Research Note
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Electricity Supply and Economic Growth: Evidence from a Large Experiment in Bihar

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We conduct a large-scale randomised experiment with two electricity distribution companies in the state of Bihar in India, to test the impact of a new power allocation rule on consumer payment rates and firm outcomes. We find small, positive effects of the assignment to the allocation rule on distribution companies' revenue, but these effects are not statistically different from zero. In terms of firm outcomes, our estimates suggest that one hour of additional power supply increases electricity-using capital by INR 531 on average on a base of INR 1690, but does not affect non-electricity using capital – with notable differences between economic sectors. However, the low compliance with the new rule that we observe means that these estimates are only suggestive of a causal link between electricity supply and profits.

Introduction

Modern rates of economic growth depend on the use of modern sources of energy. No country has ever grown rich without vastly increasing its energy use and also moving from simple, traditional forms of energy, like human and animal power, to fossil fuels and electricity. In search of growth, countries in Asia and sub-Saharan Africa have undertaken universal electrification campaigns to bring modern energy supply even to poor and rural areas. An estimated 1.2 billion people gained access to electricity in developing Asia from 2000 to 2019 (IEA, 2020). A striking feature of this wave of electrification is that it is happening at much lower levels of per capita income than has been common for electrification campaigns historically (Lee, Miguel and Wolfram, 2020a). Likely for this reason, household demand for electricity in many areas the grid has newly reached its low (Burgess et al., 2020b; Lee, Miguel and Wolfram, 2020b). The electricity grid achieves high levels of adoption and use only with heavy subsidies; otherwise, poor households may choose off-grid alternatives like solar power instead.

Are massive subsidies for grid electricity worth it? Or should countries scale back their ambitions for electricity supply in the face of low demand? Subsidising power for the poor has a direct fiscal cost. It may also, ironically, undercut power supply to the highest-value customers, by incentivising public utilities to ration power to limit their own losses (Burgess et al., 2020a). Poor power supply is one of the main complaints firms have about doing business in developing countries, according to the 2018 World Bank Enterprise Survey. The returns to a mass electrification strategy, as opposed to a more selective approach, depend on both household demand for power and the return to power for business firms that suffer from power rationing.

We conduct a large-scale randomised experiment in the state of Bihar in India. The experiment sought to investigate a new approach to increasing consumer payment rates as well as the relationship between electricity supply and firm outcomes. Our data collects outcomes on small and mostly informal-sector firms, that are not represented in national surveys such as India's Annual Survey of Industry. Therefore, very little prior evidence, causal or otherwise, exists on the relationship between firm outcomes at this scale and power supply. Nevertheless, these firms are important as they are at the frontier of enterprise activity and the consequent income generation in rural India.

Policy Context

The state of Bihar undertook in 2013 a massive electrification campaign and steadily increased both grid connections and power supply on the grid. This campaign had a high cost because of explicit tariff subsidies as well as remarkably high levels of theft and non-payment of bills (Burgess et al., 2020a). The state therefore limited electricity supply, circa 2014, to an average of 15 hours per day, in order to provide an adequate supply of electricity without exhausting its budget. Such power rationing is the norm in large parts of India.

Methodology

We worked with the two electricity distribution companies in Bihar to test a new allocation rule for power supply in a large randomised experiment. The experiment covered the electricity supply for 1.1 million people over a period of roughly 3 years, from late 2014 to early 2018. In the experiment, a set of feeders—the lowest level of the electricity distribution network, usually serving about 2,500 customers—were randomly assigned to follow the new allocation rule. The allocation rule gave more hours of power supply to areas where losses were lower, that is to say, where consumers paid a greater fraction of their electricity bills. The experiment as a whole was introduced as 'official policy', backed by formal orders and management from the heads of the two state electricity utilities and the senior-most bureaucrat in the energy department.

Under the specified regime, the best-paying areas could earn as many as 12 hours more power per day than the worst. Because these rules connected power supply to local payments, the utility called it the Revenue-Linked Supply Scheme (RLSS). A control set of feeders were assigned to receive the average level of power supply, regardless of how much they paid for the electricity they received. The intention of this regime was to increase power supply as much as possible given a limited state budget and to incentivise increased payment for power supply[1]. The allocation rule was widely publicised through a range of methods, from posters to street plays to public announcements and meetings. We designed the experiment to study the trade-offs in electricity supply from the perspective of both the utility and its customers. On the side of the utility, we ask: did the new allocation rule incentivise greater payment and increase revenue and cost recovery? On the side of the customers, we investigate the benefits of increased power supply for those firms that received it.

We collected data from two main sources to observe both sides of this trade-off. First, administrative data, including supply log books and the utility's billing database, gives us a complete picture of the implementation of the power allocation rule and its consequences for energy supply, revenue and costs. Second, we conducted a large, representative two-wave survey of firms measuring profits, revenue, inputs and technology adoption.

[1] Similar rules have been adopted in, for example, the city of Karachi, Pakistan.

The survey uses as a sampling frame a census of 146,497 business firms we enumerated in 8 districts under the experiment (see Figure 1).

Measuring the returns to electricity supply from both sides of the market is critical, in our setting, because many grid customers do not pay for the power they receive. We will use the term "utility" to refer to the electricity distribution companies that supply power in Bihar, and "firm" to refer to a business in our sample, typically small, that may or may not use power in its operations. We calculate that the utility circa 2014 (baseline) recovers on average 52.7% of the variable cost of supply. Because many firms receive power, but do not pay for it, the demand for electricity as estimated from payments to the utility may be much lower than firms' actual value of electricity supply. With our survey data, we sought to circumvent this problem by directly estimating the return to electricity supply for firms, using the variation in supply induced by our experiment.

Main Findings

Our main results correspond to the treatment effect of the utility intervention on payments and our evidence on the effect of electricity on firm outcomes.

Treatment Effects on Payment Rates

Overall, the assignment of feeders to a revenue-linked supply schedule (i.e. the treatment) did not increase utility revenue or cost recovery. We estimate small, positive effects of the assignment to treatment on revenue and revenue per unit cost, but these effects are not statistically different from zero in our preferred specifications. There are several explanations for a null effect. First, it is possible that the incentive was too weak, and that consumers were unwilling or unable to pay more even though they might receive better power in return. Weak incentives may also follow from the collective action nature of the new regime where an individual consumer's actions may have only a small effect on payment rates in their feeder (neighbourhood) as a whole. Second, it might be the case that power supply does effect revenue, but that this effect is roughly linear and so the deliberately heterogeneous treatment does not change utility revenue on average. Finally, it is possible that the utility implemented the new regime poorly so that there was little incentive to change payment behaviour in practice, even for consumers who valued better supply greatly. The degree to which the quality of implementation matters depends on whether consumers trust stated policy initially, and whether they are able to update their beliefs about the credibility of this policy.

In our setting we find that the revenue-linked supply rule was implemented poorly. Although we found a positive relationship between assigned hours of supply under the allocation regime and the actual hours delivered, the feeder level changes required by the rule are attenuated and may be due to unobserved factors. A one-hour change in supply as required under the allocation regime resulted in practice in a change of approximately 0.2 hours on average. Since consumers can observe the hours they actually receive, they would be able to judge whether the utility was fulfilling its promises and weak implementation may limit their response to the collective incentive.

Electricity Supply and Firm Outcomes

To estimate the social return on power supply, we turn to our survey data, in which we can estimate the effect of power supply on firms. These impacts should be distinguished from the firms' willingness-to-pay for

additional electricity: under a regime with widespread partial payment of bills, it is possible that firms benefit from electricity but are able to get away with not paying very much for it.

We begin with correlational evidence, which shows that power supply is strongly associated with increases in the revenue and profits of small firms. The relationship between firm profits from our survey and feeder-level hours of electricity supply indicate that a one hour increase in supply corresponds to an increase by about INR 80 in profits. These increases are greatest for service sector firms. The difficulty in interpreting these numbers as representing a causal relationship between electricity and enterprise outcomes is that it is possible that unmeasured omitted variables in these regressions may influence both the hours of electricity supply provided to feeders, as well as firm outcomes within those feeders. For instance, it is possible that political priorities may direct more public infrastructure of all types to specific feeders, so that firms getting more power also have better roads and thus better access to markets. In such a case the correlation between power supply and profits would conflate the benefits of power with those of better roads.

The experiment we conducted should in theory provide a solution to this problem by allowing us to use the treatment assignment from the experiment, interacted with baseline revenue rates, as an instrumental variable for supply. This is a variable that shifts power supply hours for specific feeders but is by construction uncorrelated with any other factors.

The results using only the variation induced by our experiment suggest larger impacts, with an average increase in profits from an additional hour of electricity supply of about INR 300. This is about 7 percent of baseline average profits (INR 4138), suggesting a very large increase in profits from a shift from the baseline level of 15 hours of supply to 24 hours of supply. We measured firm capital using a detailed inventory of assets and their costs and paid particular care to differentiating assets that used electricity (e.g., a light bulb or a power saw) from those that do not (e.g. a table). The estimates suggest that one hour of additional power supply increases electricity-using capital by INR 531 on a base of INR 1690 but does not affect non-electricity using capital. There is a rich pattern of cross-sectional heterogeneity. Many manufacturing firms make up for poor power supply by generating electricity themselves, which allows them to use electricity using assets, even in the status quo. We find that the largest effects on electricity-using assets are for service and retail firms, for whom it would not otherwise be worth it to invest in the fixed cost of a generator. We also estimate that one hour of power supply increases labour demand by 1.66 person-days per month and the total wage bill by INR 5.15 on a base of INR 152.

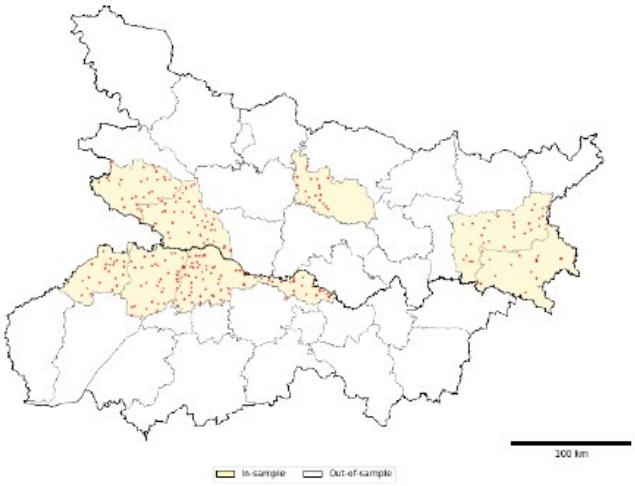
Conclusion and Policy Implications

Unfortunately, these estimates are not definitive evidence of a causal link between supply and profits. Imperfect compliance with the experiment's allocation rule means that our instrumental variable is not relevant enough. The low compliance that we observe with the schedule set out in the Revenue Linked Supply Scheme creates difficulties in using the design of the experiment as a means of cleanly identifying the effects of electricity. Although our regression specifications should be interpreted with some caution, the patterns we observe in our estimates suggest that there may be significant benefits (higher profits) to businesses from improvements in the supply of power, and thus large social returns to subsidised investment in power supply.

Moving Forward

The widespread prevalence of electricity theft and non-payment in Bihar (as in most of India and many developing countries), means that simply observing consumer willingness to pay for electricity may not be sufficient to conclude that consumers do not benefit from power or indeed value it. We observe that the utility fails to collect on all its dues even in the case of consumers who have signed up to buy power at prevailing tariffs and are legally speaking, violating the terms of their contract with the utility by not paying their bills. In this context it is difficult to infer the value of electricity from consumer payment behaviour. Our results suggest that further experimental work identifying the impacts of power supply on directly measured household and business outcomes may be very valuable in helping us understand the benefits and costs associated with expanding the grid, subsidising tariffs, or increasing hours of supply in developing countries, especially in the context of an academic literature that has largely focused on households.

Figure 1: Survey Sample Map



Panel A: Survey sample map

Panel B: Survey sample map

Note: The figures show the location of firms sampled for the business survey. We sampled one market per feeder, picking markets with probability proportional to size. Within a selected market, we sampled up to 20 retail and service shops, and up to 20 manufacturing shops. In Panel A, the red dots on the graph indicate the mean latitude and longitude coordinates of businesses in each market. The bold dark lines represent North and South Bihar divided by the river Ganges. Panel B shows an example of the location of businesses we surveyed within a given market (Satjora).

References

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