Essays on Firm Behavior in Developing Economies

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ABSTRACT

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The performance of firms is central to growth in developing economies. A burgeoning literature within development economics seeks to understand the behavior of firms in developing countries and the constraints to their performance. This dissertation explores two types of constraints - infrastructure-related constraints and trade-related constraints - faced by manufacturing firms in developing countries.

Despite the widely acknowledged importance of infrastructure for economic growth, there has been relatively little research on how infrastructure affects the decisions of firms. Electricity, in particular, is commonly cited by firms in developing countries as a major obstacle to their performance. In the first two chapters, I analyze the responses of firms to two types of electricity constraints, namely electricity prices and electricity shortages.

Chapter 1 provides evidence on how electricity prices affect a firm's industry choice and productivity growth using data on Indian manufacturing firms. 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.

Chapter 2 examines the impact of electricity shortages on firm investment. I identify this impact by studying an electricity rationing program that took place in Ghana in 1998, which placed significant constraints on the electricity available to firms. Using data on Ghanaian manufacturing firms, I find a significant decline in investment in plant and machinery during the electricity rationing period. The decline in investment is more pronounced for firms in electricity-intensive sectors. I explore alternative explanations for the reduction in investment during the electricity rationing period, including a contraction in firm credit access and economy-wide shocks unrelated to electricity constraints, and find no evidence in support of either explanation. The results, therefore, suggest that the reduction in investment during the electricity rationing period was due to the constraints on the availability of electricity. These findings highlight the potentially negative impact of the inadequate provision of electricity that frequently plagues developing countries. These electricity constraints can hinder growth in these countries by curbing investment by firms.

In Chapter 3, I turn to the investigation of the effect of a trade-related constraint. Until recently, most of the literature on firms engaged in international trade had largely focused on exporting, with little work on the role of imports in the behavior and performance of firms. Using data on Indonesian manufacturing firms, Chapter 3 analyzes the effect of a reduction in tariffs on imported inputs on the exporting activity of firms. I argue that a tariff reduction program in Indonesia, which generated exogenous variation in the tariffs imposed on imports of goods used by firms, had a positive effect on the exported share of output of firms. I explore the mechanisms underlying this positive effect and find that an increase in the use of imported inputs, facilitated by the reduction in input tariffs, generated an increase in the exported share of output of firms. I also find that this positive effect is stronger for firms in industries with a greater scope for quality differentiation and high skill intensity. These results suggest that input tariff liberalization, by increasing access to higher-quality inputs from abroad, allows firms to produce higher-quality products for export markets.

Table of Contents

List of Figures **iv**

List of Tables **vi**

Acknowledgements **viii**

Dedication **ix**

1 Electricity Cost and Firm Performance: Evidence from India **1**

1.1 Introduction 2

1.2 Electricity Sector in India 6

1.3 Data 9

1.4 Econometric Analysis 11

1.4.1 Empirical Strategy 11

1.4.2 First Stage Regression 16

1.4.3 Effect on Electricity Consumption 17

1.4.4 Effect on Industry Choice 19

1.4.5 Effect on Product Mix 22

1.4.6 Effect on Machine Intensity and Productivity 24

1.4.7 Effect on Firm Productivity Growth 25

1.4.8 Robustness Checks 27
1.5 Conclusion 28

2 The Effect of Electricity Shortages on Firm Investment: Evidence from Ghana **54**
2.1 Introduction 55
2.2 Ghana's 1998 Electricity Rationing Program 57
2.3 Data 59
2.4 Econometric Analysis 61
2.4.1 Empirical Strategy 61
2.4.2 Effect of Electricity Rationing on Investment 62
2.4.3 Alternative Hypotheses 63
2.5 Conclusion 66

3 Input Tariff Reductions, Imported Inputs and Exporting Activity **76**
3.1 Introduction 77
3.2 Indonesia's Tariff Reduction Program 80
3.3 Data 81
3.4 Econometric Analysis 82
3.4.1 Empirical Strategy 82
3.4.2 Input Tariff Reductions and Exports 86
3.4.3 Channels 86
3.4.4 2000 Input Shares 91
3.5 Conclusion 92

Bibliography **109**

A Electricity Cost and Firm Performance: Evidence from India **116**

A.1 States Classified as Industrially Backward in the ASI 116

A.2 State-Level Variables 117

A.3 Regions 117

A.4 UK Electricity Intensity 118

A.5 Industry-Level PRODY 118

A.6 Construction of TFP 118

B Input Tariff Reductions, Imported Inputs and Exporting Activity **128**

B.1 Construction of TFP 128

List of Figures

1.1 States' Thermal Share of Generation Capacity and Indian Coal Reserves . . 31
1.2 Price of Coal for Power Utilities 32
1.3 Coal Consumption by Thermal Power Plants 33
1.4 Average Electricity Price for Different Categories of Users and Average Cost of Electricity Supply 34
1.5 Indian and UK Electricity Intensities 35
1.6 Electricity Intensity and Machine Intensity 36
1.7 Electricity Intensity and Labor Productivity 37
1.8 Electricity Intensity and PRODY 38

2.1 Top 10 Constraints to Firm Investment in Ghana 68
2.2 Electricity Consumption and Production (MWh) 69
2.3 Electricity Consumption (kWh per capita) 69

3.1 Output Tariffs 94
3.2 Output Tariffs by Industry 94
3.3 Industry Pre-Reform Growth and Output Tariff Changes 95
3.4 Industry Pre-Reform Growth and Input Tariff Changes 96

A.1 States' Thermal Share of Generation Capacity 122

A.2 Price of Coal for Firms 123
A.3 Electricity Price-Thermal Share Correlations vs. Coal Price 124

List of Tables

1.1 Electricity Prices Approved by Karnataka Electricity Regulatory Commission 39
1.2 Summary Statistics 40
1.3 Pre-Trends and Initial Thermal Share 41
1.4 First Stage Regression 42
1.5 Effect of Electricity Price on Electricity Consumption 43
1.6 Effect of Electricity Price on Industry Switching 44
1.7 Effect of Electricity Price on Industry Choice 45
1.8 Effect of Electricity Price on Average Product Electricity Intensity 46
1.9 Effect of Electricity Price on Machine Intensity, Output and Employment . . 47
1.10 Effect of Electricity Price on Productivity 48
1.11 First Stage Regression for Growth Regressions 49
1.12 Effect of Electricity Price on Output and Employment Growth 50
1.13 Effect of Electricity Price on Productivity Growth 51
1.14 Robustness of Results to Different Specifications 52
1.15 Effect of Electricity Price for Sample Excluding Coal-Reliant Sectors 53

2.1 Summary Statistics by Investing Status in 1991 70
2.2 Effect of Electricity Rationing on Investment 71

2.3 Effect of Electricity Rationing on Investment - Controlling for Credit Access (Formal) . . . 72
2.4 Effect of Electricity Rationing on Investment - Controlling for Credit Access (Formal and Informal) . . . 73
2.5 Effect of Electricity Rationing on Investment - Excluding Food Sectors . . . 74
2.6 Effect of Electricity Rationing on Investment - Placebo Rationing Periods . . 75

3.1 Indonesia Tariff Reduction Schedule . . . 97
3.2 Summary Statistics by Exporting and Importing Status in 1991 . . . 98
3.3 Effect of Input Tariffs on Exported Share of Output . . . 99
3.4 Effect of Input Tariffs on Exporting Status . . . 100
3.5 Effect of Input Tariffs on Imported Share of Inputs . . . 101
3.6 Effect of Using Imported Inputs on Exported Share of Output . . . 102
3.7 Effect of Using Imported Inputs by Industry Scope for Quality Differentiation 103
3.8 Effect of Using Imported Inputs by Industry Skill Intensity . . . 104
3.9 Effect of Using Imported Inputs on Product Switching . . . 105
3.10 Effect of Using Imported Inputs on Labor Productivity . . . 105
3.11 Effect of Using Imported Inputs on Total Factor Productivity . . . 106
3.12 First Stage Regressions (2000 Input Shares) . . . 107
3.13 Effect of Using Imported Inputs on Exported Share of Output (2000 Input Shares) . . . 108

A.1 Correlations Between Coal Price Changes and Political and Manufacturing Sector Characteristics . . . 125
A.2 NIC 1998 Industry 151 . . . 126
A.3 Causes of Outages in Thermal Power Plants in India . . . 127

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Dedication

For Ebo and my family.

Chapter 1

Electricity Cost and Firm Performance: Evidence from India

1.1 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

[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).

constraint (World Bank, 2006).[2] Although the Indian government has 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

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[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, 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).

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 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

[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.

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 interactions 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 1.2 provides a brief overview of the electricity sector in India. Section 1.3 describes the data. Section 1.4 outlines the empirical strategy and presents the results. Section 1.5 concludes.

1.2 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 1.1, 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 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 1.2 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 1.3 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 1.2, 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 1.3, although coal consumption

[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).

increased substantially between 2006 and 2008, coal prices remained fairly stable over this period, as shown in Figure 1.2. Also, in Table A1 in Appendix A, 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 1.1 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 1.4 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).

1.3 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

[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.

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 A2 in Appendix A 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 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

[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.

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 1.2 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).

1.4 Econometric Analysis

1.4.1 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

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

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 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 1.2, 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 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:

$$thermal\, share = \frac{generation\, capacity\, of\, power\, plants\, using\, coal}{generation\, capacity\, of\, all\, power\, plants} \tag{1.1}$$

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 1.4.2. 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

[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 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.

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 1.2, 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 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 1.2, 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 1.4.8 I redo my analysis with a sample that excludes the firms in these three sectors. Also, as discussed in Section 1.2, 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 1.2, 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 1.3 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:

$$y_{isrt} = \beta_0 + \beta_1 log(electricity\, price)_{isrt} + \beta_2 X_{isrt} + \beta_3 S_{st} + \lambda_i + \eta_{rt} + \delta_s t + \epsilon_{isrt} \qquad (1.2)$$

$$log(electricity\, price)_{isrt} = \alpha_0 + \alpha_1 thermal\, share_s * log(coal\, price_t) \qquad (1.3)$$
$$+\alpha_2 X_{isrt} + \alpha_3 S_{st} + \lambda_i + \eta_{rt} + \delta_s t + \mu_{isrt}$$

Equation (1.2) 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 (1.3) 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

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

an estimate of the change in an outcome for a given firm given a change in the electricity price paid by the firm.

1.4.2 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 equation (1.3) are presented in Table 1.4. 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 1.2, 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).

1.4.3 Effect on Electricity Consumption

Table 1.5 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 (1.2). 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 1.3, 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 1.3, 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 1.5, 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 1.5 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.

1.4.4 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 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

[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.

[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 1.5 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

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 1.6 reports the results from the regression of the indicator variable on the log of electricity price. These regressions have fewer observations than in Table 1.5 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 1.6. The coefficients on the instrument remain positive and statistically significant. In Table 1.6, 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]

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 1.7 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.

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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 1.6 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.

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 1.6. 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 1.7, 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 1.8 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 1.8 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.

1.4.5 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

[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.

that product.[18] A caveat here is that since single-product firms may differ fundamentally from multiple-product firms (see, for example, Bernard, Redding and Schott (2010) and Goldberg et al. (2010a)), 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 1.8 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 1.4.4 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 1.8, where the weights are the shares of each product in the firm's total output. In line with the result in Section 1.4.4, I find that firms are producing higher proportions of less electricity-intensive products in response to an increase

[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 1.8 are fewer than in Table 1.4 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 1.8.

in electricity price.

1.4.6 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 1.4.4 that firms switch to less electricity-intensive industries in response to high electricity prices. As shown in Section 1.4.4, 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 1.9. 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 1.9 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 1.10. As implied by the results for output and labor in Table 1.9, 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 1.10. 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 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.

1.4.7 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 1.4.4, 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

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

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 1.11. 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 1.12. 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 1.13. 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 1.13. 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.

1.4.8 Robustness Checks

In this section, I test the robustness of my results to different specifications. In Column 2 of Table 1.14, 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 1.14 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 A3 in Appendix A, 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 1.14 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 1.14, I include both the value of coal used by the firm and the log of the state-level plant load factor as control

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

variables. The results are again very similar to the original results.

An argument made in Section 1.4.1 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 1.15 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.

1.5 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,

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

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

[23]This estimate is from the coefficient from the IV regression of the log of output on the log of electricity price in Table 1.9.

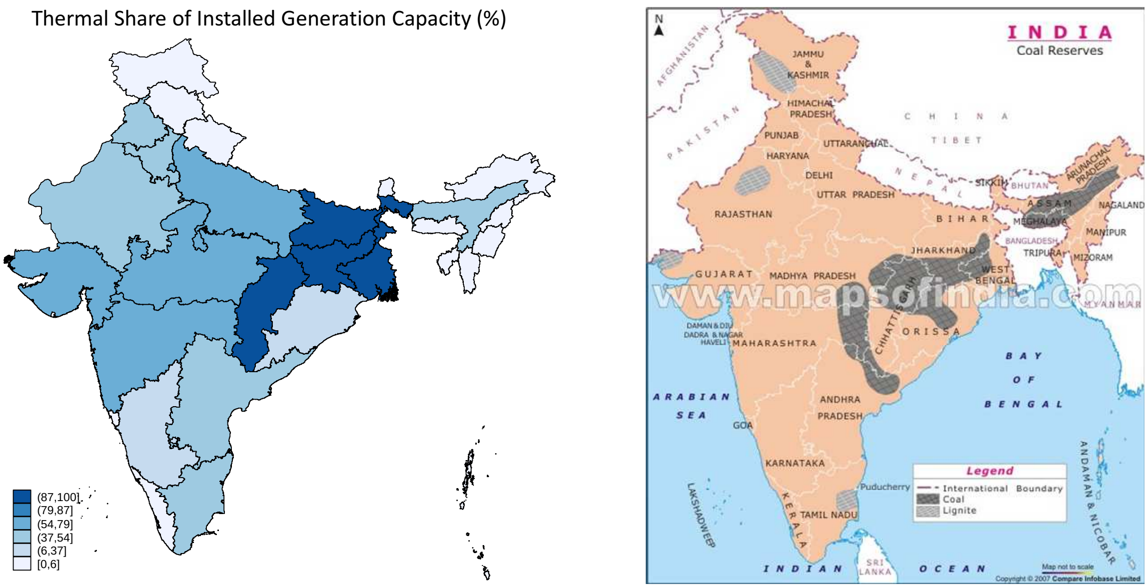
trillion rupees (Government of India, 2011c). The estimated 2.8 percent increase in output would have, therefore, meant an additional 200 billion rupees of output, which could easily have covered the 8.9 billion rupee reduction in subsidies.

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.

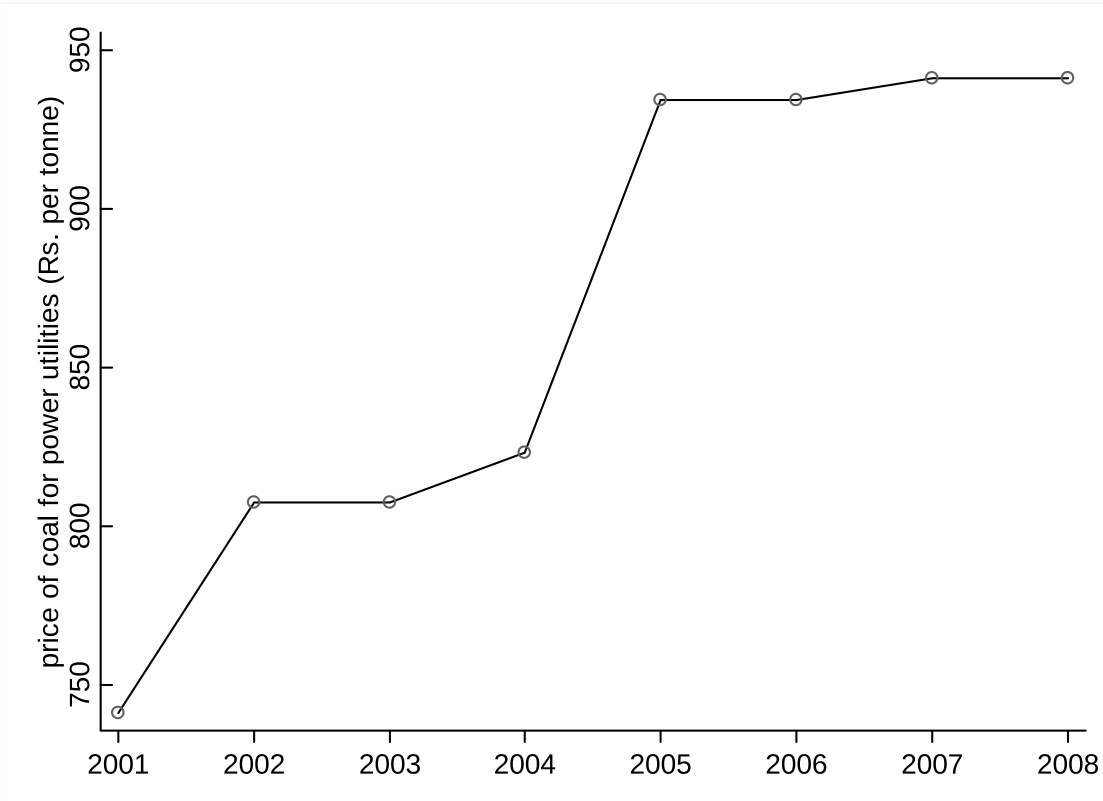
A limitation of my analysis is that I do not directly observe data on the technologies used by firms, which are generally absent from most firm-level datasets. Future data collection efforts could elicit such information from firms. Given the important role of technology in growth, such data would allow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

Figure 1.1: States' Thermal Share of Generation Capacity and Indian Coal Reserves



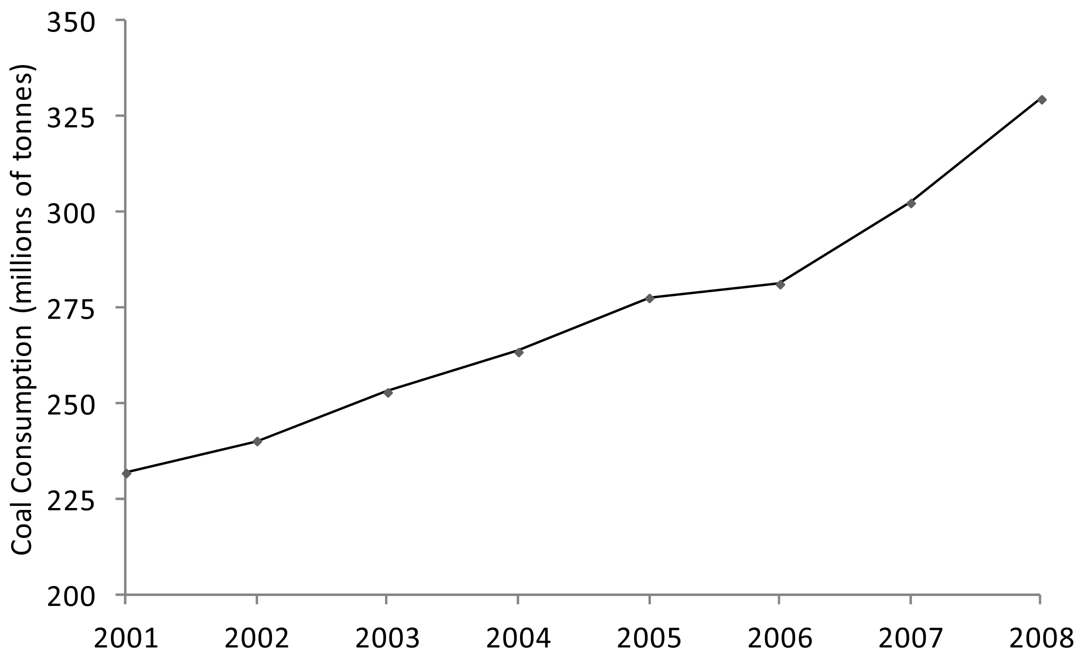
Notes: Data on installed generation capacity are from India's Ministry of Power's annual reports for 1997-1998 and 2002-2003. Map of coal reserves is from MapsofIndia.com (http://www.mapsofindia.com).

Figure 1.2: Price of Coal for Power Utilities



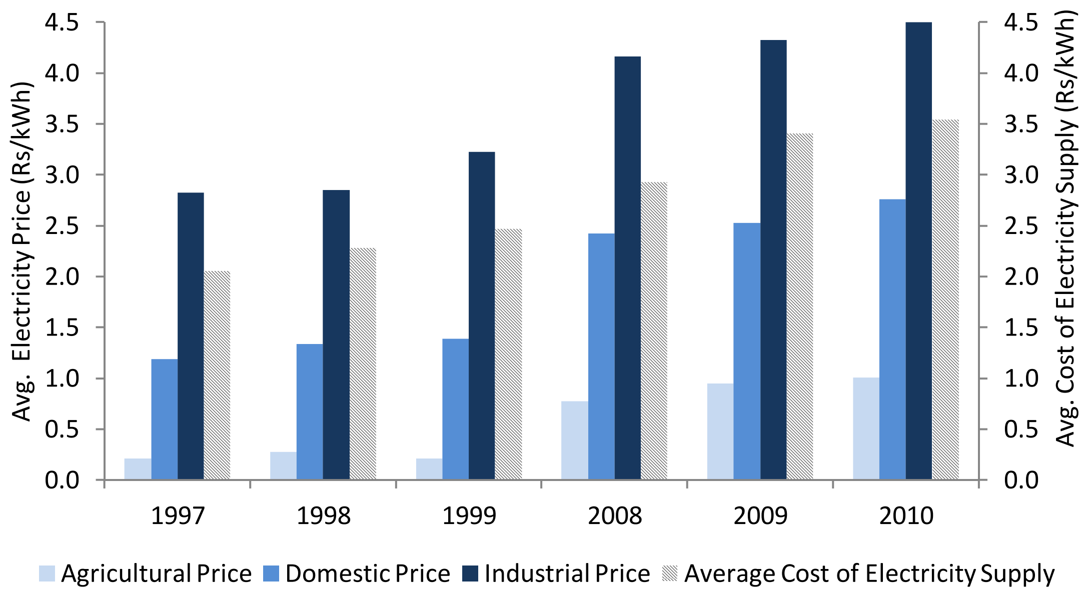
Notes: Data are from the 2010-2011 issue of the Coal Directory of India published by India's Ministry of Coal.

Figure 1.3: Coal Consumption by Thermal Power Plants



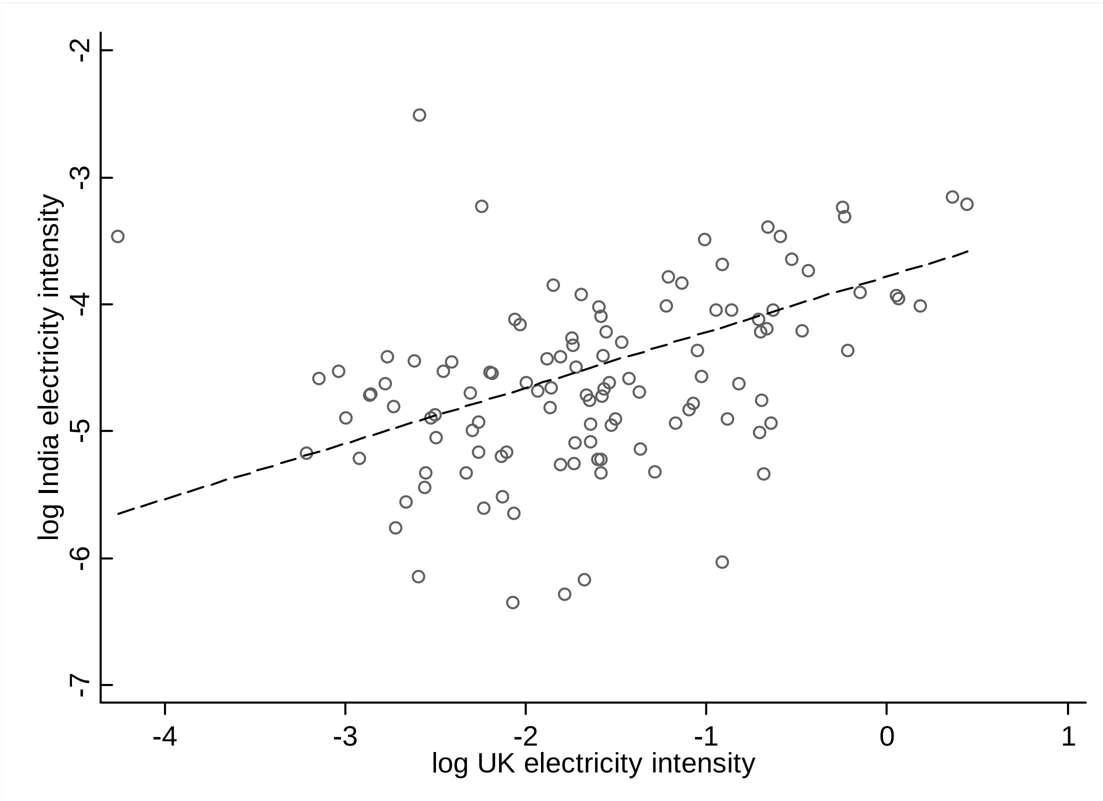
Notes: Data are from the 2002-2003, 2005-2006 and 2007-2008 issues of the Performance Review of Thermal Power Stations published by India's Central Electricity Authority.

Figure 1.4: Average Electricity Price for Different Categories of Users and Average Cost of Electricity Supply



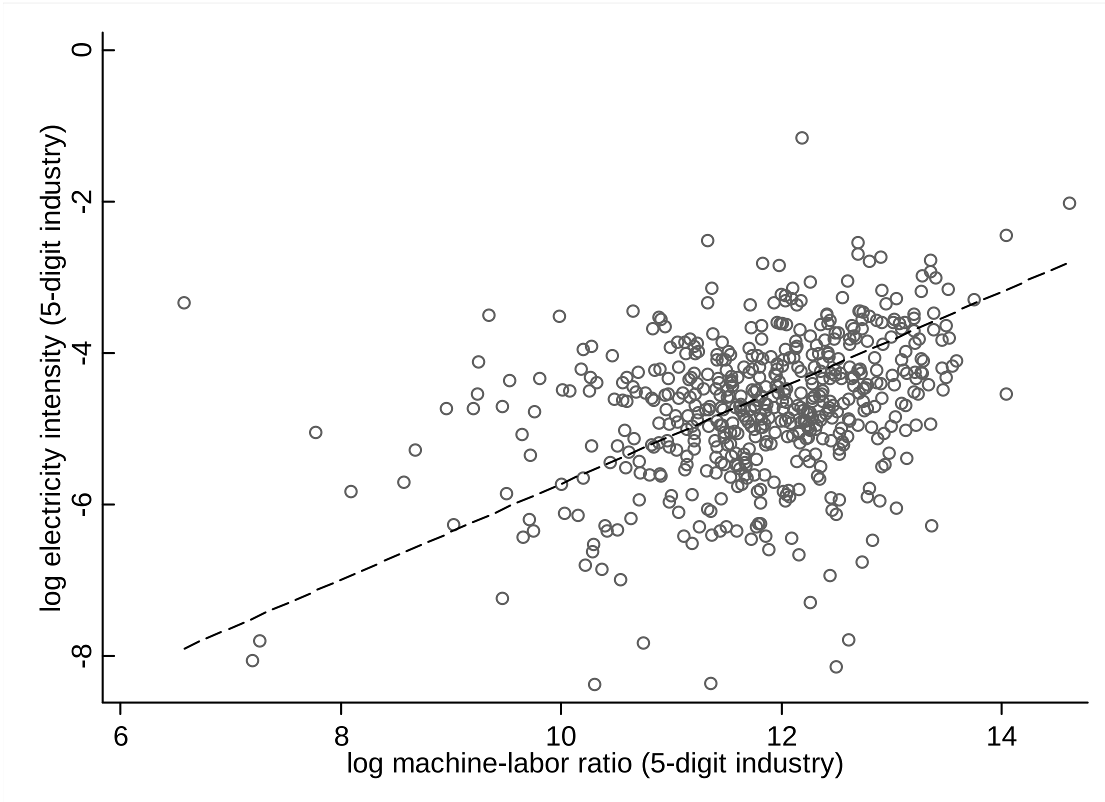
Notes: Data on electricity prices are from Government of India (1999, 2002, 2011a). Data on average cost of electricity supply are from the Indiastat database (http://www.indiastat.com).

Figure 1.5: Indian and UK Electricity Intensities



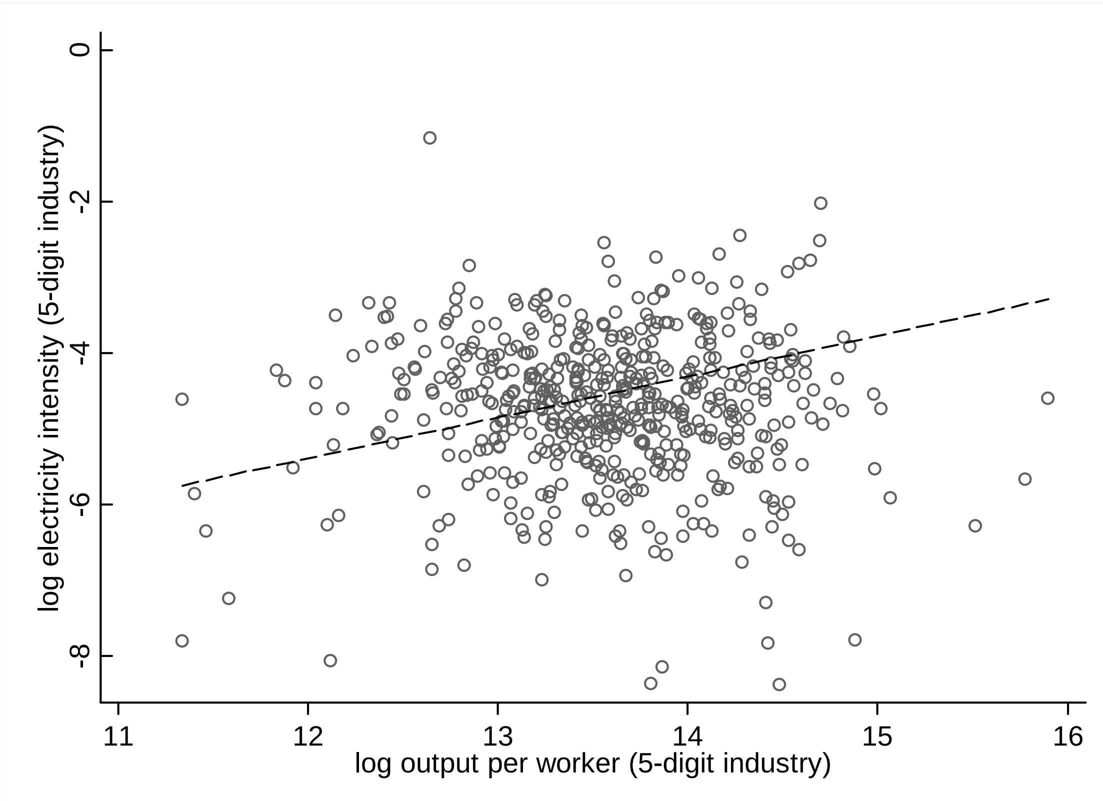
Notes: Log India electricity intensity (in rupees per kilowatt-hour) is calculated for 4-digit industries using the 1999 ASI data. Log UK electricity intensity (in pounds sterling per kilowatt-hour) is calculated for 4-digit industries using data from Department of Energy and Climate Change (2011) and 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 1.6: Electricity Intensity and Machine Intensity



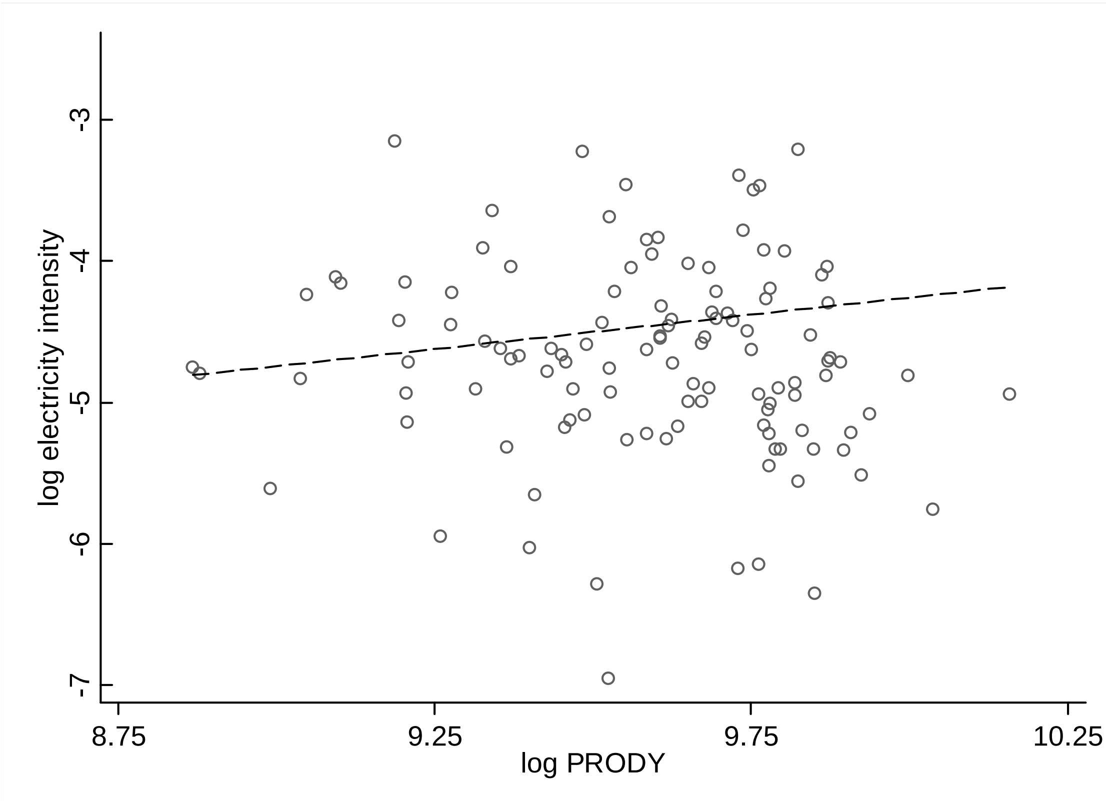
Notes: Data are from the ASI dataset. The fitted regression line is weighted by the number of Indian firms in each 5-digit industry. The slope of the line is 0.64 and is statistically significant at the one percent level.

Figure 1.7: 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 1.8: 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 1.1: 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 1.2: 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 1.3: 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 1.4: 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 1.5: Effect of Electricity Price on Electricity Consumption

	OLS (1)	OLS (2)	Reduced Form (3)	Reduced Form (4)	IV (5)	IV (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 1.6: 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 1.7: 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 1.8: Effect of Electricity Price on Average Product Electricity Intensity

	OLS	OLS	Reduced Form	Reduced Form	IV	IV
	(1)	(2)	(3)	(4)	(5)	(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 1.9: 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 1.10: Effect of Electricity Price on Productivity

	OLS (1)	OLS (2)	Reduced Form (3)	Reduced Form (4)	IV (5)	IV (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 1.11: 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 1.12: 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 1.13: 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 1.14: 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 1.15: 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.

Chapter 2

The Effect of Electricity Shortages on Firm Investment: Evidence from Ghana

2.1 Introduction

Lack of electricity is a pervasive problem in developing countries. An estimated 1.3 billion people worldwide are without electricity, over 95 percent of whom live in developing countries. In Africa alone, almost 600 million people lack electricity, representing approximately 60 percent of the continent's total population (IEA, 2011). Even in the areas where there is provision of electricity, this service is plagued by frequent interruptions. Manufacturing firms in Africa report an average of 56 days without electric power in a year (International Monetary Fund, 2008). In the 2007 World Bank Enterprise Survey, Ghanaian firms reported an average of approximately 10 power outages in a typical month (World Bank, 2007). Figure 2.1 shows the top ten constraints to firm investment in Ghana as reported in the World Bank 2007 Enterprise Survey. The top constraint was electricity. Almost 50 percent of the firms surveyed ranked electricity as the most severe obstacle to investment.

The goal of this paper is to provide empirical evidence of the effect of electricity outages on firm investment using data on manufacturing firms in Ghana and exploiting an electricity rationing program that took place in the country. A growing literature within development assesses the impact of electricity provision on firms (see, for example, Reinikka and Svensson (2002), Fisher-Vanden, Mansur and Wang (2012), Rud (2012a), Rud (2012b), Zuberi (2012) and Alby, Dethier and Straub (2013)).[1] This paper departs from the existing literature on the impact of electricity provision on firms in two ways.

First, investment has rarely been studied as an outcome variable in understanding how electricity shortages affect firms.[2] Since the low level of firm investment is often cited as one of the causes of the slow growth of developing countries, it is important to understand

[1]Some recent macroeconomic evidence also suggests that electricity outages in Sub-Saharan Africa have resulted in a substantial drag on economic growth (Andersen and Dalgaard, 2013).

[2]An exception is Reinikka and Svensson (2002).

how the frequent electricity shortages in these countries affect investment by firms. Second, few studies have examined the effect of electricity rationing programs. Most studies analyze the effect of electricity outages which tend to be unexpected and intermittent in nature and last for only a few hours at a time. Such outages are in contrast with electricity rationing programs which tend to be pre-announced and persist for an extended period of time, with outages lasting for several hours at a time. These electricity rationing programs are widespread and can last for as long as a year or more.[3]Since these electricity rationing programs are typically of longer duration relative to intermittent electricity outages, they have the potential to influence firm decisions that are based on a longer-term outlook such as investment decisions.

There are several mechanisms through which electricity shortages can affect investment. First, electricity outages affect the productivity of factors of production. Consider the case of an electric oven purchased by a bakery. Since this machine can only operate with electricity, without electricity its productivity is essentially zero. Since the investment decisions of firms are based on the productivity of capital, the reduction in productivity caused by electricity constraints reduces the incentive of firms to invest. Second, inadequate infrastructure may affect the durability of capital goods. For instance, frequent interruptions of electricity supply can damage electric machines. This reduced durability of capital goods may negatively affect the incentive to invest. Third, if production is depressed as a result of electricity outages, then these outages would have a negative effect on the present discounted value of the firm's expected profits and lead to lower investment.

The electricity rationing program I study in this paper occurred in Ghana in 1998. Under this program, consumers were supplied with electricity for only a portion of the day. The

[3]Countries that have experienced recent episodes of electricity rationing include Bangladesh, Brazil, Chile, China, Colombia, Ethiopia, Ghana, Kenya, Indonesia, the Philippines, South Africa, Tanzania, Togo, Uganda and Vietnam (Maurer, Pereira, and Rosenblatt, 2005; Heffner, Maurer, Sarkar, and Wang, 2010).

onset of this rationing program was unexpected and there was uncertainty about when it would come to an end. The rationing program therefore had the potential to influence the long-term outlook of firms and, hence, their investment decisions. Using data on Ghanaian manufacturing firms, I find that investment in plant and machinery by firms fell by about a third during the rationing period. A challenge with interpreting this result as being attributable to electricity constraints is that other factors besides the availability of electricity may have changed during the rationing period. I therefore explore other factors, including firm credit access and economy-wide shocks unrelated to electricity constraints, that may have potentially contributed to the fall in investment but find that they cannot explain the fall in investment. In addition, the decline in investment was more pronounced for firms in electricity-intensive sectors, suggesting that the reduction in investment was indeed driven by the constraints on the availability of electricity during the rationing period. The rest of the paper is organized as follows. Section 2.2 provides a brief description of the electricity rationing program in Ghana. Section 2.3 describes the data and provides some summary statistics. Section 2.4 outlines the empirical strategy and presents the results. Section 2.5 concludes.

2.2 Ghana's 1998 Electricity Rationing Program

The main source of electrical power in Ghana, until the late 1990s, was from government-owned hydro-electric power plants at the Akosombo and the Kpong dams, located on the Volta River in the southeastern part of the country. Together, they provided 1072 MW of installed generation capacity.[4] Total domestic consumption was steady at about 350MW until the early 1990s when the government embarked on nationwide electrification projects aimed at connecting more communities to the national electricity grid. By 1997, annual

[4]See Ghana's Volta River Authority at http://www.vra.com/.

demand for electrical consumption was growing at 15 percent per year. Of the total electricity output, about one-third was consumed by aluminum smelter, Volta Aluminum Company (VALCO), based on existing agreements with the government. Another 20 percent was consumed by the mining industry, leaving half the production capacity for residential, non-residential and industrial use.

Currently, an estimated 60 percent of Ghanaians have access to grid electricity.[5] All the regional capitals are connected to the public power grid. The firms in the dataset used in this study are all located in Accra, Kumasi, Takoradi and Cape Coast, which are all regional capitals.

Between 1997 and 1998 there was a severe drought in Ghana which caused the water level in the Akosombo dam to fall below the levels needed to generate enough electricity to meet the increasing demand. In the first quarter of 1998, total output from the hydro power plant and other sources had fallen by about 40 percent to 600MW. The drought and increased demand for electricity, coupled with the government's failure to retrofit existing power plants to produce at near-installed capacities, led to a severe energy crisis from late 1997 until the end of 1998.

The government subsequently embarked on a nationwide electricity rationing program, which lasted from September 1997 to November 1998, to avoid a complete shutdown of the Akosombo hydro-electric plant. Initially, the rationing schedule was such that households would be provided with 24 hours of electricity every other day. Industries would receive three continuous days of power supply and one day of no power. These schedules were later redesigned to be 12 hours with power and 12 hours without power each day for both households and industrial consumers. With these schedules, consumers would have access to electricity from 6am to 6pm and then no access from 6pm to 6am on some days. On other

[5] World Development Indicators, The World Bank (available at http://data.worldbank.org/data-catalog/world-development-indicators).

days they would have no access from 6am to 6pm and have access from 6pm to 6am.

The beginning of this rationing program was largely unexpected. There was also uncertainty regarding when the program would be terminated. The termination date was postponed on several occasions after being announced. Therefore, until the rationing program came to an end in November 1998, consumers were unsure about when it would end. Figures 2.2 and 2.3 plot the production and consumption of electricity in Ghana over the period 1991 to 2002.[6] The figures show a clear dip in both electricity production and consumption in 1998. Prior to 1998, electricity production had remained between 6 million and 7 million megawatt-hours, but dropped by about 20 percent to 5 million megawatt-hours in 1998.

As a result of the crisis, the government embarked on several initiatives to solve the crisis both in the short term and the long term. It expedited the construction of the Aboadze Thermal Plant which had been under construction for some time to provide an additional 330MW of power in 1999. It also negotiated deals with third party vendors to provide additional sources of electricity. Some other short term measures included re-negotiating the electricity import and export agreements with neighboring countries, including Ivory Coast.

2.3 Data

The results in this paper are based on data from the Ghanaian Manufacturing Enterprise Survey (GMES), which covers the period 1991 to 2002.[7] This dataset contains unbalanced panel data on a sample of firms in the Ghanaian manufacturing sector. The earlier rounds

[6] Note that the electricity production figures represent total gross electricity production as measured at the power plants and do not exclude transmission and distribution losses or the amount of electricity used in the power plants.

[7] The dataset is made available by the Center for the Study of African Economies (CSAE) at the University of Oxford. Financing for the surveys was from the Overseas Development Administration (now the Department for International Development).

of the survey were part of the World Bank's Regional Program on Enterprise Development (RPED). The later rounds were conducted by the University of Oxford together with the University of Ghana and the Ghana Statistical Office.

The original sample of firms, first surveyed in 1992, was randomly drawn from Ghana's 1987 Census of Manufacturing Firms. The sample was chosen so as to be representative of the size distribution of firms across the major sectors of the Ghanaian manufacturing industry. The sectors include the food, beverages, bakery, textile, garment, wood, furniture, machinery, and metal sectors. The firm size ranges from less than five employees to over 1,000 employees. The firms are located in Accra, Kumasi, Takoradi and Cape Coast. Firms that exited were replaced by firms of similar size and in the same sector and location. The firm-level variables available in the dataset include output, investment, capital stock and electricity expenditure.[8] All monetary values are deflated to 1991 cedis.

The investment measure used in the estimation is investment in plant and machinery. Investment in land and buildings is excluded as this type of investment tends to be infrequent and lumpy and poorly measured, and is also unlikely to be directly affected by electricity constraints. Table 2.1 reports some summary statistics for the firms in the dataset in 1991. As is typical in most developing countries, investment rates are low. Only about a third of firms invested in plant and machinery. The average investment rate was 0.04. For those firms that invested, the average investment rate was 0.11.

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[8]The data on electricity expenditure are available from 1992 onwards.

2.4 Econometric Analysis

2.4.1 Empirical Strategy

I identify the effect of electricity rationing by looking at how firm investment changed in the electricity rationing period relative to the periods without electricity rationing. The main estimating equation is

$$investment\,rate_{ijct} = \beta_0 + \beta_1 T + \lambda_i + \delta_c t + \pi_j t + \epsilon_{ijct} \quad (2.1)$$

where i, j, c and t index firm, sector, city and year, respectively. The investment rate is defined as the ratio of a firm's investment in plant and machinery to its output. T is a dummy variable equal to one if the year is 1998, the year in which the electricity rationing program took place, and zero otherwise. I include firm fixed effects, λ_i, to capture time-invariant firm characteristics that may affect investment decisions. I also include city time trends, $\delta_c t$, and sector time trends, $\pi_j t$, to account for unobserved differential trends across cities and sectors, respectively.

A concern with the empirical strategy is that there could have been other events in the rationing year, unrelated to electricity supply, that influenced firm investment. However, if any changes in investment during the rationing year are indeed due to the constraints on electricity supply, then these changes should be more evident for firms in sectors that are most reliant on electricity. To test this, I estimate the following equation which includes an interaction between the rationing period dummy variable and the electricity intensity of the firm's sector, and year effects, η_t.

$$investment\,rate_{ijct} = \alpha_0 + \alpha_1 T * log(electricity\,intensity)_j + \lambda_i + \delta_c t + \pi_j t + \eta_t + \epsilon_{ijct} \quad (2.2)$$

I define the electricity intensity of a sector as the average ratio of electricity expenditure to output for firms in that sector.[9] The coefficient of interest is α_1, which is the estimate of the impact of the electricity rationing program on investment for firms in the sectors that are most reliant on electricity.

2.4.2 Effect of Electricity Rationing on Investment

Table 2.2 presents estimates of equations (2.1) and (2.2). Column 1 reports estimates of equation (2.1) excluding city and sector time trends and year effects. The coefficient on the rationing period dummy is negative and statistically significant indicating that firm investment fell during the rationing period. The size of the coefficient suggests economically significant effects. The average firm investment rate is 0.04. Therefore, the coefficient of negative 0.012 indicates that investment fell by about a third during the rationing period. The decline in investment remains with the introduction of city and sector time trends in Column 2, although it is no longer statistically significant.

The coefficients reported in Columns 1 and 2, however, mask variation across sectors. As discussed in Section 2.4.1, the decline in investment during the rationing period may be attributable to changes in factors other than electricity supply. If the drop in investment in the rationing period is due to electricity constraints, then we should observe a larger decline for sectors with high electricity dependence.

To investigate this, I run the regression in equation (2.2) which includes an interaction between the rationing period dummy and the log of the electricity intensity of the firm's sector. The results from this regression, excluding year effects, are reported in Columns 3 and 4 of Table 2.2. The log of sector electricity intensity has been deviated from the

[9] I define the electricity intensity using data from 1992, the first year for which data on electricity expenditure are available, to avoid confounding effects from endogenous changes in sectors' electricity intensities over time. For the beverages sector, I use data from 1996 since this is the first year in which firms in this sector appear in the dataset.

overall mean. Therefore, the coefficient on the uninteracted term represents the change in investment for a firm in a sector with average electricity intensity. In line with the hypothesis that the fall in investment during the rationing period was a result of electricity rationing, the coefficient on the interaction between the rationing period dummy and the log of sector electricity intensity is negative and statistically significant across all specifications. Firms in more electricity-intensive sectors had greater reductions in investment during the rationing period.

2.4.3 Alternative Hypotheses

The analysis above provides evidence of a fall in investment during the rationing period. However, one might argue that the electricity rationing program may have had several effects on the economy, besides the direct effect on the availability of electricity, which may have driven the observed reduction in investment. The estimate of the coefficient on the interaction between the rationing period dummy and the electricity intensity of the firm's sector suggests that this reduction was more acute for firms in electricity-intensive sectors indicating that the observed effect on investment was due to constraints on the availability of electricity. Nonetheless, I perform further analyses to verify that the electricity constraint was the underlying cause of the fall in investment.

To capture economy-wide factors besides the electricity constraint that could have affected investment, I report regressions that include year effects in Column 5 of Table 2.2. The coefficient on the interaction between the rationing period dummy and sector electricity intensity is essentially unchanged. Therefore, even controlling for economy-wide shocks, firms in electricity-intensive sectors experienced a decline in investment during the rationing period.

Another potential explanation for the fall in investment is that the electricity crisis may have led to a contraction of credit, thereby reducing the ability of firms to borrow for investment. To address this concern, I make use of variables in the dataset related to a firm's credit access.[10] The first variable I use is a dummy variable equal to one if the firm applied for a loan from a formal institution such as a bank, credit union, government program or special loan facility and zero otherwise. If a reduction in credit access is the underlying cause of the fall in investment during the rationing period, then this fall may not be evident after controlling for credit access.

Columns 4 through 6 of Table 2.3 report the results from regressions that include the dummy variable for applying for a loan from a formal institution. Since the credit access variables were not available in 1991 and 1994, the sample size in Table 2.3 is smaller than in Table 2.2. For comparison purposes, I report the results from the main regressions for this smaller sample. The coefficients on the interaction between the rationing period dummy and sector electricity intensity in Columns 2 and 3 of Table 2.3 remain negative and statistically significant. The decline in investment during the rationing period for firms in electricity-intensive sectors is still evident even after controlling for whether the firm applied for a loan from a formal institution in Columns 4 through 6 of Table 2.3.

The survey also asked other questions related to the firm's credit access which allow me to further explore the credit access channel. For those firms that did not apply for a loan, the survey requested the reason for not applying for a loan. These reasons include "do not need a loan", "no collateral", "do not want to incur debt", "process too difficult", "did not think we would get a loan", "interest rate too high", "already heavily indebted", and "other". For those firms that applied for a loan, the survey asked whether the loan application was approved or rejected. I define as unconstrained those firms that did not apply for a loan because they did not need one or applied for a loan and were approved. Credit constrained

[10]The variables related to credit access are available for all years from 1991 to 2002, except 1991 and 1994.

firms are defined as firms that did not apply for a loan for reasons other than not needing one or applied for a loan and were rejected. Columns 1 through 3 of Table 2.4 present results from regressions including a dummy variable equal to one if the firm is unconstrained and zero otherwise. Again, the relationship between the rationing dummy and investment rate for firms in electricity-intensive sectors is preserved with the inclusion of this dummy variable.

Since firms in developing countries tend to also rely on informal sources of credit, the variables capturing access to credit from a formal institution may not fully reflect the credit access of firms. Fortunately, the survey also asked firms about their receipt of loans from informal sources such as friends, relatives, moneylenders and informal groups. In Columns 4 through 6 of Table 2.4, I control for a dummy variable equal to one if a firm received a loan from an informal source and zero otherwise. The results are robust to the inclusion of this variable. In sum, it does not appear that credit constraints were responsible for the fall in investment during the rationing period.

Finally, since the electricity crisis was brought on by a drought, one might expect that any contraction of agricultural output could have directly affected firms irrespective of limitations on electricity supply. Therefore, the observed reduction in investment may be driven by firms whose profitability was negatively affected as a result of their reliance on agricultural inputs. I explore this argument by redoing the analysis with a sample that excludes firms who are most likely to be reliant on agricultural inputs. The firms I exclude are those in the food, drinks, and bakery sectors. The results from the analysis with this restricted sample are reported in Table 2.5. The results are robust to the exclusion of firms in sectors that tend to rely on agricultural inputs. There is still evidence of a reduction in investment during the power rationing period for firms in electricity-intensive sectors.

As a further check of the results above, I rerun the analysis using placebo rationing periods. That is, I assume each of the years 1991 to 2002, other than the true period 1998, was the actual power rationing period. The results from these regressions are presented in Table 2.6. With the exception of 1998, the coefficients on the rationing dummy are all insignificant, with some of them being positive, that is opposite in sign to the coefficient in the true rationing period, 1998.

Finally, to my knowledge, the only other major change in the economic environment in Ghana in 1998, other than the electricity rationing program, was the reintroduction of the value-added tax (VAT) to increase the tax base and government revenue. This reintroduction followed a failed initial attempt in 1995. The initial introduction failed mainly because the public had not been adequately informed and educated about the new tax system, resulting in public riots, and because of delays in the passage of legislation related to the VAT. To avoid another failure, prior to the re-implementation of the VAT in December 1998, there were intensive and comprehensive education campaigns. Also, the legislation was enacted 10 months before implementation (World Bank, 2001). The reintroduction of the VAT in 1998 was widely expected and, hence, was not a sudden shock. In addition, the VAT was introduced at the very end of 1998 with collection of the VAT commencing on December 30, 1998. The reimplementation of this tax system should therefore not cause the decline in investment that is observed in the results. In any case, even if one were to argue that the VAT was in some way responsible for the drop in investment, it is implausible that it should have had a stronger effect on firms in more electricity-intensive sectors.

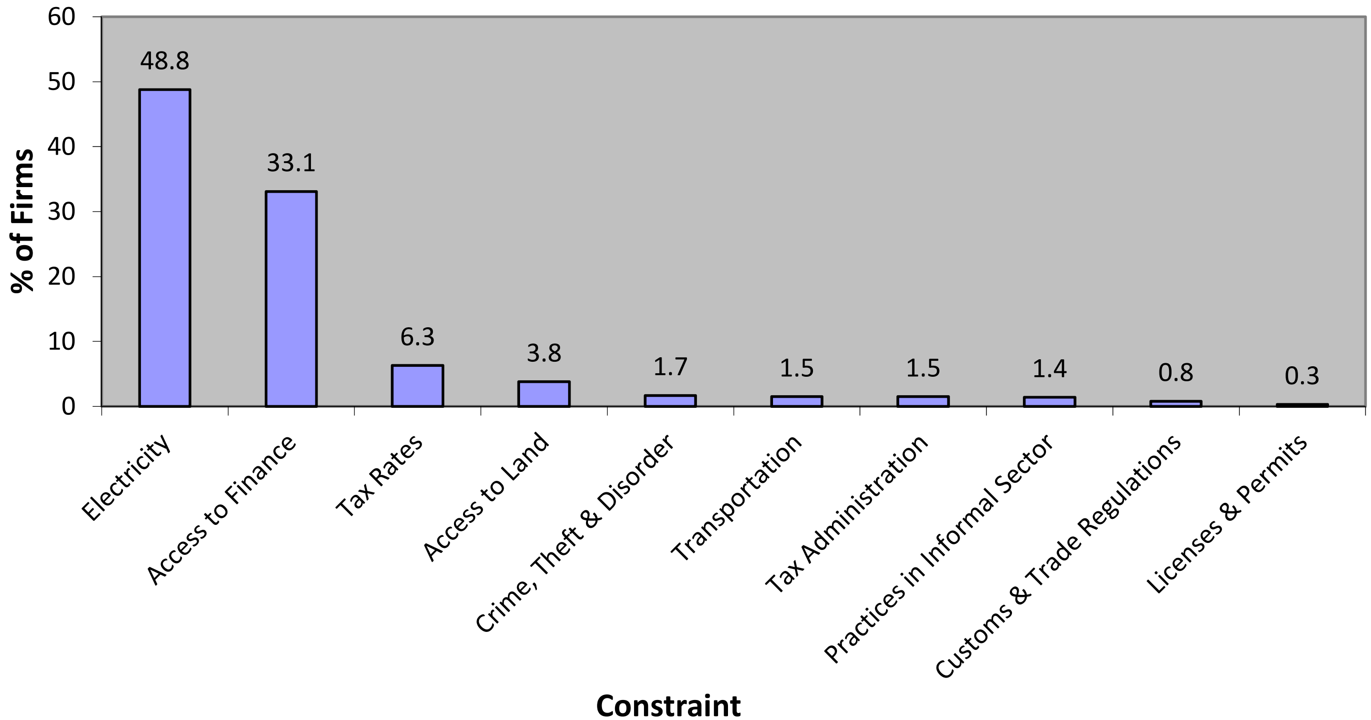
2.5 Conclusion

This paper uses data on Ghanaian manufacturing firms to examine the effect of electricity constraints posed by an electricity rationing program on firm investment. Electricity constraints can negatively affect firm investment through such channels as decreased productivity of capital, decreased durability of capital, and a reduction in expected future profits. I provide empirical evidence that investment in plant and machinery did fall during an electricity rationing program that took place in Ghana in 1998. I find that this reduction in investment was more pronounced for firms in more electricity-intensive sectors, in line with the argument that the restrictions on the availability of electricity during the rationing period led firms to curtail their investment.

I consider alternative explanations, other than electricity constraints, for the fall in investment during the rationing period. These alternative explanations include firm credit access and economy-wide shocks unrelated to electricity constraints. I find no evidence in support of either.

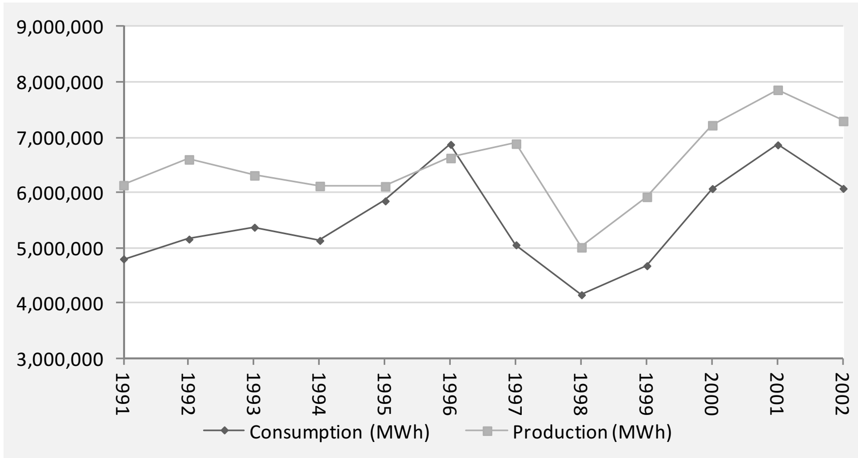
The findings of this paper are indicative of a potential role of infrastructure constraints in impeding growth in developing countries. In particular, electricity outages, which are common in developing countries, may hamper firm investment and prevent these countries from spurring economic growth through private sector investment.

Figure 2.1: Top 10 Constraints to Firm Investment in Ghana



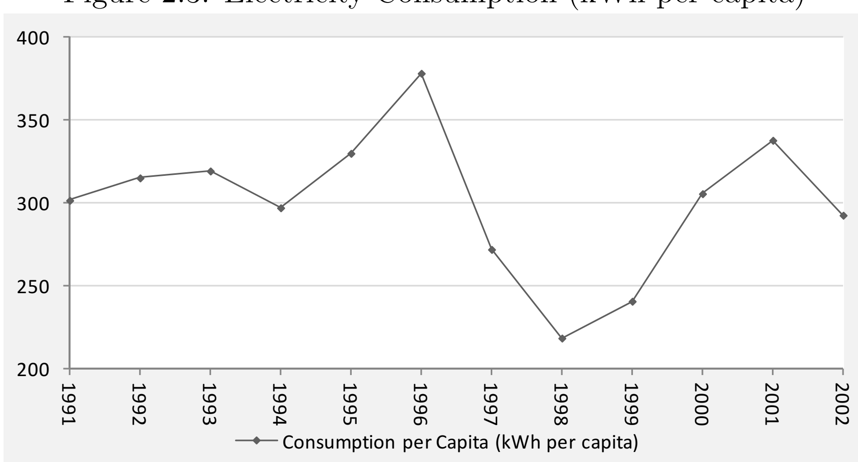
Notes: Data are from World Bank (2007). The numbers indicate the percentage of firms in the 2007 World Bank Enterprise Survey that selected the indicated constraint as the main obstacle to their investment.

Figure 2.2: Electricity Consumption and Production (MWh)



Notes: Data are from the World Bank's World Development Indicators database available at http://data.worldbank.org/data-catalog/world-development-indicators. The electricity production figures represent total gross electricity production as measured at the power plants and do not exclude transmission and distribution losses or the amount of electricity used in the power plants.

Figure 2.3: Electricity Consumption (kWh per capita)



Notes: Data are from the World Bank's World Development Indicators database available at http://data.worldbank.org/data-catalog/world-development-indicators.

Table 2.1: Summary Statistics by Investing Status in 1991

	Firms with Zero Investment	**Firms with Non-zero Investment**	**All Firms**
Investment rate		0.11	0.04
		<0.03>	<0.01>
Output (millions of cedis)	73.6	208.0	119.0
	<16.4>	<75.8>	<28.0>
Number of workers	42.3	54.2	46.3
	<9.9>	<14.2>	<8.1>
Number of firms	103	52	155

Notes: Standard errors of the means are in parentheses. All monetary values are in 1991 cedis. The investment rate is defined as the ratio of a firm's investment in plant and machinery to its output.

Table 2.2: Effect of Electricity Rationing on Investment

	(1)	(2)	(3)	(4)	(5)
	Dep. Var.: investment rate				
rationing dummy	-0.012*	-0.011	-0.012*	-0.011*	
	<0.006>	<0.007>	<0.006>	<0.006>	
rationing dummy*log(sector electricity intensity)			-0.017***	-0.014***	-0.014***
			<0.005>	<0.005>	<0.005>
No. of Observations	1,707	1,707	1,707	1,707	1,707
No. of Firms	207	207	207	207	207
Firm Effects	x	x	x	x	x
City Time Trend		x		x	x
Sector Time Trend		x		x	x
Year Effects					x

Notes: This table reports the coefficients from regressions for investment rate. The investment rate is defined as the ratio of a firm's investment in plant and machinery to its output. The rationing dummy is a variable equal to one if the year is 1998 and zero otherwise. Sector electricity intensity is defined as the average ratio of electricity costs to output value for firms in that sector and has been deviated from the overall mean. *** 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 firm level.

Table 2.3: Effect of Electricity Rationing on Investment - Controlling for Credit Access (Formal)

	(1)	(2)	(3)	(4)	(5)	(6)
	Dep. Var.: investment rate					
rationing dummy	-0.009	-0.01		-0.008	-0.009	
	<0.008>	<0.008>		<0.008>	<0.008>	
rationing dummy*log(sector electricity intensity)		-0.015***	-0.015***		-0.015**	-0.015**
		<0.006>	<0.006>		<0.006>	<0.006>
applied for a formal loan				0.016**	0.016**	0.014*
				<0.008>	<0.008>	<0.008>
No. of Observations	1,184	1,184	1,184	1,184	1,184	1,184
No. of Firms	186	186	186	186	186	186
Firm Effects	x	x	x	x	x	x
City Time Trend	x	x	x	x	x	x
Sector Time trend	x	x	x	x	x	x
Year Efects			x			x

Notes: This table reports the coefficients from regressions for investment rate. The investment rate is defined as the ratio of a firm's investment in plant and machinery to its output. The rationing dummy is a variable equal to one if the year is 1998 and zero otherwise. Sector electricity intensity is defined as the average ratio of electricity costs to output value for firms in that sector and has been deviated from the overall mean. The variable "applied for a formal loan" is a dummy variable equal to one if the firm applied for a loan from a formal financial institution (banks, non bank financial institutions (including credit unions), government programs and special loan facilities) and zero otherwise. *** 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 firm level.

Table 2.4: Effect of Electricity Rationing on Investment - Controlling for Credit Access (Formal and Informal)

	(1)	(2)	(3)	(4)	(5)	(6)
rationing dummy	-0.008	-0.009		-0.008	-0.009	
	<0.008>	<0.008>		<0.008>	<0.008>	
rationing dummy*log(sector electricity intensity)		-0.015***	-0.015***		-0.015**	-0.015**
		<0.006>	<0.006>		<0.006>	<0.006>
unconstrained in formal credit market	0.007	0.006	0.006	0.007	0.007	0.006
	<0.009>	<0.009>	<0.008>	<0.009>	<0.009>	<0.008>
borrowed from informal source				0.01	0.01	0.009
				<0.009>	<0.009>	<0.009>
No. of Observations	1,184	1,184	1,184	1,184	1,184	1,184
No. of Firms	186	186	186	186	186	186
Firm Effects	x	x	x	x	x	x
City Time Trend	x	x	x	x	x	x
Sector Time trend	x	x	x	x	x	x
Year Efects			x			x

Notes: This table reports the coefficients from regressions for investment rate. The investment rate is defined as the ratio of a firm's investment in plant and machinery to its output. The rationing dummy is a variable equal to one if the year is 1998 and zero otherwise. Sector electricity intensity is defined as the average ratio of electricity costs to output value for firms in that sector and has been deviated from the overall mean. The variable "unconstrained in formal credit market" is a dummy variable equal to one if the firm did not apply for a formal loan because it did not need one or applied for a formal loan and was approved and zero otherwise. The variable "borrowed from an informal source" is a dummy variable equal to one if the firm borrowed from an informal source (friends, relatives, moneylender, informal groups) and zero otherwise. *** 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 firm level.

Table 2.5: Effect of Electricity Rationing on Investment - Excluding Food Sectors

	(1)	(2)	(3)	(4)
	Dep. Var.: investment rate			
rationing dummy	0.001	-0.005		
	<0.007>	<0.006>		
rationing dummy*log(sector electricity intensity)		-0.029**	-0.029**	-0.033**
		<0.011>	<0.011>	<0.015>
unconstrained in formal credit market				0.001
				<0.009>
borrowed from informal source				0.012
				<0.010>
No. of Observations	1,296	1,296	1,296	907
No. of Firms	159	159	159	143
Firm Effects	x	x	x	x
City Time Trend	x	x	x	x
Setcor Time Trend	x	x	x	x
Year Effects			x	x

Notes: This table reports the coefficients from regressions for investment rate for a sample excluding firms in the food, beverages and bakery sectors. The investment rate is defined as the ratio of a firm's investment in plant and machinery to its output. The rationing dummy is a variable equal to one if the year is 1998 and zero otherwise. Sector electricity intensity is defined as the average ratio of electricity costs to output value for firms in that sector and has been deviated from the overall mean. The variable "unconstrained in formal credit market" is a dummy variable equal to one if the firm did not apply for a formal loan because it did not need one or applied for a formal loan and was approved and zero otherwise. The variable "borrowed from an informal source" is a dummy variable equal to one if the firm borrowed from an informal source (friends, relatives, moneylender, informal groups) and zero otherwise. *** 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 firm level.

Table 2.6: Effect of Electricity Rationing on Investment - Placebo Rationing Periods

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Assumed Rationing Period	**1991**[1]	**1992**	**1993**	**1994**[1]	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
						Dep. Var.: investment rate						
rationing dummy*log(sector electricity intensity)		-0.01	-0.003		0.002	0.014	0.004	-0.015**	0.003	-0.003	0.012	-0.017
		<0.010>	<0.006>		<0.012>	<0.009>	<0.006>	<0.006>	<0.011>	<0.006>	<0.012>	<0.017>
No. of Observations		1,184	1,184		1,184	1,184	1,184	1,184	1,184	1,184	1,184	1,184
No. of Firms		186	186		186	186	186	186	186	186	186	186
Firm Effects		x	x		x	x	x	x	x	x	x	x
City Time Trend		x	x		x	x	x	x	x	x	x	x
Sector Time Trend		x	x		x	x	x	x	x	x	x	x
Year Effects		x	x		x	x	x	x	x	x	x	x
Credit Controls		x	x		x	x	x	x	x	x	x	x

Notes: This table reports the coefficients from regressions for investment rate assuming the electricity rationing had taken place in the year indicated in the row labeled "Assumed Rationing Period". The actual year in which the electricity rationing took place is 1998. The investment rate is defined as the ratio of a firm's investment in plant and machinery to its output. The rationing dummy is a variable equal to one if the year is the assumed rationing period and zero otherwise. Sector electricity intensity is defined as the average ratio of electricity costs to output value for firms in that sector and has been deviated from the overall mean. Credit control variables include "unconstrained in formal credit market" (a dummy variable equal to one if the firm did not apply for a formal loan because it did not need one or applied for a formal loan and was approved and zero otherwise) and "borrowed from an informal source" (a dummy variable equal to one if the firm borrowed from an informal source (friends, relatives, moneylender, informal groups) and zero otherwise). *** 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 firm level.

[1] The years 1991 and 1994 are excluded since the control variables, "unconstrained in formal credit market" and "borrowed from an informal source", are not available for these years.

Chapter 3

Input Tariff Reductions, Imported Inputs and Exporting Activity

3.1 Introduction

Several countries have embarked on tariff reform programs in recent years, significantly reducing barriers to trade. While most of the empirical literature on trade barriers had previously focused on the impact of reductions in final goods tariffs on firm performance, a growing strand of literature has started to address the potential impact of the reduction of tariffs on inputs used by firms (see, for example, Schor (2004), Muendler (2004), Amiti and Konings (2007), Topalova and Khandelwal (2011), Halpern, Koren and Szeidl (2011) and Bas (2012)). Trade in intermediate goods has been on the rise. Imports of intermediate goods account for about 40 percent of total non-fuel merchandise imports worldwide. In Indonesia, the context for this study, this figure is about 60 percent (WTO, 2009). Thus the reduction of tariff barriers, besides increasing competition from foreign varieties of firms' final goods, has the potential to affect firms via an impact on the the tariffs of intermediate goods used by firms.

The bulk of the literature on input tariffs documents the effect of a reduction in input tariffs on firm productivity (see, for example, Schor (2004), Muendler (2004), Amiti and Konings (2007), Topalova and Khandelwal (2011) and Halpern, Koren and Szeidl (2011)).[1] While most of the evidence suggests that a reduction in input tariffs has a positive effect on productivity, some papers find no evidence of this positive link (see, for example, Muendler (2004)). Given the problems inherent in standard measures of productivity (Foster, Haltiwanger and Syverson, 2008; Katayama, Lu and Tybout, 2009), I investigate an outcome, exporting, that is easily measurable and, hence, can also be more easily targeted by policymakers.

Theoretically, there are several channels through which a reduction in input tariffs could

[1] Another set of papers examines complementarities between firm productivity and the use of high quality inputs from abroad (Blaum, Lelarge and Peters, 2013; Eslava, Fieler and Xu, 2013).

affect exporting activity. It has been documented that only the most productive firms become exporters, in line with the hypothesis that the existence of high fixed export costs allows only the most productive firms to enter the export market (Clerides et al., 1998; Bernard and Jensen, 1999; Melitz, 2003). Consequently, if, as suggested by the existing literature, a fall in input tariffs boosts productivity, the reduction in input tariffs may allow firms to increase their exporting activity.

In addition, most of the studies on the effect of input tariff reductions on productivity posit that the underlying mechanism is an increase in access to foreign inputs resulting from a reduction in the cost of purchasing foreign inputs. Increased access to imported inputs as a result of input tariff reductions can affect firm exporting activity through several channels. One such channel is the productivity channel whereby the gain in productivity from using imported inputs (Kasahara and Rodrigue (2008); Kasahara and Lapham (2013)) allows firms to enter the export market. Another channel is the quality channel. There is evidence that imported inputs tend to be of higher quality than inputs available domestically in developing countries (Kugler and Verhoogen, 2009). This evidence, coupled with the evidence that firms that produce higher-quality goods tend to export more (Crozet, Head, and Mayer, 2011), suggests that the availability of imported inputs may allow firms to increase their exports. In addition, the effect of increased access to imported inputs on exporting activity could operate via a variety channel. Access to imported inputs may increase the varieties of inputs available to firms and allow the creation of new products (Goldberg et al., 2010b; Choi and Hahn, 2009) which could then be sold on the export market.

In this paper, I use firm-level data from Indonesia to analyze whether a reduction in input tariffs affects firms' exports and investigate potential channels through which an effect might occur. I exploit a tariff reduction program introduced in Indonesia in 1995 that generated exogenous variation in tariffs across industries. I find that the reduction in tariffs on inputs used by firms resulted in an increase in their exported share of output. I then investigate if the effect on exports occurs as a result of increased access to imported inputs. To carry out this analysis, I employ the input tariff faced by a firm's industry as an instrument for the firm's imported share of inputs. I find that a reduction in input tariffs does result in an increase in the imported share of inputs. Using the input tariff as an instrument for the imported share of inputs in an instrumental variables (IV) setting, I show that an increase in the imported share of inputs leads to an increase in the exported share of output of firms.

To further analyze the channels through which access to foreign inputs, facilitated by a decline in input tariffs, affects firm exports, I examine the heterogeneity of this effect by the scope for quality differentiation and skill intensity of the firm's industry. The results indicate that the positive effect of using imported inputs on the exported share of output increases with the industry's scope for quality differentiation and skill intensity. I interpret these results as being supportive of the quality channel hypothesis, whereby access to higher quality inputs from abroad allows firm to produce higher-quality goods for the export market. On the other hand, contrary to the productivity and variety channels, I find no evidence of a positive relationship between the use of imported inputs and firm productivity or the propensity of firms to switch their main product.

This paper is closely related to recent papers by Bas (2012) and Bas and Strauss-Kahn (2010). Bas (2012) finds that the probability of entering the export market is higher for Argentinean firms in industries that experience greater reductions in input tariffs. In contrast, in this paper, I go beyond the reduced-form effect of input tariff reductions on exports by exploring the channels through which this effect occurs. I am able to show a direct link between exporting activity and the use of imported inputs by firms, brought about by reductions in input tariffs, and further provide evidence that this link appears to be driven by the higher quality of imported inputs. Using data on French firms, Bas and Strauss-Kahn (2010) find that firms that use a higher number of imported input varieties also have a higher number of export varieties. Relative to their paper, I am able to make use of Indonesia's tariff reduction program in an IV strategy to arguably better establish a causal relationship between the use of imported inputs and exporting. Another closely related paper that came out concurrently with this paper is Feng, Li, and Swenson (2012). They show that Chinese firms that increased their use of imported inputs also increased their exports. The rest of the paper is organized as follows. Section 3.2 provides a brief overview of the 1995 tariff reduction program in Indonesia. Section 3.3 describes the data I use in my analysis and provides some summary statistics. Section 3.4 outlines the empirical strategy and presents the results. Section 3.5 concludes.

3.2 Indonesia's Tariff Reduction Program

Indonesia committed to liberalizing trade with the creation of the World Trade Organization (WTO), of which the country was a founding member, in January 1995. As a member of the WTO, the country agreed to reduce the upper bound of tariffs for almost all products to 40 percent or less. Under this agreement, the country could not impose a tariff greater than 40 percent on affected imports from any member country of the WTO. As part of efforts to improve the economy's efficiency, the Indonesian government introduced a tariff reduction program in May 1995 that significantly surpassed its commitments under the WTO (World Trade Organization, 1998). The government announced a tariff reduction schedule under which tariffs on most goods would be reduced to 10 percent or lower by 2003. The tariff reduction program covered about two-thirds of the products in the country's tariff schedule.

Table 3.1 shows the planned schedule for achieving the tariff reductions. Under this program, the government succeeded in significantly reducing the average tariff on goods imported into the country. As shown in Figure 3.1, the average tariff fell from about 21 percent in 1991 to about 9 percent in 1999. Figure 3.2 shows the changes in tariffs by manufacturing industry. Since the government's aim was to reduce tariffs to a maximum of

10 percent, industries that initially had the highest tariffs experienced the greatest reduction in tariffs. These large differences in tariff cuts across industries provide identifying variation in the empirical analysis which I outline below.

3.3 Data

The analysis in this paper is primarily based on data from Indonesia's Annual Manufacturing Survey conducted by Biro Pusat Statistik (Indonesia's Central Bureau of Statistics). This survey is an annual enumeration of all manufacturing plants with 20 or more employees from 1975 onwards and covers, on average, about 15,000 firms each year. The survey provides plant-level data on output, inputs (both domestic and imported), exports, labor, capital, industry classification, foreign ownership and government ownership. To reduce the influence of outliers, I "winsorize" the plant-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.

The first year of my analysis is 1991 since this is the first year for which I have data on tariffs. Indonesia underwent a currency crisis starting in 1997 which led to a sharp depreciation of the rupiah. Despite the improved terms of trade from the depreciation of the rupiah, some studies have documented a worsening of the country's export performance during the crisis, with limited access to credit, social and political unrest and logistical issues at the ports suggested as potential causes (Blalock and Roy, 2007; Narjoko and Atje, 2007). The crisis also led the government to commit to further trade reforms in 1998 as part of conditions tied to loans provided by the IMF to assist the country during the crisis. These trade reforms implemented during the crisis were targeted at specific industries, in particular agriculture (World Trade Organization, 1998). Therefore, to avoid any confounding effects resulting from the currency crisis, the last year of the analysis is 1996.

The output tariff data used in the analysis are from Amiti and Konings (2007).[2] I construct input tariffs using the output tariff data and data on industry input shares from Indonesia's 1995 input-output table.[3]

Table 3.2 provides some summary statistics of the plant-level data disaggregated by both exporting and importing status. Exporters and importers are defined as firms with non-zero exports and non-zero imported inputs, respectively. All monetary values are expressed in real terms by deflating with wholesale price indices from the Indonesian central bank. As has been documented in previous studies (Clerides et al., 1998; Bernard and Jensen, 1999), exporters tend to be more productive than non-exporters. Exporters are also larger, are more likely to be foreign owned and are also more likely to use imported inputs. About 40 percent of exporters use imported inputs relative to 20 percent of non-exporters. On average, about 17.6 percent of exporters' inputs are imported compared to 8 percent for non-exporters.

3.4 Econometric Analysis

3.4.1 Empirical Strategy

To examine the impact of input tariff changes on the exports of firms, the empirical strategy in this paper makes use of the variation in tariff changes across industries and over time. I define the input tariff faced by firms in a given industry as the weighted average of the tariffs imposed on imports of goods used as inputs in that industry. Specifically, the input tariff faced by a firm in industry j in year t is calculated as follows:

$$input\,tariff_{jt} = \sum_{k} w_{kj} output\,tariff_{kt} \tag{3.1}$$

[2]I am grateful to Mary Amiti for allowing access to these data.

[3]Details on the construction of the tariffs are provided in Section 3.4.

where output $tariff_{kt}$ is the tariff imposed on the import of input k in year t, and w_{kj} is the share of input k in the total output of industry j. These shares are taken from the 1995 Indonesian input-output table.[4]

The regression equation I estimate is as follows:

$$y_{ijst} = \pi_0 + \pi_1 input\,tariff_{jt} + \pi_2 output\,tariff_{jt} \quad (3.2)$$
$$+\pi_3 partner\,tariff_{jt} + X_{ijst}\pi_4 + \lambda_i + \eta_{st} + \nu_{ijst}$$

y_{ijst} is an outcome for firm i in industry j on island s in year t.[5] The main outcomes of interest are the firm's exported share of output and exporting status. I also control for other variables that could affect firms' exports. These variables include output $tariff_{jt}$, the tariff imposed by Indonesia on imports of goods produced by industry j, and partner $tariff_{jt}$, the tariff imposed by Indonesia's trading partners on Indonesian exports of goods produced by industry j[6]. X_{ijst} is a vector of firm characteristics, namely foreign ownership and government ownership, that may influence firms' exports. I include firm fixed effects, λ_i, to control for time-invariant firm characteristics that may affect firms' exports. I also include island-year effects, η_{rt}, to capture shocks over time that affect all firms on a particular island in the country. Since the input tariffs are at the industry-year level, I cluster standard errors by industry and year to allow for correlations across firms in the same industry and year.

An identifying assumption for this strategy is that the tariff reform program was ex-

[4]The manufacturing sector in the input-output table is disaggregated into 90 industries.

[5]There are seven island groupings: Java, Kalimantan, Maluku, Nusa Tenggara, Papua, Sulawesi and Sumatera.

[6]For this variable, I use data on tariffs imposed by Japan, Indonesia's largest export partner. About 30 percent of Indonesia's total exports during the analysis period went to Japan (World Bank, 1997). The Japanese tariff data are obtained from the UNCTAD Trade Analysis and Information System (TRAINS) database.

ogenous. A potential concern is that the program may have reduced tariffs in a way that benefited certain industries or that was in line with the government's expectations of different industries' growth prospects. However, as shown in Figure 3.2, the magnitude of the change in the tariff was dependent on the initial tariff since the government's aim was to reduce tariffs to a maximum of 10 percent by 2003. Hence, the goods that experienced the largest tariff cuts were those that had initially high tariffs. To further check that the government did not target either lagging or growing industries in its tariff reform, I examine the correlation between the tariff changes experienced by industries and their pre-reform characteristics. Figure 3.3 shows correlations between industries' output tariff changes and output growth, export share growth and import share growth. Figure 3.4 presents similar correlations for input tariff changes. There is no evidence that the changes in tariffs were correlated with the pre-reform performance of industries.

The validity of the identification strategy might also be threatened if politically connected firms or industries were able to lobby for tariff changes. However, Mobarak and Purbasari (2006) find no relationship between Indonesian industries' tariffs and their political characteristics. They argue that this lack of a relationship is due to the fact that tariff rates are easily verifiable, not firm-specific, are subject to international trade agreements, and are under close scrutiny by international organizations. Hence, the findings of their study suggest that industries with political connections would not have been able to successfully lobby for tariff changes that benefited them.

In addition to tariffs, another form of trade protection used by Indonesia is the issuance of import licenses whereby certain goods can only be imported by holders of these licenses. Although Mobarak and Purbasari (2006) show that tariff rates are not influenced by political connections, they do find that firms with political connections are more likely to receive import licenses. I do not have data on which specific firms held import licenses but less than one percent of firms were issued these licenses (Amiti and Konings, 2007). In addition, over

97 percent of the more than 6,000 items in Indonesia's tariff schedule were not subject to import licenses (Mobarak and Purbasari, 2006). Nonetheless, to test the robustness of the results, I control for whether or not a firm has any government ownership as a proxy for the firm's political connections in some regressions.

Given that the calculation of the input tariffs are based on industry input shares, another concern with the identification strategy is that these input shares may themselves be endogenous. To avoid any confounding effects from endogenous changes in the input shares, I use input shares from a particular year, 1995.[7] As a robustness check, I also perform the analysis using input tariffs calculated using shares from the 2000 Indonesian input-output table in Section 3.4.4.

To explore the possibility that the effect of a reduction in input tariffs on exports operates through an increased use of imported inputs by firms, I first analyze the effect of input tariffs on the use of imported inputs in the following first stage regression.

$$\begin{aligned} import\,share_{ijst} &= \alpha_0 + \alpha_1 input\,tariff_{jt} + \alpha_2 output\,tariff_{jt} \\ &+ \alpha_3 partner\,tariff_{jt} + X_{ijst}\alpha_4 + \lambda_i + \eta_{st} + \mu_{ijst} \end{aligned} \tag{3.3}$$

I then estimate the following equation where I instrument for the imported share of inputs in the first stage regression shown in equation (3.3).

$$\begin{aligned} y_{ijst} &= \beta_0 + \beta_1 import\,share_{ijst} + \beta_2 output\,tariff_{jt} \\ &+ \beta_3 partner\,tariff_{jt} + X_{ijst}\beta_4 + \lambda_i + \eta_{st} + \epsilon_{ijst} \end{aligned} \tag{3.4}$$

[7] While it may have been ideal to use input shares from prior to the beginning of the sample period, the earliest year for which I have data on input shares is 1995.

Import share_{ijst} is the firm's imported inputs as a share of its total inputs. All other variables are as described above.

3.4.2 Input Tariff Reductions and Exports

Table 3.3 presents the results from estimating equation (3.2). The regression in Column 2 includes the output tariff and trading partner tariff faced by the firm's industry, while the regression in Column 3 includes these tariffs as well as dummy variable for firm foreign ownership and government ownership. The results provide some evidence that a decline in the input tariff for a firm's industry leads to an increase in the firm's exported share of output.

While these results indicate that a reduction in input tariffs results in an increase in the share of output exported by firms, it is not apparent that a decline in input tariffs causes firms that were not previously exporting to enter the export market. The effect of a reduction in input tariffs may only be on the intensive margin of exporting and not on the extensive margin. To analyze the effect on the extensive margin, in Table 3.4, I present results from regressions where the outcome variable is a dummy variable equal to one if the firm exports some of its output and zero otherwise. Although the coefficient on the input tariff is negative, it is not statistically significant in any of the specifications. This result suggests that a reduction in input tariffs does not generate entry into the export market. Thus, the negative relationship between input tariffs and the exported share of output appears to be driven by firms that were already exporting some of their output.

3.4.3 Channels

In this section, I explore the possibility that the effect of input tariff reductions on exports operates through an increase in the use of imported inputs by firms. Table 3.5 presents results from analyzing the effect of input tariffs on the use of imported inputs. As hypothesized, the estimates in Column 1 show that a reduction in the input tariff for a firm's industry results in an increase in the firm's imported share of inputs. In Column 2, I include the output tariff for a firm's industry and the tariffs imposed by Indonesia's trading partners on exports from the firm's industry. The relationship between input tariffs and the imported share of inputs remains virtually unchanged. Including firm ownership characteristics in Column 3 yields a similar estimate of the coefficient on the input tariff.

Table 3.6 presents the results for the effect of using imported inputs on the exported share of output. The estimates from the OLS regressions in Columns 1, 2 and 3 of Table 3.6 reveal that an increase in a firm's imported share of inputs is associated with an increase in the firm's exported share of output. In Columns 7, 8 and 9, I report results from IV estimations that use the input tariff as an instrument for the imported share of input. Columns 4, 5 and 6 provide the results from the reduced form regressions of the exported share of output on the input tariff that were reported in Table 3.3. The IV results in Column 7 indicate that an increase in a firm's imported share of inputs leads to an increase in the firm's exported share of output. This result is robust to the inclusion of industry and firm characteristics in Columns 8 and 9, respectively.

I now turn to exploring the mechanisms through which an increased use of imported inputs, prompted by a fall in input tariffs, might affect a firm's exports. Given the evidence in the literature that imported inputs tend to be of higher quality (Kugler and Verhoogen, 2009), the first channel I investigate is the idea that the use of imported inputs may allow firms to produce higher-quality goods that may be more successful on the export market. If this quality channel is the mechanism through which the use of imported inputs affects the exporting activity of firms, then the positive relationship between the use of imported inputs and the exported share of output should be stronger in industries where there is greater scope for quality differentiation.

In the dataset, firms report their advertising and R&D expenditures.[8] Therefore, following Kugler and Verhoogen (2012), I use an industry's R&D and advertising intensity (the ratio of R&D and advertising expenditures to sales) as a proxy of its scope for quality differentiation. This proxy is based on the argument that firms will only spend on R&D and advertising in industries where it is possible to influence product quality. In Table 3.7, I report results from regressions that include the interaction of the imported share of inputs and the log of industry R&D and advertising intensity. The log of industry R&D and advertising intensity has been deviated from the overall mean. The coefficient on the interaction term is positive and statistically significant indicating that the positive effect of using imported inputs on the exported share of output is stronger for firms in industries with greater scope for quality differentiation, as proxied by R&D and advertising intensity.

To further explore the quality channel, I run regressions similar to those in Table 3.7 and include the interaction of the imported share of inputs and the log of industry skill intensity deviated from the overall mean. The dataset provides firm-level information on the education level of workers.[9] For a given industry, I define skill intensity as the share of workers with a bachelor's degree or higher. If the most skill-intensive industries are also those that require high-quality inputs (in the spirit of the O-ring theory (Kremer (1993)) and the quality channel is responsible for the effect of using imported inputs on exports, then this effect should be more pronounced for firms in high-skill intensity industries. Consistent with this hypothesis, the coefficients on the interactions between the imported share of inputs and the log of industry skill intensity in Table 3.8 are positive and statistically significant. Overall, these results provide some evidence that the positive effect of using imported inputs on exports is driven by the quality channel.

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[8]These data are available from 1992.

[9]These data are available from 1995.

The second channel I examine is the variety channel. Goldberg et al. (2010b) show that access to new imported input varieties via trade liberalization allowed Indian firms to expand their product scope. Using data on Korean firms, Choi and Hahn (2009) also show that greater access to imported inputs increases a firm's propensity to switch its products. It is plausible that when firms change their product scope, the new products added to their product mix are those that might be successful on the export market. Hence, the use of imported inputs, by giving firms access to a wider variety of inputs than what are available domestically, may lead firms to begin producing new products that they can then export. An ideal way of examining this channel would be to check if firms change their product mix when they increase their use of imported inputs. Although the dataset does not provide information on a firm's product mix, I can infer whether a firm switches its main product since this corresponds to a change in its 5-digit industry code. Table 3.9 shows results from regressions where the dependent variable is a dummy variable equal to one if the firm's 5-digit industry code in a given year is different from its previous 5-digit industry code. Firms do not appear to be switching their main product in response to an increase in their imported share of inputs. This conclusion is however subject to the caveat that I do not observe a firm's entire product mix.

I now investigate the possibility that increased productivity may be the mediating factor between the use of imported inputs and increased export share. Several papers have studied the link between access to imported inputs and productivity. While most of the evidence indicates the existence of a positive relationship between access to imported inputs and productivity (Schor, 2004; Amiti and Konings, 2007; Kasahara and Rodrigue, 2008; Topalova and Khandelwal, 2011; Halpern, Koren and Szeidl, 2011; Kasahara and Lapham, 2013), there is also some evidence that there is no link between the two (Muendler, 2004; Vogel and Wagner, 2010). A widely documented fact in the literature is the existence of a positive correlation between exporting status and productivity, in line with the hypothesis that the existence of high fixed export costs allows only the most productive firms to enter the export market (Clerides et al., 1998; Bernard and Jensen, 1999; Melitz, 2003). If the use of imported inputs does indeed increase productivity, then this may subsequently generate an increase in firm exporting activity.

In Tables 3.10 and 3.11, I check if the use of imported inputs increases productivity in the Indonesian context. Table 3.10 provide results for labor productivity. An increase in the use of imported inputs does not appear to be associated with an increase in labor productivity. In Table 3.11, I look at the effect of using imported inputs on two measures of total factor productivity.[10] The first measure of TFP (TFP (OLS)) is calculated as residuals from industry-specific production functions, while the second measure (TFP (Olley-Pakes)) is constructed following the method developed in Olley and Pakes (1996).[11] For both measures of total factor productivity, the coefficients on the imported share of inputs, although positive, are not statistically significant. Thus, I find no strong support for the hypothesis that the positive effect of imported inputs on exporting operates through an increase in productivity. However, it should be noted that any changes in total factor productivity resulting from the use of higher quality inputs may not be captured by the standard measures of total factor productivity used. Since the deflators used are not firm-specific, these standard measures of total factor productivity may be biased as a result of input and output price differences that may reflect quality differences (Foster, Haltiwanger and Syverson, 2008; Katayama, Lu and Tybout, 2009).

In sum, I find evidence in support of the idea that increased access to higher-quality inputs from abroad via input tariff reductions results in an increase in export share. Increased

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[10] The sample for the regressions for total factor productivity is smaller than in the previous tables since a substantial number of firms have missing values for capital.

[11] Details on the construction of the TFP measures are provided in Appendix B.

productivity and a change in product scope[12], on the other hand, do not appear to be responsible for the effect of using imported inputs on exports.

3.4.4 2000 Input Shares

The input tariffs used in the paper are calculated using input shares from the 1995 Indonesian input-output table as described in Section 3.4.1. I use the input shares from 1995 as this is the only year within the sample period for which these data are available. In addition, I use constant input shares to avoid confounding effects from changes in input shares as a result of endogenous changes in industries' production technologies. An input-output table is also available for 2000. However, as the year 2000 falls substantially outside the sample period and immediately followed the end of the Indonesian currency crisis in 1999, the input shares from the 2000 input-output table may not accurately reflect industries' production technologies during the sample period. Nonetheless, as a robustness check, I redo the analysis using input tariffs calculated using input shares from the 2000 input-output table.

The main results from this analysis are reported in Table 3.13.[13] In the regressions without interactions in Columns 1 and 2, the coefficients on the imported share of inputs, are positive but not statistically significant. In the specifications in Columns 3 through 6 where I include interactions between the imported share of output, industry R&D and advertising intensity and skill intensity, the coefficients on the interactions are positive and mostly statistically significant. This lends credence to the conclusions from above that input tariff liberalization positively affects export share for firms in industries for which the availability of high-quality inputs is particularly valuable.

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[12]This is subject to the caveat that I observe only a firm's main product and not its entire product mix.

[13]The estimates from the first stage regressions for this analysis are reported in Table 3.12.

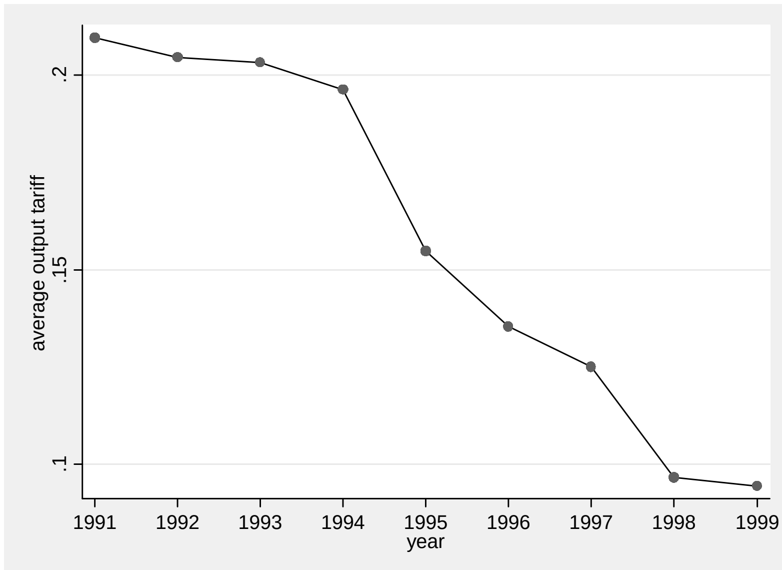
3.5 Conclusion

This paper establishes a negative relationship between input tariffs and firms' exports using data on Indonesian manufacturing firms. I exploit a tariff reform program in Indonesia that generated exogenous variation in input tariffs across industries and find that the reductions in input tariffs resulted in an increase in the exported share of output of firms. However, I find no effect on entry into the export market suggesting that the effect of input tariff liberalization mainly accrues to firms that are already engaged in exporting.

Given that the reduction in input tariffs reduces the costs of using imported inputs, I explore the use of imported inputs as a possible mechanism underlying the negative relationship between input tariffs and firm exports. To do this, I use the input tariff faced by a firm's industry as an instrument for the firm's use of imported inputs and find that the use of imported inputs leads firms to increase their exported share of output. I further investigate potential channels through which the increased use of imported inputs brought about by input tariff liberalization affects exports. The results of this analysis reveal that the positive effect of using imported inputs may be driven by the higher quality of imported inputs. Specifically, I find that the positive effect of using imported inputs on exports is more pronounced for firms in industries with a greater scope for quality differentiation and high skill intensity.

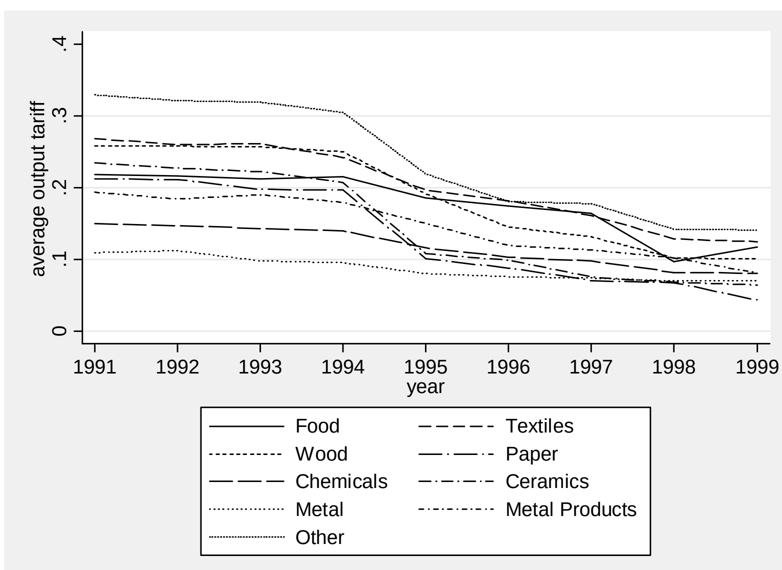
Some data limitations prevent a more in-depth analysis of the mechanisms through which reductions in input tariffs affect firms' exports. For instance, the lack of data on a firm's product mix does not permit me to undertake a more thorough analysis of whether the positive impact of access to foreign inputs operates through the production of new products. In addition, the proxies used to capture quality are not without imperfections. Notwithstanding these limitations, the findings of this paper add to the debate on how trade liberalization, by facilitating access to imported inputs, may influence the performance of firms in developing economies. For policy-makers pursuing export expansion, it is also useful to understand how access to imported inputs may play a role in achieving this target. Richer datasets may allow future studies to undertake a more rigorous investigation of the mechanisms underlying the positive effect of input tariff liberalization on exporting activity.

Figure 3.1: Output Tariffs



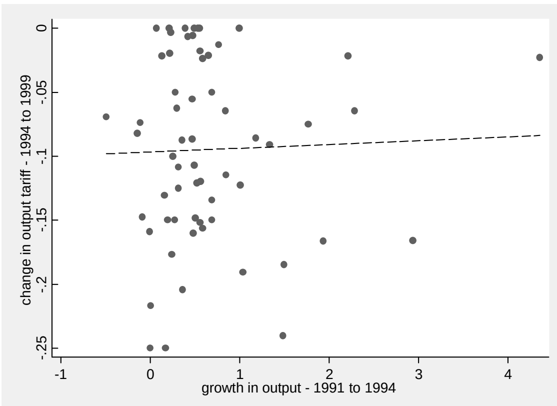
Notes: Data on output tariffs are from Amiti and Konings (2007).

Figure 3.2: Output Tariffs by Industry



Notes: Data on output tariffs are from Amiti and Konings (2007).

Figure 3.3: Industry Pre-Reform Growth and Output Tariff Changes



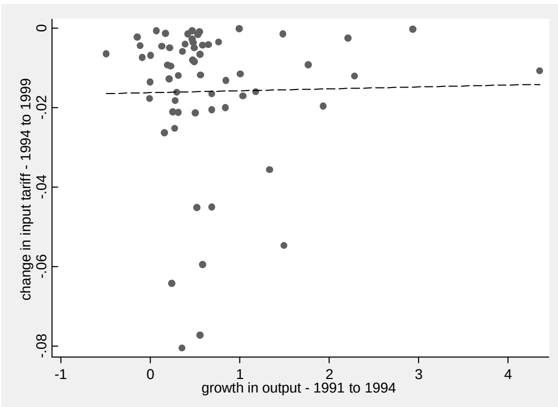
The slope of the line is 0.003 with a standard error of 0.012.

The slope of the line is 0.002 with a standard error of 0.009.

The slope of the line is -0.01 with a standard error of 0.03.

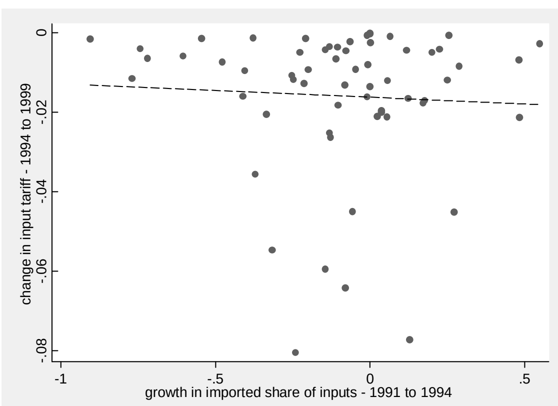
Notes: Data on industry output, exported share of output and imported share of inputs are from Indonesia's Annual Manufacturing Survey. Data on output tariffs are from Amiti and Konings (2007).

Figure 3.4: Industry Pre-Reform Growth and Input Tariff Changes



The slope of the line is 0.0004 with a standard error of 0.003.

The slope of the line is -0.0001 with a standard error of 0.002.



The slope of the line is -0.003 with a standard error of 0.008

Notes: Data on industry output, exported share of output and import share of inputs are from Indonesia's Annual Manufacturing Survey. Input tariffs are constructed using data on output tariffs from Amiti and Konings (2007) and data on input shares from the 1995 Indonesian input-output table. Details on the construction of the input tariffs are provided in Section 3.4.

Table 3.1: Indonesia Tariff Reduction Schedule

Tariff before May 1995 %	1995 %	1996 %	1997 %	1998 %	1999 %	2000 %	2001 %	2002 %	2003 %
0	0	0	0	0	0	0	0	0	0
5	5	5	5	5	5	5	5	5	<= 5
10	5	5	5	5	5	5	5	5	<= 5
15	10	10	5	5	5	5	5	5	<= 5
20	15	15	10	10	5	5	5	5	<= 5
25	20	15	15	10	10	10	10	10	<= 10
30	25	20	20	15	15	10	10	10	<= 10
35	30	25	25	20	20	15	15	10	<= 10
40	30	25	25	20	20	15	15	10	<= 10
>45	30	25	25	20	20	15	15	10	<= 10

Notes: This table shows the tariff reduction schedule for the 1995 Indonesian tariff reform program. Tariffs were scheduled to be less than or equal to the numbers shown in the last column by 2003. Data are from Food and Agriculture Organization (2003).

Table 3.2: Summary Statistics by Exporting and Importing Status in 1991

	Non-Exporters			Exporters			All
	Non-importers	**Importers**	**All**	**Non-importers**	**Importers**	**All**	
Exported share of output				0.563	0.466	0.525	0.056
				<0.013>	<0.017>	<0.011>	<0.002>
Export value				2.870	5.012	3.722	0.399
				<0.290>	<0.430>	<0.246>	<0.029>
Imported share of inputs		0.386	0.080		0.442	0.176	0.091
		<0.009>	<0.003>		<0.017>	<0.010>	<0.003>
Imported input value		1.008	0.210		1.984	0.789	0.272
		<0.052>	<0.012>		<0.144>	<0.066>	<0.013>
Output (billions of rupiah)	0.956	4.769	1.750	4.419	11.176	7.105	2.324
	<0.045>	<0.236>	<0.063>	<0.371>	<0.717>	<0.378>	<0.072>
Number of workers	105	253	136	371	607	465	171
	<2.876>	<10.095>	<3.176>	<20.642>	<30.587>	<17.803>	<3.592>
Output per worker (billions of rupiah per worker)	0.002	0.005	0.002	0.003	0.006	0.004	0.003
	<0.0001>	<0.0003>	<0.0001>	<0.0003>	<0.0005>	<0.0003>	<0.0001>
Foreign ownership dummy	0.011	0.112	0.032	0.049	0.247	0.128	0.042
	<0.001>	<0.008>	<0.002>	<0.009>	<0.023>	<0.011>	<0.002>
Government ownership dummy	0.039	0.049	0.041	0.110	0.042	0.083	0.046
	<0.003>	<0.005>	<0.002>	<0.013>	<0.011>	<0.009>	<0.002>
No. of firms	5,988	1,576	7,564	547	361	908	8,472
% of firms	71%	19%	89%	6%	4%	11%	100%

Notes: Standard errors of the means are in parentheses. All monetary values are in 1983 rupiah. Exporters are firms with non-zero exports and importers are firms with non-zero imported inputs.

Table 3.3: Effect of Input Tariffs on Exported Share of Output

	(1)	(2)	(3)
	Dependent Variable: exported share of output		
input tariff	-0.141	-0.133*	-0.133*
	<0.077>	<0.060>	<0.060>
output tariff		0.029	0.026
		<0.020>	<0.019>
trading partner tariff		-0.029	-0.029
		<0.015>	<0.015>
foreign ownership dummy			0.061***
			<0.014>
government ownership dummy			-0.017**
			<0.006>
No. of Observations	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914
Firm Effects	x	x	x
Island-Year Effects	x	x	x

Notes: This table reports the coefficients from regressions for the exported share of output. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year.

Table 3.4: Effect of Input Tariffs on Exporting Status

	(1)	(2)	(3)
	Dependent Variable: exporting dummy		
input tariff	-0.089	-0.111	-0.11
	<0.204>	<0.164>	<0.163>
output tariff		0.081	0.077
		<0.052>	<0.051>
trading partner tariff		-0.04	-0.04
		<0.031>	<0.031>
foreign ownership dummy			0.108**
			<0.030>
government ownership dummy			-0.024**
			<0.006>
No. of Observations	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914
Firm Effects	x	x	x
Island-Year Effects	x	x	x

Notes: This table reports the coefficients from regressions for the firm's exporting status. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year.

Table 3.5: Effect of Input Tariffs on Imported Share of Inputs

	Dependent Variable: imported share of inputs		
	(1)	(2)	(3)
input tariff	-0.229**	-0.259**	-0.259**
	<0.064>	<0.070>	<0.070>
output tariff		-0.009	-0.012
		<0.024>	<0.024>
trading partner tariff		0.036**	0.036**
		<0.010>	<0.010>
foreign ownership dummy			0.063**
			<0.0220>
government ownership dummy			-0.003
			<0.0060>
F-statistic (1st Stage Instrument)	12.66	13.49	13.57
No. of Observations	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914
Firm Effects	x	x	x
Island-Year Effects	x	x	x

Notes: This table reports the coefficients from the first stage regression for the imported share of inputs. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year.

Table 3.6: Effect of Using Imported Inputs on Exported Share of Output

	OLS	**OLS**	**OLS**	**Red. Form**	**Red. Form**	**Red. Form**	**IV**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Dep. Var.: exported share of output				
imported share of inputs	0.035***	0.035***	0.032***				0.615*	0.515***	0.511***
	<0.010>	<0.010>	<0.010>				<0.346>	<0.187>	<0.186>
input tariff				-0.141	-0.133*	-0.133*			
				<0.077>	<0.060>	<0.060>			
output tariff		0.026*	0.024*		0.029	0.026		0.033***	0.032***
		<0.014>	<0.014>		<0.020>	<0.019>		<0.010>	<0.010>
trading partner tariff		-0.034***	-0.034***		-0.029	-0.029		-0.047***	-0.047***
		<0.013>	<0.013>		<0.015>	<0.015>		<0.016>	<0.017>
foreign ownership dummy			0.059***			0.061***			0.029***
			<0.013>			<0.014>			<0.010>
government ownership dummy			-0.017**			-0.017**			-0.015**
			<0.008>			<0.006>			<0.006>
No. of Observations	59,932	59,932	59,932	59,932	59,932	59,932	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914	13,914	13,914	13,914	13,914	13,914	13,914
Firm Effects	x	x	x	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x	x	x	x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions for the exported share of output. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year except for the OLS regressions which cluster standard errors at the firm level. The imported share of inputs is instrumented with the firm's industry's input tariff. The results of the first stage regressions are reported in Table 3.5.

Table 3.7: Effect of Using Imported Inputs by Industry Scope for Quality Differentiation

	OLS	**OLS**	**Red. Form**	**Red. Form**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dep. Var.: exported share of output						
imported share of inputs	0.035***	0.032***			0.503	0.352*
	<0.011>	<0.011>			<0.354>	<0.189>
imported share of inputs x log(R&D and advertising intensity)	0.001	0.001			0.590**	0.641**
	<0.013>	<0.013>			<0.274>	<0.321>
input tariff			-0.122	-0.112		
			<0.062>	<0.060>		
input tariff x log(R&D and advertising intensity)			0.329*	0.317*		
			<0.143>	<0.134>		
log(R&D and advertising intensity)	0.011	0.01	0.0020	0.001	-0.053	-0.058
	<0.007>	<0.007>	<0.008>	<0.008>	<0.033>	<0.036>
Panel B. First Stage. Dep. Var.: imported share of inputs						
input tariff	-0.219**	-0.248**				
	<0.076>	<0.079>				
input tariff x log(R&D and advertising intensity)	0.188**	0.181**				
	<0.069>	<0.064>				
log(R&D and advertising intensity)	-0.002	-0.003				
	<0.008>	<0.007>				
F-statistic (1st Stage Instruments)	8.14	9.50				
Panel C. First Stage. Dep. Var.: imported share of inputs x log(R&D and advertising intensity)						
input tariff	-0.021	-0.039				
	<0.083>	<0.080>				
input tariff x log(R&D and advertising intensity)	0.398**	0.395**				
	<0.132>	<0.132>				
log(R&D and advertising intensity)	0.095***	0.094***				
	<0.023>	<0.023>				
F-statistic (1st Stage Instruments)	12.08	11.48				
No. of Observations	59,932	59,932	59,932	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914	13,914	13,914	13,914
Firm Effects	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions for the exported share of output. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year except for the OLS regressions which cluster standard errors at the firm level. The imported share of inputs and the imported share of inputs interacted with the log of industry R&D and advertising intensity are instrumented with the firm's industry's input tariff and the firm's industry's input tariff interacted with the log of industry R&D and advertising intensity. The log of industry R&D and advertising intensity is the ratio of industry R&D and advertising expenditures to sales and has been deviated from the overall mean. The results of the first stage regressions are reported in Panels B and C. Control variables include industry output tariff, trading partner tariff, dummy variable for foreign ownership of firm and dummy variable for government ownership of firm.

Table 3.8: Effect of Using Imported Inputs by Industry Skill Intensity

	OLS	**OLS**	**Red. Form**	**Red. Form**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dep. Var.: exported share of output						
imported share of inputs	0.034***	0.031***			0.26	0.202
	<0.012>	<0.012>			<0.316>	<0.236>
imported share of inputs x log(skill intensity)	0.015	0.017			1.878**	1.650**
	<0.034>	<0.034>			<0.841>	<0.676>
input tariff			0.024	0.02		
			<0.081>	<0.087>		
input tariff x log(skill intensity)			0.802**	0.739**		
			<0.221>	<0.225>		
log(skill intensity)	-0.017	-0.016	-0.0350	-0.032	-0.212*	-0.189*
	<0.025>	<0.025>	<0.031>	<0.031>	<0.116>	<0.102>
Panel B. First Stage. Dep. Var.: imported share of inputs						
input tariff	-0.241**	-0.256**				
	<0.091>	<0.089>				
input tariff x log(skill intensity)	-0.068	0.009				
	<0.282>	<0.247>				
log(skill intensity)	-0.028	-0.028				
	<0.037>	<0.037>				
F-statistic (1st Stage Instruments)	10.24	11.20				
Panel C. First Stage. Dep. Var.: imported share of inputs x log(skill intensity)						
input tariff	0.046	0.043				
	<0.050>	<0.049>				
input tariff x log(skill intensity)	0.437*	0.447*				
	<0.178>	<0.175>				
log(skill intensity)	0.098**	0.098**				
	<0.028>	<0.028>				
F-statistic (1st Stage Instruments)	6.16	6.49				
No. of Observations	59,932	59,932	59,932	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914	13,914	13,914	13,914
Firm Effects	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions for the exported share of output. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year except for the OLS regressions which cluster standard errors at the firm level. The imported share of inputs and the imported share of inputs interacted with the log of industry skill intensity are instrumented with the firm's industry's input tariff and the firm's industry's input tariff interacted with the log of industry skill intensity. The log of industry skill intensity is the share of workers with a bachelor's degree or higher and has been deviated from the overall mean. The results of the first stage regressions are reported in Panels B and C. Control variables include industry output tariff, trading partner tariff, dummy variable for foreign ownership of firm and dummy variable for government ownership of firm.

Table 3.9: Effect of Using Imported Inputs on Product Switching

	OLS	**OLS**	**Red. Form**	**Red. Form**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)
	Dep. Var.: switches main product					
imported share of inputs	0.024***	0.024***			0.451	0.388
	<0.008>	<0.008>			<0.774>	<0.696>
input tariff			-0.103	-0.101		
			<0.214>	<0.214>		
No. of Observations	59,932	59,932	59,932	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914	13,914	13,914	13,914
Firm Effects	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions for switching the main product (dummy variable equal to one if a firm's 5-digit industry code is different from its previous value). *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year except for the OLS regressions which cluster standard errors at the firm level. The imported share of inputs is instrumented with the firm's industry's input tariff. The results of the first stage regressions are reported in Table 3.5.

Table 3.10: Effect of Using Imported Inputs on Labor Productivity

	OLS	**OLS**	**Red. Form**	**Red. Form**	**IV**	**IV**
	(1)	(2)	(3)	(4)	(5)	(6)
	Dep. Var.: log(output per worker)					
imported share of inputs	0.127***	0.118***			1.874	1.957
	<0.053>	<0.051>			<3.359>	<2.835>
input tariff			-0.429	-0.508		
			<0.832>	<0.768>		
No. of Observations	59,932	59,932	59,932	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914	13,914	13,914	13,914
Firm Effects	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions for the log of output per worker. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year except for the OLS regressions which cluster standard errors at the firm level. The imported share of inputs is instrumented with the firm's industry's input tariff. The results of the first stage regressions are reported in Table 3.5.

Table 3.11: Effect of Using Imported Inputs on Total Factor Productivity

	OLS (1)	**OLS** (2)	**Reduced Form** (3)	**Reduced Form** (4)	**IV** (5)	**IV** (6)
Panel A. Dep. Var.: log(TFP(OLS)						
imported share of inputs	0.027	0.028			0.28	0.615
	<0.019>	<0.019>			<1.115>	<0.985>
input tariff			-0.076	-0.186		
			<0.340>	<0.329>		
Panel B. Dep. Var.: log(TFP(Olley-Pakes)						
imported share of inputs	0.033*	0.033*			0.096	0.434
	<0.019>	<0.019>			<1.115>	<0.983>
input tariff			-0.026	-0.131		
			<0.335>	<0.327>		
Panel C. First Stage. Dep. Var.: imported share of inputs						
imported share of inputs	-0.272**	-0.303**				
	<0.068>	<0.079>				
input tariff	16.03	14.65				
F-statistic (1st Stage Instrument)						
No. of Observations	51,189	51,189	51,189	51,189	51,189	51,189
No. of Firms	12,335	12,335	12,335	12,335	12,335	12,335
Firm Effects	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the OLS, reduced form and IV regressions for total factor productivity.*** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year except for the OLS regressions which cluster standard errors at the firm level. The imported share of inputs is instrumented with the firm's industry's input tariff. The results of the first stage regressions are reported in Panel C. Details on the construction of the total factor productivity measures, log(TFP(OLS)) and log(TFP(Olley-Pakes)), are provided in Appendix B.

Table 3.12: First Stage Regressions (2000 Input Shares)

	(1)	(2)	(3)	(4)	(5)	(6)
	Dep. Var.: imported share of inputs					
input tariff	-0.434**	-0.428***	-0.420**	-0.412**	-0.434**	-0.419**
	<0.111>	<0.102>	<0.112>	<0.103>	<0.113>	<0.106>
input tariff x log(R&D and advertising intensity)			0.141	0.145		
			<0.105>	<0.095>		
log(R&D and advertising intensity)			0.000	-0.002		
			<0.009>	<0.008>		
input tariff x log(skill intensity)					-0.04	0.091
					<0.240>	<0.260>
log(skill intensity)					-0.028	-0.029
					<0.037>	<0.037>
F-statistic (1st Stage Instruments)			12.27	13.85	13.34	13.56
			Dep. Var.: imported share of inputs x log(R&D and advertising intensity)		*Dep. Var.: imported share of inputs x log(skill intensity)*	
input tariff			-0.108	-0.124	-0.033	-0.028
			<0.095>	<0.086>	<0.064>	<0.058>
input tariff x log(R&D and advertising intensity)			0.357**	0.360**		
			<0.127>	<0.127>		
log(R&D and advertising intensity)			0.097***	0.097***		
			<0.023>	<0.023>		
input tariff x log(skill intensity)					0.393*	0.427*
					<0.184>	<0.175>
log(skill intensity)					0.101**	0.101**
					<0.029>	<0.028>
F-statistic (1st Stage Instruments)			6.54	6.47	4.71	5.59
No. of Observations	59,932	59,932	59,932	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914	13,914	13,914	13,914
Firm Effects	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the first stage regressions with input tariffs calculated using 2000 input shares. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year. The log of industry R&D and advertising intensity is the ratio of industry R&D and advertising expenditures to sales and has been deviated from the overall mean. The log of industry skill intensity is the share of workers with a bachelor's degree or higher and has been deviated from the overall mean. Control variables include industry output tariff, trading partner tariff, dummy variable for foreign ownership of firm and dummy variable for government ownership of firm.

Table 3.13: Effect of Using Imported Inputs on Exported Share of Output (2000 Input Shares)

	IV (1)	IV (2)	IV (3)	IV (4)	IV (5)	IV (6)
			Dep. Var.: exported share of output			
imported share of inputs	0.145	0.292	-0.155	0.008	-0.112	0.088
	<0.308>	<0.312>	<0.352>	<0.346>	<0.310>	<0.307>
imported share of inputs x log(R&D and advertising intensity)			0.898*	0.731		
			<0.529>	<0.485>		
log(R&D and advertising intensity)			-0.0830	-0.067		
			<0.058>	<0.052>		
imported share of input x log(skill intensity)					1.984**	1.473***
					<0.906>	<0.566>
log(skill intensity)					-0.235*	-0.173**
					<0.121>	<0.087>
No. of Observations	59,932	59,932	59,932	59,932	59,932	59,932
No. of Firms	13,914	13,914	13,914	13,914	13,914	13,914
Firm Effects	x	x	x	x	x	x
Island-Year Effects	x	x	x	x	x	x
Controls		x		x		x

Notes: This table reports the coefficients from the IV regressions for the exported share of output. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered by industry and year. The log of industry R&D and advertising intensity is the ratio of industry R&D and advertising expenditures to sales and has been deviated from the overall mean. The log of industry skill intensity is the share of workers with a bachelor's degree or higher and has been deviated from the overall mean. The results of the first stage regressions are reported in Table 3.12. Control variables include industry output tariff, trading partner tariff, dummy variable for foreign ownership of firm and dummy variable for government ownership of firm.

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Appendix A

Electricity Cost and Firm Performance: Evidence from India

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:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + w_{it} + \eta_{it} \tag{A.6.1}$$

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:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \phi_{it} + \eta_{it} \tag{A.6.2}$$

where

$$\phi_{it} = \beta_0 + \beta_k k_{it} + f(i_{it},\, k_{it}) \tag{A.6.3}$$

$f(i_{it},\, k_{it})$ 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.6.2). 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:

$$\hat{\phi}_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} \tag{A.6.4}$$

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.6.2). The coefficient on the log of capital is then estimated in the regression equation below using non-linear least squares.

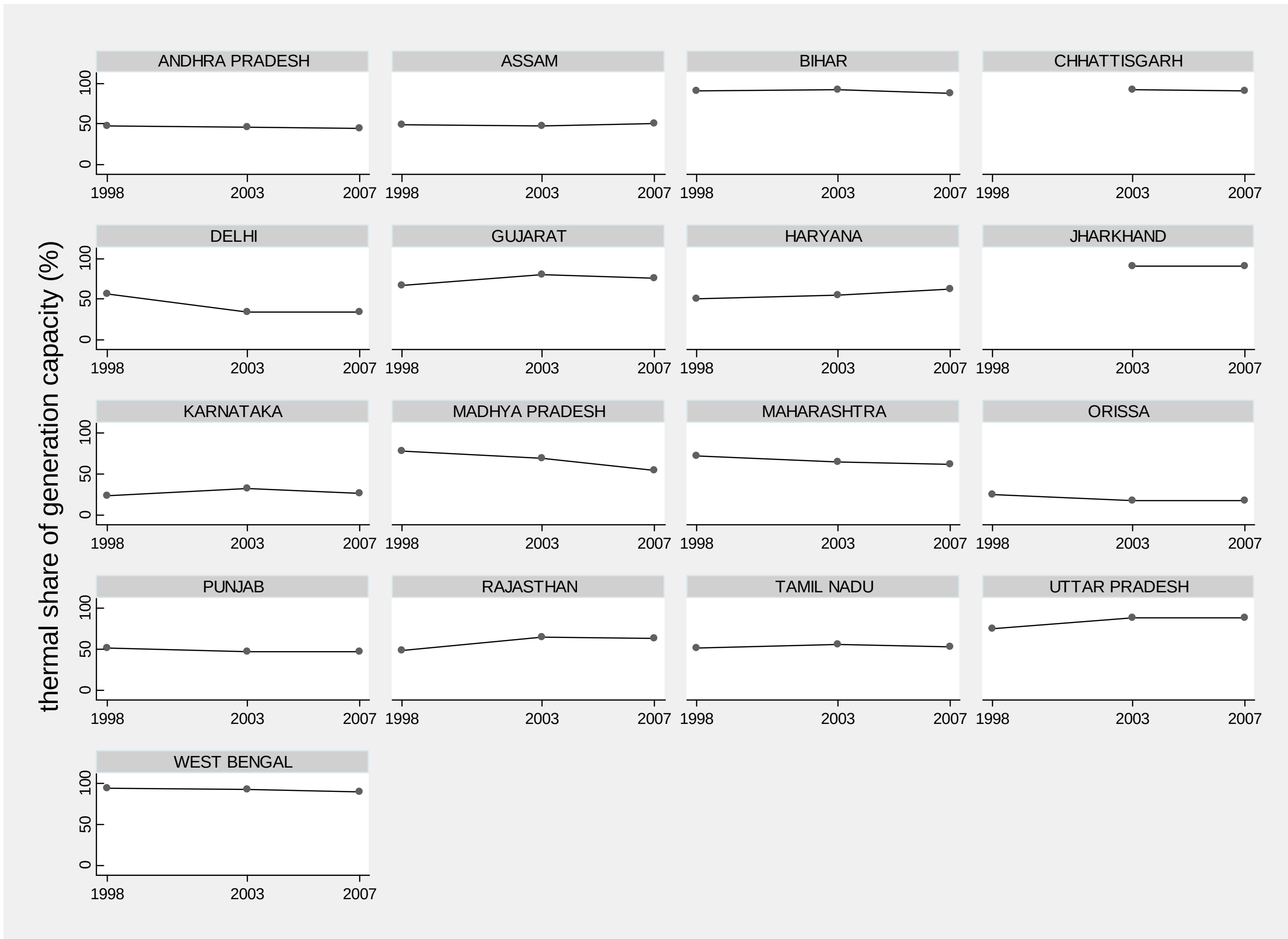
$$y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} = \alpha_0 + \beta_k k_{it} + g(\hat{P}_{it-1},\, \hat{\phi}_{it-1} - \beta_k k_{it-1}) + u_{it} \tag{A.6.5}$$

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:

$$log(TFP_{it}) = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it} \tag{A.6.6}$$

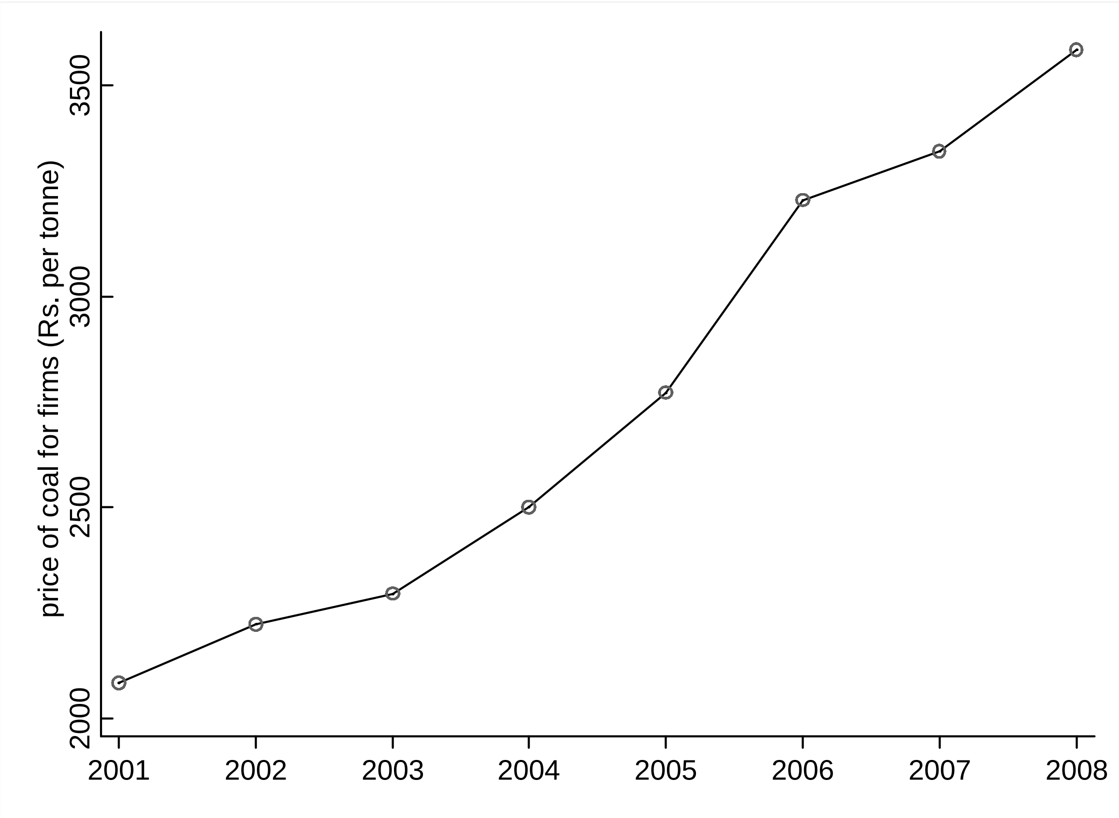
The estimations for TFP using the Olley and Pakes (1996) method are also carried out separately for each 2-digit industry as was done for the measure of TFP obtained using OLS regressions described above.

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



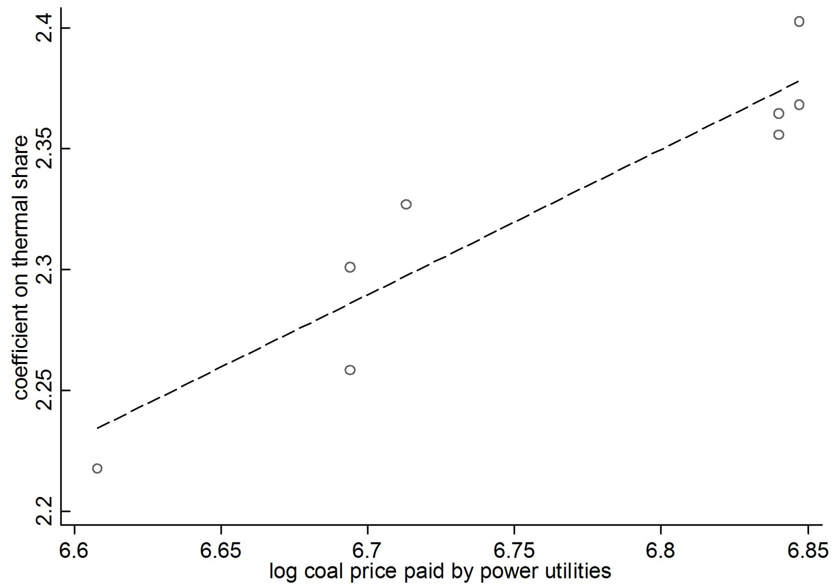
Notes: Data on installed generation capacity are from India's Ministry of Power's annual reports for 1997-1998, 2002-2003 and 2006-2007. For Jharkhand and Chhattisgarh, the earliest year for which data on installed generation capacity is available is 2003 since these states were created in late 2000.

Figure A.2: Price of Coal for Firms



Notes: Data are from the ASI dataset.

Figure A.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 A.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 A.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 A.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.

Appendix B

Input Tariff Reductions, Imported Inputs and Exporting Activity

B.1 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 nine 2-digit industries. However, two 2-digit industries, industry 37 (basic metal) has too few firm observations to allow for a separate regression. I therefore combine industry 37 with industry 38 (fabricated metal products, machinery and equipment). I therefore estimate the OLS regressions separately for eight 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:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + w_{it} + \eta_{it} \tag{B.1.1}$$

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:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \phi_{it} + \eta_{it} \tag{B.1.2}$$

where

$$\phi_{it} = \beta_0 + \beta_k k_{it} + f(i_{it},\, k_{it}) \tag{B.1.3}$$

$f(i_{it},\, k_{it})$ 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 (B.1.2). 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:

$$\hat{\phi}_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} \tag{B.1.4}$$

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 (B.1.2). The coefficient on the log of capital is then estimated in the regression equation below using non-linear least squares.

$$y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} = \alpha_0 + \beta_k k_{it} + g(\hat{P}_{it-1}, \hat{\phi}_{it-1} - \beta_k k_{it-1}) + u_{it} \tag{B.1.5}$$

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:

$$log(TFP_{it}) = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it} \tag{B.1.6}$$

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.