.196)	(0.178)	(0.222)	(0.169)	(0.309)	(0.176)
Average outage hrs sq	0.006	−0.006	0.001	−0.004	0.002	−0.002
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)

Maximum Likelihood Parameter Estimates

Average outages sq	0.026	−0.020	−0.026	−0.023	−0.011	0.019
	(0.005)	(0.009)	(0.011)	(0.007)	(0.011)	(0.008)
Average outage hrs	−0.822	1.063	−0.200	0.587	−0.125	0.213
	(0.196)	(0.178)	(0.222)	(0.169)	(0.309)	(0.176)
Average outage hrs sq	0.006	−0.006	0.001	−0.004	0.002	−0.002
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Stratum 2 households[e]	10.522	−4.350	2.711	10.355	−4.033	−0.255
	(7.139)	(3.650)	(3.341)	(2.088)	(5.446)	(3.714)
Stratum 3 households	29.832	−6.436	15.045	15.989	−4.754	−10.111
	(22.711)	(10.461)	(3.903)	(3.693)	(6.152)	(10.991)
Stratum 4 households	23.727	−12.396	22.272	35.720	−1.246	1.832
	(26.488)	(15.882)	(5.156)	(4.774)	(6.796)	(14.146)
Stratum 5 households	41.459	−54.487	62.635	34.421	26.367	16.280
	(42.848)	(38.825)	(8.086)	(7.313)	(8.508)	(28.720)
Stratum 6 households	−28.377	74.633	92.827	−3.366	43.599	−23.913
	(47.304)	(37.069)	(11.193)	(9.491)	(10.487)	(42.178)
σ_{η_i}	53.528	24.548	59.790	50.062	53.002	26.475
	(2.639)	(3.137)	(3.736)	(4.750)	(6.677)	(4.465)

Results

- Previous table parameter from the maximum likelihood estimation.
- Dependent variable is monthly electricity consumption
- Mean price elasticity: -0.32, closer to zero for lower strata
- Reiss, White (2005):-0.39
- Mean income elasticity: 0.06
- Outage effect: effect of one additional outage hour on the monthly electricity consumption of households
- Reduce consumption by 0.165 kWh, higher for Strata 5 and 6

Correlation Matrix for Appliance-Level η_i

	Base	Fridge	Washer	Fan	Computer	Television
Base	1.00					
Fridge	0.00	1.00				
Washing machine	0.00	−0.30	1.00			
Fan	0.00	0.64	−0.09	1.00		
Computer	0.00	−0.49	−0.11	−0.13	1.00	
Television	0.00	−0.78	0.28	−0.08	0.29	1.00

Price Elasticities, Income Elasticities, and Outage Effects

	Price elasticities[a]		Income elasticities		Outage effect[b]	
	Mean	Median	Mean	Median	Mean	Median
All households	−0.32	−0.18	0.06	0.05	−0.165	−0.151
Stratum 1	−0.13	−0.09	0.07	0.05	−0.132	−0.126
Stratum 2	−0.22	−0.14	0.06	0.04	−0.147	−0.136
Stratum 3	−0.47	−0.43	0.06	0.05	−0.181	−0.171
Stratum 4	−0.68	−0.64	0.08	0.07	−0.230	−0.218
Stratum 5	−0.73	−0.70	0.09	0.08	−0.270	−0.257
Stratum 6	−0.62	−0.61	0.10	0.10	−0.332	−0.324

Predicted Monthly Electricity Consumption by Appliance

Appliance	% hhs[a]	Pred. cons. (kWh)[b]		Implied usage		US cons.[c]
		Mean	SD	Watts[d]	Hours[e]	
Air conditioner	3	41.9	3.7	1,400	1.0	48.3
Blender	80	3.5	0.4	500	0.2	
Computer	20	14.8	14.8	150	3.3	21.8
Electric shower	17	8.4	0.9	4,400	0.1	
Fan	36	22.6	14.4	80	9.4	4.2
Fridge	81	25.2	20.4	200	4.2	103.3
Microwave	14	13.5	1.3	800	0.6	17.4
Oven[f]	22	3.4	0.4	3,600	0.0	36.7
Stereo	51	4.3	0.5	100	1.4	6.7
Television	89	6.4	6.0	200	1.1	11.4
Washing machine	38	21.9	19.0	600	1.2	10.0
Water heater[f]	11	8.7	0.7	2,000	0.1	213.0
Baseload[g]	100	104.1	94.7			

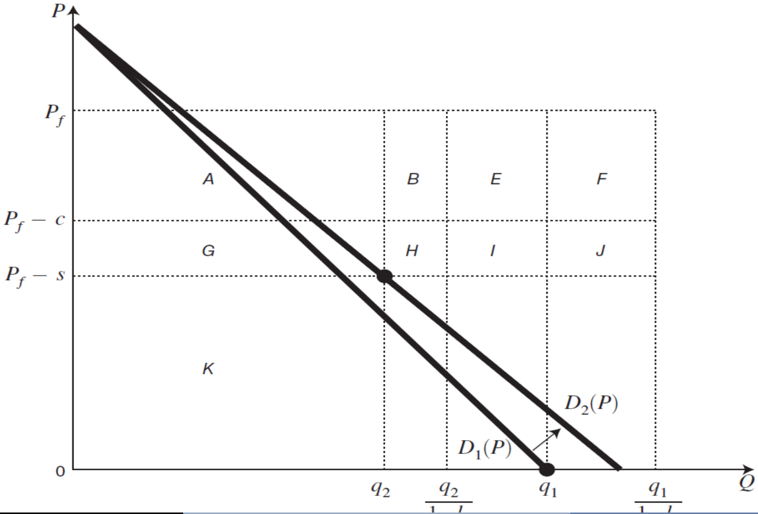
Firm Investment in Infrastructure Upgrades

- Firm's decision to upgrade infrastructure in informal settlements
- Consumption before upgrade: demand model with zero marginal price & unreliable service
- Consumption after upgrade: marginal price, reliable service
- Model
  - lower outage, higher consumption
  - higher prices, lower consumption
- Next graph, $D_1(p)$ unreliable service,
- Unmetered, demand before upgrade $q_1 = D_1(0)$
- Firm observes total consumption, if loss in network is l_1, bill settlement $q_1/(1-l_1))$

Firm Investment in Infrastructure Upgrades

- s is subsidy: so payment to firm: $A+B+C+E+F+G+H+I+J$
- marginal cost: $A+B+E+F$
- Firm profit: $G+H+I+J$
- Upgrade, then demand to $D_2(p)$, b/c reliability
- Marginal price: $p_f - s$, so consumption $D_2(P_f - s)$
- Now, subsidy based on q_2
- New government transfer to firm $A+G$

Firm Profit in Upgrade



Firm Investment in Infrastructure Upgrades

- Payment to firm is K
- Variable cost $A + B$
- Revenue $G + K - B$
- Revenue of upgrade $K - B - H - I - J$
- Sum over all household must cover upgrade capital cost
- Otherwise, low quality

Results

- 100 counties, first two column assume 0% pay before and 100% pay after upgrade
- Column 3, 10% before and 90% pay bill respectively
- Column 4,5 lowest & highest profit before the upgrade
- Mean consumption before upgrade 125 kWh/month
- Mean consumption is lower after : 119 kWh/month
- Profit before \$4.05 per household per month
- $\Rightarrow$ subsidy transfers cover variable costs
- After the upgrade, subsidies falls to \$6.05 per household per month
- Household payment:\$6.58 per household per month
- Profit after \$6.67 per household per month

Firm Profit in Upgrade

	Scenario[a]			County examples[b]	
	Mean+ loss	Av. Strat. 1	Part pay	Low profit	High profit
Consumption (kWh/month)					
Before upgrade	125	125	125	190	80
Price effect	−12	−12	−12	−17	−11
Reliability effect	6	6	6	−3	10
After upgrade	119	119	119	169	80
Billed quantity (kWh/month)					
Before upgrade	192	183	192	290	123
After upgrade	119	119	119	169	80
Pre-upgrade Profit[c] ($/month)					
Stratum 1 subsidy (A+B+E+F+G+H+I+J)	8.25	7.52	8.25	8.01	9.12
Social Energy subsidy	3.72	3.56	3.72	5.63	2.38
User revenue	0.00	0.00	0.82	0.00	0.00
Cost of electricity consumed (A+B+E)	−5.18	−5.18	−5.18	−7.93	−3.10
Cost of line losses (F)	−2.74	−2.74	−2.74	−4.20	−1.64
Total (G+H+I+J)	4.05	3.16	4.87	1.51	6.76
Post-upgrade Profit ($/month)					
Stratum 1 subsidy (A+G)	6.05	6.05	6.05	7.01	5.96

Firm Profit in Upgrade-Continue

	Scenario[a]			County examples[b]	
	Mean+ loss	Av. Strat. 1	Part pay	Low profit	High profit
Post-upgrade Profit ($/month)					
Stratum 1 subsidy (A+G)	6.05	6.05	6.05	7.01	5.96
Social Energy subsidy	0.00	0.00	0.00	0.00	0.00
User revenue (K)	6.58	6.58	5.92	8.66	5.96
Cost of electricity consumed (A)	−4.94	−4.94	−4.94	−7.08	−3.10
Cost of line losses (B)	−1.03	−1.03	−1.03	−1.48	−0.65
Total (G+K−B)	6.67	6.67	6.01	7.11	8.17
Change in profit ($/month) (K−B−H−I−J)	2.62	3.50	1.14	5.60	1.41
Capital cost ($/month)	5.65	5.65	5.65	5.65	5.65
Number of upgrades	1	15	0	0	0

Results

- Cost of capital 13%
- Upgrade capital cost equivalent to $5.65 per household per month
- Therefore, upgrade will only take place in single county with different profit more than this.
- Why no upgrades: high profits for firms before upgrade .
- Why high profits: high subsidies + consumption in unmetered, exceeds their true consumption

Policy Counterfactuals

- Four government strategies
  - reduce transfers before upgrade
  - additional transfers after upgrade
  - increase consumption of households after the upgrade
  - subsidize cost of upgrade.
- Six policies:
  1. a reduction in Social Energy subsidy
  2. a reduction in Stratum 1 subsidy for unmetered
  3. limits on the distribution losses before upgrade
  4. transfers to firms conditional on an improvement in service quality
  5. provision of free appliances to upgraded households
  6. full or partial funding of the capital cost of the upgrade

Policy Counterfactuals

- Compare over 47.8 million combinations of different levels of these six policies
- Next table policies, given consumption:
  - current subsidy program (P0)
  - P1: optimal policy s.t. minimizes cost to government, upgrades for 86 counties, cost 55% lower than current program, permanent disconnection to 14 counties (profit before upgrade negative), political concern
  - P2: optimal policy s.t. maximizes number of upgraded counties at minimum cost to government, every county upgraded, average firm value falls by 30 %, political concern
  - P3: maximizes number of upgraded counties at minimum cost to government + firms cannot be worse off: problem some counties shut-down until upgrade
  - P4: P3+no counties can be unprofitable (and potentially disconnected) before the upgrade

Firm Profit in Upgrade-Continue

Alternative programs[a]	P0	P1	P2	P3	P4
Policy parameters[b]					
Pre-upgrade Stratum 1 (percent)	50	28	25	25	50
Pre-upgrade Social Energy (c/kWh)	2.0	2.0	2.0	2.0	2.0
Pre-upgrade billed losses (percent)	100	15	55	55	65
Capital subsidy (percent)	0.0	0.0	32.5	22.5	90.0
Quality subsidy (c/kWh)	0.0	0.0	0.0	0.4	0.0
Appliance	—	—	—	—	—
Consumption (kWh/month)					
Before upgrade	125	125	125	125	125
After upgrade	119	119	119	119	119
Pre-upgrade profit ($/month)					
Government subsidies	11.96	6.34	6.81	6.81	10.91
Variable costs	−7.92	−7.92	−7.92	−7.92	−7.92
Total	4.05	−1.57	−1.11	−1.11	2.99
Post-upgrade profit ($/month)					
Government subsidies	6.05	6.05	6.05	7.83	6.05
User revenue	6.58	6.58	6.58	6.58	6.58
Variable costs	−5.97	−5.97	−5.97	−5.97	−5.97
Total	6.67	6.67	6.67	8.44	6.67
Upgrade cost ($/household)					
Share paid by firm	506	506	342	392	51
Share paid by government	0	0	165	114	456
Capitalized value ($/household)					
Firm	363	97	255	363	546
Government	1,065	480	706	815	998
Number of counties					
Shutdown	0	14	0	0	0
Upgraded	1	86	100	100	100
Disconnect before upgrade	0	69	71	71	0