How Do Electricity Shortages Affect Industry? Evidence from India

Hunt Allcott   Allan Collard-Wexler   Stephen D.O'Connell

Presentation by Sherry Tang

This slides refer to the presentation slides for Ito & Zhang (2020)

Electricity shortage crisis is very severe in India

Image: Jitendra Prakash (Reuters), downloaded from Google

Research question: How do electricity shortages affect input choices, revenue, and productivity in the Indian manufacturing sector?

- Electricity is an essential input $\implies$ shortages could significantly reduce output

- Firms insure themselves against outages by purchasing generators / substituting away from grid electricity

- Why this question is difficult to answer empirically?

    1. **Data**: Hard to obtain high-quality data on electricity shortages
    2. **Identification**: Shortages are not exogenous to productivity or production

Data

- Comprehensive data from 1992 to 2010 on weather, the power sector, and manufacturing production
  - ▶ The only systematic dataset including historical electricity shortages (now publicly available)
- The CEA measure of shortages:

$$S_{st} = \frac{\text{Assessed Demand}_{st} - \text{Energy Available}_{st}}{\text{Assessed Demand}_{st}} \tag{1}$$

  - ▶ Shortage depends on an administrative assessment of counterfactual demand $\implies$ Measurement error $\implies$ Need instruments
  - ▶ Simultaneity $\implies$ OLS may underestimate losses
- Plant-level panel: Annual Survey of Industries (ASI) $\implies$ 600 k plant-by-year obs, rich input/output data

Background

- Indian electricity sector: 80 percent of electricity supply in 2010 remained government owned
- Reasons for electricity shortages: the retail distribution companies cannot raise retail prices to clear the market
  - "infrastructure quality and subsidy trap"
  - underinvestment in new generation capacity
  - existing capacity is systematically underutilized
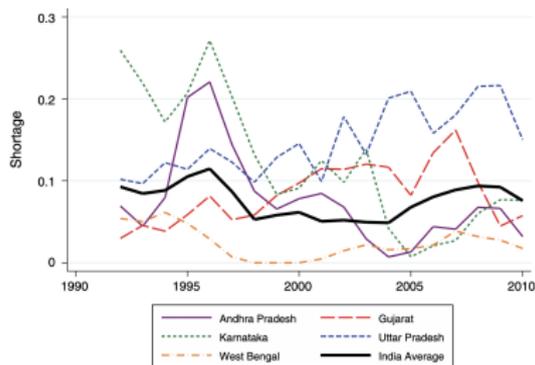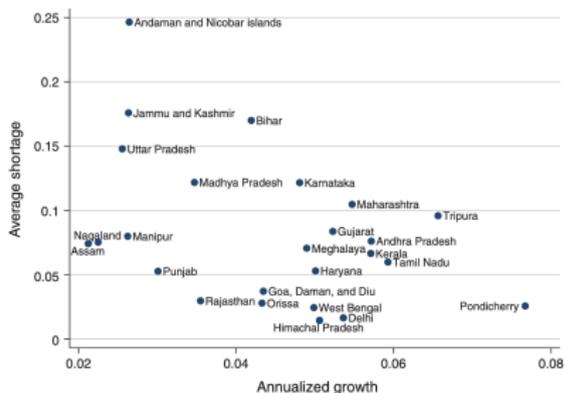- Shortage vary substantially across states and over time

Figure 2. Shortages Over Time in Five Large States

Model Overview

- They present a modified Cobb-Douglas production function model to predict how variation in electricity shortages affects existing plants
  - ▶ Plants with generators: shortages cause the cost of self-generating electricity to increase (like time-varying electricity input tax)
  - ▶ Plants without generators: shut down during outages (like infinite input tax)

- This "input tax effect" causes all plants to contract, especially those without generators

- Shortage Predicts: ↑ self-generation, ↓ electricity & materials & labor, smaller TFPR loss compared to the revenue loss because of contract

- Economies of scale in generator costs $\implies$ larger plants hurt less

Empirical Strategy

- Estimate how variation in shortages affects plant in India's official manufacturing survey (ASI)
- Supply shift from hydroelectric power availability $\implies$ IV for shortages
  - $$\text{hydro availability share} = \frac{\text{predicted hydro generation}}{\text{predicted electricity demand}}$$
  - Controls: rainfall bins, cooling-degree days, state trends, plant & year FE
- **First stage**: 1 pp hydro-supply $\uparrow \to 0.177$ pp shortage $\downarrow$
- **Exclusion restriction**: the instrument only shifts without affecting manufacturing other than through shortages (e.g. not associated with electricity demand, agricultural output, electricity prices)

TABLE 4—EVALUATING THE HYDRO INSTRUMENT

	Shortage (1)	ln(Energy available) (2)	ln(Assessed demand) (3)	ln(Agri output) (4)	ln(Median price) (5)
Hydro	−0.163 (0.059)***	0.206 (0.074)***	0.029 (0.092)	−0.274 (0.246)	−0.149 (0.140)
Observations	536	536	536	518	540

Notes: Observations weighted by number of ASI establishments in the state-year cell. Robust standard errors.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Empirical Results

- 1 pp shortage $\uparrow$ $\rightarrow$ 0.442 pp self-generation share $\uparrow$; 3.3 % fuel/revenue $\uparrow$; electricity intensity weak; materials 1.137 % $\downarrow$; labor weak; revenues 1.091 % $\downarrow$ per pp; TFPR 0.30 % $\downarrow$ (not significant)

- Long-run effect: plants in electricity-intensive industries are less likely to enter when shortages worsen

TABLE 6—EFFECTS OF SHORTAGES ON ENERGY INPUTS

	Self-Gen share (1)	ln(Fuel rev share) (2)	ln(Electric intensity) (4)
Panel A. OLS			
Shortage	0.282	0.917	−0.539
	(0.0337)***	(0.176)***	(0.122)***
Panel B. IV			
Shortage	0.442	3.294	0.0926
	(0.153)***	(1.032)***	(0.755)
Observations	240,743	291,759	479,616
Clusters	47,575	55,939	111,819
Clusters (2)	535	535	536
First stage *F*-statistic	17.00	16.53	14.98

Notes: This table presents estimates of equation (21). Panel B instruments for Shortage using hydro availability. Samples for columns 1 and 2 are limited to plants that ever self-generate electricity. *F*-statistic is for the heteroskedasticity and cluster-robust Kleibergen-Paap weak instrument test. Robust standard errors, with two-way clustering by plant and state-year.
 ***Significant at the 1 percent level.
  **Significant at the 5 percent level.
   *Significant at the 10 percent level.

TABLE 7—EFFECTS OF SHORTAGES ON MATERIALS, LABOR, REVENUE, AND TFPR

	ln(Materials) (1)	ln(Workers) (2)	ln(Earnings/ worker) (3)	ln(Revenue) (4)	ln(TFPR) (5)
Panel A. OLS					
Shortage	−0.00711	−0.0138	0.161	0.116	0.0543
	(0.0631)	(0.0461)	(0.0421)***	(0.0631)*	(0.0387)
Panel B. IV					
Shortage	−1.137	−0.243	−0.267	−1.091	−0.304
	(0.511)**	(0.339)	(0.218)	(0.536)**	(0.259)
Observations	495,043	502,724	456,443	501,130	479,313
Clusters	115,040	116,803	110,213	116,231	112,371
Clusters (2)	536	536	482	536	536
First stage *F*-statistic	14.23	14.19	14.63	14.17	14.90

Notes: This table presents estimates of equation (21). Panel B instruments for Shortage using hydro availability. *F*-statistic is for the heteroskedasticity and cluster-robust Kleibergen-Paap weak instrument test. Robust standard errors, with two-way clustering by plant and state-year.
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Counterfactual Simulations

- Calibrate the production function model by 2005 ASI data to simulate the effects of shortage: smaller TFPR losses than revenue losses $\implies$ decrease in revenues due to decreased input use
- Validate the structural model using the agreement of the model's prediction with the reduced form results $\implies$ estimates are reasonable
- The assessed level of shortages reduced producer surplus by 9.5 percent (of which 3.9 percent is due to the capital costs of backup generators), revenue by 5.6 percent

TABLE 9—EFFECT OF SHORTAGES

	Simulation percent (1)	IV estimate percent (2)	p-value for columns (1) versus (2) (3)	World Bank Survey percent (4)
Panel A. Effects of shortages: Model and IV estimates				
Self-generation share increase	3.1	3.1	(0.98)	
Materials reduction	5.6	8.1	(0.49)	
Labor reduction	5.6	1.7	(0.11)	
Revenue loss	5.6	7.7	(0.57)	7.8
TFPR loss	1.5	2.2	(0.72)	

	All percent	With generators percent	Non-generators percent
Panel B. Producer surplus effects of shortages			
Producer surplus loss	9.5	8.0	10.0
of which Δ generator costs	3.9	7.7	NA
of which Δ variable profit	5.6	0.3	10.0
of which Δ TFPR	1.5	0.0	2.6
Panel C. Producer surplus effects of shortages with interruptible contracts			
Share of plants opting into interruptible contracts	8	13	3
Variable profit loss	0.4	0.1	0.7
of which Δ TFPR	0.0	0.0	0.1

Counterfactual Simulations

Panel A. Generator ownership and plant size
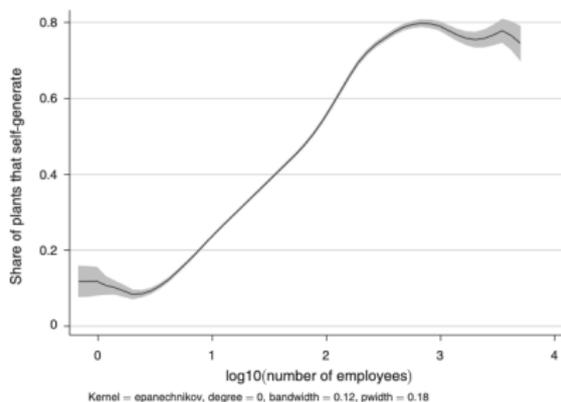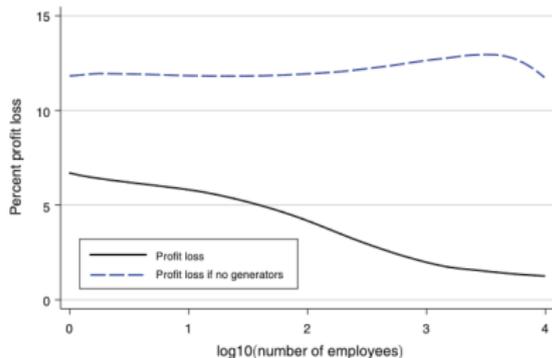
Panel B. Simulated profit loss and plant size

Figure 4. Generator Ownership and Shortage Effects by Plant Size

• Two insights from the simulation
  ▶ Shortages more severely affect plants that do not have generators; generator costs have significant economies of scale $\implies$ distort India's plant size distribution in favor of large plants
  ▶ Offer interruptible retail electricity contracts could substantially reduce producer surplus losses

What I like about this paper

1. Novel comprehensive dataset on shortages + made it public available (thanks to the cooperation with authority and research assistants)

2. Quantify the loss from electricity shortages can be useful for policymakers in developing countries

3. Clever IV as shifts supply: strong first stage & placebo tests

4. Combine reduced form with structural model & welfare simulations

5. I personally like the discussion about introducing interruptible contracts as a potential solution, which could be more politically feasible than completely market liberalization

What I dislike about this paper

1. ASI covers registered factories – omits some of the manufacturing employment; informal sector may suffer more

2. Hydro IV might affect agriculture or other sectors beyond electricity supply; could prove more about the exclusion restriction

3. Production function estimation seems to be criticized in recent years. Is it possible to use a nonparametric approach?

Discussion

- External validity: would similar shortages in other developing countries show bigger TFPR drops?

- How would incorporating entry/exit and informal firms change aggregate costs?

- How have solar and wind changed the relevance of shortages in recent years in India? What if we use solar and wind production as instruments?

- Could smart-meter demand response outperform diesel generators environmentally?