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Electricity Cost and Firm Performance: Evidence from India

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Abstract

Despite the widely acknowledged importance of infrastructure for economic growth, there has been relatively little research on how infrastructure affects the decisions of firms. Using data on Indian manufacturing firms, this paper provides evidence on how electricity prices affect a firm's industry choice and productivity growth. I construct an instrument for electricity price as the interaction between the price of coal paid by power utilities, which is arguably exogenous to firm characteristics, and the initial share of thermal generation in a state's total electricity generation capacity. I find that, in response to an exogenous increase in electricity price, firms reduce their electricity consumption and switch to industries with less electricity-intensive production processes. I also find that firm output, machine intensity and labor productivity decline with an increase in electricity price. In addition to these level effects, I show that firm output and productivity growth rates are negatively affected by high electricity prices. These results suggest that electricity constraints faced by firms may limit a country's growth by leading firms to operate in industries with fewer productivity-enhancing opportunities.

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1 Introduction

Infrastructure is widely perceived to be important for development. The World Bank's single largest business line is spending on infrastructure, which more than quadrupled from $5.2 billion in 2000 to $25.1 billion in 2011 (World Bank, 2012). While there is an active literature on the effects of infrastructure on various facets of economic development,[1] there has been relatively little research on how infrastructure affects the behavior of firms. Since firms are an important engine of growth in the economy and infrastructure is an essential input in firms' production processes, identifying how firms respond to infrastructure is crucial for understanding the micro-foundations of growth in developing economies.

This paper examines the responses of firms to electricity costs in India. Using panel data on manufacturing firms, I study how electricity costs influence firms' decisions on which industries to operate in and firm growth. In most developed countries, industrial users pay lower prices for electricity compared to other users because the cost of supplying electricity to industrial users is typically lower (IEA, 2012). However, in India, politicians' desire to curry favor with households and farmers who form crucial voting blocs, and to a lesser extent the social objective of making electricity affordable for the poor, have led to a system of cross-subsidization where agricultural and domestic users pay low prices for electricity at the expense of industrial users. For instance, in 2000, industrial users in India paid about 15 times the price paid by agricultural users for electricity (Government of India, 2002). In a 2006 World Bank survey, Indian manufacturing firms were asked to indicate which element posed the biggest constraint to their operations out of a list of 15 elements including electricity, access to finance, and corruption. Electricity was the most common major obstacle indicated, with more than 36 percent of firms listing electricity as their biggest constraint (World Bank, 2006).[2] Although the Indian government has

[1]Recent papers include Reinikka and Svensson (2002), Duflo and Pande (2007), Donaldson (2010), Dinkelman (2011), Banerjee, Duflo and Quian (2012), Fisher-Vanden, Mansur and Wang (2012), Rud (2012a), Rud (2012b) and Alby, Dethier and Straub (2013).

[2]In contrast, the proportion of firms listing the next most common major constraints, tax rates and corruption, were 16.8 and 10.8 percent, respectively. The complete list of constraints from which firms chose included access to finance, access to land, business licensing and permits, corruption, courts, crime, theft and disorder, customs and trade regulations, electricity, inadequately educated workforce,

undertaken steps to reduce the extent of cross-subsidization, industrial users still pay high prices for electricity relative to domestic and agricultural users, and to industrial users in other countries.[3]

The potential for other variables to move in tandem with electricity prices presents a challenge in establishing a causal link between electricity cost and firm outcomes. To address this challenge, I construct an instrumental variable (IV) for electricity price based on the characteristics of electricity provision in India. Much of the electricity generated in India comes from thermal power plants which use coal as the source of fuel. Thus the price of coal affects the cost of generating electricity and, hence, its price. I therefore use the price of coal paid by power utilities interacted with each Indian state's initial share of installed electricity generation capacity from coal-fired thermal power plants as an instrument for the electricity price faced by firms in that state. Using this instrument in an IV estimation, I find that firm behavior and performance respond to electricity prices. First, firms reduce their consumption of electricity and switch to less electricity-intensive industries in response to an increase in electricity price. Second, firm output, machine intensity and labor productivity fall with an increase in electricity price. Third, in addition to these level effects, I find that high electricity prices negatively affect the growth of firm output and productivity. These results taken together suggest that firms switch to less electricity-intensive industries as a means of coping with high electricity costs and that this has negative implications for firm growth.

Although there is a small development literature on the effects of electricity provision on firms, there has not yet been research on the potential effect of electricity constraints on firms' industry choices. Recent studies include Reinikka and Svensson (2002) who show that electricity shortages cause firms to reduce investment, and Fisher-Vanden, Mansur and Wang (2012) who show that firms reduce energy expenditures and increase material expenditures when there are electricity shortages, possibly as a result of the outsourcing

labor regulations, political instability, practices of the informal sector, tax administration, tax rates, and transportation.

[3]As of 2011, the average electricity price paid by industrial users in India was about 4 times the price paid by agricultural users (Government of India, 2011a).

of the production of intermediate goods. Electrification has also been shown to raise female employment potentially via an increase in micro-enterprises (Dinkelman, 2011). Two recent papers, Rud (2012a, 2012b), investigate the effects of electricity provision on firms in India. Rud (2012a) finds that an increase in rural electrification in Indian states starting in the mid 1960s led to an increase in aggregate manufacturing output in the affected states, while Rud (2012b) shows that more productive firms are able to adopt captive power generators to cope with unreliable electricity provision. Similarly, Alby, Dethier and Straub (2013) find that in developing countries with a high frequency of power outages, electricity-intensive sectors have a low proportion of small firms since only large firms are able to invest in generators to mitigate the effects of outages. In the context of developed countries, some recent papers have investigated the pricing of electricity for manufacturing firms. Davis et al. (2008) find that, within a given industry, U.S. manufacturing firms that pay higher electricity prices are more energy efficient, while Davis et al. (forthcoming) examine the factors that determine the pricing of electricity for U.S. manufacturing firms.[4]

The contribution of this paper to the existing literature is twofold. First, to my knowledge, this is the first paper that studies how access to electricity can affect the types of industries in which firms choose to operate. Understanding the impact of electricity on firms' industry and hence technology choices is important as this may have implications for firms' growth. Second, the existing firm-level studies in the development literature have largely focused on the provision of electricity without emphasis on how the price of electricity may play a crucial role in firms' decisions and performance. In contrast, I analyze the extent to which, even with the availability of electricity, its cost may cause firms to change their production patterns in favor of less electricity-reliant technologies, which may have consequences for firm productivity growth.

The findings of this paper also add to a recent strand of literature on the interac-

[4]There is also a large literature, mostly focused on developed countries, on the structure of electricity pricing. See, for example, Borenstein, Bushnell and Wolak (2002), Borenstein (2002, 2005), Borenstein and Holland (2005), Joskow and Tirole (2007), Puller (2007), and Joskow and Wolfram (2012). These papers are mainly concerned with the determination of prices in the electricity market while my paper's main focus is on how electricity prices affect firms rather than on how these prices are determined.

tions among firm-level distortions, resource misallocation and productivity differences (see, for example, Restuccia and Rogerson (2008) and Hsieh and Klenow (2009)). For India in particular, Hsieh and Klenow (2009) show that distortions cause significant resource misallocation across firms and that a reallocation of resources could raise aggregate productivity by as much as 40 to 60 percent. While this strand of research has identified misallocation of resources as a cause of the productivity variation across firms, the exact sources of these distortions remains an open question in the literature. The results of this paper suggest that high electricity prices are a possible source of the distortions that result in resource misallocation in developing countries, and making electricity more affordable could lead to aggregate productivity gains. In a related paper, Hsieh and Klenow (2012) argue that a particular type of resource misallocation, namely barriers facing large firms, can discourage firms from making productivity-enhancing investments and may be the reason firms in India exhibit little growth as they age. An important question raised in their paper is what exactly are the barriers faced by large plants in India. My findings suggest that high electricity cost is a potential barrier faced by large firms. Indian firms could choose to operate in industries with high levels of technological sophistication and electricity reliance and boost their productivity. However, firms may have no incentive to move to these productivity-enhancing industries and grow larger since doing so comes with the cost of having to rely on exorbitantly priced electricity.

My results provide a potential explanation for the low and stagnant share of manufacturing in India's gross domestic product. The share of manufacturing has remained between 15 and 16 percent for the past three decades. This share is low in comparison to other fast-growing Asian economies, including China and Indonesia, whose manufacturing shares range from 25 to 34 percent, and has prompted the recent formulation of a national manufacturing policy by the government with the aim of increasing the share of manufacturing in the country's gross domestic product (Government of India, 2011b). Although this low share is arguably the result of numerous policies and characteristics of the Indian economy, my findings suggest that high electricity prices faced by industrial users have played a part in suppressing growth in the manufacturing sector.

The rest of the paper is organized as follows. Section 2 provides a brief overview of the electricity sector in India. Section 3 describes the data. Section 4 outlines the empirical strategy and presents the results. Section 5 concludes.

2 Electricity Sector in India

Each state in India is responsible for the generation, distribution and pricing of electricity for its residents. Electricity generation in India is mostly from thermal plants, which account for about 84 percent of the electricity generated in the country. Hydroelectric plants account for about 14 percent of electricity generation, while plants using nuclear energy, wind and other renewable resources account for the rest. The dominant fuel for the thermal power plants is coal which accounts for about 83 percent of installed thermal generation capacity (Government of India, 2012). The cost of coal can account for about 66 percent of the total cost of power production in coal-fired thermal power plants (Government of India, 2006). The share of a state's installed generation capacity that comes from coal-fired thermal power plants is determined in large part by the state's proximity to India's coal mines. As shown in the map in Figure 1, states that are located near coal mines are more likely to have a higher share of their installed generation capacity coming from coal-fired thermal power plants.

Almost all of the coal used in India is produced by two central government-owned companies, Coal India Limited, which produces about 80 percent of the coal consumed in the country, and Singareni Collieries Company Limited, which produces about 8 percent (Government of India, 2008a).[5] These two companies set the price of coal and revise prices from time to time. Price revisions are driven mainly by cost pressures rather than changes in coal demand. The companies' reasons for revising prices have included offsetting inflationary pressures on their costs, offsetting increases in their wage bill and

[5]Of the remaining 12 percent, 5 percent is produced by captive coal mines and other private coal mining companies and 7 percent is imported (Government of India, 2008a). For power utilities, 94 percent of their total coal consumption comes from the two central government-owned companies, Coal India Limited and Singareni Collieries Company Limited, 3 percent comes from captive coal mines and the remainder comes from coal imports (Government of India, 2008b and 2008c).

achieving parity between domestic and international coal prices, which are much higher than Indian domestic coal prices. The coal companies set separate prices for power utilities and for other categories of consumers. Figure 2 shows how the coal price paid by power utilities has changed over time. The large increase in 2005 coincided with a sharp spike in global coal prices. Although India engages in very little international trade of coal (India exports only about one percent of its coal and coal imports account for only 7 percent of total coal consumption in the country), the coal companies took advantage of the spike in global coal prices to increase the Indian coal prices. Figure 3 shows the consumption of coal by thermal power plants over time. Comparing this chart to the chart of coal prices paid by power utilities in Figure 2, the price setting of the coal companies does not appear to be in response to coal demand by the power utilities. For instance, as shown in Figure 3, although coal consumption increased substantially between 2006 and 2008, coal prices remained fairly stable over this period, as shown in Figure 2. Also, in Table B1 in Appendix B, I check if changes in coal prices were correlated with political factors or the performance of the manufacturing sector. I find no evidence of any strong correlations.

The electricity used by residents of a state comes from one or more of four sources. Power plants owned by the state's government provide the bulk of electricity used, with other states' power plants, the central government's power plants, and independent power producers providing the remainder. States' power plants produce about 60 percent of total electricity generated in the country. Each state determines the price paid for electricity by its residents irrespective of the electricity source. Electricity pricing in India is generally based on an incremental block tariff structure in which the marginal price of electricity increases with the amount consumed. As an example, Table 1 shows the electricity price list for the state of Karnataka. For example, the first 100,000 kilowatt-hours of electricity consumed by industrial users cost 3.5 rupees per kilowatt-hour, while consumption above 100,000 kilowatt-hours costs a higher price of 3.75 rupees per kilowatt-hours.

The electricity sector in India is characterized by a system of cross-subsidization between agricultural and domestic users on one hand and industrial users on the other. The former group pays low prices for electricity at the expense of the latter group which faces high electricity prices, although the cost of supplying electricity to the latter group is lower. For instance, in India, electricity consumption by agricultural users for extracting groundwater with electric pumpsets for irrigation is largely unmetered. These users are charged a low flat rate for electricity based on the capacity of their pumpsets. This practice makes the marginal cost of using electricity essentially zero for farmers and has been criticized for leading to the excessive use of electricity and the depletion of groundwater. The catering of politicians to farmers who form dominant voting blocs, and to a lesser extent the social objective of providing affordable services for the poor, have contributed to the system of cross-subsidization. Figure 4 shows the average electricity prices paid by various categories of users in India and the power utilities' average cost of electricity supply between 1997 and 2010. The price paid by industrial users for electricity has consistently been much higher than that paid by agricultural and domestic users. In addition, the industrial user electricity prices have remained significantly above the average cost of electricity supply. On the other hand, the agricultural and domestic user prices have remained substantially below the average cost even though, as previously noted, the cost of supplying power to industrial users is generally lower than the cost of supplying power to other users.

In an effort to correct this price distortion, the government passed a law in 2003 that required states to set up electricity regulatory commissions whose main responsibility was to ensure fair pricing of electricity and to rid the price setting process of any political interference. Although most states have set up these commissions, a high level of cross-subsidization still exists. As recently as 2011, the average prices (in rupees per kilowatt-hour) paid by agricultural and domestic users were 1.23 and 3, respectively, compared to 4.78 for industrial users (Government of India, 2011a). Despite being poorer than the average OECD country, India's average electricity price for industrial users, at about 11 cents per kilowatt-hour, is about the same as the OECD average industrial electricity price. On the other hand, at about 7 cents per kilowatt-hour, India's average electricity price for domestic users is less than half of the OECD average domestic price (IEA, 2012).

3 Data

My analysis is based on manufacturing firm-level panel data from the Indian Annual Survey of Industries (ASI) for the years 2001 to 2008.[6] The ASI is an annual survey of registered factories in India and covers about 30,000 firms each year. All factories are required to register if they have 10 or more workers and use electricity, or if they do not use electricity but have at least 20 workers. This population of factories is divided into two categories: a census sector and a sample sector. The census sector consists of all large factories and all factories in states classified as industrially backward by the government.[7] For the 2001 to 2005 surveys, large factories were defined as those with 200 or more workers. From the 2006 survey onwards, the definition was changed to those with 100 or more workers. All the factories in the census sector are surveyed each year. The remaining factories make up the sample sector, of which a third is randomly selected each year for the survey.[8] In the survey, firms report the quantity, in kilowatt-hours, of electricity purchased and consumed, its value in rupees, and the average price paid per kilowatt-hour of electricity. Firms also report the quantity, in kilowatt-hours, of electricity generated by the firm itself for its use. The survey also includes firm-level data on output, employment, capital, material inputs and industry.

In the ASI, a firm's 5-digit industry[9] in a given year corresponds to the product that accounts for the highest share of the firm's total output in that year. There are 530 5-digit industries in the dataset corresponding to 127 4-digit industries and 61 3-digit industries. As an example of the level of detail in the industry classification, Table B2 in Appendix B lists the 4- and 5-digit industries within the 3-digit industry code 151 "Production, processing and preservation of meat, fish, fruits, vegetables, oils and fats".

For constructing the instrument for electricity price, I obtain data on coal prices from

[6]A year in the dataset corresponds to the Indian fiscal year which runs from April 1 to March 31. For instance, the year 2001 refers to the fiscal year beginning on April 1, 2000 and ending on March 31, 2001.

[7]The states classified as industrially backward are listed in Appendix A.

[8]The ASI provides sampling weights for each firm. I have also performed the analysis using these sampling weights to weight the observations and the conclusions remain unchanged.

[9]The 5-digit industry codes are from India's National Industrial Classification (NIC) 1998. The NIC 1998 is identical to the ISIC Rev. 3 system up to the 4-digit level.

the Indian Ministry of Coal's 2011 Coal Directory of India and data on installed electricity generation capacity from the Indian Ministry of Power's annual reports for 1997-1998 and 2002-2003. To reduce the influence of outliers, I "winsorize" the firm-level variables within each year by setting values below the 1st percentile to the value at the 1st percentile and values above the 99th percentile to the value at the 99th percentile. I deflate all monetary values using wholesale price indices from the Indian Ministry of Commerce and Industry.

To control for state-level characteristics in my regressions, I use data on state gross domestic product and population.[10]

Table 2 presents some summary statistics of the firm-level data disaggregated by firm size. Firms rely on both purchased electricity and self-generated electricity. About 44 percent of firms generate some electricity which, on average, accounts for about 9 percent of their total electricity consumption. Firms primarily use self-generation of electricity as a means of coping with electricity outages rather than with electricity prices since the cost per kilowatt-hour incurred by a firm in generating its own electricity in India is generally much higher than the price of electricity purchased from power utilities. For instance, based on a firm-level survey, it is estimated that for Indian manufacturing firms the cost of generating their own electricity is 24 percent higher than the price paid for the electricity provided by power utilities (Bhattacharya and Patel, 2007).

4 Econometric Analysis

4.1 Empirical Strategy

A simple regression of a firm outcome on electricity price may yield inconsistent and biased estimates of the effect of electricity price due to the potential endogeneity of prices. This endogeneity may come from several sources. For instance, some firms may have managers who have the foresight to locate in states with low electricity prices and these may also be the firms that perform well along other dimensions. To the extent that the unobserved firm characteristics that affect both the electricity price firms pay and other

[10] Details on the sources of the state-level variables are provided in Appendix A.

outcomes are time-invariant, controlling for firm fixed effects in the regressions would alleviate any endogeneity from this source. However, these unobserved firm characteristics may not be time-invariant, making the solution described above insufficient for dealing with the endogeneity of electricity prices. For instance, firms may develop relationships with state governments over time that allow them to obtain favorable pricing of electricity through corruption. Additionally, changes in the electricity price in a state may be correlated with changes in other unobserved state variables which also affect firm outcomes. Another concern is the direction of causality. States may be changing electricity prices in response to changes in firms' patterns of electricity consumption. For instance, firms may switch to electricity-intensive industries and increase their demand of electricity for reasons unrelated to electricity prices. States may respond to this increased demand by increasing electricity prices, leading to a positive bias in OLS estimates. Alternatively, if firms reduce their purchases of electricity, states may increase electricity prices in order to generate enough revenue to sustain the cross-subsidization of farmers and households, leading to a negative bias in OLS estimates.

To address this concern about the potential endogeneity of electricity prices, I rely on an identification strategy that exploits the nature of electricity generation and the organization of the electricity sector in India. Since most of the electricity used in a state is generated by the state's own power plants, changes in the price paid by electricity users in the state will largely reflect changes in the cost of producing electricity in the state's power plants. As the primary mode of electricity generation in India is thermal generation using coal-fired power plants, the price of coal plays a critical role in the cost of electricity generation, and, hence, electricity prices. As described in Section 2, coal prices are set independently by the two coal companies responsible for the production of coal in India. The coal companies set prices for power utilities and other users separately. Given the reliance on coal for electricity generation, I construct a variable equal to the interaction between the price of coal paid by power plants in a given year and the initial[11] coal-fired

[11]I use the initial thermal share to avoid confounding effects from endogenous changes in the thermal share over time. Figure A1 in Appendix A shows that states' thermal shares have remained largely stable over time. With the exception of two states, Jharkhand and Chhattisgarh, the initial thermal share is as

thermal share of a state's installed electricity generation capacity. The initial coal-fired thermal share of electricity generation capacity is the ratio of the installed generation capacity, in kilowatts, of a state's coal-fired thermal power plants to the total installed capacity of all of the state's power plants. For a given state, the thermal share is defined as follows:

$$thermal\ share = \frac{generation\ capacity\ of\ power\ plants\ using\ coal}{generation\ capacity\ of\ all\ power\ plants} \tag{1}$$

I then use the interaction variable as an instrument for the electricity price paid by a firm in IV regressions of firm outcomes on electricity prices. The instrument makes use of two sources of variation: the variation over time in coal prices and the variation across states in initial thermal shares.

The validity of using this IV approach to establish a causal relationship between electricity prices and firm outcomes hinges on the instrumental variable satisfying two conditions. The first is that the instrument, the interaction between coal price and thermal generation share, should be correlated with electricity price, which I show in the first stage regressions in Section 4.2. The second condition is that the instrument should affect the firm outcome of interest only via its effect on electricity price. Although there is no way of formally testing this second condition, I present some evidence below that suggests that it holds.

The instrument consists of two parts: the price of coal paid by power utilities and the initial thermal share of a state's installed generation capacity. The price used in constructing the instrument is the price of coal paid by power utilities. Although some firms use coal as an input in their production, as discussed in Section 2, the coal prices set for power utilities by the coal companies is different from the coal prices paid by firms. Therefore, arguably, other than through its effect on electricity prices, the coal price paid by power utilities should not influence firm outcomes. Figure A2 in Appendix A shows the

of 1998, which precedes the first year of the data used in the analysis. There are no data on Jharkhand and Chhattisgarh prior to 2000 since these states were created in late 2000. Therefore, I use data from 2003 which is the earliest year for which data on installed generation capacity is available for these states.

movement of the coal price paid by firms over time. The coal price paid by firms follows a different pattern from that paid by power utilities. Relative to the stepwise increases in the coal price paid by power utilities shown in Figure 2, the coal price paid by firms exhibits a smoother increase over time. Nonetheless, I have firm-level data on coal inputs and so I control for the value of coal used by the firm in some regressions. Only about 12 percent of firms in the sample consume any coal and these firms are concentrated in three sectors: glass, ceramics and cement, iron and steel, and paper. As a robustness check, in Section 4.8 I redo my analysis with a sample that excludes the firms in these three sectors. Also, as discussed in Section 2, changes in coal prices by the coal companies do not appear to be driven by political factors or the performance of the manufacturing sector. As noted in Section 2, the second part of the instrument, the initial thermal share of a state's installed generation capacity, is determined in large part by a state's proximity to India's coal mines and should be plausibly exogenous to firm outcomes conditional on controlling for state fixed effects.

A potential concern is that the IV strategy would be invalidated if states exhibit trends that are correlated with both the instrument and firm outcomes. For instance, states with high thermal shares may follow different trends compared to other states. To explore this possibility, I regress the change between 1994 and 1998 (the year in which the thermal share is measured) in the log of state-level variables that reflect the economic environment and are possibly related to firm outcomes on the state's thermal share. The state-level variables I examine are state gross domestic product per capita and population. Table 3 reports the results of these regressions. The coefficients are small in magnitude and statistically insignificant suggesting that states' thermal shares are not correlated with economic trends. However, as a precautionary step and because there may be trends in unobserved variables that are correlated with both firm outcomes and the instrument, I control for state time trends in the regressions.

The system of equations I estimate are as follows:

$$y_{isrt} = \beta_0 + \beta_1 log(electricity\, price)_{isrt} + \beta_2 X_{isrt} + \beta_3 S_{st} + \lambda_i + \eta_{rt} + \delta_s t + \epsilon_{isrt} \quad (2)$$

$$log(electricity\, price)_{isrt} = \alpha_0 + \alpha_1 thermal\, share_s * log(coal\, price_t) \quad (3)$$
$$+\alpha_2 X_{isrt} + \alpha_3 S_{st} + \lambda_i + \eta_{rt} + \delta_s t + \mu_{isrt}$$

Equation (2) is the outcome equation of interest where y_{isrt} is an outcome for firm i in state s in region r in year t, electricity $price_{isrt}$ is the price in rupees paid by a firm per kilowatt-hour of electricity, X_{isrt} is the value in rupees of coal used by a firm, S_{st} is a vector of state-level variables, namely the log of state gross domestic product per capita and the log of state population, λ_i is a firm fixed effect, η_{rt} is a region-year[12] effect, and $\delta_s t$ is a state time trend. Equation (3) is the first-stage regression equation in which the log of electricity price is regressed on the interaction between the state thermal share and the log of coal price and all the other covariates in the outcome equation. All regressions include firm fixed effects to account for time-invariant firm characteristics which may simultaneously affect both the electricity price paid by firms and other firm outcomes. In the dataset, firms do not change the state in which they are located so the firm fixed effects also capture state fixed effects. I also control for region-year effects to absorb shocks that affect all firms in a particular region as well as state-specific time trends. Thus, the coefficient of interest, β_1, is an estimate of the change in an outcome for a given firm given a change in the electricity price paid by the firm.

4.2 First Stage Regression

Figure A3 in Appendix A provides a graphical depiction of the first stage. The figure plots the coefficients from year by year regressions of electricity price on thermal share against coal price. The correlation between electricity price and thermal share is increasing with the price of coal paid by power utilities. The results from the first stage regression in

[12] A list of the states in each region is provided in Appendix A.

equation (3) are presented in Table 4. Since the instrument varies at the state level, all the standard errors in the IV regressions are clustered at the state level to allow for correlations across firms in the same state. Column 1 shows the results from the first stage regression without controlling for state time trends. The estimate of the coefficient on the instrument is positive and statistically different from zero at the one percent level. In Column 2, I control for state time trends. The coefficient remains positive and statistically significant but is smaller than the estimate in Column 1. This suggests that the coal price trend is correlated with state-specific trends in other variables that vary with electricity prices. I, therefore, control for state time trends in the following regressions. In Column 3, I include state-level variables, namely the log of state gross domestic product per capita and the log of state population, as well as the value of coal consumed by the firm. The coefficient on the instrument changes little with the inclusion of these control variables. The results of the first-stage regressions indicate that as coal price rises, firms in states that rely on thermal electricity generation experience an increase in electricity price. In terms of magnitudes, the coefficient of 0.51 on the instrument in Column 3 implies that, for instance, firms in Delhi, which has a thermal share of 57 percent, would experience a 0.3 percent increase in electricity price given a one percent increase in coal price, while firms in West Bengal, which has a thermal share of 94 percent, would experience a 0.5 percent increase in electricity price. This magnitude is plausible given that, as noted in Section 2, the cost of coal can account for about 66 percent of the total cost of power production in thermal power plants (Government of India, 2006).

4.3 Effect on Electricity Consumption

Table 5 reports results on the effects of electricity prices on electricity consumption, in kilowatt-hours, by firms. Columns 1 and 2 present estimates from OLS regressions of equation (2). All standard errors in the OLS regressions are clustered at the firm level to allow for correlations across years within firms. All regressions control for firm fixed effects, state time trends and region-year effects. In addition to these controls, the regression in Column 2 controls for the log of state gross domestic product per capita, the log of state population and the value of coal consumed by the firm. The statistically significant negative coefficients on the log of electricity price suggest that firms reduce the quantity, in kilowatt-hours, of electricity purchased as electricity price increases. Because of the potential endogeneity of electricity prices discussed in Section 3, caution should be exercised in interpreting the result from the OLS regression as evidence of a causal relationship between electricity price and firm outcomes.

Columns 3 and 4 present the reduced form results while Columns 5 and 6 present the IV results correcting for the potential endogeneity of electricity prices. The results from the IV regressions are similar to and permit a causal interpretation of the findings from the OLS regression. In response to high electricity prices, firms reduce the quantity of electricity they purchase. As indicated by the coefficients in Columns 5 and 6, a one percent increase in electricity price leads to between a 1.19 and a 1.29 percent fall in the quantity of electricity purchased by firms. These estimates of the price elasticity of electricity demand are closely in line with the range (-1.25 to -1.94) found for industrial consumers in the existing literature (Iimi, 2010).

If firms are able to generate enough electricity to offset the reduction in the quantity of electricity purchased, then there may not be a reduction in the quantity of electricity they use. However, as discussed in Section 3, firms primarily use self-generation to mitigate the effects of outages rather than prices since it is much costlier for firms to generate their own electricity than it is to purchase electricity from the power utilities. It is therefore unlikely that firms would increase self-generation of electricity in response to an increase in electricity price.

In Panel B of Table 5, the coefficient on the log of electricity price from regressing the log of the total quantity of electricity used by the firm, both purchased and self-generated, on the log of electricity price is negative and statistically significant. This result confirms the hypothesis that firms are not able to use self-generation to offset the reduction in the quantity of electricity purchased and therefore experience a reduction in their total electricity consumption. To further explore the effect, if any, of electricity price on the self-generation of electricity, Panels C and D of Table 5 report estimates from regressions of an indicator variable for self-generation and the generated share of electricity on the log of electricity price. The coefficients on the log of electricity price from the IV regressions are negative and statistically significant implying a negative correlation between electricity price and self-generation of electricity by firms. This finding is consistent with firms switching to less electricity-intensive industries in response to an increase in electricity price, as is shown below, and, hence, reducing their total consumption of electricity. This reduction in total consumption would come from a reduction not only in electricity purchased but also from a reduction in self-generated electricity as self-generation is costlier than purchasing electricity from the power utilities.

4.4 Effect on Industry Choice

The reduction in the consumption of electricity as electricity price rises suggests that firms may be altering their production to rely less on electricity in order to mitigate the effects of high electricity prices. To become less dependent on expensive electricity, firms may change their production to focus on goods that are less electricity-intensive. At the 5-digit level, industries within the same 4-digit industry exhibit similarities in terms of their main inputs and final products. For instance, within the 4-digit industry code 1512 (processing and preserving of fish and fish products), the 5-digit industry code 15121 refers to the sun-drying of fish, while code 15122 refers to the artificial dehydration of fish, which requires the use of electrically powered drying machines. Both industries use the same primary input, fish, and have the same end product, dried fish, but differ in terms of the processes used, with industry 15121 using a less electricity-intensive process. Given the similarities between 5-digit industries within the same 4-digit industry, we might expect that firms can switch between 5-digit industries in response to changes in electricity price.

To explore this, I define the electricity intensity of a 5-digit industry as the average kilowatt-hours of electricity consumed per rupee of output by firms in that industry.[13] This corresponds to the standard measure of electricity intensity used by the International

[13] I define the 5-digit electricity intensities using data from 1999, which precedes the first year of the data used in the analysis, to avoid confounding effects from endogenous changes in industries' electricity intensities over time.

Energy Agency, which is the ratio of electricity consumption in kilowatt-hours to the value of output.[14] I define an indicator variable equal to one if a firm's current 5-digit industry is different from its previous 5-digit industry and zero otherwise. In the ASI, a firm's 5-digit industry in a given year corresponds to the product that accounts for the highest share of its total output in that year. Table 6 reports the results from the regression of the indicator variable on the log of electricity price. These regressions have fewer observations than in Table 5 since I lose the first observation for each firm in constructing the indicator variable. The results from the first-stage regressions using this lower number of observations are shown in Panel B of Table 6. The coefficients on the instrument remain positive and statistically significant. In Table 6, Columns 1 and 2 of Panel A present the OLS results, Columns 3 and 4 present the reduced form results and Columns 5 and 6 present the IV results. The hypothesis that firms switch their industries in response to changes in electricity price is supported by the positive and statistically significant relationship between the indicator variable and the log of electricity price shown in Columns 5 and 6 of Panel A.[15]

[14]To check the reliability of the electricity intensities calculated from the Indian data, I compare them to the electricity intensities of industries in the UK. The most disaggregated level at which electricity intensities for comparable industries are available for other countries is the 4-digit level of the ISIC. Since the UK data are available at the 4-digit industry level, I construct the Indian industry electricity-intensity at the 4-digit level for comparison purposes. Details on the sources of the UK data are provided in Appendix A. Figure 5 plots the log of the Indian industry electricity intensities at the 4-digit level against the log of the UK industry electricity intensities. The fitted line is from a regression weighted by the number of firms in each 4-digit industry in the Indian data. There is a strong positive and statistically significant relationship between the two sets of electricity intensities suggesting that the electricity intensities calculated from the Indian data are reliable. Since the electricity intensities at the disaggregated 5-digit industry level are only available from the Indian data, I rely on the Indian electricity intensities for my analysis.

[15]I also estimate regressions similar to those in Table 6 using indicator variables for whether the firm switches its 3- and 4-digit industries, respectively. The coefficients on the log of electricity price in these regressions are statistically insignificant indicating that firms do not switch their 3- or 4-digit industry in response to changes in electricity price. This is perhaps not surprising since at the 3- and 4-digit levels industries vary significantly in terms of the goods produced and inputs used, making it more difficult and less likely for firms to switch between industries at this level. For instance, within the 2-digit industry code 15 (manufacture of food products and beverages), the 3-digit industry code 151 refers to the production, processing and preservation of meat, fish, fruits, vegetables, oils and fats, while code 152 refers to the manufacture of dairy products. Also, within the 3-digit industry code 151, the 4-digit industry code 1511 refers to the production, processing and preserving of meat and meat products while code 1512 refers to the processing and preserving of fish and fish products, highlighting how the main inputs can differ even between two 4-digit industries in the same 3-digit industry.

To check if the industries firms switch to are less electricity-intensive, I run regressions of the electricity intensity of a firm's 5- digit industry on electricity price. Table 7 reports the estimates from these regressions. The coefficient on the log of electricity price is negative and statistically significant supporting the idea that firms switch to less electricity-intensive industries as electricity price rises.

Is the electricity intensity of an industry related to its productivity? This question is an important one in understanding whether switching to less electricity-intensive industries in response to increases in electricity price has any dire consequences for firms. If electricity-intensive industries are indeed those that rely on productivity-enhancing technologies, then operating in a less electricity-intensive industry may affect firms' productivity growth. As most innovations in production processes are reliant on electricity, we might expect it to be the case that the electricity intensity of an industry is positively associated with both its technology intensity and productivity.

As a way of checking if a positive relationship exists between an industry's electricity intensity and its technology intensity, I look at the correlation between an industry's electricity intensity and its machine intensity since, arguably, industries using more advanced technologies are more machine-intensive. I plot the log of the electricity intensity for each 5-digit industry against the log of its machine-labor ratio in Figure 6. The fitted regression line is weighted by the number of firms in each 5-digit industry. This plot supports the idea that an industry's electricity intensity is positively correlated with its machine intensity, and this correlation is statistically significant. In Figure 7, I plot a similar graph to check the correlation between an industry's electricity intensity and its labor productivity. Similar to the finding for machine intensity, there is a positive and statistically significant relationship between an industry's electricity intensity and its labor productivity.

To corroborate this finding, I examine the correlation between electricity intensity and a variable that has been used as a proxy for product sophistication or the productivity level of a good and has been linked to growth in the literature. This proxy is an index called PRODY which was developed in Hausmann, Hwang, and Rodrik (2007) and has been used in several papers including Mattoo and Subramanian (2009) and Wang, Wei, and Wong

(2010). PRODY is defined as the weighted average of the per capita GDPs of countries exporting a given product, where the weights are the ratios of the share of the product in a country's exports to the sum of the shares for all countries exporting the product. The motivation for this measure is the assumption that richer countries produce more sophisticated goods. Figure 8 plots the log of electricity intensity for India against the log of PRODY, both at the 4-digit industry level.[16] The fitted line in the Figure 8 is weighted by the number of firms in each 4-digit industry. A positive relationship is discernible between the log of electricity intensity and the log of PRODY in the graph, lending support to the idea that electricity-intensive industries tend to have higher productivity levels.

4.5 Effect on Product Mix

In the previous section, I showed that firms switch to less electricity-intensive 5-digit industries in response to an increase in electricity price. As noted above, a firm's 5-digit industry in a given year in the ASI corresponds to the product that accounts for the highest share of the firm's total output in that year. Therefore, the result that firms are switching to a less electricity-intensive 5-digit industry indicates that firms are changing their main product but does not provide information about the firms' other products in the case of multiple-product firms. About 47 percent of the firms in the dataset are multiple-product firms and the average number of products per firm is 2.14.[17] To get a sense of how a firm's product mix responds to changes in electricity prices, I calculate the average electricity intensity of a firm's product mix. I first define the electricity intensity of each product as the average kilowatt-hours of electricity consumed per rupee of output by single-product firms producing that product.[18] A caveat here is that since single-product firms may

[16] I use the electricity intensity at the 4-digit instead of the 5-digit level because I am able to obtain the PRODY values at the 4-digit industry level but not at the 5-digit industry level. Details on the construction of the PRODY values at the 4-digit industry level are provided in Appendix A.

[17] In the ASI surveys, firms are asked to list their top 10 products in terms of their contribution to the firm's total output. Therefore, the number of products per firm is top-coded at 10. However, almost all the firms (98.6 percent) list fewer than 10 products. Each product is identified by a unique code from India's Annual Survey of Industries Commodity Classification (ASICC). There are 4,452 product codes in the dataset.

differ fundamentally from multiple-product firms (see, for example, Bernard, Redding and Schott (2010) and Goldberg et al. (2010)), the product electricity intensities calculated from data on single-product firms may not be the most valid measures. However, since the survey only provides information on total electricity consumption at the firm level and not at the product-firm level, it is not feasible to calculate the product electricity intensities using multiple-product firms. Using the measures of product electricity intensity obtained from the data on single-product firms, I calculate the average of the electricity intensities of each firm's products. I then regress the log of the average electricity intensity of a firm's product mix on the log of electricity price. Panel A of Table 8 reports the results from these regressions.[19] The negative and statistically significant coefficient on the log of electricity price implies that firms alter their product mix in favor of products whose production processes are less electricity-intensive in response to an increase in electricity price. However, it may be the case that although firms are including less electricity-intensive products in their product mix as electricity prices rise, high electricity intensity products still account for the bulk of their output. The result in Section 4.4 that firms are changing their main industry in response to changes in electricity prices suggests that this is not the case. To further check this, I look at the effect of electricity price on the weighted average product electricity intensity for a given firm in Panel B of Table 8, where the weights are the shares of each product in the firm's total output. In line with the result in Section 4.4, I find that firms are producing higher proportions of less electricity-intensive products in response to an increase in electricity price.

4.6 Effect on Machine Intensity and Productivity

In this section, I examine whether the effects of electricity prices on other firm outcomes are consistent with the result in Section 4.4 that firms switch to less electricity-intensive

[18] I define the product electricity intensities using data from 2001, the first year for which detailed product classification is available, to avoid confounding effects from endogenous changes in products' electricity intensities over time.

[19] The number of observations in Table 8 are fewer than in Table 4 since some firms do not provide information on their product mix. The results from the first stage regressions for this smaller sample are reported in Panel C of Table 8.

industries in response to high electricity prices. As shown in Section 4.4, the electricity intensity of an industry is positively correlated with its machine intensity. Thus, if firms are switching to less electricity-intensive industries in response to an increase in electricity price, then we might expect their machine intensity to also fall with electricity price. The estimates from a regression of the log of machine-labor ratio on the log of electricity price are reported in Panel A of Table 9. The negative and statistically significant coefficients on the log of electricity price in the IV regressions suggest that firms become less machine-intensive as electricity prices increase in line with the finding that an industry's electricity intensity is positively related to its machine intensity. Next, I analyze the relationship between labor productivity and electricity prices. Before turning to the effect of electricity prices on firm labor productivity, I look at the effect on firm output and employment separately. The IV results in Panels B and C of Table 9 imply that an increase in electricity price results in a reduction in output and employment, with a much greater reduction in output than in employment.

I present the results for the effect of electricity prices on labor productivity in Panel A of Table 10. As implied by the results for output and labor in Table 9, labor productivity falls with an increase in electricity price. This result is in accordance with the positive correlation found between an industry's electricity intensity and its labor productivity and the previous result that firms switch to less electricity-intensive industries as electricity prices rise. In addition to labor productivity, I also investigate the effect of electricity prices on a firm's total factor productivity (TFP). The results of this analysis are reported in Panels B and C of Table 10. I construct TFP using two methods. The first measure of TFP, which I refer to as TFP(OLS), is the residual from industry-specific OLS regressions of the log of output on the logs of labor, capital and firm inputs. The second measure of TFP, which I refer to as TFP (Olley-Pakes), is constructed following the method proposed in Olley and Pakes (1996).[20] Although negative, the coefficients on the log of electricity price for the TFP regressions are not statistically significant. However, these conventional measures of TFP may be biased since they do not take into account firm heterogeneity

[20]Details on the construction of the TFP measures are provided in Appendix A.

in input and output quality and mark-ups and so the results for the TFP measures may not be reliable.

To summarize the results so far, an increase in electricity price causes firms to reduce their electricity consumption and switch to less electricity-intensive industries. Consistent with this switch and the positive correlations between an industry's electricity intensity on one hand and its machine intensity and productivity on the other, I find that as electricity prices rise, firms experience a reduction in their machine intensity and labor productivity.

4.7 Effect on Firm Productivity Growth

In addition to the level effects on productivity found in the previous section, changes in electricity prices may have growth effects on firms. In Section 4.4, I showed that a negative relationship exists between electricity prices and the electricity intensity of the industry in which firms choose to operate. If these electricity-intensive industries are arguably more technologically advanced, as suggested by the positive correlations between industry electricity intensity and machine intensity and productivity, then switching to such industries may give firms the opportunity to use more advanced technologies. If these technologically advanced industries generate more opportunities for learning and further innovation than the less technologically advanced industries, then switching to such industries may subsequently have a positive effect on firm productivity growth. To explore this possibility, I run regressions of a firm's productivity growth rate between time t-1 and time t on electricity price at time t-1. I calculate the growth rate of a firm outcome as the log difference between the firm outcome this year and the previous year.

The results from the first stage regression for the growth rate regressions are presented in Table 11. The relationship between electricity price and the instrument remains positive and statistically significant. Before looking at the effect of electricity price on labor productivity growth, I present results on the effects of electricity price on the growth rates of firm output and employment separately in Table 12. The coefficients on the log of electricity price in the IV regressions provide some evidence that firm output growth falls as electricity price increases. However, there is no evidence of a correlation between electricity price and employment growth. The lack of an effect could be the result of two opposing effects on employment. On one hand, firms are contracting, as suggested by the negative effect on output, which would imply a reduction in employment growth. On the other hand, firms are becoming more labor intensive, which would imply an increase in employment growth. The estimates for the effect of electricity price on labor productivity growth are reported in Table 13. The IV coefficients on the log of electricity price are negative and statistically significant. This result is consistent with the conjecture that an increase in electricity price, by causing firms to switch to less electricity-intensive industries, results in fewer learning and innovation opportunities for firms and, therefore, negatively affects their productivity growth

In addition to labor productivity growth, I also analyze the relationship between electricity price and TFP growth. The results of this analysis are presented in Panels B and C of Table 13. Similar to the result for labor productivity, an increase in electricity price results in a decline in the growth rate of TFP. In sum, aside from the level effects on labor productivity and output observed in the previous section, an increase in electricity price has persistent effects on firms by negatively affecting the growth rates of firm output, labor productivity and TFP.

4.8 Robustness Checks

In this section, I test the robustness of my results to different specifications. In Column 2 of Table 14, I test the robustness of the results to the exclusion of the value of coal used by the firm as a control variable. For comparison purposes, Column 1 of Table 14 presents the previous results which included this control variable. The results in Columns 1 and 2 are essentially the same implying that the results are robust to the exclusion of the value of coal used by the firm.

A potential concern is that coal prices may be correlated directly with power outages, independently of electricity prices, and hence the IV regressions may be picking up the effects of power outages and not the effects of electricity prices, per se. However, as shown in Table B3 in Appendix B, coal-related issues are not a common cause of outages in India. Coal-related issues accounted for between 0.8 and 4.1 percent of kilowatt-hours of generation lost in thermal power plants due to outages over the period 2001 to 2008. I do not have state-level data on outages. However, I have state-level data on the plant load factor of thermal power plants.[21] The plant load factor is the ratio of actual electricity generation to the maximum possible generation of power plants and is negatively correlated with outages. I therefore control for the log of the state-level plant load factor in the regressions in Column 3 of Table 14 to proxy for the extent of outages in the state. The results are very similar to the original results reported in Column 1. In Column 4 of Table 14, I include both the value of coal used by the firm and the log of the state-level plant load factor as control variables. The results are again very similar to the original results.

An argument made in Section 4.1 to support the validity of the identification strategy was that the coal price used in the instrument is set specifically for power utilities and is different from the coal price paid by firms. Therefore, this coal price should not affect firm outcomes other than through its effect on electricity price. To further alleviate any concern that the coal price used in the instrument may affect firm outcomes directly since some firms use coal as an input, I controlled for the value of coal used by the firm in some regressions. As another check that my results are not being driven by a violation of the exclusion restriction, I redo my analysis with a sample that excludes firms in sectors that are heavily dependent on coal. The manufacturing sectors that are the largest consumers of coal are the glass, ceramics and cement industry, the iron and steel industry, and the paper industry.[22] These three sectors have the highest proportions of coal as a share of inputs in the dataset. Table 15 presents the main results for the sample that excludes firms in these three sectors. Reassuringly, the conclusions from above still hold. Firms switch to less electricity-intensive industries and experience declines in machine-intensity, output and labor productivity as electricity prices rise.

[21]Details on the source of the state-level plant load factor data are provided in Appendix A.

[22]These sectors correspond to the ISIC Rev. 3 2-digit industry codes 26, 27 and 21, respectively.

5 Conclusion

Drawing on Indian firm-level data, this paper analyzes the effect of electricity price on the type of industry firms choose to operate in and the implications for their productivity growth. Addressing the potential endogeneity of electricity prices by exploiting the nature of electricity generation in India, I show that firms respond to increases in electricity prices by shifting to products with less electricity-intensive production processes. I provide evidence that an increase in electricity price has negative consequences for firm output, labor productivity, and machine intensity. In addition to these level effects, I find that firm output and productivity growth are negatively affected by increases in electricity prices. Taken together, these results suggest that high electricity prices cause firms to operate in low electricity intensity industries and hence forego the productivity-enhancing opportunities available in more electricity-intensive and, arguably, more technologically advanced industries.

An observed pattern in India's manufacturing sector is that firms grow very little as they age (Hsieh and Klenow, 2012). Explanations put forth for the poor performance of the manufacturing sector have included, among others, the country's restrictive labor market regulations. The findings of this paper suggest that electricity constraints may also contribute to the observed growth pattern. I find that high electricity prices have negative consequences for firm output and growth and these high prices may therefore be suppressing the expansion of India's manufacturing sector. My analysis suggests that even a small step towards achieving fairer pricing of electricity for industrial users could result in significant gains in manufacturing output. As an example, industrial users were charged about an extra 89 billion rupees to cover electricity subsidies to agricultural and domestic users in 2008. Electricity consumption by industrial users in that year was 157 giga kilowatt-hours at a price of 4.16 rupees per kilowatt hour equivalent to total sales of 653 billion rupees (Government of India, 2011a). Therefore, about 14 percent of the total electricity revenue from industrial users was for the purpose of covering subsidies to agricultural and domestic users. If these subsidies had been reduced by as little as 10 percent (that is, by 8.9 billion rupees), electricity prices for industrial users could have been reduced by 1.4 percent. My results imply that a one percent fall in electricity price leads to about a two percent [23] increase in firm output. Hence, the 1.4 percent reduction in electricity price could have resulted in about a 2.8 percent increase in output. India's aggregate manufacturing output in 2008 was 7.3 trillion rupees (Government of India, 2011c). The estimated 2.8 percent increase in output would have, therefore, meant an additional 200 billion rupees of output, which could easily have covered the 8.9 billion rupee reduction in subsidies.

The results of this paper shed light more broadly on the literature on productivity growth in developing countries. The findings highlight a channel through which infrastructure constraints may affect firm productivity. Faced with infrastructure constraints, in this case high electricity prices, firms may use less efficient production processes in an attempt to become less reliant on that infrastructure. Although this paper addresses electricity specifically, one can imagine ways in which firms may change their processes in potentially undesirable ways to cope with other infrastructure constraints.

Additionally, while most of the literature on infrastructure constraints in developing countries has focused on the availability of infrastructure, this paper emphasizes the importance of considering the affordability of infrastructure as well. Even with the provision of infrastructure, high prices may instigate coping strategies that have negative consequences.

A limitation of my analysis is that I do not directly observe data on the technologies used by firms, which are generally absent from most firm-level datasets. Future data collection efforts could elicit such information from firms. Given the important role of technology in growth, such data would allow more in-depth analyses of the factors influencing firms' technology choices and how these choices shape productivity growth in developing countries.

[23] This estimate is from the coefficient from the IV regression of the log of output on the log of electricity price in Table 9.

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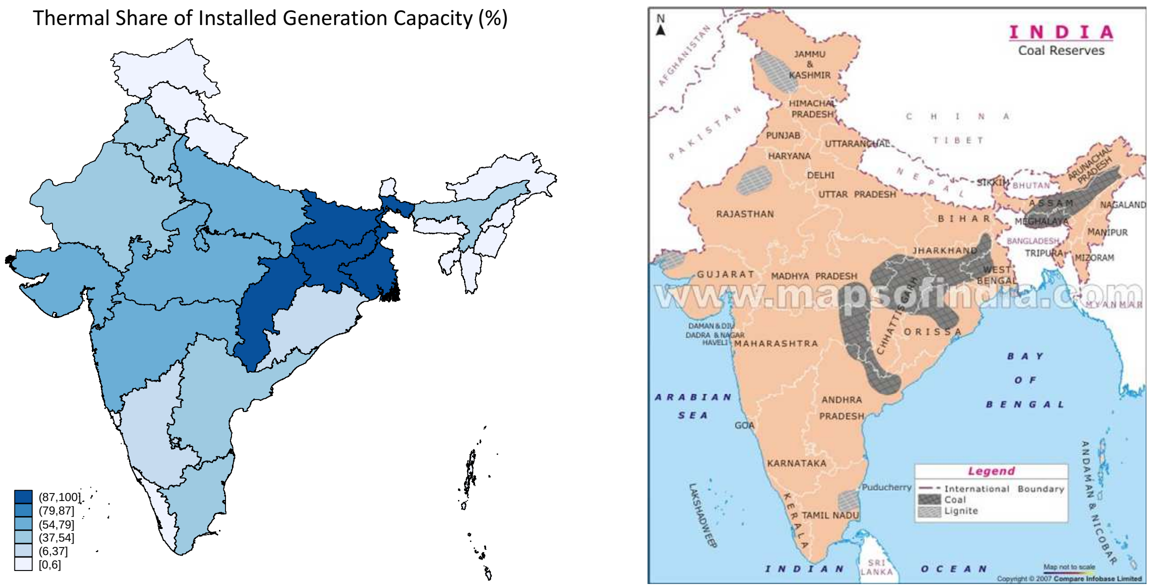
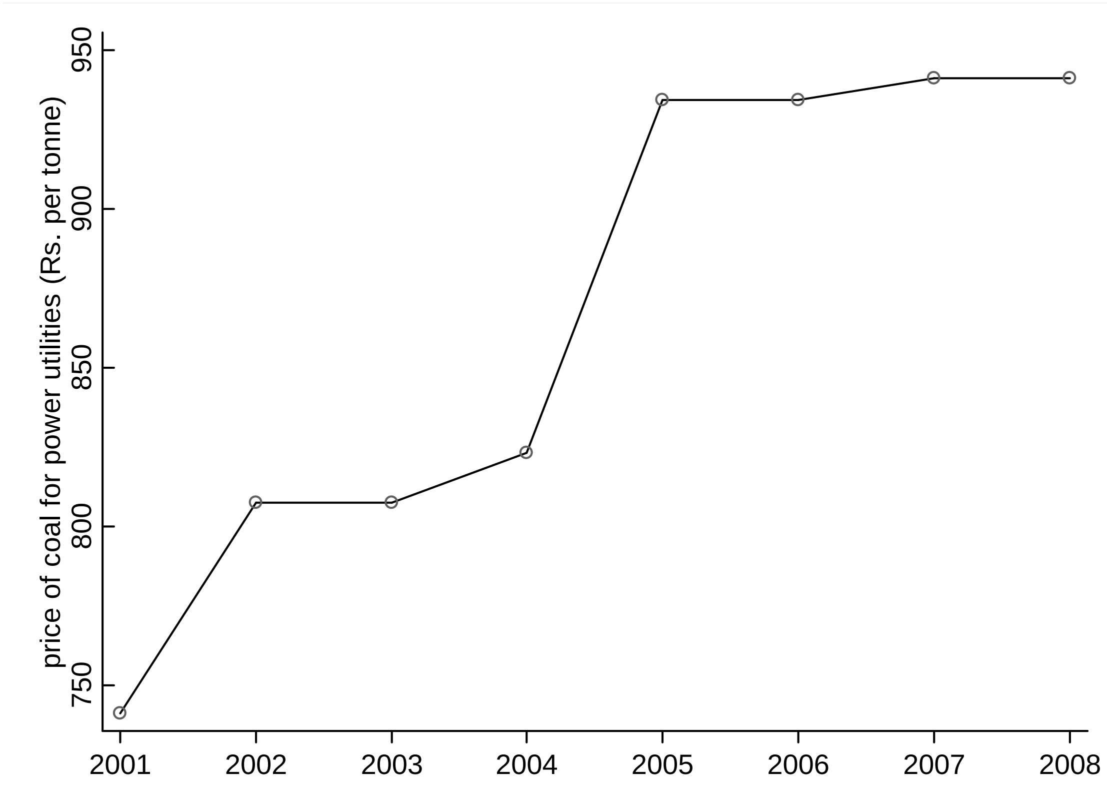
Figure 1: States' Thermal Share of Generation Capacity and Indian Coal Reserves



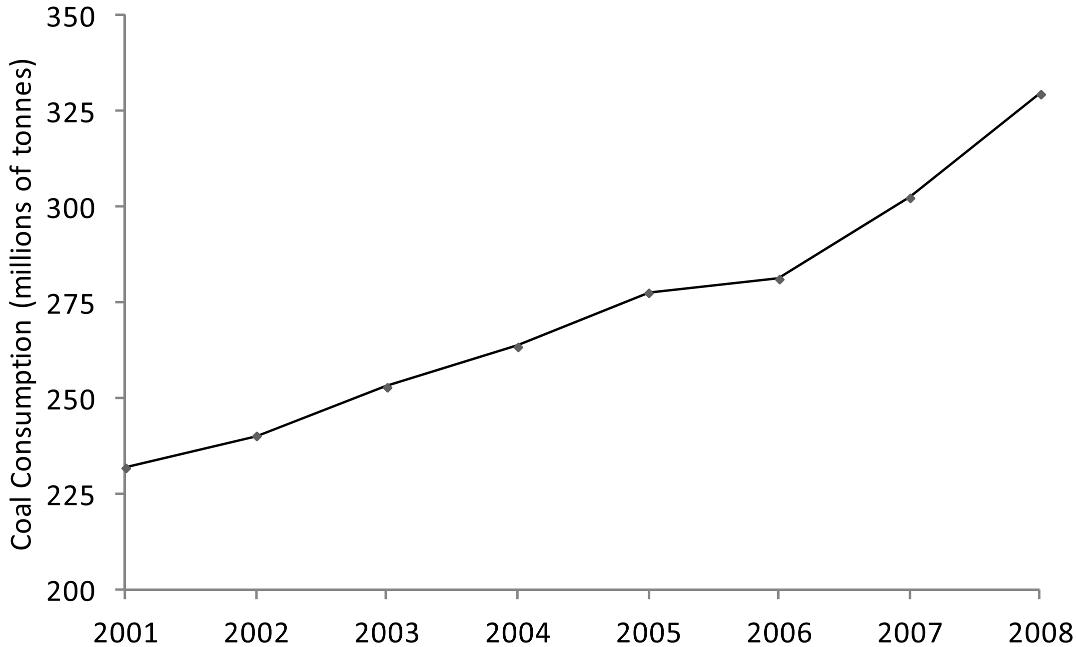
Notes: Data on installed generation capacity are from India's Ministry of Power's annual reports for 1997-1998 and 2002-2003. Map of coal reserves is from MapsofIndia.com (http://www.mapsofindia.com).

Figure 2: Price of Coal for Power Utilities



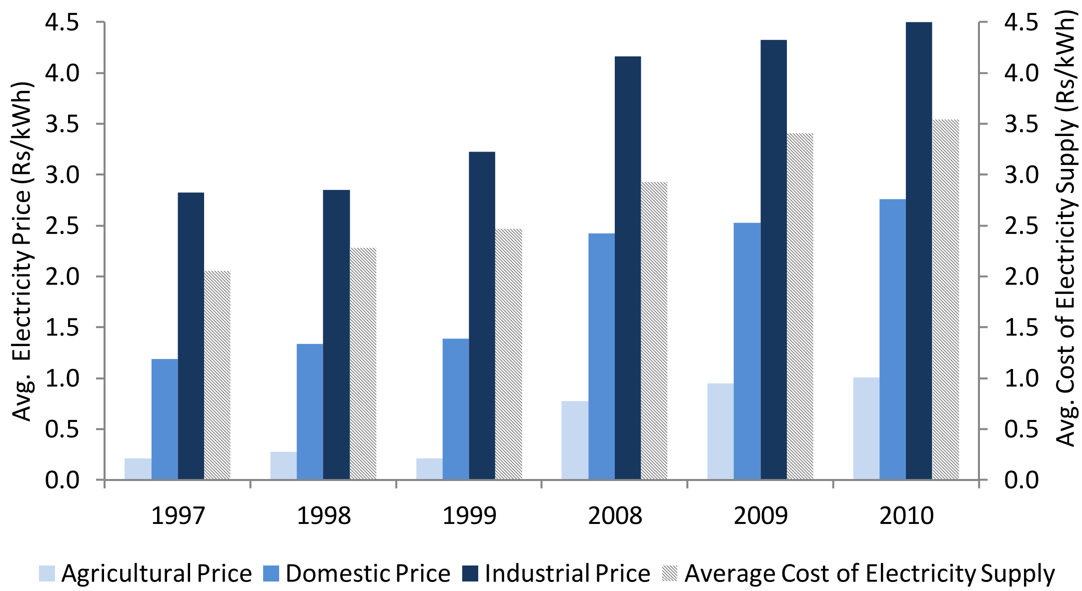
Notes: Data are from the 2010-2011 issue of the Coal Directory of India published by India's Ministry of Coal.

Figure 3: Coal Consumption by Thermal Power Plants



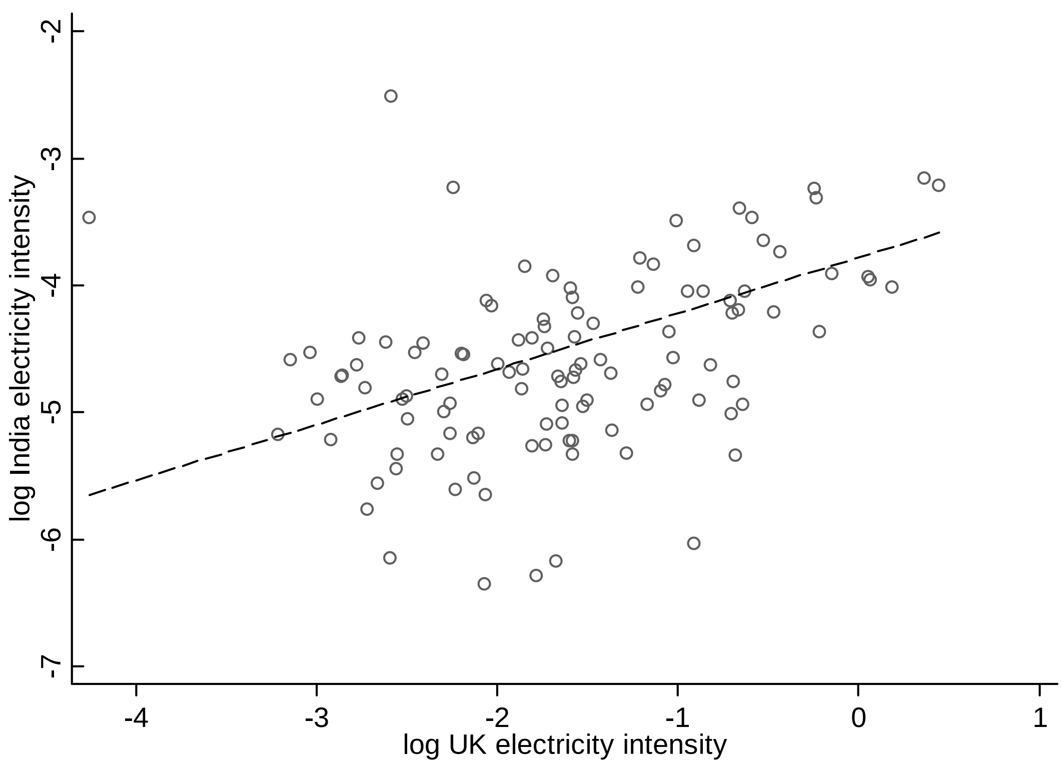
Notes: Data are from the 2002-2003, 2005-2006 and 2007-2008 issues of the Performance Review of Thermal Power Stations published by India's Central Electricity Authority.

Figure 4: Average Electricity Price for Different Categories of Users and Average Cost of Electricity Supply



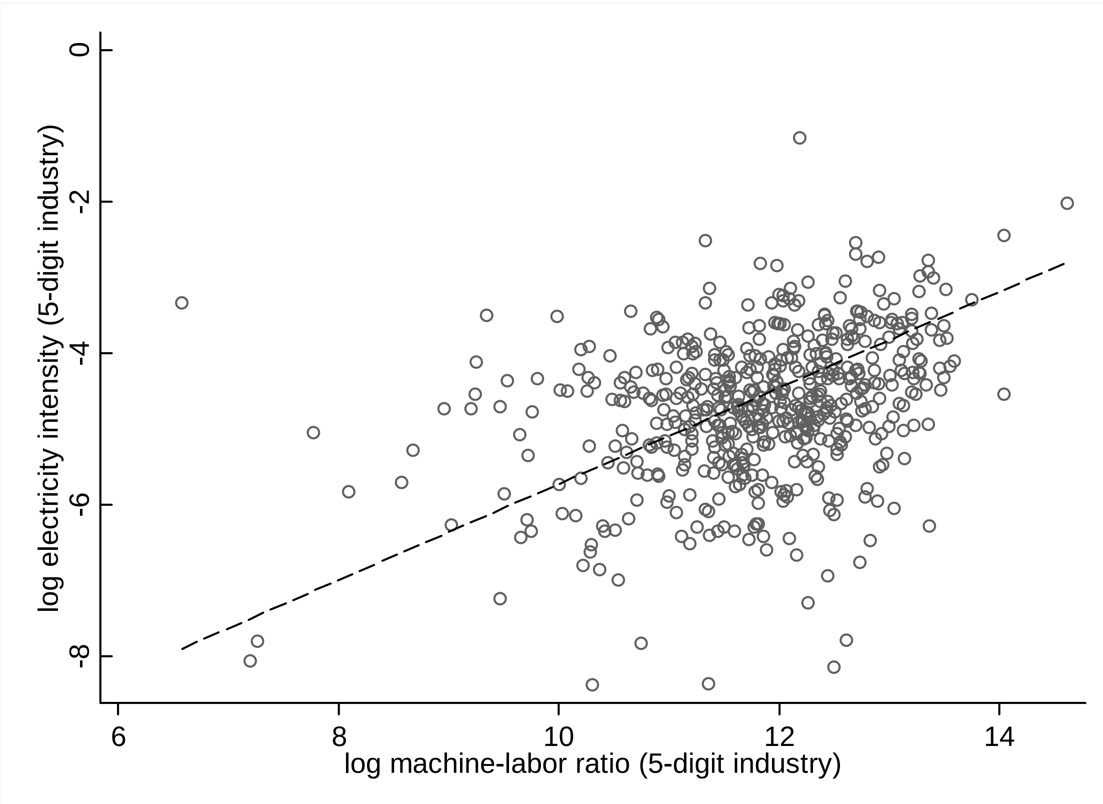
Notes: Data on electricity prices are from Government of India (1999, 2002, 2011a). Data on average cost of electricity supply are from the Indiastat database (http://www.indiastat.com).

Figure 5: Indian and UK Electricity Intensities



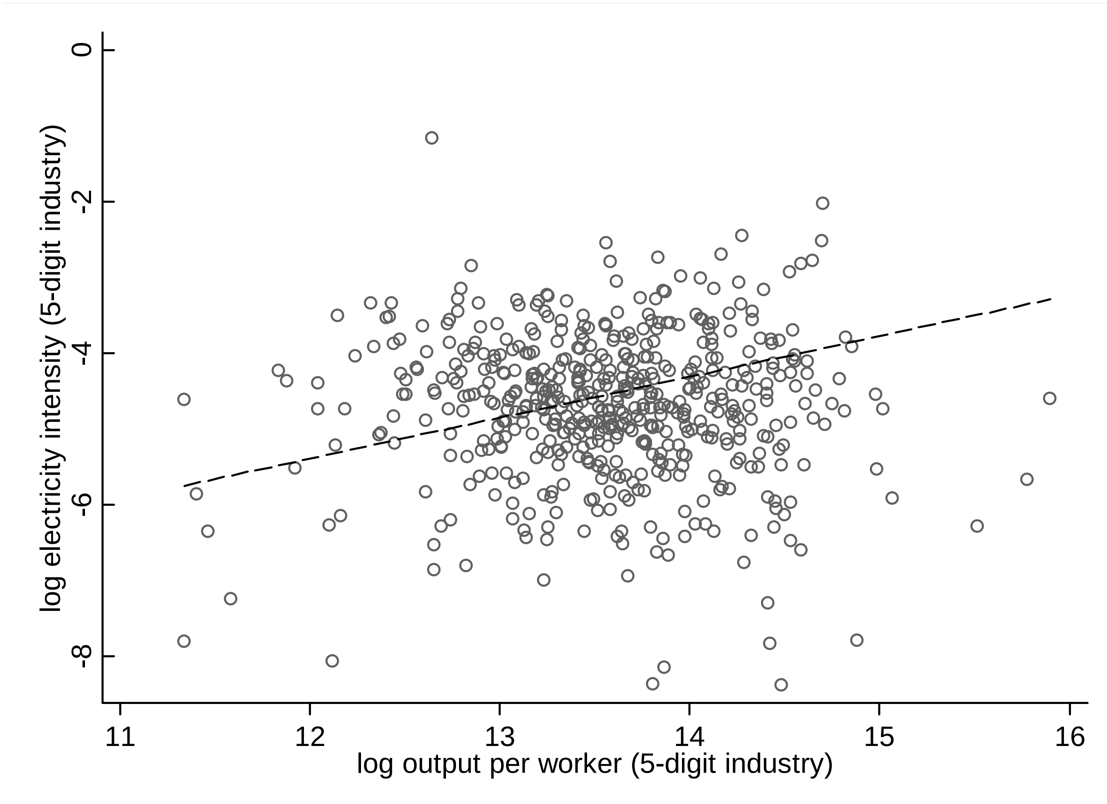
Notes: Log India electricity intensity (in rupees per kilowatt-hour) is calculated for 4-digit industries using the 1999 ASI data. Log UK electricity intensity (in pounds sterling per kilowatt-hour) is calculated for 4-digit industries using data from Department of Energy and Climate Change (2011) and Office for National Statistics (2010). The fitted regression line is weighted by the number of Indian firms in each 4-digit industry. The slope of the line is 0.44 and is statistically significant at the one percent level.

Figure 6: Electricity Intensity and Machine Intensity



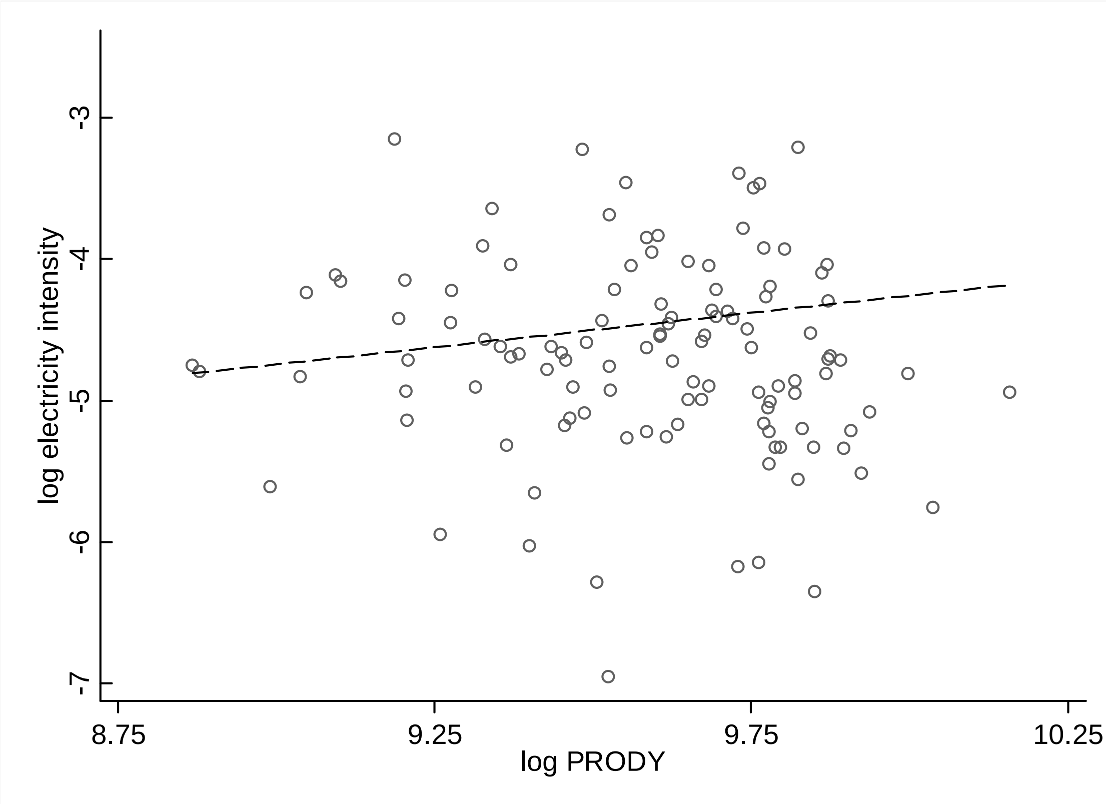
Notes: Data are from the ASI dataset. The fitted regression line is weighted by the number of Indian firms in each 5-digit industry. The slope of the line is 0.64 and is statistically significant at the one percent level.

Figure 7: Electricity Intensity and Labor Productivity



Notes: Data are from the ASI dataset. The fitted regression line is weighted by the number of Indian firms in each 5-digit industry. The slope of the line is 0.54 and is statistically significant at the one percent level.

Figure 8: Electricity Intensity and PRODY



Notes: Log electricity intensity (in rupees per kilowatt-hour) is calculated for 4-digit industries using the 1999 ASI data. Log PRODY is calculated using data from Hausmann, Hwang, and Rodrik (2006). The fitted regression line is weighted by the number of firms in each 4-digit industry. The slope of the line is 0.49 and is statistically significant at the five percent level.

Table 1: Electricity Prices Approved by Karnataka Electricity Regulatory Commission

Category of Consumer	Electricity Price (Rupees per kWh)	
Industrial	Up to 100,000 kWh	3.50
	100,001 kWh and above	3.75
Domestic	Up to 30 kWh	1.50
	31kWh to 100 kwH	2.55
	101kWh to 200 kwH	3.25
	201kWh to 300 kwH	3.75
	301kWh to 400 kwH	4.00
	401 kWh and above	4.25
Agricultural	All kWh	0.40

Notes: Data are from Karnataka Electricity Regulatory Commission (2002).

Table 2: Summary Statistics

	Less than 50 Employees	Between 50 and 100 Employees	100 or More Employees	All
Electricity used (GWh)	0.29	0.93	4.99	2.26
	(0.005)	(0.017)	(0.033)	(0.015)
Electricity bought (GWh)	0.27	0.84	4.04	1.85
	(0.005)	(0.016)	(0.028)	(0.013)
Electricity generated (GWh)	0.02	0.10	0.96	0.40
	(0.001)	(0.004)	(0.012)	(0.005)
Electricity generation dummy	0.29	0.46	0.61	0.44
	(0.002)	(0.003)	(0.002)	(0.001)
Electricity generated share	0.06	0.09	0.14	0.09
	(0.001)	(0.001)	(0.001)	(0.000)
Electricity price (Rs. Per kWh)	2.33	2.36	2.36	2.35
	(0.001)	(0.003)	(0.002)	(0.001)
Output (millions of Rs.)	21.0	74.4	371.0	168.0
	(0.3)	(1.0)	(2.4)	(1.0)
Number of workers	25	88	405	185
	(0.1)	(0.6)	(1.6)	(0.8)
Output per worker (millions of Rs. per worker)	0.74	0.87	0.90	0.82
	(0.01)	(0.01)	(0.01)	(0.00)
Machinery (millions of Rs.)	3.07	13.80	96.00	41.70
	(0.06)	(0.29)	(0.75)	(0.32)
Machine-labor ratio (millions of Rs. per worker)	0.10	0.16	0.23	0.16
	(0.003)	(0.003)	(0.002)	(0.002)
Capital-labor ratio (millions of Rs. per worker)	0.21	0.28	0.48	0.32
	(0.004)	(0.005)	(0.007)	(0.003)
No. of observations	71,514	21,473	61,863	154,850
No. of firms	26,844	6,858	12,001	45,703

Notes: Standard errors of the means are in parentheses. All monetary values are in 1994 rupees.

Table 3: Pre-Trends and Initial Thermal Share

	log difference in state GDP per capita (1998-1994)	log difference in state population (1998-1994)
	(1)	(2)
thermal share	-0.120	0.011
	<0.087>	<0.019>
No. of Observations	17	17

Notes: This table reports the coefficients from regressing the log difference in state characteristics on the thermal share of the state in 1998. Two of the states, Jharkhand and Chhattisgarh, were created in late 2000. The thermal share for these two states is as of 2003 since that is the earliest year for which data on installed generation capacity is available for these states. India's Ministry of Statistics and Programme Implementation provides estimates for state GDP per capita and population for these two states prior to 2000. The dependent variable in Column 1 is the change from 1994 to 1998 in the log of state GDP per capita. The dependent variable in Column 2 is the change from 1994 to 1998 in the log of state population. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors are in parentheses.

Table 4: First Stage Regression

	Dependent Variable: log(electricity price)		
	(1)	(2)	(3)
thermal share x log(coal price)	1.612***	0.597***	0.514***
	<0.433>	<0.132>	<0.100>
log(state GDP per capita)			-0.034*
			<0.017>
log(state population)			0.052
			<0.039>
value of firm coal consumption			0.0001
			<0.0001>
F-statistic (1st Stage Instrument)	13.89	20.46	26.61
No. of Observations	154,850	154,850	154,850
No. of Firms	45,703	45,703	45,703
Firm Effects	x	x	x
Region-Year Effects	x	x	x
State Time Trend		x	x

Notes: This table reports the coefficients from the first stage regression for the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level. The value of firm coal consumption is measured in millions of rupees.

Table 5: Effect of Electricity Price on Electricity Consumption

	OLS	OLS	Reduced Form	Reduced Form	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dep. Var.: log(electricity bought)						
log(electricity price)	-0.932***	-0.930***			-1.287***	-1.194**
	<0.020>	<0.020>			<0.475>	<0.576>
thermal share x log(coal price)			-0.768**	-0.613**		
			<0.283>	<0.289>		
Panel B. Dep. Var.: log(electricity used(bought + self-generated))						
log(electricity price)	-0.785***	-0.784***			-1.778***	-1.946***
	<0.019>	<0.019>			<0.476>	<0.522>
thermal share x log(coal price)			-1.061***	-1.000***		
			<0.233>	<0.240>		
Panel C. Dep. Var.: generation dummy						
log(electricity price)	0.01	0.007			-1.160***	-1.590***
	<0.010>	<0.010>			<0.327>	<0.552>
thermal share x log(coal price)			-0.692***	-0.817***		
			<0.184>	<0.250>		
Panel D. Dep. Var.: share of self-generated electricity						
log(electricity price)	0.060***	0.060***			-0.352*	-0.494**
	<0.005>	<0.005>			<0.182>	<0.202>
thermal share x log(coal price)			-0.210**	-0.254**		
			<0.091>	<0.097>		
No. of Observations	154,850	154,850	154,850	154,850	154,850	154,850
No. of Firms	45,703	45,703	45,703	45,703	45,703	45,703
Firm Effects	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x
State Time Trend	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of the dependent variables on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Table 4. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population.

Table 6: Effect of Electricity Price on Industry Switching

	OLS	OLS	Reduced Form	Reduced Form	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dep. Var.: firm changes 5-digit industry						
log(electricity price)	-0.002	-0.006			1.608***	1.844***
	<0.012>	<0.012>			<0.328>	<0.429>
thermal share x log(coal price)			0.866**	0.858**		
			<0.367>	<0.368>		
Panel B. First Stage. Dep. Var.: log(electricity price)						
thermal share x log(coal price)	0.538***	0.465***				
	<0.155>	<0.119>				
F-statistic (1st Stage Instrument)	12.08	15.19				
No. of Observations	104,517	104,517	104,517	104,517	104,517	104,517
No. of Firms	27,926	27,926	27,926	27,926	27,926	27,926
Firm Effects	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x
State Time Trend	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of an indicator variable for whether a firm changes its 5-digit industry on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Panel B. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population.

Table 7: Effect of Electricity Price on Industry Choice

	Dependent Variable: log(5-digit industry electricity intensity)					
	OLS	**OLS**	**Reduced Form**	**Reduced Form**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)
log(electricity price)	-0.016	-0.015			-0.254**	-0.272**
	<0.010>	<0.010>			<0.129>	<0.135>
thermal share x log(coal price)			-0.152*	-0.140*		
			<0.084>	<0.076>		
No. of Observations	154,850	154,850	154,850	154,850	154,850	154,850
No. of Firms	45,703	45,703	45,703	45,703	45,703	45,703
Firm Effects	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x
State Time Trend	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of the log of the electricity intensity of a firm's 5-digit industry on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Table 4. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population.

Table 8: Effect of Electricity Price on Average Product Electricity Intensity

	OLS (1)	OLS (2)	Reduced Form (3)	Reduced Form (4)	IV (5)	IV (6)
Panel A. Dep. Var.: log(average product electricity intensity)						
log(electricity price)	-0.015	-0.013			-0.711**	-0.734*
	<0.017>	<0.017>			<0.306>	<0.388>
thermal share x log(coal price)			-0.442**	-0.396**		
			<0.157>	<0.158>		
Panel B. Dep. Var.: log(weighted average product electricity intensity)						
log(electricity price)	-0.002	-0.002			-0.791***	-0.965***
	<0.016>	<0.016>			<0.297>	<0.367>
thermal share x log(coal price)			-0.492***	-0.520***		
			<0.128>	<0.124>		
Panel C. First Stage. Dep. Var.: log(electricity price)						
thermal share x log(coal price)	0.622***	0.539***				
	<0.130>	<0.105>				
F-statistic (1st Stage Instrument)	22.89	26.56				
No. of Observations	108,402	108,402	108,402	108,402	108,402	108,402
No. of Firms	33,483	33,483	33,483	33,483	33,483	33,483
Firm Effects	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x
State Time Trend	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of the log of the average electricity intensity of a firm's products on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Panel C. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population.

Table 9: Effect of Electricity Price on Machine Intensity, Output and Employment

	OLS	**OLS**	**Reduced Form**	**Reduced Form**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A .Dep. Var.: log(machine-labor ratio)						
log(electricity price)	-0.008	-0.01			-1.142**	-1.281*
	<0.025>	<0.025>			<0.571>	<0.727>
thermal share x log(coal price)			-0.682**	-0.658*		
			<0.289>	<0.317>		
Panel B. Dep. Var.: log(output)						
log(electricity price)	-0.027	-0.023			-1.977***	-2.113***
	<0.017>	<0.017>			<0.317>	<0.429>
thermal share x log(coal price)			-1.180***	-1.086***		
			<0.271>	<0.231>		
Panel C. Dep. Var.: log(employment)						
log(electricity price)	0.002	0.004			-0.613**	-0.687*
	<0.011>	<0.011>			<0.302>	<0.364>
thermal share x log(coal price)			-0.366	-0.353		
			<0.222>	<0.219>		
No. of Observations	154,850	154,850	154,850	154,850	154,850	154,850
No. of Firms	45,703	45,703	45,703	45,703	45,703	45,703
Firm Effects	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x
State Time Trend	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of the dependent variables on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Table 4. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population.

Table 10: Effect of Electricity Price on Productivity

	OLS	**OLS**	**Reduced Form**	**Reduced Form**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dep. Var.: log(output per worker)						
log(electricity price)	-0.028*	-0.027*			-1.364***	-1.426***
	<0.016>	<0.016>			<0.234>	<0.346>
thermal share x log(coal price)			-0.814***	-0.732***		
			<0.109>	<0.111>		
Panel B. Dep. Var.: log(TFP(OLS))						
log(electricity price)	-0.015	-0.013			-0.096	-0.052
	<0.017>	<0.017>			<0.071>	<0.103>
thermal share x log(coal price)			-0.057	-0.027		
			<0.040>	<0.053>		
Panel C. Dep. Var.: log(TFP(Olley-Pakes))						
log(electricity price)	-0.017*	-0.016*			-0.067	-0.017
	<0.009>	<0.009>			<0.130>	<0.165>
thermal share x log(coal price)			-0.04	-0.009		
			<0.078>	<0.087>		
No. of Observations	154,850	154,850	154,850	154,850	154,850	154,850
No. of Firms	45,703	45,703	45,703	45,703	45,703	45,703
Firm Effects	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x
State Time Trend	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of the dependent variables on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Table 4. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population. Details on the construction of the total factor productivity measures, log(TFP(OLS)) and log(TFP(Olley-Pakes)), are provided in Appendix A.

Table 11: First Stage Regression for Growth Regressions

	Dependent Variable: log(electricity price)		
	(1)	(2)	(3)
thermal share x log(coal price)	0.577***	0.556***	1.078***
	<0.162>	<0.169>	<0.316>
log(state GDP per capita)		-0.023	-0.095**
		<0.025>	<0.042>
log(state population)		0.052	-0.025
		<0.063>	<0.060>
value of firm coal consumption		0.0001	0.0001
		<0.0001>	<0.0001>
F-statistic (1st Stage Instrument)	12.74	10.87	11.61
No. of Observations	73,387	73,387	73,387
No. of Firms	17,675	17,675	17,675
Firm Effects	x	x	x
Region-Year Effects	x	x	x
State Time Trend	x	x	

Notes: This table reports the coefficients from the first stage regression for the growth regressions in Tables 12 and 13. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level. The value of firm coal consumption is measured in millions of rupees.

Table 12: Effect of Electricity Price on Output and Employment Growth

	OLS	**OLS**	**OLS**	**Reduced Form**	**Reduced Form**	**Reduced Form**	**IV**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Dep. Var.: output growth									
log(electricity price)	-0.017**	-0.017**	-0.028***				-0.865**	-0.894*	-0.754***
	<0.008>	<0.008>	<0.008>				<0.432>	<0.474>	<0.270>
thermal share x log(coal price)				-0.499**	-0.497**	-0.812***			
				<0.209>	<0.217>	<0.240>			
Panel B. Dep. Var.: employment growth									
log(electricity price)	-0.031**	-0.032**	-0.032**				0.093	0.116	0.037
	<0.013>	<0.013>	<0.013>				<0.443>	<0.467>	<0.267>
thermal share x log(coal price)				0.054	0.065	0.039			
				<0.272>	<0.278>	<0.304>			
No. of Observations	73,387	73,387	73,387	73,387	73,387	73,387	73,387	73,387	73,387
No. of Firms	17,675	17,675	17,675	17,675	17,675	17,675	17,675	17,675	17,675
Firm Effects	x	x	x	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x	x	x	x
State Time Trend	x	x		x	x		x	x	
Controls		x	x		x	x		x	x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of the dependent variables on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Table 11. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population. Each growth variable is defined as the log difference between the outcome at time t and time t-1, and the independent variable is the log of electricity price at time t-1.

Table 13: Effect of Electricity Price on Productivity Growth

	OLS	**OLS**	**OLS**	**Reduced Form**	**Reduced Form**	**Reduced Form**	**IV**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Dep. Var.: labor productivity growth									
log(electricity price)	0.015	0.015	0.003				-0.958**	-1.010**	-0.790***
	<0.014>	<0.014>	<0.013>				<0.390>	<0.420>	<0.176>
thermal share x log(coal price)				-0.553*	-0.562*	-0.851**			
				<0.275>	<0.273>	<0.321>			
Panel B. Dep. Var.: TFP(OLS) growth									
log(electricity price)	0.012	0.011	0.009				-0.948***	-0.925***	-0.507***
	<0.013>	<0.013>	<0.013>				<0.332>	<0.317>	<0.171>
thermal share x log(coal price)				-0.547***	-0.515***	-0.546***			
				<0.131>	<0.132>	<0.120>			
Panel C. Dep. Var.: TFP(Olley-Pakes) growth									
log(electricity price)	0.014	0.014	0.013				-0.908**	-0.892**	-0.484**
	<0.014>	<0.014>	<0.013>				<0.363>	<0.354>	<0.201>
thermal share x log(coal price)				-0.524**	-0.496**	-0.521***			
				<0.189>	<0.190>	<0.160>			
No. of Observations	73,387	73,387	73,387	73,387	73,387	73,387	73,387	73,387	73,387
No. of Firms	17,675	17,675	17,675	17,675	17,675	17,675	17,675	17,675	17,675
Firm Effects	x	x	x	x	x	x	x	x	x
Region-Year Effects	x	x	x	x	x	x	x	x	x
State Time Trend	x	x		x	x		x	x	
Controls		x	x		x	x		x	x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions of the dependent variables on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level except for the OLS regressions which cluster standard errors at the firm level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Table 11. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population. Details on the construction of the total factor productivity measures, TFP(OLS) and TFP(Olley-Pakes), are provided in Appendix A. Each growth variable is defined as the log difference between the outcome at time t and time t-1, and the independent variable is the log of electricity price at time t-1.

Table 14: Robustness of Results to Different Specifications

	IV	**IV**	**IV**	**IV**
	(1)	(2)	(3)	(4)
Panel A				
	Independent variable: log(electricity price)			
Dependent variables:				
log(electricity bought)	-1.194**	-1.194**	-1.117**	-1.117**
	<0.576>	<0.575>	<0.564>	<0.565>
log(electricity used(bought + self-generated))	-1.946***	-1.947***	-1.931***	-1.930***
	<0.522>	<0.522>	<0.528>	<0.528>
log(5-digit industry electricity intensity)	-0.272**	-0.272**	-0.281**	-0.281**
	<0.135>	<0.135>	<0.143>	<0.143>
log(machine-labor ratio)	-1.281*	-1.282*	-1.266*	-1.265*
	<0.727>	<0.726>	<0.739>	<0.740>
log(output)	-2.113***	-2.117***	-2.185***	-2.180***
	<0.429>	<0.428>	<0.462>	<0.464>
log(employment)	-0.687*	-0.689*	-0.719*	-0.717*
	<0.364>	<0.364>	<0.375>	<0.375>
log(output per worker)	-1.426***	-1.428***	-1.466***	-1.463***
	<0.346>	<0.346>	<0.366>	<0.366>
log(TFP(OLS))	-0.052	-0.051	-0.044	-0.045
	<0.103>	<0.103>	<0.103>	<0.103>
log(TFP(Olley-Pakes))	-0.017	-0.016	-0.014	-0.015
	<0.165>	<0.165>	<0.177>	<0.177>
Panel B: First Stage. Dep. Var.: log(electricity price)				
thermal share x log(coal price)	0.514***	0.514***	0.507***	0.507***
	<0.100>	<0.100>	<0.101>	<0.101>
F-statistic (1st Stage Instrument)	26.61	26.61	25.29	25.28
No. of Observations	154,850	154,850	154,850	154,850
No. of Firms	45,703	45,703	45,703	45,703
Firm Effects, Region-Year Effects, State Time Trend	x	x	x	x
Controls:				
log(state GDP per capita)	x	x	x	x
log(state population)	x	x	x	x
value of firm coal consumption	x			x
log(state plant load factor)			x	x

Notes: This table reports the coefficients from IV regressions of the dependent variables on the log of electricity price. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Panel B.

Table 15: Effect of Electricity Price for Sample Excluding Coal-Reliant Sectors

	IV	**IV**
	(1)	(2)
Panel A		
	Independent variable: log(electricity price)	
Dependent variables:		
log(electricity bought)	-1.549***	-1.518***
	<0.516>	<0.587>
log(electricity used(bought + self-generated))	-2.033***	-2.243***
	<0.481>	<0.486>
log(5-digit industry electricity intensity)	-0.386**	-0.437*
	<0.189>	<0.233>
log(machine-labor ratio)	-1.400**	-1.509*
	<0.602>	<0.773>
log(output)	-2.103***	-2.316***
	<0.307>	<0.451>
log(employment)	-0.452	-0.544
	<0.291>	<0.357>
log(output per worker)	-1.651***	-1.772***
	<0.232>	<0.383>
log(TFP(OLS))	-0.227**	-0.215**
	<0.088>	<0.097>
log(TFP(Olley-Pakes))	-0.185	-0.162
	<0.181>	<0.200>
Panel B: First Stage. Dep. Var.: log(electricity price)		
thermal share x log(coal price)	0.655***	0.575***
	<0.111>	<0.082>
F-statistic (1st Stage Instrument)	34.92	48.79
No. of Observations	127,605	127,605
No. of Firms	37,092	37,092
Firm Effects	x	x
Region-Year Effects	x	x
State Time Trend	x	x
Controls		x

Notes: This table reports the coefficients from IV regressions of the dependent variables on the log of electricity price. The sample excludes firms in coal-reliant sectors, namely the glass, ceramics and cement industry, the iron and steel industry, and the paper industry. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the state level. The log of electricity price is instrumented with the interaction between a state's thermal share and the log of coal price. The results of the first stage regressions are reported in Panel B. Control variables include the value of coal used by the firm, the log of state GDP per capita and the log of state population.

A Appendix: Data

A.1 States Classified as Industrially Backward in the ASI

The population of factories covered by the ASI is divided into two categories: a census sector and a sample sector. The census sector consists of all large factories and all factories in states classified as industrially backward by the government. All the factories in the census sector are surveyed each year. A third of the remaining factories which make up the sample sector are randomly selected each year for the survey. For the 2001 to 2005 surveys, large factories were defined as those with 200 or more workers. From the 2006 survey onwards, the definition was changed to those with 100 or more workers. For the 2001 to 2004 surveys, twelve states were classified as industrially backward. These states are Himachal Pradesh, Jammu and Kashmir, Manipur, Meghalaya, Nagaland, Tripura, Puducherry, Andaman and Nicobar Islands, Chandigarh, Goa, Daman and Diu, Dadra and Nagar Haveli. From the 2005 survey onwards, only 5 states were classified as industrially backward. These states are Manipur, Meghalaya, Nagaland, Tripura, and Andaman and Nicobar Islands.

A.2 State-Level Variables

The state-level variables used in my analysis are the state gross domestic product, state population and the plant load factor of thermal power plants in the state. The gross domestic product and population data are from the Central Statistics Office, National Account section of the Ministry of Statistics and Programme Implementation's website (http://mospi.nic.in). The data on the plant load factor of thermal power plants are from the the 2001-2002 issue of the Annual Report on the Working of State Electricity Boards and Electricity Departments and the 2011-2012 issue of the Annual Report on the Working of State Power Utilities and Electricity Departments published by India's Planning Commission, and the Indiastat database (http://www.indiastat.com).

A.3 Regions

The country is divided into the following regions which are used for the region-year effects in the regressions: Northern comprising the states of Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan, Delhi and Chandigarh, Central comprising the states of Chhattisgarh, Uttarakhand, Uttar Pradesh and Madhya Pradesh, Eastern comprising the states of Bihar, Jharkhand, Orissa, and West Bengal, Western comprising the states of Goa, Gujarat, Maharashtra, Daman and Diu, and Dadra and Nagar Haveli, Southern comprising the states of Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Puducherry, and Northeastern comprising the states of Assam, Arunachal Pradesh, Manipur, Tripura, Mizoram, Meghalaya and Nagaland.

A.4 UK Electricity Intensity

The electricity intensities of the UK industries are calculated using data on industry-level electricity consumption from the UK Department of Energy and Climate Change (Department of Energy and Climate Change, 2011) and data on industry-level output from the UK Annual Business Inquiry (Office for National Statistics, 2010). The UK data are available at the 4-digit level of the SIC 2003 which is identical to the 4-digit level of the NACE Rev 1.1. I converted the SIC 2003 codes to the ISIC Rev. 3 codes (which are identical to India's NIC 1998 codes at the 4-digit level) using a concordance between the NACE Rev 1.1 and the ISIC Rev. 3 codes from the website of the United Nations Statistics Division (http://unstats.un.org).

A.5 Industry-Level PRODY

The PRODY data are obtained from Hausmann, Hwang, and Rodrik (2006). The data are available for products at the 6-digit level of the Harmonized System (HS). Using a concordance between the HS codes and the ISIC Rev. 3 4-digit industry codes from the World Bank's World Integrated Trade Solution (WITS) system, I calculate the PRODY for each 4-digit industry as the average of the PRODY values for the HS products within that industry.

A.6 Construction of TFP

I use two measures of TFP in my analysis. The first measure, log(TFP(OLS)), is the residual from industry-specific OLS regressions of the log of firm output on the logs of capital, labor and inputs. The regressions are run separately for each 2-digit industry. There are 23 2-digit industries. However, two 2-digit industries, industry 30 (manufacture of office, accounting and computing machinery) and industry 37 (recycling) have too few firm observations to allow for separate regressions. I therefore combine industry 30 with industry 29 (manufacture of machinery and equipment, not elsewhere classified) and industry 37 with industry 36 (manufacturing not elsewhere classified and manufacturing of furniture). I therefore estimate the OLS regressions separately for 21 2-digit industries.

The second measure of TFP, log(TFP(Olley-Pakes)), is constructed following a two-stage method proposed in Olley and Pakes (1996). Firms are assumed to use the following Cobb-Douglas production function:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + w_{it} + \eta_{it} \tag{A.1}$$

where y is the log of output for firm i at time t, k is the log of capital, l is the log of labor, m is the log of intermediate inputs and w and η are firm-specific productivity shocks. w is observed by the firm but not by the econometrician. The method in Olley and Pakes (1996) takes into account two sources of bias: the simultaneity between the unobserved firm-specific productivity shock and input choices and the sample selection bias induced by the relationship between the unobserved productivity shock and firms' exit decisions. Olley and Pakes (1996) show that investment, if non-zero, is strictly increasing in productivity. This monotonicity allows the investment function to be inverted to obtain an expression for the unobserved productivity shock variable. Therefore in the first stage, to address the simultaneity bias, I construct a proxy for the unobserved productivity shock as a third-order polynomial in firm investment and capital. This proxy is then included in a regression of the log of output on the logs of labor and intermediate inputs as follows:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \phi_{it} + \eta_{it} \tag{A.2}$$

where

$$\phi_{it} = \beta_0 + \beta_k k_{it} + f(i_{it},\, k_{it}) \tag{A.3}$$

$f(i_{it},\, k_{it})$ is a third-order polynomial in the log of investment, i_{it}, and the log of capital, k_{it}. The coefficients on the logs of labor and intermediate inputs are then obtained from an estimation of equation (A.2). In the second stage, two proxies are used to account for the sample selection bias. The first proxy is the predicted probability of survival estimated from a probit regression of firm survival on a third-order polynomial in firm investment and capital. The second proxy is the predicted value of ϕ_{it} defined as follows:

$$\hat{\phi}_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} \tag{A.4}$$

where $\hat{\beta}_l$ and $\hat{\beta}_m$ are the estimated coefficients on the log of labor and the log of intermediate inputs, respectively, from equation (A.2). The coefficient on the log of capital is then estimated in the regression equation below using non-linear least squares.

$$y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} = \alpha_0 + \beta_k k_{it} + g(\hat{P}_{it-1},\, \hat{\phi}_{it-1} - \beta_k k_{it-1}) + u_{it} \tag{A.5}$$

where g is a third-order polynomial in $\hat{P}_{it-1}$ (the predicted value of the survival probability) and $\hat{\phi}_{it-1} - \beta_k k_{it-1}$. I obtain the estimate of the coefficient on the log of capital, $\hat{\beta}_k$, and define TFP as follows:

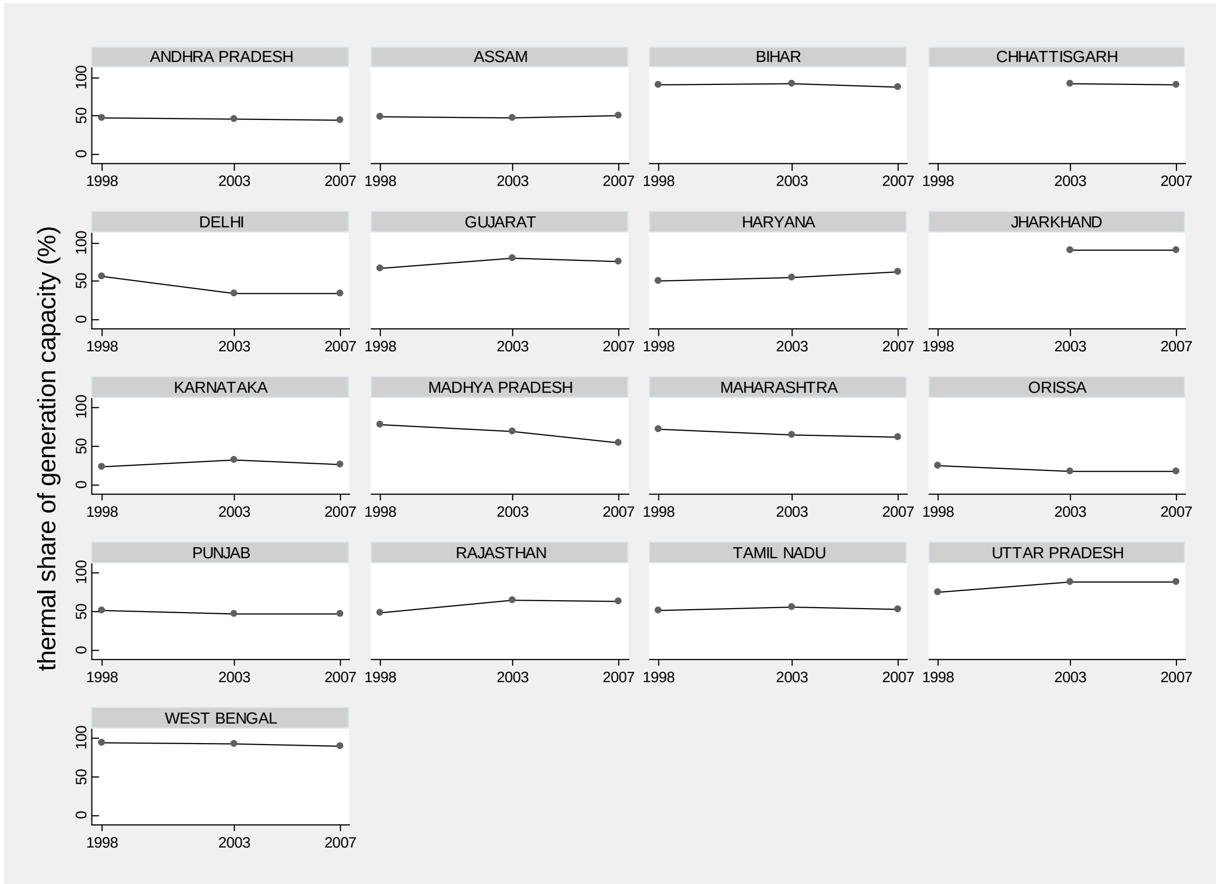
$$log(TFP_{it}) = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it} \tag{A.6}$$

The estimations for TFP using the Olley and Pakes (1996) method are also carried out separately for each 2-digit industry as was done for the measure of TFP obtained using

OLS regressions described above.

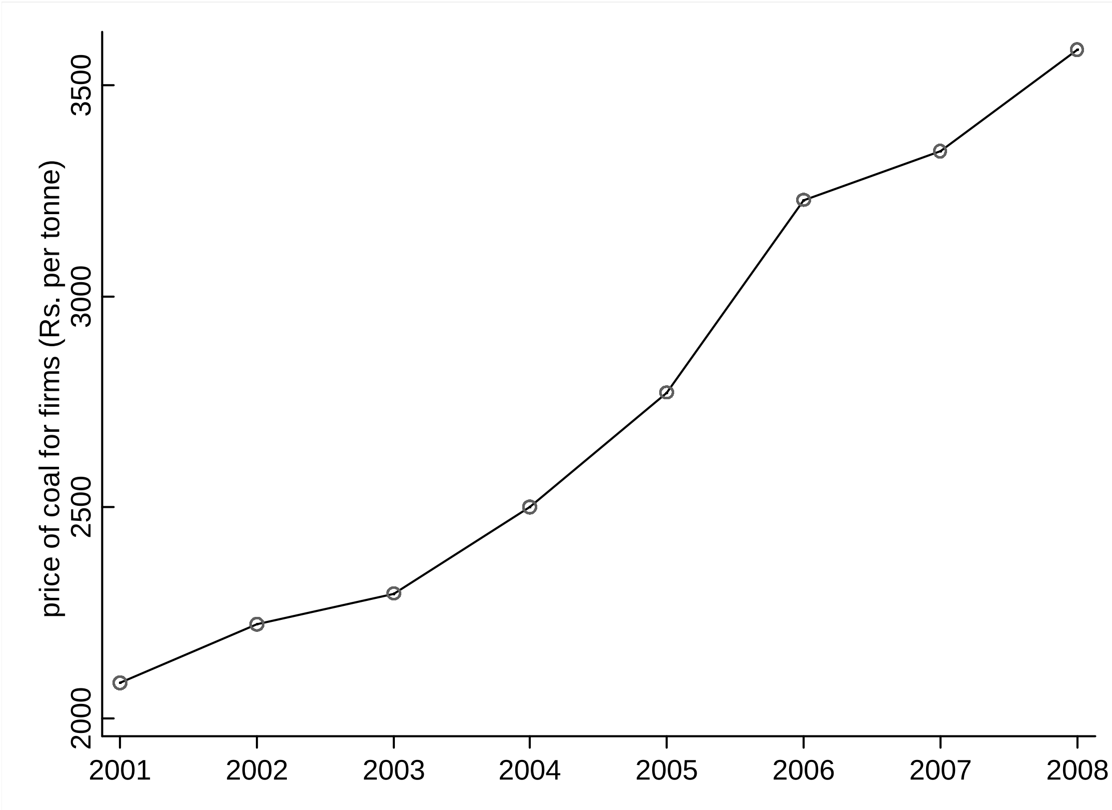
B Appendix: Figures and Tables

Figure B.1: States' Thermal Share of Generation Capacity



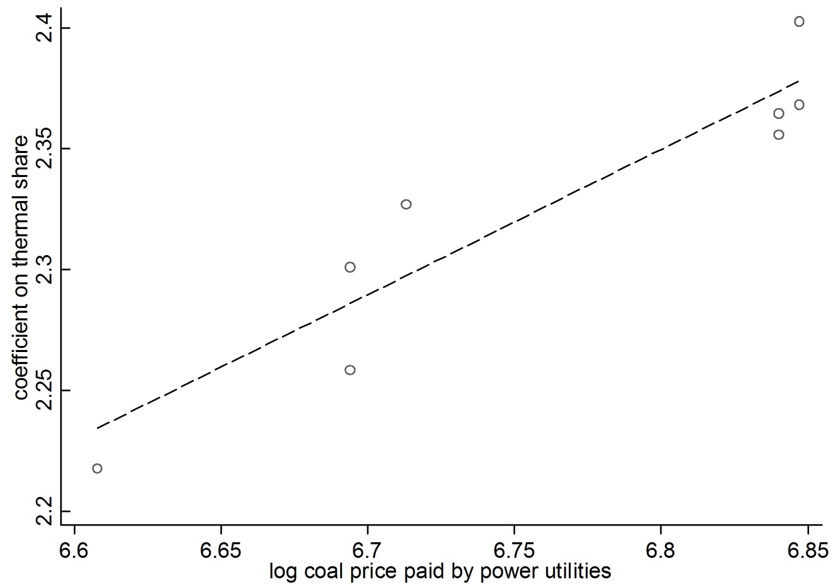
Notes: Data on installed generation capacity are from India's Ministry of Power's annual reports for 1997-1998, 2002-2003 and 2006-2007. For Jharkhand and Chhattisgarh, the earliest year for which data on installed generation capacity is available is 2003 since these states were created in late 2000.

Figure B.2: Price of Coal for Firms



Notes: Data are from the ASI dataset.

Figure B.3: Electricity Price-Thermal Share Correlations vs. Coal Price



Notes: This figure plots the coefficients from year by year regressions of the log of electricity price on thermal share against the log of the price of coal paid by power utilities. The dashed line is a fitted regression line.

Table B.1: Correlations Between Coal Price Changes and Political and Manufacturing Sector Characteristics

	election year dummy	share of seats held by Indian National Congress in parliament	growth in manufacturing output	growth in manufacturing employment
growth in coal price paid by power utilities	-0.19	-0.16	-0.22	-0.11

Notes: This table reports the correlation coefficients between the annual growth in the coal price paid by power utilities and the variables in the first row. The election year dummy is a dummy variable equal to one if presidential or parliamentary elections took place in India in a given year. The share of seats refers to the fraction of seats in parliament held by India's dominant political party, the Indian National Congress. Data on coal prices are from the 2010-2011 issue of the Coal Directory of India published by India's Ministry of Coal. Electoral data are from the Election Commission of India and the Rajya Sabha Secretariat. Data on manufacturing output and employment are from the Indian Ministry of Statistics and Programme Implementation and Ministry of Labour and Employment. Each growth variable is defined as the log difference between the variable at time t and time t-1.

Table B.2: NIC 1998 Industry 151

3-Digit Industry	4-Digit Industry	5-Digit Industry	Industry Description
151	**Production, processing and preservation of meat, fish, fruits, vegetables, oils and fats**		
	1511	*Production, processing and preserving of meat and meat products*	
		15111	Mutton-slaughtering, preparation
		15112	Beef-slaughtering, preparation
		15113	Pork-slaughtering, preparation
		15114	Poultry and other slaughtering, preparation
		15115	Preservation of meat except by canning
		15116	Processing and canning of meat
		15117	Rendering and refining of lard and other edible animal fats
		15118	Production of flours and meals of meat and meat offals
	1512	*Processing and preserving of fish and fish products*	
		15121	Sun-drying of fish
		15122	Artificial dehydration of fish and sea food
		15123	Radiation preservation of fish and similar food
		15124	Processing and canning of fish
		15125	Manufacturing of fish meal
		15126	Processing and canning of froglegs
		15127	Processing and preserving of fish crustacean and similar foods
	1513	*Processing and preserving of fruit and vegetables*	
		15131	Sun-drying of fruit and vegetables
		15132	Artificial dehydration of fruit and vegetables
		15133	Radiation preservation of fruit and vegetables
		15134	Manufacturing of fruit/vegetable juices and their concentrates, squashes and powder
		15135	Manufacture of sauces, jams, jellies and marmalades
		15136	Manufacture of pickles, chutneys, murabbas etc.
		15137	Canning of fruit and vegetables
		15138	Manufacture of potato flour & meals and prepared meals of vegetables
		15139	Fruit and vegetables preservation n.e.c. (including preservation by freezing)
	1514	*Manufacture of vegetable and animal oils and fats*	
		15141	Manufacture of hydrogenated oils and vanaspati ghee etc.
		15142	Manufacture of vegetable oils and fats (excluding corn oil)
		15143	Manufacture of vegetable oils and fats through solvent extraction process
		15144	Manufacture of animal oils and fats
		15145	Manufacture of fish oil
		15146	Manufacture of cakes & meals incl. residual products, e.g. Oleostearin, Palmstearin
		15147	Manufacture of non-defatted flour or meals of oilseeds, oilnuts or kernels

Notes: Data from Indian 1998 National Industrial Classification.

Table B.3: Causes of Outages in Thermal Power Plants in India

Cause of Outage	Percentage of Total Kilowatt-Hours of Generation Lost							
	2001	2002	2003	2004	2005	2006	2007	2008
Main Equipment	34.0	34.8	37.6	34.2	30.5	27.7	29.1	31.0
Auxiliary Equipment	6.5	5.4	4.0	5.0	4.7	4.0	3.3	3.2
Reserve Shutdown	0.0	4.4	1.8	3.0	2.2	4.4	1.7	1.8
Other Forced Outages	10.1	7.9	10.9	10.2	12.7	11.9	15.1	15.6
Of which coal issues:								
Shortage of Coal	0.0	0.6	0.2	1.0	3.6	1.6	1.2	1.3
Coal Feeding Issues	0.4	0.4	0.3	0.2	0.1	0.4	0.3	2.0
Wet Coal	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0
Poor Quality Coal	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0
Miscellaneous Coal Issues	0.5	0.0	0.1	0.0	0.1	0.3	0.2	0.1
Total Coal Issues	0.9	1.1	0.8	1.5	4.1	2.2	1.9	3.3
Planned Maintenance	49.4	47.4	45.7	47.6	50.0	52.0	50.9	48.4
Total	100	100	100	100	100	100	100	100

Notes: The percentages are based on data from the 2000-2001 through 2007-2008 issues of the Review of the Performance of Thermal Power Stations published by India's Central Electricity Authority.