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You Get What You Pay For: Electricity Quality and Firm Dynamics

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Meera Mahadevan

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You Get What You Pay For: Electricity Quality and Firm Response

Meera Mahadevan*

May 15, 2025

Abstract

Electricity sectors in many developing countries are stuck in a vicious cycle of low prices, financial insolvency, and unreliable service. India's state-owned utilities are emblematic of this problem, costing the government billions in bailouts while delivering poor electricity reliability. This paper leverages a large-scale reform in India's power sector to show that raising electricity prices—while seemingly counterintuitive—can help propel the sector out of this cycle. Using state-level variation in the implementation of the reforms, I find that manufacturing firms in states where electricity reliability improved increased their consumption of grid electricity by 19%, despite a 3% rise in average prices. Firms also increased worker hours and output, highlighting that previously, unreliable electricity was a binding constraint on production. These results suggest that raising prices, when coupled with improved service quality, is a viable strategy for breaking the cycle of low investment and poor utility performance in the developing world.

Keywords: Electricity, Energy sector reform, Manufacturing firms, Public utilities, India
JEL Classification Codes: L94, Q48, O14, O13, O38, H54

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1 Introduction

In India, millions of consumers connected to the electrical grid face blackouts and brownouts primarily because state-owned utilities make large financial losses, and are forced to restrict electricity supply (Burlig, Jha, and Preonas, 2020). Some of the reasons for utility losses are the lower-than-market prices for most consumer groups, high bill non-payment, and theft or unmetered supply: Indeed, Burgess, Greenstone, Ryan, and Sudarshan (2020) discuss the presence of a vicious cycle, where low electricity prices and bill non-payment contribute to financial losses for utilities and unreliable electricity. Consumers, in turn, are not willing to pay for an irregular electricity supply,[1] and hours of supply are often a binding constraint on their consumption.

The state of electricity in India has proven to be a major obstacle to industry. A majority of surveyed Indian firms report electricity outages as one of the biggest obstacles to production (World Bank, 2014). Electricity outages damage firm productivity in the short run (Fisher-Vanden et al., 2015), and even modest improvements can boost productivity significantly (Allcott et al., 2016). Indeed, in the longer term, improvements in reliability could increase the productivity of firms by as much as 25% (Fried and Lagakos, 2020). This is in addition to the wide-ranging implications extensive-margin electricity access has for economic development more broadly (Dinkelman, 2011; Lipscomb, Mobarak, and Barham, 2013), and for industrial development (Kassem, 2021) and manufacturing (Meeks et al., 2021) in particular.

In order to break out of the low-electricity equilibrium, either utility revenue collection or electricity reliability has to change.[2] Studies examining the effect of outages on firms often rely on survey data, theoretical models, or temporary exogenous shocks that vary power availability, and focus on a relatively static state of the electricity sector. But, there is little empirical evidence on what factors may fix electricity reliability issues in the long run, and how permanent transitions or large-scale reforms to institutional frameworks may affect firm outcomes. Further, it is difficult to study the effects of price or revenue changes at scale because any experimental variation would be impossible.

In this paper, I leverage variation from electricity reforms in India aimed at improving production efficiency by unbundling vertically integrated utilities. From 1998 to 2003, the

[1] Potentially perpetuating low infrastructure investments (McRae, 2015).

[2] Chatterjee (2020) provides multiple examples of successful lobbying by farmers' groups and urban residents in several South Asian countries, including India, to keep electricity tariffs low. Once cheap electricity is seen as a right, any price increases are met with public opposition.

Indian government passed the Electricity Act reforms to unbundle generation, transmission, and distribution to enhance efficiency (Ministry of Law and Justice, 2003). In India, electricity is largely state-owned and provided.[3] States implemented these reforms differently: as a result, some states ended up with a single statewide distributor, while others had multiple distributors. This led to unintended effects on prices and reliability. This variation provides an at-scale natural experiment to examine how institutional structures affect electricity provision.[4] I study the differential impacts of single versus multiple distributors on prices and reliability, exploring how institutional factors can improve utility management and offer a path out of the low-electricity equilibrium.

Electricity has historically been underpriced (Burlig et al., 2020), leading utilities to regularly appeal for price hikes to cover their costs. Regulators, however, must balance equitable pricing and avoiding steep increases that would burden consumers, creating conflicting incentives. In states with a single distributor, revising prices upwards might be easier since regulators don't need to compare rates with another utility. A single entity allows for better accountability, improved bill collection, and more efficient cross-subsidies, which can enhance electricity reliability (Pargal and Banerjee, 2014). Conversely, states with multiple utilities might benefit from competition, which could drive better service quality and revenue collection. Therefore, it remains theoretically ambiguous which setup performs better.

I use an event study design to estimate the causal effects of each type of reform on firm outcomes. I simultaneously estimate the effects of the different types of unbundling, comparing outcomes in states that received a specific type of unbundling to states that would receive it in the future or never receive it at all. In doing so, I can simultaneously discern the dynamics in outcomes as a result of each type of institutional structure. Using an event study allows there to be level differences across these states, but requires parallel trends in the absence of reforms. Since each state chose its own configuration, my event study design helps isolate the Average Treatment Effect on the Treated (ATT), rather than an Average Treatment Effect (ATE), as a different assignment rule may produce different estimates.[5]

I investigate outcome dynamics in two stages. First, I assess how each reform-institution structure affects electricity supply quality, retail electricity prices for firms, and electricity

[3] As is the case in several countries across South Asia, Central Asia, and Latin America.

[4] Other provisions of the reform were largely uniformly implemented across states (Pargal and Banerjee, 2014).

[5] I follow recent work on staggered-entry difference-in-differences designs (Goodman-Bacon, 2018; Callaway and Sant'Anna, 2020; Sun and Abraham, 2020; de Chaisemartin and D'Haultfuille, 2020) and adapt the proposed solutions outlined by Callaway and Sant'Anna (2020) and Sun and Abraham (2020) to produce difference-in-differences estimates.

consumption. Second, I analyze firms' responses to changing prices and reliability. The staggered implementation of reforms over six years allows me to isolate the effects from other coincident changes. I test for differential pre-trends to address potential challenges to identification, assuming that in the absence of the reforms, trends across states with different configurations would have been similar. Using data from the Annual Survey of Industries (ASI) from 1998 to 2012, I examine how reforms impacted electricity prices, consumption, output, and production days.

I find that in states with one unified distribution network, there was greater reliability in electricity supply (9% higher than comparison states), while there is no evidence of positive impacts on reliability under other institutional structures. Interestingly, firms responded to the greater electricity reliability with higher consumption of grid-generated electricity (almost 19% higher), despite the higher per-unit prices (3% higher), suggesting that firms may be willing to pay more for better electricity quality. Consequently, these firms benefited in terms of increased worker hours (due to factories staying open longer in the presence of better electricity reliability) and added value of final output, which increased by almost 17% in these states.

It may sound counter-intuitive that less competition from just a single distributor is good for consumers. Yet, with a single distribution entity for the state, there is likely greater accountability, and therefore better bill-collection rates and more efficiently designed cross-subsidies in tariffs (Pargal and Banerjee, 2014), leading to better electricity reliability, in contrast with the difficulties of coordinating tariff increases or designing jurisdiction-spanning cross-subsidies in states with multiple non-competing utilities (Foster and Rana, 2020).[6] While the reforms led to a reduction in power outages overall (Malik et al., 2011), this paper shows that these reductions were driven by certain regions, and this result is crucial in determining how future policy should be designed if we are to break out of the vicious cycle in Indian electricity. Such unexpected results demonstrate the unintended effects of reform interpretation and implementation (Sen and Jamasb, 2012), and highlight the importance of understanding these varied implications when designing policies.

It is difficult to unequivocally establish why some states chose one reform implementation strategy over another. Reassuringly for identification, states that chose certain types of reforms are similar in characteristics, and, the event study results indicate that for the primary variables, such as average electricity price and electricity consumption, parallel pre-

[6]Qualitative evidence from India's Annual Revenue Reports for multiple states 2003-2011 suggest that cross-subsidies in tariffs (charging industrial users more and residential users less) were made more efficient in states with single utilities, and they also do better on bill collection rates.

trends may also be established.

Most broadly, this paper contributes to the growing literature on the importance of energy, and specifically electricity supply, in developing countries. Prior work has focused more on electrification itself, and its effects (Lipscomb et al., 2013; Dinkelman, 2011; Greenstone and Jack, 2015; Burlig and Preonas, 2017), more than reliability. I find that increases in power supply reliability enable firm growth.

Second,this paper also contributes to the literature on the political economy of electricity prices. Electricity is a key voter issue (Chhibber et al., 2004), creating pressure to keep prices low (Chatterjee, 2018), which complicates efforts to raise prices. State electricity utilities in India widely under-price their electricity to subsidize select groups (Burgess et al., 2020; Burlig et al., 2020) or engage in corrupt practices with the same end (Mahadevan, 2024). Such subsidies sometimes lead to perverse incentives and reduce infrastructure investment and electricity reliability (McRae, 2015). While raising electricity prices seems politically difficult due to the culture of "freebies" (Khemani, 2024), linking higher prices to better service quality can drive Pareto-efficient outcomes. The paper shows that addressing chronic underpricing and poor reliability can potentially imply a "free lunch" (Muralidharan, 2024). Without separating states by policy, the effects on manufacturing outcomes would appear minimal on net. However, revealed preferences from single-distributor states show that firms, in particular, prioritize reliability over cost, indicating that unreliable supply, not price, is the real constraint on production.

Finally, I contribute to a broader literature on the consequences of electricity reforms, by providing among the first studies in a developing-country context (Malik et al., 2011). In contrast to the previous literature studying electricity restructuring in the US, there is scope for increased prices and reliability in developing countries. I find that the reforms enabled utilities to charge higher prices, and as a result, were able to provide more reliability. In contrast, there is mixed evidence from the work on the effects of restructuring in the US. There may be gains in the efficiency of power generation from reforms (Fabrizio et al., 2007; Knittel, 2002; Davis and Wolfram, 2012; Cicala, 2015, Forthcoming), but because electricity access is universal, there are no clear benefits to higher prices, and indeed prices not falling were considered adverse outcomes (Apt, 2005; Mansur, 2007; Wolfram, 1999; Borenstein et al., 2002; Joskow and Kahn, 2002).

The rest of the paper is organized as follows: Section 2 discusses the institutional context in India, while Section 3 describes the datasets used in this study. Section 4 lays out the empirical strategy, followed by results in Section 5. Section 6 shows that the results remain

robust to different specification. Finally, Section 7 discusses the results, possible mechanisms and how to interpret them, and Section 8 concludes.

2 The Power Sector in India

The Indian power sector has long been plagued by inefficiencies, especially in the distribution segment, which has emerged as the critical bottleneck in the sector's performance. Historically, distribution companies (discoms) were characterized by massive financial losses. These losses, driven by poor cost recovery, technical inefficiencies, and theft, reached unsustainable levels, necessitating sector-wide reforms. By 2011, distribution companies and bundled utilities accounted for over 80% of the power sector's accumulated losses, which had more than doubled since 2003 to Rs. 1,146 billion ($25 billion) (Pargal and Banerjee, 2014).

The financial instability of discoms had far-reaching implications. They struggled to make investments in infrastructure or pay for power purchases, which in turn led to reduced electricity availability, underutilization of generation capacity, and, ultimately, the need for repeated government bailouts. For example, a bailout in 2012 included a restructuring plan amounting to Rs. 1.9 trillion ($18.7 billion), aimed at salvaging the financially insolvent discoms (Ministry of Power, Government of India, 2012). The tariff structure that was in place did not allow cost recovery for power plants and distributors, and therefore the electricity sector was highly subsidized to keep it operational (Tongia, 2003). These efforts acknowledge the importance of discom creditworthiness in determining the broader power sector's stability.

Recognizing the critical role of distribution companies in ensuring sector viability, the Electricity Act of 2003 mandated the unbundling of state electricity boards (SEBs). This reform allowed generation, transmission, and distribution companies to operate independently. However, the management of distribution companies remains paramount, as they are the consumer-facing entities responsible for delivering electricity, billing, and ensuring access and affordability.

The central challenge, and the focus of this paper, is to explore how the management of discoms can help states break free from the vicious cycle of low prices, poor reliability, and financial insolvency that has long plagued the sector. While it is difficult to directly measure the impact of management strategies on this cycle, the variation across Indian states in how they chose to unbundle their electricity sectors offers a valuable opportunity.

Some states created multiple distribution companies, while others opted for a single entity, providing a natural experiment to examine the effects of different management structures on service delivery, and consumer outcomes. By leveraging this variation, we aim to understand whether and how better management of discoms can pave the way for a more financially sustainable and reliable electricity supply across India.

3 Data and Variables

The goal of this paper is to examine the effects of variation in state discom management on firm outcomes. Electricity is a crucial input to industrial production, and they serve as a litmus test for how well the electricity sector is functioning. My main source of data on manufacturing firms is from the Annual Survey of Industries (ASI) for the years 1998-99 until 2011-12. This data spans the period covering the Electricity Acts, through the 2000s, which saw the enforcement of the 2003 Act.

To study the impact of the restructuring, one of the key variables I look at is the price paid by the firm for per unit of electricity. I calculate the price per unit by dividing the total purchase amount of electricity by the number of units consumed. When either one of these variables is missing, I use the reported rate per unit when it is available.[7] The calculated per-unit prices of electricity are consistent with average annual tariff prices for manufacturing firms reported by the World Bank. [8]

Table 1 presents summary statistics of the main variables I use for this paper. I use data on the number of days a firm is operational, number of worker days, output produced, and inputs to the firms, such as amount of electricity consumed. I compute worker days by summing across all the different employees across each firm.

I obtain information on the unbundling status of various states from their respective State Electricity Regulatory Commission (SERC) websites, and verify this data with Pargal and Banerjee (2014). The states are listed in Appendix Table A1. States chose to unbundle across different years, and also chose different configurations. Most relevant to the research question in this paper, some states chose to end up with a single statewide discom and some

[7] In certain cases, the quantity of electricity consumed is reported as 0, but the price of electricity is reported. In these cases, I report these observations as missing with respect to the price of electricity. I lose about 1% of observations through this step, because of the number of firms who reported consuming no electricity.

[8] Some variables, such as the quantity of electricity consumed, total worker days, value of output have outliers. I winsorize the data for these variables at the 1st and 99th percentile.

Table 1: Summary statistics for outcome variables of manufacturing firms (in a year)

Restricted Sample			
Variable	**Obs.**	**Weighted mean**	**SD**
No. of manufacturing days	436151	219.87	123.74
No. of non-manufacturing days	436151	8.38	38.32
Quantity of electricity consumed (KWh) (mill.)	399344	0.45	1.28
Price of electricy consumed (Rs. per KWh)	399344	4.85	1.36
Total number of worker days	415134	16080.13	32747.04
Value of finished goods (Rs.) (mill.)	294132	6.39	20.5

Note: Annual Survey of Industries (1998-2012). SD - standard deviation of variable. Obs. - number of observations. Time-horizon for outcome measures is one year (e.g., 219 manufacturing days per year). Monetary variables in current rupees (Rs.). Exchange rate approximately Rs. 66 per 1 USD, over the time period.

states chose multiple state discomes. Table 3 below presents various state-level characteristics across states that chose either configuration, and shows ex-ante balance, suggesting no obvious observable difference that may have driven the adoption of one reform over the other.

Finally, I use luminosity data from the Defense Meteorological Satellite Program's Operational Landscan System (DMSP-OLS). This data is constructed as an annual average of satellite images of the earth taken daily between 20:30 and 22:00 local time. The raw data is at a 30-second resolution, which implies that each pixel in the raw data is roughly one square kilometer. I average over pixels within sub-districts. The raw luminosity data for each pixel is reported as a six-bit integer ranging from 0 to 63. Following the literature (Henderson et al., 2012), I use the log of the light density per capita. Since the average within a district is never 0, the natural log is taken. In the absence of any data on the quality of electricity and blackouts, this data serves as a good measure of extensive electricity supply and reliability (Burlig and Preonas, 2017; Alam, 2015), and an intensive margin indicator of electricity consumption as well (Mahadevan, 2024; Mann et al., 2016).

4 Empirical Strategy: Event Study Design

Using an identification strategy similar to Cicala (2015); Malik et al. (2011); Markiewicz et al. (2004), I exploit the variation in timing and nature of the restructuring in various

Indian states in order to find their effect on electricity price, electricity reliability, and other manufacturing outcomes. I explore two forms of restructuring and identify the marginal effects of separating all three sectors and (I) setting up a single distribution company, and (II) setting up multiple distribution companies.

I estimate the net effect of two forms of unbundling on various outcome variables. I conduct an event study analysis in order to understand the effects on outcomes including the unit price of electricity, the amount of electricity consumed by a firm, days worked, and total output of the firm. I estimate the following specification for my event study.

$$Y_{fist} = \sum_{z=1}^{2} \left[\sum_{y=-9, y\neq 0}^{7} \delta_{zy} Unbundled_{zs} \mathbb{1}(t - T_s = y) \right] + SERC_{st} + \theta_s + \theta_t + \theta_i + \nu_{fist} \quad (1)$$

The outcome is Y_{fist} for firm f, industry i, state s, and year t. The variable $Unbundled_{zs}$ refers to the nature of restructuring in a particular state s. When $z = 1$, it is an indicator variable that takes the value 1 for states that separate generation from distribution and transmission, i.e. separate all three sectors, and end up with one state-wide distribution company. When $z = 2$, $Unbundled_{zs}$ is an indicator variable that takes the value 1 for states that set up multiple distribution companies. The omitted category includes the states that did not undergo any unbundling at all or states that did not completely unbundle all sectors.

So, for instance, the state of Maharashtra restructured in 2005 ($T_s = 2005$), and separated all three sectors (generation, transmission, and distribution), resulting in a single state-wide distribution company ($Unbundled_2 = 1$). Here, when I have a firm-level observation in year 2000 ($t = 2000$), the expression within the indicator function in Equation 1 is 1 when $t - T_s = -5$. Therefore, we would estimate the effects of unbundling in the year 2000, and state of Maharashtra through period$\delta_{2,-5}$. The EA 2003 also included the setup of an independent State Electricity Regulatory Commission (SERC). I include the indicator variable $SERC_{st}$, which takes a value of 1 for all years, including and after the year y in which a state s sets up the SERC, and 0 otherwise.

This regression specification also includes state, year, and industry fixed effects, as well as a linear time trend for each state. Given that my data is based on self-reported prices and outcomes by manufacturing firms, I use these fixed effects to control for year-specific, state-specific, and industry-specific differences. In my main specification, I exclude the year of unbundling, and so all outcomes should be interpreted as relative to that period. (Borusyak

and Jaravel, 2017) also suggest robustness checks that avoid under-identification issues; and so in alternative appendix exercises, I restrict the pre-period to be zero for all periods (See Appendix Section A.2). I cluster my standard errors at the state level.

Table 2: Explanation of indicator variables used in event study

Features	$Unbundled_1$	$Unbundled_2$
Generation, transmission and distribution separated, single discom	1	0
Generation, transmission and distribution separated, multiple discoms	0	1

Source: State Electricity Discom websites, Pargal and Banerjee (2014)

Table 3: Balance of characteristics across states with different reform configurations

Variable	(1) Type 1	(2) Type 2	(3) Difference (1) - (2)
GDP (Billions INR, constant prices 1999-2000)	813.588	922.014	108.426
	(992.042)	(449.691)	(0.767)
Population Density (persons per sq. km.)	329.000	1,276.400	947.400
	(296.781)	(2,843.134)	(0.436)
Literacy Rate	68.590	61.693	-6.897
	(5.430)	(9.652)	(0.134)
Number of Energy Consumers (Thousands)	4,467.278	6,173.716	1,706.438
	(6,290.055)	(4,233.849)	(0.525)
Electricity Generation (MW)	20,631.334	25,905.500	5,274.167
	(25,165.795)	(23,984.768)	(0.682)
Energy Sales (GWH)	13,029.979	16,474.400	3,444.420
	(19,012.201)	(10,622.303)	(0.646)
Observations	6	10	16

Notes: Type 1 states consist of states with generation, transmission, and distribution separated, and with a single distribution company. Type 2 states consist of states with generation, transmission, and distribution separated, and with multiple distribution companies. Data sources include Gross State Domestic Product (SDP) from the Reserve Bank of India; Literacy Rate data from Rayja Sabha Unstarred Question No. 5109 and Lok Sabha Starred Question No. 34; Population Density from the Office of the Registrar General and Census Commissioner, India; State-wise Electricity Generation data from various Lok Sabha Questions and Indiastat; and Energy Sales and Consumer data from Central Electricity Authority reports and Indiastat. Years of data vary by state as follows: GDP for 1999-00 (Orissa, Haryana, Karnataka) and 2001-02 (all other states), Population Density from the 2001 census, Literacy Rate from 1997 or 2001, Electricity Generation and Energy Sales from 1996-2003 depending on the state. Standard errors are in parentheses for columns (1) and (2), while p-values are in parentheses for column (3). $^*p < 0.1$; $^{**}p < 0.05$; and $^{***}p < 0.01$.

Table 3 provides the means of a few relevant variables across the two sets of states being examined in this paper. Economic, demographic and power related means across the two

kinds of states suggests that they are relatively similar before the reforms, and there is no obvious difference leading to their different reform configurations. The event study design further helps to understand the full set of dynamic changes and visually inspect the pre-trends, and by relying on changes that occurred in many different years, the variation is not driven by one single year that may have witnessed other aggregate shocks to the economy. I find that my results from this identification strategy on overall outages are consistent with those in Allcott et al. (2016); Malik et al. (2011), who use different identification strategies. Despite showing balance in characteristics across states, since the configurations were not randomized across states, states may have yet chosen the type of unbundling that may have best suited their context. As such, we are estimating a treatment on the treated (ATT) rather than an average treatment effect (ATE). In this case of multiple treatments, we should interpret the ATT of a specific configuration as relative to the other states.

I follow the event-study design and discipline my analysis with recent work on staggered-entry difference-in-differences designs (Goodman-Bacon, 2018; Callaway and Sant'Anna, 2020; Sun and Abraham, 2020; de Chaisemartin and D'Haultfuille, 2020). These papers show that in many instances, a traditional two-way fixed effects model does not recover easily interpretable estimates of the Average Treatment Effect (ATE) or the Treatment on the Treated (ATT). This is especially relevant in my instance, since the effects of the policy may evolve over time (i.e., the treatment effects are "dynamic"), and there may be heterogeneity in responses across states. I follow the proposed solutions outlined by Callaway and Sant'Anna (2020) and Sun and Abraham (2020), as their frameworks adhere closely to my context.[9] [10]

Following these papers, instead of a traditional two-way fixed effects model (pooled Diff-in-Diff), the event study I estimate carefully considers the effective comparison units (for instance, not having as a control, the previously treated units). Given the differential timing of the treatments, this implies that certain units will have more pre-treatment periods, and certain others will have more post-treatment outcome measures.

In Appendix A.1, I explore further specification tests suggested by Callaway and Sant'Anna (2020) and Sant'Anna and Zhao (2020), which include their doubly-robust inverse probability tilting and weighted least squares specifications, and inverse probability weighted OLS

[9] Another set of solutions suggested by Cengiz et al. (2019) in their Online Appendix D uses "stacked-events" when studying changes to the minimum wage. In my context (unlike the minimum wage), a unit is treated only once, and the units are treated in relatively short spans of time.

[10] In Appendix A.1 I show robustness to the various definitions of the control group, different methodologies for estimating two-way fixed effects, as well as for different sub-samples of the data.

design with wild bootstrapped errors. I also vary the definition of the control groups, including (a) states that received a different reform, (b) a combination of states that either did not reform or adopted a different reform. My results are not sensitive to these definitions.

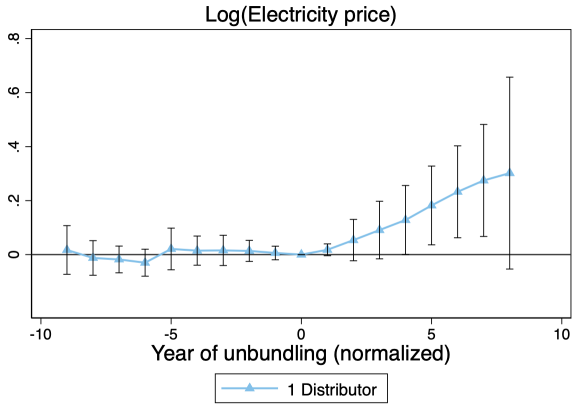
5 Results

In this section, I present the results of the event study analysis using Equation 1. While the effects on states in either type of reform are estimated simultaneously in a regression, I present the effects of each type of state on firm outcomes separately for visual clarity. On the left hand side, I show the event study for firms located in states that end up with a single discom, while on the right hand side, I present results for states that ended up with multiple discoms. The relevant comparison group here is states that did not adopt any reforms. I show in Appendix A.1 that the estimates remain robust to varying this comparison group. An important assumption for identification is the lack of pre-trends. The event study is helpful in providing visual clarification of this assumption for each of the outcomes separately.

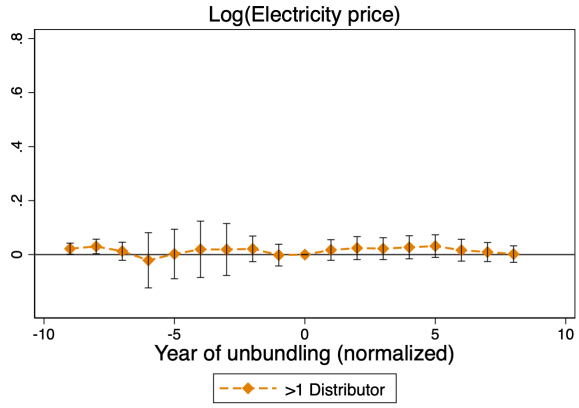
Figure 1 present the event studies for the three main outcomes examined in this paper: electricity price, electricity consumed and electricity reliability (as proxied by light density from satellites). The line representing complete separation, with one distribution company (coefficient of $Unbundled_1$: δ_{1y}) is presented in the left-hand side graphs. The total effect in the case of this kind of complete separation with one distribution firm on electricity price, electricity consumption and electricity reliability appears to be positive (Figures 1a, 1c, 1e). Given the lack of pre-trends, we may be able to causally infer that blackouts differentially fell in these states. The net effect of complete separation with multiple distribution companies on electricity prices and consumption appears to be near zero (coefficient of $Unbundled_2$: δ_{2y}). The effect on electricity reliability however, is negative, post reform adoption.

What is particularly striking is that states with a single discom exhibit significantly higher levels of electricity consumption, even though these states also face higher average electricity prices (Figure 1a). This could be explained by the tiered tariff structure, where firms consuming more electricity are pushed into higher pricing brackets, thereby raising the average cost per unit consumed. However, the increased consumption, despite the higher prices, suggests that previously, electricity unreliability was a binding constraint on production. As reliability improved, firms were willing to consume more electricity even at a higher cost, highlighting the critical role that dependable power plays in enabling production growth.

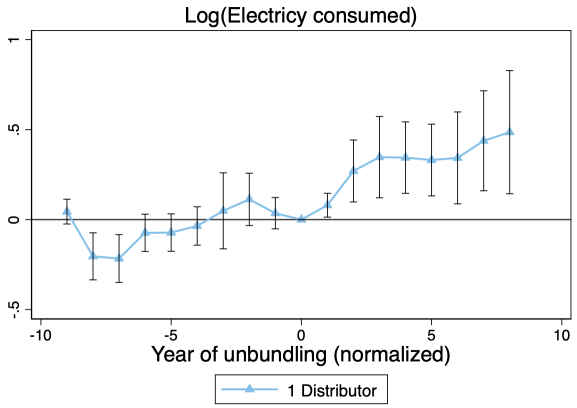
Figure 1: The effect of restructuring on electricity reliability and firm response



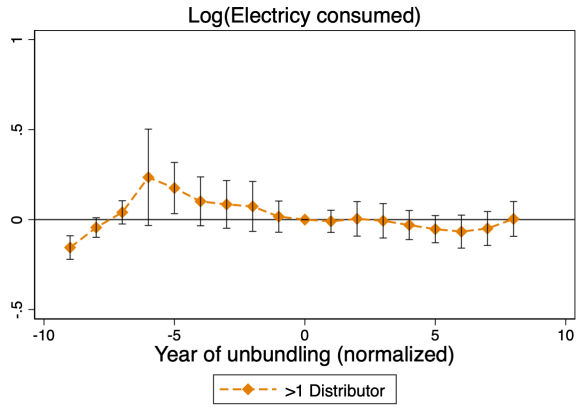
(a) Single distributor



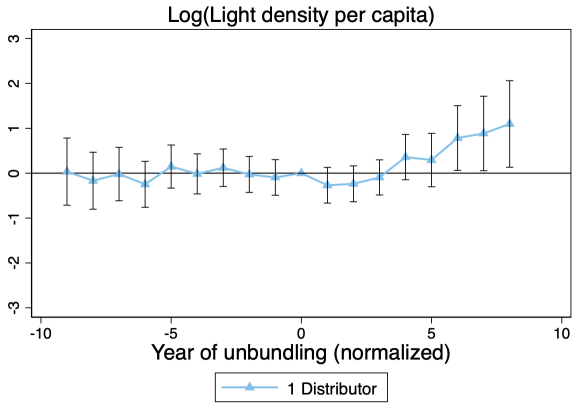
(b) Many distributors



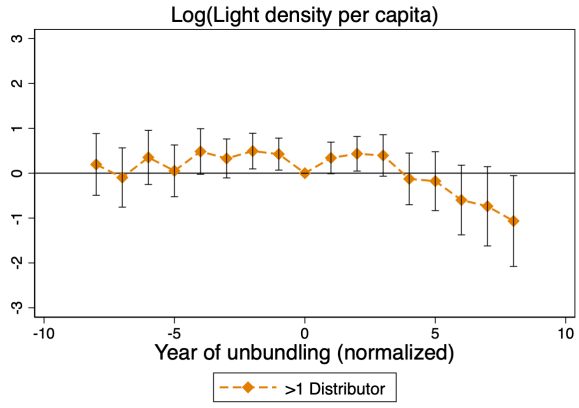
(c) Single distributor



(d) Many distributors



(e) Single distributor



(f) Many distributors

Note: The graphs plot coefficients from regressions following Equation 1. Figures 1a-1b show results from a regression run on 507,942 observations, while Figures 1c-1d shows the results from a regression with 507,224 firm-level observations. Standard errors clustered at the state level. Electricity price and consumption are sourced from the Annual Survey of Industries, while Electricity Reliability is sourced from the DMSP-OLS. For other specification tests, see Appendix A.1 and A.2.

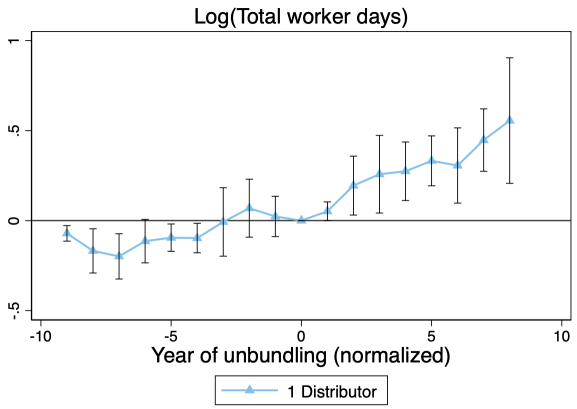
The figures show how the magnitudes evolve over time. Given the dynamic nature, and the fact that each state was treated at a different point of time, the ATTs differ by when each state was treated. Callaway and Sant'Anna (2020) describe the concept of a group-specific ATT, where each group is defined by the cohort when they received the reform. For instance, for our main reform of interest (unbundled with one distributor), and the large group (2005 cohort), the ATT(g) for Log(electricity price) as an outcome, ranges from 0.02 and 0.034.[11] That is, on average, states that unbundled, but created just one distributor saw an increase in electricity prices of between 2 and 3.4%. Firms in these states are also observed as raising their electricity consumption, in contrast to states with multiple distributors, where we do not observe any change in consumption.

It may seem theoretically ambiguous why such a strong effect may only be observed in states that completely unbundled all three sectors, but formed only a single distribution company rather than more. One possible reason is that there was a differential improvement in the quality of the electricity supply (reduced blackouts) in states that passed this specific legislation. This could plausibly result in firms purchasing more electricity if it is more reliable than before. This may further lead to re-optimization of other inputs within the firm in such states. Given that a high proportion of firms state that electricity blackouts are a major constraint to their production, an improvement in the quality of electricity supply may well lead to such behavior. In Figures 1e and 1f, we see this expectation bear out, where there is a marked improvement in electricity reliability in single-discom states, providing an plausible explanation for why we observe an increase in electricity consumption despite price increases.

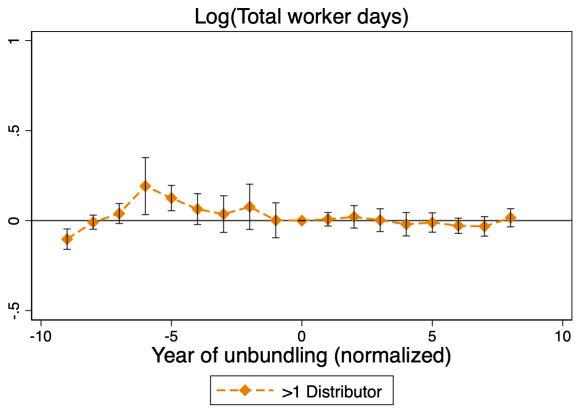
The results in Figure 2 further support the idea that firms, for whom the quality of electricity is a major factor, increase their electricity consumption , and re-optimize production. These figures show that the total days worked by firm employees rose post-reforms in states with single discoms. Interestingly, the number of non-manufacturing days (when factories are forced to shut operations) fall in the presence of more reliable electricity. This may be interpreted as evidence that these manufacturing firms also increase their labor input, which complements their increased electricity purchases. This is consistent with the observation that blackouts were a major constraint to their production, since they may have had to shut down production on days when there was no power. However, the variable for non-manufacturing days remains noisy, and so it is important to remain cautious against overinterpreting the result. Finally, as a consequence of increasing electricity consumption and labor, the value of the total output produced by the firm, rises.

[11] The range is because there are two different estimators described in Sant'Anna and Zhao (2020).

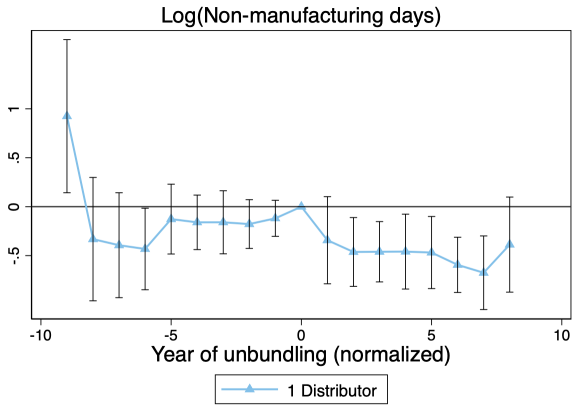
Figure 2: The effect of restructuring on electricity reliability and firm response



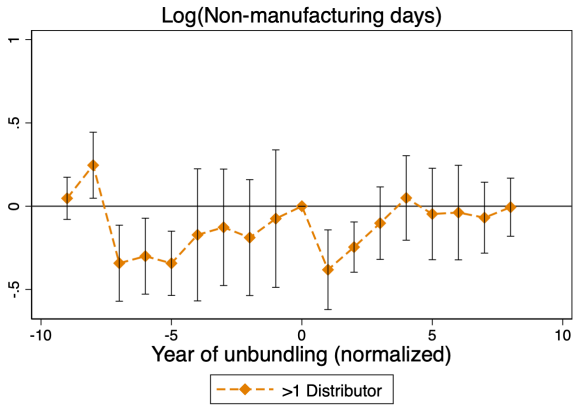
(a) Single distributor



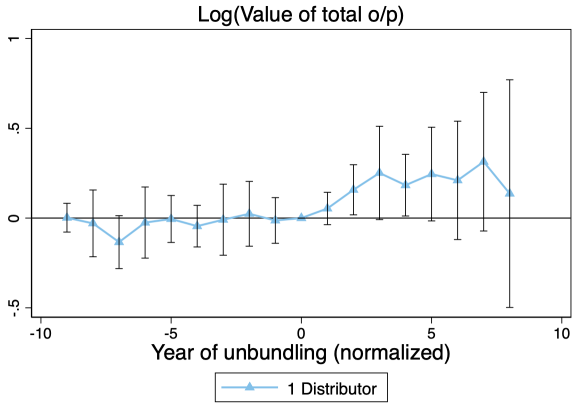
(b) Many distributors



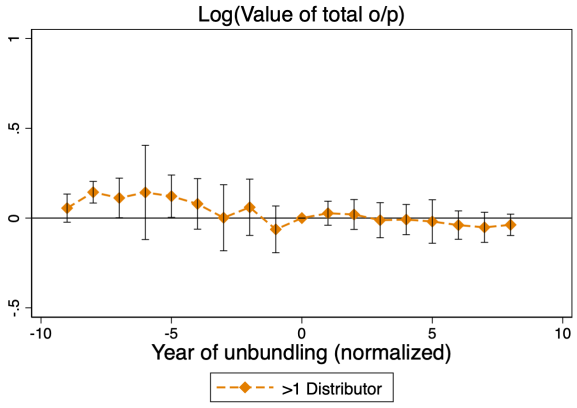
(c) Single distributor



(d) Many distributors



(e) Single distributor



(f) Many distributors

Note: The graphs plot coefficients from regressions following Equation 1. Figures 2a-2b and Figures 2e-2f show results from regressions run on 506,734 observations, while Figures 2c-2d show the results from regressions with 80,750 firm level observations. Outcome variables are sourced from the Annual Survey of Industries. Standard errors clustered at the state level. For other specification tests, see Appendix A.1 and A.2.

In states with multiple discoms, however, the reforms do not appear to have similar effects, or any effects. The variable non-manufacturing days is reported for only a subset of firms and is consequently once again noisy, so one cannot over-interpret the results for this variable, but total worker days (Figure 2a) and value of total output (Figure 2e) remain convincingly unchanged.

Table 4 presents the two-way fixed effect estimates for each of the above outcomes, and this provides a better sense of the magnitudes. The relevant control group here is all other states in the country that did not adopt a particular reform configuration. E.g. when computing the effect of being in a state with a single distributor, the estimates presented are relative to states with other types of unbundling, as well as states that did not unbundle, or have have not unbundled yet. Following Callaway and Sant'Anna (2020), the table presents the pre-treatment and post-treatment means for each variable (relative to the comparison groups), and the difference provides us with the causal effect of the reform. The result is consistent with what we observe from the event studies for the states that chose to end up with a single distributor. To understand the magnitudes better, this analysis focuses on the manufacturing firms that are electriocity intensive, as reported in Table A2. The estimates suggest that prices rose by as much as 50% with corresponding large increases in consumption, fall in non-manufacturing days, and a rise in value of total output and electricity reliability. The change is electricity reliability however is not statistically significant in this case, but its sign is consistent with the event study results.

Contrary to the all-firm event studies, the estimates in Table 4 in fact suggest that prices for electricity-intensive manufacturing may have fallen in states with multiple distributors, but non-manufacturing days rose. Despite this, there is a modest increase in the value of total output, but it is almost a third of the magnitude observed in states with a single distributor. Once again, while not statistically precise, the direction of the effect on electricity reliability is negative.

Combining all results, the takeaway remains consistent across estimation strategies, with both methods suggesting significant firm benefits from raised electricity prices stemming in states with a single distributor.

Table 4: Firm outcomes in states that unbundled their electricity sector in different ways – Callaway and Sant'Anna (2020) (IPW method) with a comparison group of all other states

	Log(Elec. price)	Log(Elec. cons.)	Log(Non-mfg days)	Log(Total o/p)	Elec. reliability
States which ended up with a single distributor					
Pre-treatment	-0.011	-0.071	-0.091	-0.049	-0.003
Post-treatment	0.017	0.116	-0.373	0.137	0.089
Difference	**0.028**	**0.187**	**-0.281**	**0.186**	**0.092**
P-value	0.00***	0.00***	0.00***	0.00***	0.84
States which ended up with multiple distributors					
Pre-treatment	0.018	-0.021	-0.149	-0.003	0.094
Post-treatment	-0.035	0.008	0.947	0.071	-0.259
Difference	**-0.053**	**0.030**	**1.096**	**0.074**	**-0.353**
P-value	0.00***	0.45	0.00***	0.08*	0.43

Notes: This table shows the mean values for all outcome pre-treatment (i.e. pre-restructuring) and post-treatment from 1998-2012. The first four columns are variables extracted from the Annual Survey of Industries while the last column is electricity reliability measured by satellite nighttime lights. The estimates use the Sant'Anna and Zhao (2020) doubly robust DiD estimator based on stabilized inverse probability weighting and OLS. The control group is any other state (i.e., those that received a different reform or those that received no reforms.) *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

6 Robustness

In Appendix A.1 and A.2 I discuss various specification tests suggested by Callaway and Sant'Anna (2020); Sant'Anna and Zhao (2020); Borusyak and Jaravel (2017) and Sun and Abraham (2020) to the event study designs. The results remain robust to different CSDID specifications. They are also robust to the subset of the data that would be most affected: I restrict the dataset to only those firms that are privately owned. This is because government-owned firms may get preferential rates, and would not accurately reflect the effect of these reforms. I also restrict the data to include firms from only electricity-intensive manufacturing industries (full list in table A2). The results are similar in direction and magnitude for this subset of the data as well.

7 Discussion and Mechanisms

The patterns observed in this paper show that higher prices, greater consumption of electricity, and higher reliability, differentially occur in states with a single distribution company. A question that follows is why they did not occur, for instance, in states with the same separation of the three sectors, but with multiple distribution companies. According to analyses by Pargal and Banerjee (2014), multiple utilities in a single state may result in better outcomes if benchmark competition exists, but in practice, because they serve different areas and different consumer bases, they do not compete. In fact, this may prevent them from effectively

cross-subsidizing across consumer groups if, for instance, one firm serves only agricultural users and another only industrial users. Difficulties associated with cross-jurisdictional coordination and cooperation across multiple utility management groups within a state have also been observed in other countries (Foster and Rana (2020) in the context of Peru).

Among the states that ended up having a single distributor, there are a number of unique features that may explain their differentially better performance. They are able to effectively cross-subsidize across consumer groups, adopting progressive tariffs with the highest prices for industrial users.[12] All but one of the states with a single utility set tariff rates at or above cost-recovery levels by 2011, while considerably fewer states with multiple utilities achieve that. To provide a more specific example, in Maharashtra (where there is one unified distribution company, Bhiwandi Power sector), bill collection efficiency increased from 58% in 2006/07 to 99% in 2010-11. In fact, the majority of states that ended up with a single distributor were among the top performers in terms of utility cost recovery (Deloitte, 2013). While states like Maharashtra (single distributor) reduced losses from distribution, the worst performing states were Uttar Pradesh and Orissa (with multiple distributors), where losses from distribution worsened over time after the reforms.

One of the biggest reasons why states with single utilities may have performed better is that they were able to coordinate a successful cross-subsidization schedule as they cover all consumers. Further, Pargal and Banerjee (2014) note that regulators impose higher accountability standards for single distributors as the onus of state-wide supply is on a single entity. Finally, it may be possible that in states with only one distribution company, a hike in electricity tariffs, at least to cover all costs, is administratively easier to pass and justify. With multiple distribution companies, with varying levels of overhead and, therefore costs, it may be harder to explain price tariff increases in one distribution area versus another. State regulators are also responsible for ensuring parity in prices across states, and therefore the worst-managed utilities may serve as the binding constraint on price hikes.

[12]These figures are drawn from metadata in Pargal and Banerjee (2014), combined with statistics from the Annual Revenue Requirement (ARR) reports of Maharashtra, Orissa, Uttar Pradesh, Bihar, West Bengal, Karnataka, Assam, Himachal Pradesh, Punjab and Andhra Pradesh from 2003-2011. These reports are submitted by utilities to the independent regulatory council.

8 Conclusion

The Indian experience with restructuring appears to have mixed results. This paper shows that the 2003 electricity reforms resulted in different state configurations for electricity provision. Surprisingly, whether a state ends up with a single distributor or multiple results in highly divergent patterns. States with single distributors increase reliability, manufacturing firms pay more and consume more electricity, and increase output. I show supporting evidence that single distributors face fewer coordination hurdles and are able to cross-subsidize or restructure their electricity tariffs in a more revenue-increasing manner. They successfully increase bill payments, and consequently, electricity reliability, as they face greater accountability from regulators who have only one utility to manage.

States with multiple distributors, however, are amongst the worst performers across the country. The losses these utilities face create a vicious cycle of poor-performing utilities and unreliable supply. The central government in India has a fund called UDAY to systematically bail these utilities out, perpetuating this loss-making cycle and reducing accountability (Chatterjee, 2017). Apart from the opportunity cost of taxpayer funds being channeled towards utility bailouts, low revenues reduce investment in generation and transmission (Kumi, 2017, examines the case of Ghana). Other evidence from Colombia shows how government subsidies can perpetuate a cycle of low investment in electricity (McRae, 2015).

This paper is among the first to show evidence in the Indian case of how institutions and politics matter for effective electricity supply, and when they allow for better tariff-redesign, electricity reliability improves in a way that increases firms' willingness-to-pay for electricity. The latter is crucial if the country is to break out of the low-quality, low-revenues equilibrium it is in. Making the link between greater reliability and paying higher bills more salient is crucial in increasing consumer willingness-to-pay for electricity. Power debt in India amounts to almost 2.4% of national GDP (Engelmeier, 2015). Unbilled electricity and non-payment of bills that perpetuate this debt are problems with solutions. It is important to consider the institutional and political contexts of energy policy more broadly in order to fix them.

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A Appendix

Table A1: Different styles of restructuring in various states

States			
Type 1 Treatment 1	**Type 2 Treatment 2**	**Control Group Incomplete Unbundling**	**Control Group No Unbundling**
Maharashtra	Andhra Pradesh	Tamil Nadu	Goa
Meghalaya	Delhi	Punjab	Jammu and Kashmir
Uttaranchal	Gujarat	Himachal Pradesh	Jharkhand
Assam	Haryana		Kerala
West Bengal	Karnataka		Manipur
Chhattisgarh	Madhya Pradesh		Nagaland
	Orissa		Sikkim
	Rajasthan		Tripura
	Uttar Pradesh		
	Bihar		

Type 1 Generation, transmission and distribution separated, single distribution company
Type 2 Generation, transmission and distribution separated, multiple distribution companies
Control Group: incomplete States that unbundled incompletely during the study period
Control Group: No Unbundling States that did not restructure during the study period
Source: Various state discom websites and Pargal and Banerjee (2014)

Table A2: Electricity-intensive manufacturing industries included in the ASI data

List of included manufacturing industries
Manufacture Of Food Products And Beverages
Manufacture Of Textiles
Manufacture Of Wood And Of Products Of Wood And Cork,Except Furniture
Manufacture Of Articles Of Straw And Plating Materials
Manufacture Of Paper And Paper Products
Manufacture Of Coke, Refined Petroleum Products And Nuclear Fuel
Manufacture Of Chemicals And Chemical Products
Manufacture Of Other Non-Metallic Mineral Products
Manufacture Of Basic Metals
Manufacture Of Fabricated Metal Products, Except Machinery And Equipments
Manufacture Of Machinery And Equipment
Manufacture Of Electrical Machinery And Apparatus
Manufacture Of Other Transport Equipment
Manufacture Of Furniture
Manufacture Of Office, Accounting And Computing Machinery
Manufacture Of Radio, Television And Communication Equipment And Apparatus
Manufacture Of Medical, Precision And Optical Instruments, Watches And Clocks
Manufacture Of Motor Vehicles, Trailers And Semi-Trailers

A.1 Robustness to Event-Study Designs

Recent developments in the study of staggered-entry difference-in-differences designs suggest numerous specification tests (Goodman-Bacon, 2018; Callaway and Sant'Anna, 2020; Sun and Abraham, 2020; de Chaisemartin and D'Haultfuille, 2020). While my main estimates try to adhere to the recommendations, in this appendix I follow various other specification tests suggested by the authors. First, I test the various estimators proposed by Callaway and Sant'Anna (2020), and described in detail by Sant'Anna and Zhao (2020). In the following tables, Table A3 uses the Sant'Anna and Zhao (2020) doubly robust DiD estimator based on stabilized inverse probability weighting and OLS. Tables A4 and A5 use the Sant'Anna and Zhao (2020) doubly robust DiD estimator based on inverse probability tilting and weighted least squares. These estimators produce very similar results. The results also closely mirror the results from the event-study graphs.

Second, I test robustness to the control groups. The unique setting in my case suggests a few alternative tests. In the traditional Difference-in-Differences framework, there is one type of treatment, whereas here we have two different types of unbundling. This raises the question of what is the control group. While this is not a question of bias, it does change the interpretation of the estimated ATT and what 'treatment' necessarily implies in this case.

Table A3: Firm outcomes in states that unbundled their electricity sector in different ways – Callaway and Sant'Anna (2020) (IPW method) with a comparison group of all other states that restructured

	Log(Elec. price)	Log(Elec. cons.)	Log(Non-mfg days)	Log(Total o/p)	Elec. reliability
States which ended up with a single distributor					
Pre-treatment	-0.011	-0.066	-0.090	-0.046	-0.003
Post-treatment	0.024	0.106	-0.380	0.144	0.089
Difference	**0.034**	**0.172**	**-0.290**	**0.191**	**0.092**
P-value	0.00***	0.00***	0.00***	0.00***	0.84
States which ended up with multiple distributors					
Pre-treatment	0.022	-0.010	-0.143	0.007	0.094
Post-treatment	-0.022	0.032	0.975	0.111	-0.259
Difference	**-0.043**	**0.043**	**1.118**	**0.103**	**-0.353**
P-value	0.00***	0.28	0.00***	0.02**	0.43

Notes: This table shows the mean values for all outcome pre-treatment (i.e. pre-restructuring) and post-treatment from 1998-2012. The first four columns are variables extracted from the Annual Survey of Industries while the last column is electricity reliability measured by satellite nighttime lights. The estimates use the Sant'Anna and Zhao (2020) doubly robust DiD estimator based on stabilized inverse probability weighting and OLS. The control group is any other restructured state (i.e., those that received a different reform.) *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

In Tables 4 in the main paper, and A3, A4 and A5, I explore two different definitions of 'treatment.' In Tables 4 and A4, I use any other state (whether they received no treatment, or received a different type of unbundling) as the control group. In Tables A3 and A5, I use any other reform (type of unbundling) as a control group, and exclude the non-reform

states altogether. This may compare somewhat more similar states, but changes the interpretation of the ATT to be relative to other types of reform. Yet, the results are similar. In implementing the specific Callaway and Sant'Anna (2020) specifications, I follow their recommendations and wild-bootstrap the errors.

Table A4: Firm outcomes in states that unbundled their electricity sector in different ways – Sant'Anna and Zhao (2020) (Improved doubly-robust method) with a comparison group of all other states

	Log(Elec. price)	Log(Elec. cons.)	Log(Non-mfg days)	Log(Total o/p)	Elec. reliability
States which ended up with a single distributor					
Pre-treatment	-0.011	-0.073	-0.093	-0.050	-0.327
Post-treatment	0.017	0.120	-0.378	0.139	0.112
Difference	**0.028**	**0.192**	**-0.284**	**0.189**	**0.439**
P-value	0.00***	0.00***	0.00***	0.00***	0.68
States which ended up with multiple distributors					
Pre-treatment	0.018	-0.021	-0.150	-0.002	0.061
Post-treatment	-0.032	0.008	0.893	0.075	-0.354
Difference	**-0.050**	**0.029**	**1.043**	**0.077**	**-0.416**
P-value	0.00***	0.45	0.00***	0.07*	0.67

Notes: This table shows the mean values for all outcome pre-treatment (i.e. pre-restructuring) and post-treatment from 1998-2012. The first four columns are variables extracted from the Annual Survey of Industries while the last column is electricity reliability measured by satellite nighttime lights. The comparison group here is all other states in the country. The method used to estimate these Difference-in-difference treatment effects is Callaway and Sant'Anna (2020), specifically the improved doubly robust DiD estimator based on inverse probability of tilting and weighted least squares (Sant'Anna and Zhao, 2020). The standard errors are estimated using a multiplicative WildBootstrap procedure with 999 repetitions using mammen approach. Dataset restricted to privately-owned, electricity-intensive manufacturing firms. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table A5: Firm outcomes in states that unbundled their electricity sector in different ways – Sant'Anna and Zhao (2020) (Improved doubly-robust method) with a comparison group of all other states that restructured

	Log(Elec. price)	Log(Elec. cons.)	Log(Non-mfg days)	Log(Total o/p)	Elec. reliability
States which ended up with a single distributor					
Pre-treatment	-0.011	-0.067	-0.093	-0.048	-0.327
Post-treatment	0.023	0.111	-0.386	0.147	0.112
Difference	**0.034**	**0.178**	**-0.294**	**0.195**	**0.439**
P-value	0.00***	0.00***	0.00***	0.00***	0.68
States which ended up with multiple distributors					
Pre-treatment	0.022	-0.010	-0.143	0.009	0.061
Post-treatment	-0.017	0.034	0.915	0.120	-0.354
Difference	**-0.039**	**0.045**	**1.059**	**0.111**	**-0.416**
P-value	0.00***	0.25	0.00***	0.01***	0.67

Notes: This table shows the mean values for all outcome pre-treatment (i.e. pre-restructuring) and post-treatment from 1998-2012. The first four columns are variables extracted from the Annual Survey of Industries while the last column is electricity reliability measured by satellite nighttime lights. The comparison group here is all other states in the country that restructured their electricity sector but did not adopt the particular reform being evaluated. The method used to estimate these Difference-in-difference treatment effects is Callaway and Sant'Anna (2020), specifically the improved doubly robust DiD estimator based on inverse probability of tilting and weighted least squares (Sant'Anna and Zhao, 2020). The standard errors are estimated using a multiplicative WildBootstrap procedure with 999 repetitions using mammen approach. Dataset restricted to privately-owned, electricity-intensive manufacturing firms. *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

A.2 Under-Identification in Event Studies

I follow Borusyak and Jaravel (2017)'s suggestion to include robustness checks that avoid under-identification issues; and so in the following exercise, I restrict the pre-period to be zero for all periods. Imposing the condition that there are no pre-reform trends is a very strong restriction, given that I do not see clear evidence in the data that there are no pre-trends, particularly for the outcome variables other than electricity price. However, I use the results from this specification only to test whether the effect of a particular type of restructuring is jointly different from 0 for all the post-treatment years. I use the following specification for this model:

$$Y_{fist} = \gamma + \sum_{z=1}^{3}\left[\sum_{y=1}^{7}\delta_{zy} Unbundled_{zs}\mathbb{1}(t - T_s = y)\right] + SERC_{st} + \theta_s + \theta_t + \theta_i + \nu_{fist} \quad (2)$$

I show results using the above specification in the Appendix. I use these results only to check whether there is a significant aggregate effect of restructuring on the outcomes of interest. I find the trends confirm my main results.

Figure A1: The effect of restructuring on electricity purchase (intensive margin) - Model with 0 pre-trends

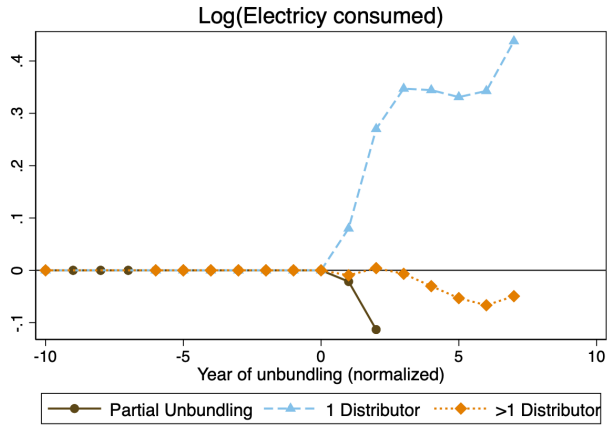
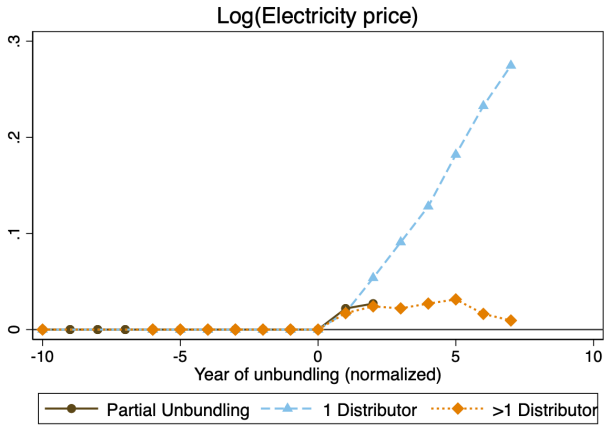


Figure A2: The effect of restructuring on electricity price - Model with 0 pre-trends



Note: The coefficients are reported from Equation 2