The Effect of Smart Metering on Revenue Collection: Evidence from an Experiment in Haryana

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Abstract

We conduct an impact analysis of smart meter feature activation in urban households in the state of Haryana in India. Using a cluster randomized control trial covering over 25,000 urban consumers we test the impact of switching consumers from having their bills generated based on manual meter readings, to automated online billing using data transmitted by smart meters. We find that the movement to online billing slightly reduces revenue collection because it leads to a 8 percent reduction in bills. We also sought to test the impact of introducing a rule-based remote disconnection regime for consumers with high arrears. The rule-based disconnection regime was announced but was not adhered to in the field and was quickly discontinued by the utility. Finally, although smart meters make alternative payment contracts such as pre-paid metering feasible, the utility chose not to introduce these changes alongside new metering. Thus the rollout of smart meters in our setting did not lead to improvements in revenue collection, more effective enforcement, or reduced losses. Although this study is informative only about short-run outcomes, we conclude that unless smart meters are actively used to reform enforcement and payment practices, capital investments into the technology alone may not deliver either utility or consumer benefits.

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1 Introduction

A growing body of research has identified a causal relationship between access to electricity and various measures of economic output or welfare[1]. Yet even though providing reliable electricity is a stated policy priority shared by developing countries the world over, over 800 million people still lack access to power, with hundreds of millions more forced to endure frequent, crippling power outages (Burgess et al. 2020).

Why is reliable power so hard to deliver? One reason may be that the largely state-run electricity utilities in developing countries are trapped in an equilibrium characterized by poor revenue recovery from consumers on the one hand, and correspondingly low-quality electricity supply on the other (Burgess et al. 2020). When utilities cannot prevent electricity theft or collect on the bills they issue to their consumers, they have less money to invest in infrastructure maintenance, modernization, and technical upgrades. They may also be forced to ration power, resulting in unreliable supply. In turn, if the quality of energy is unsatisfactory, customers may feel justified in not paying their bills, tampering with meters, or tapping directly into power lines.

How might utilities break this vicious cycle? A potential solution is to rely on new technology, specifically smart meters. In India, the National Smart Grid Mission run by the Ministry of Power envisages spending about 20 billion dollars between 2020-2025 as part of a rollout of about 250 million smart meters across the country. These devices enable two-way communication between the utility and its customers, allowing the distributer of power to monitor consumption remotely, automatically connect and disconnect consumers, and implement new tariff contracts such as pre-paid metering and time of day pricing.

Remote monitoring provides for dramatically improved measurement of energy use. Automatic disconnections make enforcement easier by minimizing staff time and effort. They may also increase transparency by switching to rule-based enforcement rather than the status-quo of decentralized and often discretionary actions carried out by field staff. Finally new payment contracts may increase efficiency (time of day pricing) or reduce arrears (pre-paid metering). [2]

In theory at least, these features would solve a thorny incentive problem in the relationship between the utility and the people it pays to read traditional analogue meters, and to distribute and collect on bills. These agents, be they subcontracted private parties or utility employees, have better information than management about the amount of power a consumer uses. They may profit by misreporting consumption, in return for side payments from consumers. They may also decline to disconnect customers who steal from the grid, and generally turn a blind eye to non-payment for electricity. In addition, when non-payment is common, large-scale manual enforcement through disconnections can be prohibitively expensive for state-run utilities functioning under severe budget constraints.

Notwithstanding this potential, we have little evidence on realized impacts in low income countries with high levels of theft. Existing evaluations of smart metering in developed countries have largely focused on information interventions targeted at consumers (Ito, Ida, and Tanaka 2018; Jessoe and Rapson 2014). Other work in middle income countries has been done in environments of lower theft and higher incomes than India, with evaluations focused on alternative payment contracts or better reliability (Meeks et al. 2022; Jack and Smith 2020). In high-theft environments, it is possible

[1] Examples include evidence from South Africa (Dinkelman 2011), Brazil (Lipscomb, Mobarak, and Barham 2013), and India (Allcott, Collard-Wexler, and O'Connell 2016)). Some recent evidence suggests benefits are more muted for very small or poor rural communities (Lee, Miguel, and Wolfram 2020), (Burlig and Preonas 2022)).

[2] We do not discuss alternative payment contracts in this paper. Such contracts have rarely accompanied the rollout of smart meters in India and did not do so in Haryana. An exception to this norm is the state of Bihar in India which has introduced pre-paid metering alongside an early rollout of smart meters.

that better monitoring through meters only leads customers to informally connect to the grid without any meter whatsoever. Additionally, it is not self-evident that incentive problems, poor information, or implementation costs are the main reasons why utilities do not enforce payments. If unwritten local political preferences determine the behaviour of these largely state-run utilities, then paying for expensive new technology may not change outcomes.

This paper evaluates the impacts of smart metering using a novel field experiment in the district of Karnal in Haryana. In 2019 Haryana launched a large metering scheme to commission 1 million smart meters for domestic and commercial consumers across selected urban towns. The smart meters used in this scheme are able to transmit a consumer's daily consumption data wirelessly to utility servers. They also give the utility the capacity to remotely disconnect non-paying consumers from their electricity connections.

We sought to test two new features made possible by smart meters: online billing and rule-based remote disconnections. The first feature changes how electricity consumption is measured by substituting manual in-field measurements with remotely transmitted high-frequency data. This eliminates the middleman role of meter readers. The second feature involves a policy change - moving away from discretionary and decentralized enforcement by field officials, and towards more predictable and automated disconnections. The evaluation took the form of a cluster-based randomized control trial implemented through a formal partnership with the Energy Department of the Government of Haryana and the state electricity utilities. A cluster in our setting is a group of consumers known as a *binder*, which is an administrative classification used by the electricity utility to organize administrative data and undertake meter reading activities. All consumers in a binder also have addresses located close to one another. Our sample covered 23,541 consumers across 125 binders with an average of 188 consumers per binder.

We use a combination of administrative data on billing and payments as well as two household surveys as our main sources of data. An important advantage of the setting we work in is that prior to the experiment, all consumers - treatment and control - had their old meters replaced with new smart meters. The difference between the two was only that for control households, no *features* of the new technology were used in utility operations. Their bills were generated based on manual readings as with analogue meters, even though they had the ability to transmit information online. This novel deployment has two advantages. First, it allows us to independently measure the true electricity consumption of control households as distinct from the manual readings reported by utility staff. Second, because treatment and control meters are of a similar age, we can isolate the impact of *smart features*, without our results being conflated with the effect of simply installing new meters. Old devices might suffer from miscalibration or become non-functional so that there may be benefits to new equipment, smart or otherwise.

We report four main findings in this paper. First, as a practical matter, the technology worked as advertised - information on electricity consumption was remotely communicated to the utility and was accordingly used to generate bills automatically. Installation was not prevented by consumer protests or logistical challenges.

Second, the change in how bills were generated did not increase the revenues recovered from consumers. We find that the bills of treatment households whose data was transmitted directly by smart meters was about 8 percent *lower* than was recorded through manual readings. This translates to a small decline in revenue collection, albeit estimated somewhat imprecisely. This change is not in itself undesirable since it may correct manual billing inaccuracies, and ex-ante it is not obvious whether these are more likely to be biased upwards or downwards.[3]Third, utility management was unable to implement a rule-based remote disconnection regime. This failure was not due to problems in the technology but due to push-back from operational staff who were unwilling to give up discretion. An initially announced rule-based policy was

[3] Meter-readers might under-report consumption in exchange for bribes from consumers. But they might also overreport usage, for example if some consumers are over-billed to hide the presence of illegal connections that are not metered at all. Over billing might also occur if functioning meters are reported as malfunctioning by meter readers. In such cases the utility uses a generous placeholder estimate.

first ignored and then retracted by the utility. As a result, we find no improvement in revenue recovery in the remote disconnections treatment group.

Finally, even though the rule-based regime was ignored, some consumers were nevertheless disconnected. We conducted an endline survey of consumers who were disconnected as well as those who were not. We found little evidence of differences in observable characteristics, suggesting that utility employees are not simply using a different but nevertheless objective rule to target enforcement.

Overall, we interpret these outcomes as being consistent with a setting where lax enforcement is a function of unwritten institutional and political priorities, and not merely information or incentive considerations. We conclude that unless smart meters are actively used to reform enforcement and payment practices, capital investments into the technology alone may not deliver either utility or consumer benefits.

The remainder of this paper is organized as follows: Section 2 provides further background on electricity distribution losses in India and the context in which we implemented this study. Section 3 describes the design of our field experiment. Section 3 provides results, and we conclude in Section 4.

2 Background

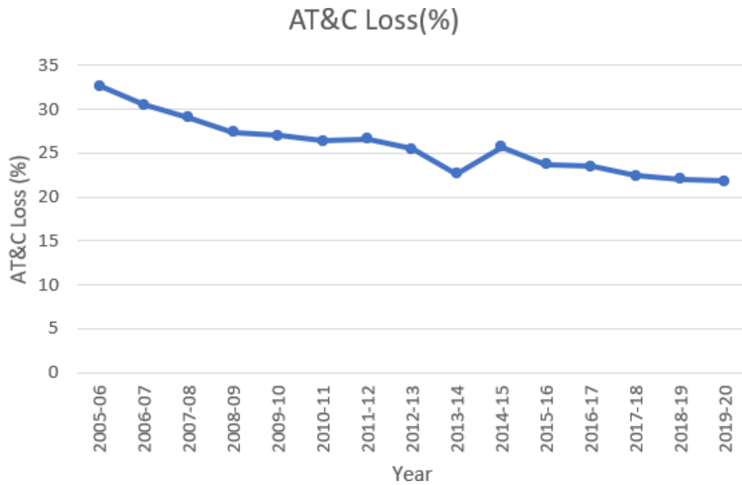
India's largely state-run utilities have consistently struggled to recover the costs of the electricity they supply. In 2005 the Aggregate Technical and Commercial losses (AT&C losses) of Indian utilities exceeded 30%.[4] Although losses have gradually reduced in many parts of the country (see Figure 1), they remain remarkably high in some of India's largest states - in July 2022 for example, the Ministry of Power's UDAY dashboard reported average AT&C losses of 28% and 30% in Uttar Pradesh and Bihar. These states had a combined population of just under 350 million people in 2021-2022. Since technical losses - present in every country – should not normally exceed 10 percent, these numbers underline the major role of theft and non-payment.

Furthermore, these numbers ignore the costs of explicit state subsidies. These subsidies do not qualify as losses but they nevertheless contribute to the broader challenge of failing to recover the costs of power from the people who use it. All told, between subsidies, theft through illegal connections, an inability to collect on bills, and technical losses, the state may recover as little as 30 cents from consumers for every dollar of electricity injected into the grid (Burgess et al. 2020). Figure 2 shows the distribution of these AT&C losses across Indian states.

The persistence of high AT&C losses in many parts of India has led to a series of both centralized and state-level schemes designed to fund measures that might improve revenue recovery. One of the most ambitious such efforts is the Smart Meter National Programme (SMNP) under the National Smart Grid Mission (NSGM) which envisages replacing about 250 million conventional meters with modern technology. As of July 2022, the NSGM reported that about 4.7 million smart meters have been installed across the country. With an eye to increasing utility revenues, this rollout has prioritized urban regions with high losses. Specifically, electricity divisions in India that have more than 50% urban consumers and also had losses of more than 15% in 2019-20, are expected to switch to smart meters by December 2023.

[4] Aggregate Technical and Commercial losses (AT&C losses) combine both *technical* losses that occur when electricity is transmitted long distances through wires, as well as avoidable *commercial* losses due to non-payment of bills and electricity theft.

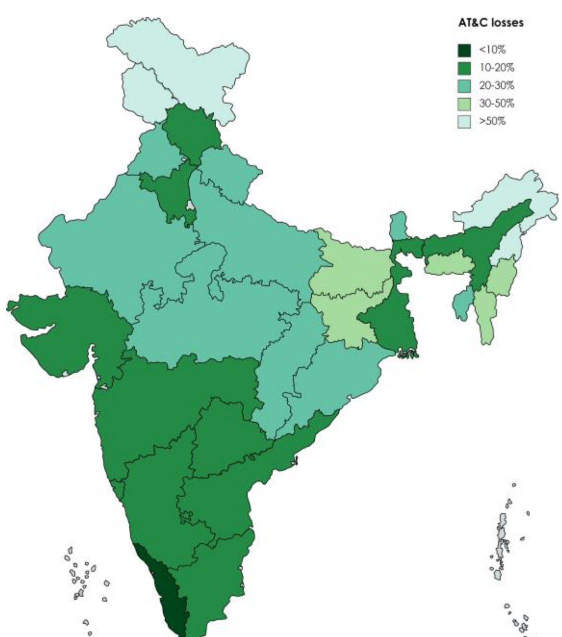
Figure 1: Trend in AT&C losses



Source: PFC's report on State Power Utilities 2019-20

The experiment we run is in the context of this initial rollout. We focus on the state of Haryana, whose electricity sector has been characterized both by large subsidies to agricultural users and average AT&C losses of around 18% in 2019-20. In 2019, the two Haryana state run utilities - Uttar Haryana Bijli Vitran Nigam (UHBVN) and Dakshin Haryana Bijli Vitran Nigam (DHBVN) - commissioned a rollout of 1 million smart meters for domestic and non-domestic consumers in high-loss urban towns.

Figure 2: Aggregate Technical and Commercial losses in India



Source: Data for April 2022 from the website of Ujwal Discom Assurance Yojna, GOI

At the request of the Energy Department of the Government of Haryana, the research team partnered with one of the state utilities to carry out an evaluation of smart meters, focusing on whether they could improve cost recovery, and thereby energy reliability and access. Haryana identified Karnal district as a pilot location for installing smart meters in 2019 and had installed close to 60,000 meters in the district before the launch of our study in March 2021. Crucially, although new hardware had been put in place, these meters were being used exactly as traditional meters were. No new features had been activated and they were being read manually. This allowed us to design an experiment where smart meter features could be tested within a treatment group, while being able to access similar data from identical hardware in both treatment and control. As a consequence, we can identify the benefits of using smart features to change utility operations, without conflating these effects with the mechanical impact of replacing old meters with newer ones.[5]

3. Experiment Design

We use a cluster randomized control trial design to study the impact of the smart metering scheme from the perspective of both the distribution company (discom) and its customers. On the side of the discom, we ask: did the new scheme led to positive returns on investment in the form of greater revenue and reduced losses? On the side of the customers, we ask: what was the benefit of real time monitoring and the satisfaction level for those consumers who received it?

Our experiment covered 23,541 urban consumers located in 125 binders in Karnal district in Haryana. A *binder* is an administrative grouping of consumers who live in the same neighbourhood that is used by the utility to organize billing and metering activities. For instance, consumers in a binder share a common billing cycle. We study the impact of two treatments, implemented in sequence and cross-randomized.

i. Remote Billing:

The first treatment involves a switch from manually reading meters to obtaining consumption data remotely, using the two-way data transfer capabilities of smart meters. This change did not influence the billing cycle or payment deadlines, only the data used to generate bills.

The switch to online billing was implemented as follows: In 25 binders (covering about 4,369 consumers), the utility introduced a universal shift to online billing. In 75 binders (13,912 consumers), only 80 percent of consumers were moved to online billing. The control included 25 binders (5,260 consumers). The sample of 125 binders was assigned at random to one of these three conditions. Table 1 presents a balance table using administrative data for the online billing arm showing that consumers were well balanced on baseline administrative variables.

This design allows us to detect both impacts on treated consumers, and spill overs on untreated consumers whose neighbours had moved to remote billing.[6] Table 2, Columns 4 and 5 show the allocation for the first treatment, where all assignments are randomized across the 125 clusters and consumers within them. This treatment arm was maintained for 6 months (March-August 2021) after which all consumers were moved to online billing and the second treatment arm was initiated.

[5] Replacing old meters with new ones might change bills or consumption if the existing stock of meters is poorly maintained or malfunctioning. However, utilities do not need to invest in new monitoring technologies to achieve such benefits.

[6] These spill overs may occur for several reasons. For instance, field staff in the 80% saturation group have reduced workloads and fewer opportunities to strike side deals with consumers. Both these factors may change how they interact with the remaining households with whom they still interact.

Table 1: Balance of binder level administrative data by online billing treatment arms

	0% Group A	80% Treatment B	100% Group C	Difference A-B	A-C
Consumers	309.80	327.41	350.08	-17.61	-40.28
	(23.20)	(13.75)	(56.72)	(27.32)	(61.28)
Bill Amount	2253.72	2191.17	2814.95	62.55	-561.23*
	(164.12)	(96.73)	(213.34)	(192.47)	(269.10)
Collection	2532.73	2347.41	2809.65	185.32	-277.92
	(141.97)	(65.68)	(186.23)	(140.04)	(234.17)

Notes: All figures are in INR with values winsored at the 98th percentile and then averaged over 8 months (Jan-Aug 2020) as the randomization for the study was done in October 2020. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Cluster randomized control trial design with a remote billing treatment and a remote disconnection treatment implemented in sequence with the latter cross-randomized as shown.

(1)	(2)	(3)	(4)	(5)
	Remote Disconnection Consumers		Total	Clusters
Remote Billing	**50% Eligible**	**90% Eligible**		
Control (Manual Billing)	5	20	25	4369
80% Consumers Treated	15	60	75	13912
100% Consumers Treated	5	20	25	5260
Total	25	100	125	23541

Notes: Cluster randomized control trial design with a remote billing treatment and a remote disconnection treatment implemented in sequence with the latter cross-randomized as shown. Column 4 provides cluster counts for the three remote billing treatment arms listed column 1. Columns 2 and 3 show how the two treatment arms for the remote disconnection experiment are assigned.

ii. Automatic Disconnections:

The second treatment involved a change from the status-quo of essentially discretionary and in-person disconnections of non-paying consumers by local field staff, to a rule-based regime where consumers whose arrears crossed a specified cut-off were automatically disconnected using their smart meters. As with online billing this change breaks the interaction between local staff and households and reduces the costs of disconnections (and any subsequent reconnections). This treatment was implemented 6 months after the first, and cross-randomized as shown in Table 2. A total of 25 binders (about 4700 consumers) were assigned to a treatment where 50% of consumers were eligible for rule-based disconnections. The remaining 100 binders had 90% of consumers eligible for rule-based disconnections.

Rule-based disconnections were introduced through an internal notification to utility staff. Specifically in the context of our evaluation, utility leadership approved the procedure described below to be applied only to treatment consumers:

1. Identify domestic consumers with positive arrears and also assigned to treatment
2. Drop consumers whose arrears were below INR 1000.
3. Drop consumers whose arrears were above the cut-off only for one month
4. Randomly sample 10% of remaining eligible consumers and assign them to be remotely disconnected.

We collected data from two main sources to track outcome variables. First, administrative data, including monthly billings and payments data, give us a complete picture of the implementation smart metering scheme and its consequences on billings, payments, and consumption. Second, two follow-up telephone surveys following the first and second treatments, with 1801 and 1567 respondents respectively.

4. Results

a Online Billing

We begin our analysis by examining the effect of online billing (the first phase of the experiment) on billing, consumption, and collections. Figure 3 shows average values of these variables for consumers in different types of binders. Most of the variation in collections and consumption during the year comes from seasonal variations in consumption, with a peak in the summer months. The impact of introducing smart meters is small. To quantify effects more formally we run the following model:

$$log(y_{it}) = \alpha_1 \text{Treat80}_i + \alpha_2 \text{Treat100}_i + \gamma \text{Post}_t + \beta_1 \text{Treat80}_i \times \text{Post}_t + \beta_2 \text{Treat100}_i \times \text{Post}_t + \lambda_i + \vartheta_t + \varepsilon_{it}$$

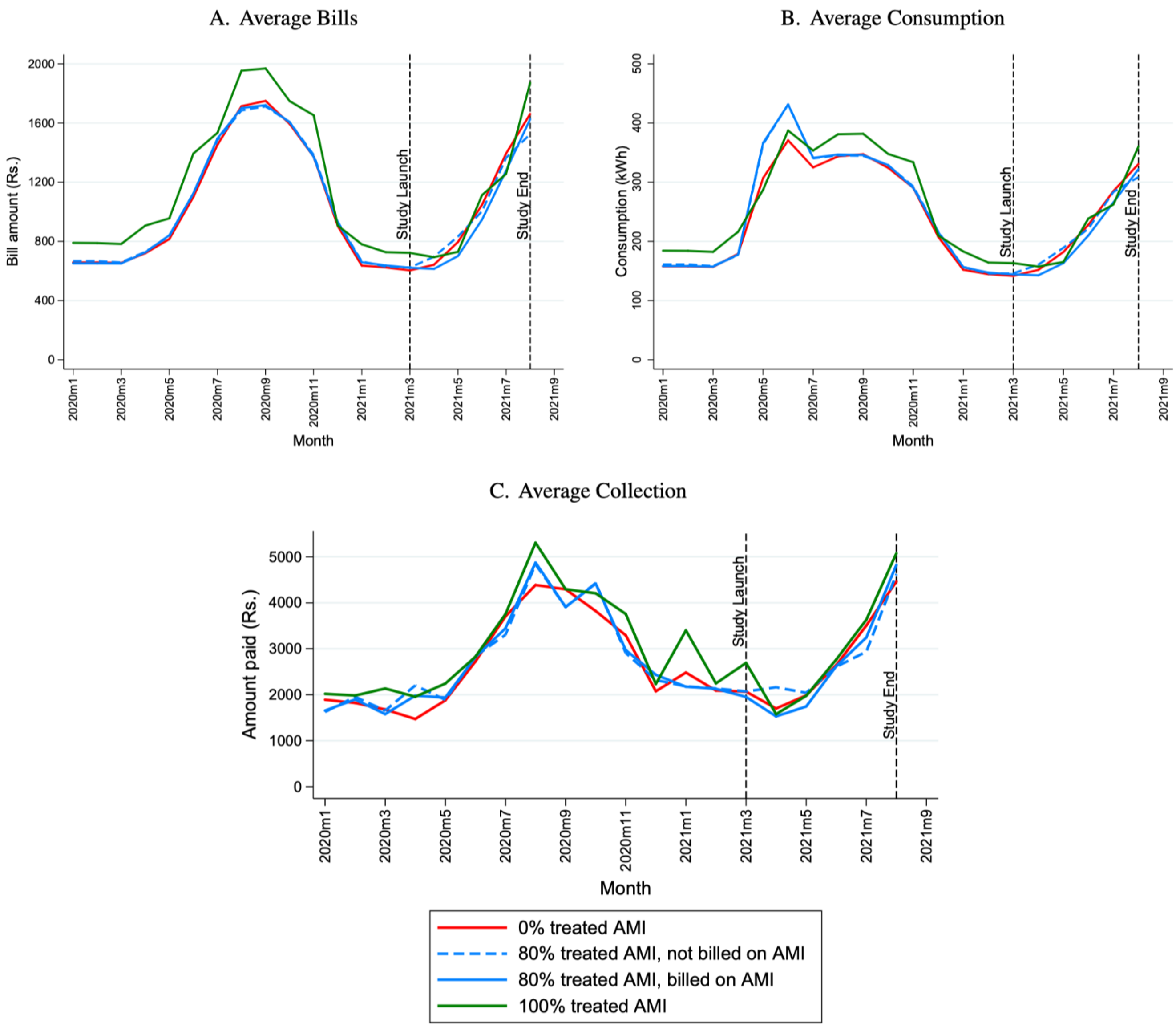
Here y_{it} is the bill amount, consumption and payments collected by binder i in month t. Treat80_i and Treat100_i are indicators taking the value 1 if binder i is assigned to 80% treatment group and 100% treatment group respectively. Post_t takes the value 1 for months following the initiation of study i.e. March 2021 to August 2021. The co-efficients of interest here are β_1 and β_2 whose estimates can be interpreted as a percentage change in the outcome. λ_i are binder fixed effects. θ_t are a set of month fixed effects.

Table 3 shows the results of estimating this model with billed amounts, consumption, and collections as outcome variables. The different columns present different econometric specifications that have no additional controls (cols 1,4,7), month-year fixed effects controlling for time variations affected all binders (2,5,8), and a pair of fixed effects controlling for monthly disturbances while also adjusting for baseline levels of outcome variables for each binder (cols 3,6,9). This last is our preferred specification.

We find evidence that all three of these variables decreased slightly in binders where all or most consumers switched to online billing. Billed amounts fall by about 6 and 8.5 percent respectively for binders with 80% or 100% online billing. Consistent with this, measured consumption also reduces by similar amounts. Finally, collections fall by about 4.8% and 2.9% respectively, although these estimates are noisier.

The direction in which collection rates move after the transition to online billing is not what a utility hoping to increase revenues might have wished. However, these results are not inconsistent with improved billing accuracy since manual measurements might be biased either downwards or upwards. Although the difference is not large, to the extent that more accurate technology changes outcomes in our setting, it does so by lowering bills and correspondingly collections.

Figure 3: Average bills, consumption and collection over time (two month moving average)



b Consumer Response to Smart Meters

The rollout of smart meter-based billing, both in India and in developed countries, has often been accompanied by consumer protests. This pushback has not necessarily been grounded in real failures of these meters but is nevertheless extremely important to determining whether utilities use this new technology.

In California for instance, the rollout of wireless smart meters by the utility Pacific Gas & Electric was followed by widespread protests and political opposition, on the grounds that this technology violated privacy and pose a health threat (Barringer 2011). Closer home, the state of Bihar in India delayed a planned rollout of about 200,000 smart meters in 2018 due to consumer protests at the announcement. More recently, farmer unions in the state of Punjab in India have threatened widespread protests against a proposal to install pre-paid smart meters for all agricultural consumers.[7]

Although widespread protests were not observed in the context of the rollout of meters in Karnal, Haryana, there remain questions about how consumers feel about the new meters. In particular, we might be interested in knowing whether there are differences in how consumers react to bills generated through automatic online measurements.

To answer this question, we ran a phone survey of consumers between August 22, 2021 and September 15, 2021. Of 1801 completed surveys, 577 belonged to the control group of the experiment, and 1224 to the treatment whose bills had recently been generated using the remote data transmitted by smart meters.

We focus here on three main findings from this survey. First, we find evidence that consumers do notice how their bill was generated. Slightly over 50% of control group consumers reported that a utility official took their meter reading with the corresponding number for the treatment group at 30%. Note that meter readers do not have to physically interact with the consumers to read meters since they are almost exclusively located outside the house. Therefore, this response is probably best interpreted as being an indication of consumer perceptions.

Second, consumers in both treatment and control group slightly *prefer* meter readings when conducted by a human being. About 47% of respondents said they preferred human readings and about 37% indicated they prefer that a computer generate bills, with the remainder being indifferent. These numbers do not vary by treatment status. Over 80% of those preferring manual readings reported that they did so because they could see the reading had been taken and that the resulting bill would therefore be more reliable.

Third, about 35% of consumers claimed their most recent bill was 'too high'. This number did not vary between treatment and control. Nevertheless about 70% of those making this statement blamed new meters for these perceived errors, once again with an almost identical share across treatment and control.

These responses suggest that many consumers do not trust their bills, with a bias towards believing they are too high. The blame for these perceived errors seems likely to be placed on new technology even when it has not actually been used in operationally different ways. Indeed, as a statistical matter, bills may even have reduced slightly after the shift away from manual billing (Table 3).

C Remote Disconnections

An important benefit of smart meters is that they allow distribution utilities to carry out more efficient and lower- cost enforcement. Specifically, these meters allow consumers to be remotely disconnected based on objective criteria. For example, a utility might specify that all consumers with arrears that exceed a threshold would be disconnected automatically and reconnected only after new payments are registered.

Although rule-based disconnections can in theory be carried out without smart meters, they require staff to physically visit consumers and disconnect the electricity line. This is time consuming and difficult to scale to many defaulters given a fixed number of staff. In-person enforcement action may also lead to conflicts between consumers and utility field staff, including the possibility of physical violence. Lastly, in-person disconnections also introduce opportunities for field staff to strike side deals with consumers in exchange for not disconnecting them.

[7] As reported in the Tribune newspaper, March 2027. URL: https://www.tribuneindia.com/news/punjab/farm- unions-threaten-statewide-stir-over-prepaid-smart-meters-381313

Phase two of this experiment involved the introduction of an objective criteria to identify consumers who would be automatically disconnected by the utility. The leadership of the electricity utility issued an internal notification to staff to implement remote disconnections based on a cut-off level of arrears, as described earlier. The treatment assignment here is at the consumer level. As shown in Table 2, in 25 clusters 50% of the population was assigned to the treatment. In the remaining 100 clusters 90% of the population was assigned to the treatment.

Unfortunately, even though this regime was developed with the utility and cleared by senior management, we found that staff were unwilling to implement it. Field officials disconnected only 17 percent of consumers identified by this rule in the treatment group. Importantly this was not because of an unwillingness to disconnect any consumers at all. Control group households - where the experiment required disconnections to be avoided - also saw enforcement action by the utilities. We found no statistical difference in the probability that a household with high arrears would be disconnected when comparing the treatment to control. Since there was no compliance with the stated policy, the experiment was unable to identify the impacts of the proposed regime. In informal conversations with utility staff, the research team was told that following a rule-based protocol was not possible because disconnection requests arrive from multiple directives and officials and that local sub-divisions must consider various factors that 'cannot always be put on paper'. These objections were also raised by field staff to the utility management and after attempting to enforce the rule-based regime for two months, the order was withdrawn.

This failure to implement phase two of the experiment provides some lessons in thinking about the returns to installing smart meters. In the Haryana setting we found that utility field officials were both unwilling to give up discretion in their enforcement choices and unwilling to take consistent action against households with high arrears. Eventually their preferences prevailed to overturn the attempted policy change. These operational decisions suggest that the technology used to meter is not always the primary constraint in effective enforcement. Replacing old meters with new and expensive smart meters involves an upfront capital cost that cannot be recovered if smart metering features are not used and if operational practices do not change.

A back of the envelope cost benefit calculation helps make this point more clearly. In Haryana, electricity utilities had contracted with vendors to pay INR 103 per month per consumer over an eight-year period towards the capital costs of meters. The utility estimated that replacing in-person meter readings with online billing reduces costs by only INR 9.62 per month per consumer. For these meters to provide a positive return on investment it is critical that they also generate more revenue, either by improving the reliability of supply so that consumers may use more power, or through reduction in theft and non-payment.

Table 3 : Treatment effect on billings, payments and consumption

	Log Bill Amount			Log Consumption Units			Log Collections		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Treat80%	-0.0181			0.0119			-0.0195		
	(0.0641)			(0.0472)			(0.0540)		
Treat100%	0.145**			0.101*			0.110*		
	(0.0722)			(0.0538)			(0.0645)		
Post Scheme	0.0794**	0.396***	0.414***	-0.00940	0.0261	0.0416	-0.00167	0.138**	0.145***
	(0.0321)	(0.0602)	(0.0380)	(0.0303)	(0.0450)	(0.0297)	(0.0209)	(0.0536)	(0.0318)
Treat80% XPost	-0.0481	-0.0451	-0.0606*	-0.0723**	-0.0447	-0.0734***	-0.0251	-0.0535	-0.0485**
	(0.0332)	(0.0676)	(0.0310)	(0.0327)	(0.0523)	(0.0262)	(0.0247)	(0.0548)	(0.0211)
Treat100% XPost	-0.0617*	0.00575	-0.0850**	-0.0485	-0.00707	-0.0906***	-0.0243	0.0630	-0.0291
	(0.0355)	(0.0771)	(0.0357)	(0.0360)	(0.0597)	(0.0298)	(0.0278)	(0.0627)	(0.0222)
Months-Year FEs		Yes	Yes		Yes	Yes		Yes	Yes
Binder FEs			Yes			Yes			Yes
Mean of dep. var	6.858	6.858	6.858	5.416	5.416	5.416	7.824	7.824	7.824
No. of binders	125	125	125	125	125	125	125	125	125
No. of month-year	20	20	20	20	20	20	20	20	20
Observations	2050	2050	2050	2050	2050	2050	3872	3872	3872

Notes: Standard errors in parentheses, Clustered at binder level. All figures for Bill amount and Collections in INR and for consumption in KW. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

d Observable Determinants of Manual Disconnections

The decision by the utility not to follow an automated rule-based protocol did not mean that disconnections did not take place at all. Across both treatment and control, 847 households in the experiment sample were disconnected between December 2021 and May 2022. A disconnection in this context is not permanent, households could make a payment towards their dues and be reconnected by utility field staff.

To learn whether there are observable variables that predict which households were disconnected by field staff, we ran an additional survey on a sample of 2652 consumers. This included all 847 households recorded as having been disconnected in the last six months and 1847 additional consumers. The survey combined an initial set of phone calls followed by some attempted in-person follow-ups. Overall, we obtained a 59% response rate, resulting in a total of 1567 completed surveys of which 506 were households that were recorded as having been disconnected in the past. The survey was conducted between May 11, 2022 and June 5, 2022.

We draw attention to two main findings from this exercise. First, over 92% of the sample reported that when power was disconnected it was restored within two weeks with 78% of the sample reporting that the reconnection was completed when the bill was paid. Since the administrative data does not show arrears going to zero for households that are disconnected, it appears that reconnections occur even when only partial payments are made.

Second, we were unable to uncover observable characteristics that predict which households are disconnected. Table 4 compares responses of households that the utility recorded as having been disconnected vs not disconnected in the last 6 months. There are no statistically significant differences across a host of variables, with the sole exception that disconnected households were slightly less likely to have paid their latest bill before the due date. There was no significant difference in arrears - if anything, households who had been spared disconnections had slightly higher arrears at baseline than those that did face enforcement action.

5. Conclusion

India's largely state-run utilities have struggled to recover the costs of the electricity they provide from consumers. In both academic and policy discourse, these losses are increasingly seen as a major barrier to improving electricity access and reliability. Indeed, the Prime Minister of India, Narendra Modi, in a July 2022 speech accompanying the launch of a 38 billion dollar package for distribution sector reforms, focused specifically on this problem, while blaming India's 'freebie culture in politics'.[8]

Although the problem may be widely recognized by policymakers, it has proved remarkably challenging to solve. Smart meters have been held up as a possible answer, with India and other developing countries allocating billions of dollars to replacing old meters. Yet although this technology places new tools in the hands of electricity utilities, this does not by itself imply that their operations will improve. As the Prime Minister's terminology suggests, the reasons for India's inability to recover the costs of electricity from consumers are not merely a function of monitoring costs or misaligned incentives, but also of politics, social norms, and institutional priorities. In prior work in Burgess et al. (2020) we discuss the problem of non-payment of electricity as caused in part by a social norm, expressed both by consumers on the one hand, and politicians and government officials on the other.

The results of the randomized control trial that we describe here suggests that at least in the context of Haryana, smart

[8] PM Modi blames freebie culture for power sector's losses. Times of India. July 31, 2022.

meters may not have increased revenue recovery. The meters we study allowed for a suite of new features of which the distribution utility initially wanted to study online billing and remote disconnections. The first of these was successfully implemented but improving the accuracy of billing does not necessarily imply that bills will go up. In our setting the converse seems to have been true.

The second feature - disconnections - is more directly linked to better enforcement of payments, but we found that the distribution utility was unable or unwilling to use these options to introduce a rule-based disconnection regime. Overall Haryana's capital investments in new smart meters may be unlikely to lead to lower utility losses, at least in the short to medium term.

That said, the Haryana experiment described here represents only a limited use of smart meters. It is possible that adopting alternative payment regimes such as pre-paid contracts - which are enabled by these meters - may perform better. Some states in India, and other countries, are using meters in these ways. It would be valuable for future research to test both options such as pre-paid contracts, and to evaluate smart meters in a broader set of institutional contexts.

Table 4: Balance Tests for all consumers in the survey

	Not-Disconnected (1061)	Disconnected (506)	Difference
Panel A: Household Characteristics			
Home state is Haryana	0.95	0.96	0.0056
	[0.21]	[0.20]	(0.011)
Living in the area since childhood	0.72	0.71	-0.014
	[0.45]	[0.46]	(0.025)
Income source- Private job	0.37	0.33	-0.035
	[0.48]	[0.47]	(0.026)
Income source- Self Employed	0.30	0.31	0.0094
	[0.46]	[0.46]	(0.025)
Own the current house	0.89	0.91	0.013
	[0.31]	[0.29]	(0.016)
Annual income- Below Rs.2.5 lakhs	0.62	0.61	-0.0097
	[0.49]	[0.49]	(0.026)
Panel B: Relations in Govt. sector			
Knows someone in Govt. sector	0.24	0.28	0.039
	[0.43]	[0.45]	(0.024)
Knows someone in Dept. of power	0.085	0.091	0.0061
	[0.28]	[0.29]	(0.015)
Panel C: Bill payments			
Last time bill received (in months)	0.97	1.00	0.029
	[1.27]	[1.43]	(0.074)
Last bill paid before the due date	0.73	0.66	-0.066^{***}
	[0.45]	[0.47]	(0.025)
Amount owed to discom	12787.3	9358.6	-3428.8
	[31100.4]	[20724.3]	(3311.0)
Panel D: Power in the house			

Average hours of power supply	21.9	21.9	0.010
	[2.10]	[2.25]	(0.13)
Average power cuts in a week	15.4	14.3	-1.10*
	[10.8]	[10.7]	(0.60)

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

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