Infrastructure Regulation and Industry Equilibrium when Firms Have an Outside Option: Evidence from Indian Firms

Juan Pablo Rud*

May 2009

Abstract

I explore how regulatory outcomes of an infrastructure good affect industry equilibrium when firms have access to an outside option. In particular, I look at electricity regulation and the adoption of captive power generators by Indian firms. In a setting that combines upstream regulation with downstream heterogeneous firms in a monopolistic competition framework, I model how regulator's preferences and the economic environment (i.e. regulation and openness) determine firms' decision to adopt a cost-reducing device and the subsequent industrial aggregate productivity. The mechanisms I propose are present for a representative repeated cross-section sample of Indian firms in the 1990s. I show that firms that are more productive, in states where regulator's pricing schemes over-charge industrial producers and in industries more protected from competition are more likely to adopt a captive power generator.

1 Introduction

The lack of adequate infrastructure is one of the main challenges that firms in developing countries face on a daily basis. Infrastructure costs for firms in the developing world can be up to four times higher than they are in OECD countries, making infrastructure one of the main concerns for entrepreneurs (Gonzalez et al. (2007)). In many cases, bad infrastructure stems from countries' financial inability to invest in infrastructure (e.g. because of the stress or inefficiency of the tax system), but in others, it is the consequence of direct institutional failures such as weak governance, lack of capacity or poor regulation (Laffont (2005), World Bank (2006)). However,

*London School of Economics. I thank Oriana Bandiera, Tim Besley, Robin Burgess, Rocco Macchiavello, Paolo Masella, Guy Michaels, Steve Redding, Jon Temple and EOPP-STICERD seminar participants for useful comments.

problems associated with high tariffs and poor quality in infrastructure can be mitigated if firms have access to outside options for the public provision of infrastructure goods. In the case of electricity, in regions like Sub-Saharan Africa and South Asia–where only 1 in 4 people and 2 in 5, respectively, have access to electricity from the network–firms turn to the installation of captive power generators. For example, in a survey of manufacturing firms in India in 2002, almost 30% of firms reported that the state of the electricity network was a major or a very severe obstacle for business and 64% owned an electricity generator. In Pakistan, firms reported 40% and 42% to the same questions, respectively. In Sri Lanka and Bangladesh, 41% and 71%, respectively, reported that electricity was a major or very severe obstacle and, in both cases, the adoption rate exceeded 70% (Asian Development Bank (2002)). Arnold et al.(2008) show data from a similar survey for firms in Sub-Saharan Africa: in Kenya, 71% of firms in the sample owned a generator; in Tanzania, 55% and almost 40% in Uganda and Zambia. In all countries, the average score for electricity as an obstacle was between "moderate" and "major".

This set of stylized facts suggests that, at least in South Asia and Sub-Saharan Africa, the inadequate provision of electricity hinders the development of the manufacturing sector and that some firms can find alternative arrangements to deal with the problem, but some cannot. It follows that if firms that adopt captive power coexist with firms that do not, then this must somehow affect the configuration of an industry (i.e. who survives, distribution of profits, etc.) In this paper I investigate these questions by analysing the underlying determinants of captive power adoption by firms and their effects on industry outcomes. To that end, I develop a model that links the regulatory process in the upstream (e.g. electricity provision) to firms' behaviour in the downstream and the resulting industry equilibrium. I subsequently use data from firms in India to analyse their decision to set up a captive power generator to deal with inadequate provision and pricing schemes in the electricity sector. I am interested in identifying not just which firms adopt a generator to back up their network provision but also in looking at how this phenomenon affects industry-wide outcomes. Furthermore, I provide some insight into the nature of different regulatory outcomes, by using the institutional features of the electricity sector in India, where each state controls the supply and decides on the pricing schedule.

Pricing schemes in Indian states are generally biased towards agricultural and domestic consumers, who enjoy below cost or even free energy, while the industrial sector has to contend with high tariffs and unreliable supply. These regulatory practices have a political economy component (e.g. an agricultural voting base gives power to pro-agricultural political parties) and a socioeconomic component (e.g. keeping agricultural inputs cheap so agricultural and food prices remain low). They may also generate a vicious circle in which the agricultural sector, because of its importance, controls the political lever lobbying for subsidies that affect a manufacturing sector which remains politically and economically restrained. To account for this asymmetry in lobbying power, I build on the analysis of the regulatory process in the baseline model developed by Laffont and Tirole (1993, Ch. 2). The authors show that under the standard assumption that the regulator collects the money and makes transfers to the producer, optimal pricing is above marginal and below monopolistic price, because transfers to the supplier can only be done at a positive cost. The key idea is that because transferring funds from taxpayers is socially costly, society is better off by allowing the regulated monopoly to charge above marginal cost, thus reducing the need for transfers. In this setting, I complement this model by introducing a measure of the power of lobbies in the regulator's objective function: the price set will depend on the relative importance the regulator gives to the welfare of the industrial sector, the consumer of the monopolistically supplied good. Intuitively, with zero transfer costs, if the regulator cares fully about consumers' well being, then the weight given to the consumer surplus in a utilitarian social welfare function would be highest and the price should be set equal to the marginal cost. Conversely, if the regulator does not care about consumers, then the price would be set at the unconstrained monopolistic price. Intermediate values of the pro-consumer preference would imply a price somewhere in between.

I analyse how regulatory outcomes affect the behaviour of firms that have access to an electricity-cost-reducing device (such as captive power generators) in a setting where consumers have a taste for variety and firms are heterogeneous, as in Melitz (2003) and Bernard et al.(2006). I am interested in characterising firms that adopt this technology and how changes in the environment (such as trade protection and licensing schemes) affect industry and firm outcomes. In particular, the model shows that adoption of captive power follows higher electricity prices and lower quality and is more prevalent in environments that are shielded from competition. This provides an interesting finding that links infrastructure regulation with the process of market deregulation. Since it is easier for firms to recoup the cost of setting up a captive generator in a more protected environment, the outside option (e.g. a captive generator) becomes less feasible when the sector is subject to more competition.

From the model, I derive a set of predictions that are tested using a repeated cross-section of manufacturing factories in India for the years 1990, 1994 and 1997. The data are merged with information on regulatory outcomes at the state level (such as prices for industrial consumers and indicators of quality) and at the industry level (such as protection from trade or barriers to entry, i.e. licenses). By looking at data from State Electricity Boards (SEB) I find that industries have to pay relatively more for their electricity in states where farmers use an electricity-intensive technology, providing evidence for the political economy mechanism of the regulatory process described above. Other results confirm that the mechanisms related to firm and industry outcomes described in the model are at work, such as the link between industry regulation (e.g. licensing schemes and trade tariffs), and firms' adoption, survival and productivity. I also find evidence that the regulatory process has heterogeneous effects along dimensions such as location, with rural and urban firms reacting more to high electricity tariffs and metropolitan firms reacting to low quality and reliability in the electricity provision. Overall, results suggest that an industry's equilibrium after a process of opening to foreign competition and deregulation varies according to quality and pricing policies in the provision of infrastructure goods.

This investigation adds to the literature on the impact of regulation of the industrial sector in developing countries by bringing together the regulatory process in the provision of an infrastructure good and the economic environment that determines firm's behaviour and industries' performance. Others have looked at price formation in input markets and industrial outcomes. Besley and Burgess (2004), for example, analyse the drivers of labour regulation in Indian states and the effects of pro-labour regulation on investment and productivity. Aghion et al. (2007) find that pro-labour regulation has a negative effect on industrial outcomes when sectors are delicensed. From an infrastructure perspective, Dollar et al. (2003) analyse the "investment climate" by using indicators of performance of telecoms, electricity and banking sectors as perceived by firms and find that firms are affected more by inadequate or badly regulated infrastructure than by higher corruption or poor governance. In particular, they find that the performance of the electricity sector (as measured by power outages) takes the higher toll in terms of productivity and profitability. Arnold et al. (2008) show that total factor productivity in manufacturing industries is positively correlated with generator ownership and negatively correlated with power outages for eight countries in Sub-Saharan Africa. In a similar vein, but with different emphasis, and concentrating specifically on regulatory issues in developing countries, a recent strand in the regulation literature investigates how the economic environment affects the quality of public utilities regulation, underlining corruption and enforcement problems (see for ex, Guasch et al. (2003) and Laffont (2005)).

The remainder of this paper is organised as follows. The next section presents the model and derives a set of testable predictions in the context of Indian firms. Section 3 discusses the data and sources of variation and Section 4 presents the results. Section 5 concludes.

2 The Model

The model is composed of two parts. In the first one, I investigate the captive power adoption decision for heterogeneous firms and the subsequent industry equilibrium for a given level of quality-adjusted price of electricity. In the second part, I model the regulatory process to determine the drivers of electricity pricing and how they affect firms' decisions and the industry equilibrium.

2.1 Set up: downstream

Demand

All consumers have similar Cobb-Douglas preferences over two types of goods, agricultural and manufactured goods denoted by A and M, respectively. There is a continuum range of varieties V_i of manufacturing goods, over which consumers have preferences defined by a constant elasticity of substitution (CES) utility function. The taste for variety of goods is denoted by ρ, such that $0 < \rho < 1$ and the elasticity of substitution is defined as $\sigma = 1/(1-\rho) > 1$. Consumers' utility function is

$$U = M^{\alpha} A^{1-\alpha} = [\int_{v \in V} m(v)^{\rho} dv]^{\frac{\alpha}{\rho}} A^{1-\alpha} \tag{1}$$

where $m(v)$ is the consumption of each variety of manufactured goods. Following Dixit-Stiglitz (1977) and Fujita et al. (1999, Chapter 2), the demand for a manufacture j is

$$m(j) = \alpha Y \frac{p(j)^{-\sigma}}{H^{1-\sigma}} \tag{2}$$

and the demand for the agricultural good is

$$A = (1-\alpha)\frac{Y}{p_a}$$

where Y is a given level of income, $p(j)$ and p_a are the prices of the good j and the agricultural good respectively and H is the aggregate price of manufactures such that

$$H = [\int_{v \in V} p(v)^{1-\sigma} dv]^{\frac{1}{1-\sigma}} \tag{3}$$

Firms

There is a continuum of heterogeneous firms, each producing a different variety using labour and electricity. For simplicity, in the short run, firms are assumed to pay a fixed cost F in labour to produce l units of output and can produce in excess of l by using electricity with different degrees of success. In particular, heterogeneity is captured by a positive productivity factor φ with uniform density function $d(\varphi)$ on $(0, \Phi)$ and cumulative distribution $D(\varphi) = \varphi/\Phi$. Demand for electricity is then a linear function of firm's output (q_f) of the form $e = \dfrac{q_f - l}{\varphi}$ if $q_f > l$ and 0 otherwise. I assume the demand of a variety represented in equation (2) is such that $m(j) > l$ and redefine $q = q_f - l$. It follows that total and marginal costs for variety j increase with electricity price P_e and decrease with productivity φ and can be expressed as

$$TC(\varphi_j) = F + \frac{P_e}{\varphi_j} q \tag{4}$$

The combination of (2) and (4) gives a profit function with a variable net revenue of $(p - \dfrac{P_e}{\varphi_j})\alpha Y \dfrac{p(j)^{-\sigma}}{H^{1-\sigma}}$. The first order condition for the profit-maximising price is

$(1-\sigma)+\frac{\sigma}{p}\frac{P_e}{\varphi_j}=0$. Replacing $\sigma=1/(1-\rho)$ and solving for p, produces an optimal price equal to the marginal cost indexed by the productivity level and a fixed mark up $1/\rho$. This price captures the local market power producers have, derived from consumers' taste for variety ρ

$$p(\varphi_j)=\frac{P_e}{\varphi_j\rho} \tag{5}$$

and a profit for firm j

$$\pi(\varphi_j)=\alpha(1-\rho)Y[\frac{\varphi_j\rho H}{P_e}]^{\sigma-1}-F \tag{6}$$

Note that profits increase when consumers spend more on many manufactures, driven by preferences (α) or income (Y), for example. Given these parameters, firms' idiosyncratic productivity (φ) determines whether firms can cover their fixed costs and survive in the market. That means that less productive firms will not be able to remain active if productivity is below a value φ^*, such that $\pi(\varphi^*)=0$. Average productivity and the subsequent aggregate price and market equilibrium will be determined by the pool of existing firms in the market and not by the pool of potential entrants. As a consequence, I need to redefine the distribution of productivity to account for the low productivity firms that will not remain active. The resulting conditional distribution of productivity is $g(\varphi)=\frac{d(\varphi)}{1-D(\varphi^*)}=\frac{1}{\Phi-\varphi^*}$ if $\Phi>\varphi^*$ and 0 otherwise. To rule out the latter, I assume that there is a taste for variety large enough to allow a cut-off level below the maximum, i.e. $\Phi\rho>\varphi^*$ or $\pi(\varphi=\Phi\rho)>0$. The aggregate price is $H(\varphi^*)=[\int_{\varphi^*}^{\Phi}p(\varphi)^{\sigma-1}g(\varphi)d\varphi]^{\frac{1}{1-\sigma}}$. Also note that higher marginal cost will increase firms' profit per unit sold but, because consumers' expenditure in manufacturing goods is fixed, it will reduce demand for each variety. The role of the aggregate price and the electricity price will be explored further below.

Market equilibrium in a closed economy

In a closed economy, only domestic firms with a similar technology compete. As firms in an industry are assumed to differ only in their productivity, changes affecting the marginal cost of one firm will affect symmetrically the whole industry, meaning that not just the final price of a firm will increase with a higher marginal cost, but also the aggregate price level H. Note that by combining (5) for all firms and (3), H can be rewritten as

$$H^c=p(\tilde{\varphi})M^{\frac{1}{1-\sigma}}=\frac{P_e}{\rho\tilde{\varphi}}M^{\frac{1}{1-\sigma}} \tag{7}$$

where $p(\tilde{\varphi})$ is the price of the average firm, as $\tilde{\varphi}(\varphi^*)=[\int_{\varphi^*}^{\Phi}\varphi^{\sigma-1}g(\varphi)d\varphi]^{\frac{1}{\sigma-1}}$ is the weighted average productivity, and M is the mass of surviving firms in the market. By combining equation (7) with (6), profits can be expressed as

$$\pi^c(\varphi_j)=\alpha(1-\rho)\frac{Y}{M}[\frac{\varphi_j}{\tilde{\varphi}}]^{\sigma-1}-F \tag{8}$$

which is independent of the price of electricity. The fact that equilibrium profits are independent of changes in the marginal cost reproduces a result found in the classical microeconomic literature. When final goods' markets are assumed to be perfectly competitive, the supply of final goods depends on an input's price via its demand. An increase in the factor's price would simply shift upwards the supply curve. This means that changes in variables increasing firms' marginal cost would simply induce a new market equilibrium with a higher price and lower quantity traded in the final good's market. In brief, in a closed economy, changes in the marginal cost that affect all firms will not affect the cut-off productivity level φ^*, i.e. $\dfrac{\partial\varphi^*(P_e)}{\partial P_e} = 0$.

Following Melitz (2003) and Bernard et al. (2006), market equilibrium will be characterized by a Zero Cut-off Profit Condition (ZCP) where the average profit can be written

$$\tilde{\pi} = \pi(\tilde{\varphi}) = [\frac{\tilde{\varphi}(\varphi^*)}{\varphi^*}]^{\sigma-1}[\alpha(1-\rho)Y[\frac{\varphi_j^*\rho H}{P_e}]^{\sigma-1}] - F = Fk(\varphi^*) \tag{9}$$

where $k(\varphi^*) = [\frac{\tilde{\varphi}(\varphi^*)}{\varphi^*}]^{\sigma-1} - 1$ is a monotonically decreasing function of φ^*, from infinity to zero under density distribution $d(\varphi)$[1].

The Free Entry Condition (FEC) implies that the expected net value of entry for the average firm (v_e)–considering the discounted (by a factor δ) probability of successful entry after paying entry fee f_e–should be equal to 0: $v_e = \frac{[1-D(\varphi^*)]}{\delta}\tilde{\pi} - f_e = 0$, or

$$\tilde{\pi} = \frac{f_e\delta}{[1-D(\varphi^*)]} \tag{10}$$

which is monotonically increasing in φ^*. This is because the lower the probability of succeeding, the higher the average profit has to be. The cut-off equilibrium level φ^* will satisfy simultaneously both ZCP and FEC: as $k(\varphi^*)[1-D(\varphi^*)] = f_e\delta/F$. The existence of equilibrium is ensured by the fact that k decreases from infinity to zero and $[1-D(\varphi^*)]$ decreases from 1 to 0.

2.2 Adoption of captive power generators

The following part of the model draws from anecdotal evidence on the adoption of captive power generators by Indian firms. In particular, this section introduces the possibility that firms set up a technology which allows them to reduce their marginal cost by reducing the price P_e they pay for their electricity of a determined quality. In this setting, an excessive price or reduced quality in the provision of electricity could increase the costs of industrial production and affect the competitiveness of firms when some firms have an outside option such as a captive generator and others

[1]Under the uniform distribution $[\frac{\tilde{\varphi}(\varphi^*)}{\varphi^*}]^{\sigma-1} = \dfrac{\Phi^{\sigma-1} - \varphi^{*\sigma-1}}{\varphi^{*\sigma-1}(\Phi-\varphi^*)}$ that is decreasing in φ^* under the assumption that $\Phi\rho > \varphi^*$.

do not. It is well documented (see for example TERI (1999) and Tongia (2003)) that Indian firms choose to set up their own electricity generator to hedge against power failures or voltage fluctuations, thereby ensuring adequate quality (small generators) or lower costs (bigger power plants), and that this practice has increased over the years. As Biswas et al. (2004) point out when analysing the captive generation in Gujarat, some industries like metal producers rely critically on the provision of energy. Sometimes, as in the aluminium industries, it can determine up to 40% of total production costs.

Assume firms can pay a fixed amount G to introduce a marginal cost-reducing technology that scales down the tariff paid to the electricity by $\Theta(P_e)$, so that the price of electricity enters marginal cost as $P_e\Theta(P_e)$. The idea is that firms can buy a generator to hedge against erratic quality in supply. A few assumptions are needed to characterize this technology: if the electricity supplier charges the marginal cost of producing a unit (adjusted by quality) of electricity c, then using a generator does not reduce firms' marginal cost ($\Theta(c) = 1$). The greater the price paid for electricity, the more effective is this technology at reducing cost ($\partial\Theta(P_e)/\partial P_e < 0$), even though marginal cost is still increasing in P_e ($0 < \partial P_e\Theta(P_e)/\partial P_e < 1$)[2] . An example of such a function would be $\Theta(P_e) = \theta^{\frac{c-Pe}{P_M}}$ where $\theta > 1$ and P_M is the maximum price the electricity supplier can charge (i.e. monopolistic price).

Adoption and productivity cut-off

An individual firm j will be willing to adopt this technology if the reduction in marginal cost that drives profits up compensates the extra fixed cost G, or if

$$\begin{aligned} \Delta\pi(\varphi_j) &= \pi(P_e\Theta(P_e);\varphi_j) - \pi(P_e;\varphi_j) \\ &= \alpha(1-\rho)Y[\frac{\varphi_j H\rho}{P_e}]^{\sigma-1}[(\Theta(P_e))^{(1-\sigma)} - 1] - G \geq 0 \end{aligned} \quad (11)$$

There is a cut-off level of productivity $\hat{\varphi}$ for which a firm is indifferent between adopting or not, such that $\Delta\pi(\hat{\varphi}) = 0$. The productivity of the marginal firm adopting the captive power can be obtained as a function of φ^* by noting that $\Delta\pi(\hat{\varphi}) = \pi(\varphi^*) = 0$:

$$\hat{\varphi} = \varphi^*(\frac{G}{F})^{\frac{1}{\sigma-1}}[(\Theta(P_e))^{(1-\sigma)} - 1]^{-\frac{1}{\sigma-1}}$$

Rearranging the second term, if $\frac{F+G}{F} < (\Theta(P_e))^{(1-\sigma)}$, the productivity of the marginal adopter would be lower than the productivity of the marginal surviving firm, and all firms in the market would adopt the generator. Using $\Theta(P_e) = \theta^{\frac{c-Pe}{P_M}}$, I can obtain a threshold

$$\hat{P}_e = c + \frac{\log(1+\frac{G}{F})}{\log\theta}\frac{P_M}{(\sigma-1)}$$

[2]Since $\partial P_e\Theta(Pe)/\partial Pe = (\partial\Theta/\partial Pe)P_e + \Theta$ where $\partial\Theta/\partial Pe < 0$ and $\Theta \leq 1$

such that if $P_e > \hat{P}_e$, all firms will adopt the technology. Note that the threshold is increasing in the cost of the generator (G) and decreasing on the effectiveness of the technology (θ). The intuition is that adoption is profitable when the cost of the generator relative to fixed costs is lower than the extra profits obtained for reducing the marginal cost. If the generator was freely available, all firms would adopt it even when the price of electricity was at its lowest possible level, c. On the other hand, when $P_e = c$, the technology does not reduce costs and no firm finds it profitable to pay a positive set-up cost. However, I assume that the most productive firms find adoption worthwhile for any small increase ε above c, i.e. $\Delta\pi(\Phi; c+\varepsilon) > 0$. At the firm level, it follows that for values $\hat{P}_e \geqslant P_e > c$, adoption is increasing in the price of electricity or reductions in quality ($\partial\Delta\pi/\partial P_e > 0$), and for $P_e > \hat{P}_e$, all surviving firms adopt.

I next analyse how the presence of a generator plays out at the industry level when some firms adopt and other don't. The uniform distribution of productivity provides a simple way of measuring the proportion of firms adopting (A), as $A = \dfrac{\Phi - \hat{\varphi}}{\Phi - \varphi^*}$. Note that firms adopting the captive power generator (with weighted average productivity $\tilde{\varphi}_a$) will coexist with firms relying exclusively on the network (with weighted average productivity $\tilde{\varphi}_n$) and the aggregate price will be

$$H^g = M^{\frac{1}{1-\sigma}}[(\frac{P_e}{\rho\tilde{\varphi}_n})^{1-\sigma} + (\frac{\Theta(P_e)P_e}{\rho\tilde{\varphi}_a})^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{12}$$

In this situation, a price change in the electricity supply will not affect all firms symmetrically. As a matter of fact, firms that have adopted the captive generator will suffer the price hike less and their marginal cost will increase less than firms that have not adopted the generator. The change in profits for the marginal firm φ^* will depend on the sign of the change in the aggregate price relative to its own price, namely the quotient $\dfrac{H^g}{P_e}$. By inspection of equation (12) it follows that

$$sign\ \partial(\frac{H^g}{P_e})/\partial P_e = sign\ \partial(\Theta(Pe))/\partial P_e < 0$$

The marginal consumer will not be able to remain in the market and will exit. Whenever most productive firms have an alternative to network provision of electricity, less productive firms will be more vulnerable to changes in the input price and may face market exit: the productivity threshold for survival will increase, i.e. $\partial\varphi^*(P_e)/\partial P_e > 0$. The intuition is as follows: when the price of electricity increases in the case with no captive generator it does so for all firms. This means that the marginal cost and the aggregate price move together and the marginal firm will not be affected. When the cost-reducing technology is available more productive firms find it worthwhile to adopt, and increases in the electricity price are not matched by an increase in the aggregate price. As a consequence, the marginal firm makes negative profits and exits the market.

On the other hand, whenever there is an increase in price P_e firms in the adoption margin (i.e. with productivity $\hat{\varphi}$) will now find it worthwhile to adopt unambiguously, since the captive generator absorbs part of the increase in P_e. It follows that the cut-off productivity is decreasing in P_e, i.e. $\partial\hat{\varphi}(P_e)/\partial P_e < 0$. As a consequence, an increase in the price of electricity will affect the population and composition of firms, both by inducing the exit of firms on the margin of survival and by inducing more adoption of the marginal cost-reducing technology within the pool of surviving firms, i.e. $\partial A/\partial P_e > 0$.

Market equilibrium

The average productivity when some firms adopt a captive generator can be expressed as

$$\tilde{\varphi}^g = [\tilde{\varphi}_n{}^{\sigma-1} + (\Theta^{-1}\tilde{\varphi}_a)^{\sigma-1}]^{\frac{1}{\sigma-1}} \tag{13}$$

By replacing (13) in the profit function, the new average product can be expressed as $\pi(\tilde{\varphi}^g) = \pi(\tilde{\varphi}_n) + \pi(\tilde{\varphi}_a)$, which is greater than $\pi(\tilde{\varphi})$ for a given cut-off productivity level φ^*, since profits for users of the captive generator are greater than the profit they would have obtained had they not adopted. This would imply a ZPC shifted up with respect to the case where the captive generator was not available. Note that this holds even for the case when all firms adopt. As the expression for FEC remains the same, the new equilibrium will happen at a greater cut-off productivity[3].

2.3 Changes in the environment

Barriers to entry: open economy and entry fees

The equilibrium outcomes in terms of survival and adoption of captive power depend on the economic environment that determine the parameter values in the model. For example, when the economy is opened to foreign competition, the entry of new firms will affect the aggregate price H and, subsequently, sales and profits (see Fujita et al. (1999)). This would affect the Zero Cut-Off Profit Condition and market equilibrium, since in a more competitive environment, the required productivity increases. In a similar vein, the level of the entry fee, f_e, determines the required probability of success needed for firms to attempt entry, and changes in its level correspond to shifts in the Free Entry Condition curve.

To look at changes in H, assume the economy is open and transport costs are modelled as firms having to send $\tau > 1$ units to export 1 unit of output. For simplicity, I concentrate on the effect of new products entering the market on domestic firms (abstracting from their export decision, since I am interested in looking at the reaction of domestic firms to bad regulation in a more competitive environment). Foreign firms will be able to enter the market if they can meet the equilibrium cut-off price

[3] This result is similar to Melitz (2003), but rather than it being exporting firms profits that push the ZPC up, it is the availability of a cost-reducing technology which produces the increase in profits for a set of more productive firms.

of entry $p(\varphi_f) = \dfrac{\tau P_e^f}{\varphi_f \rho} \leq \dfrac{P_e}{\varphi^* \rho}$[4]. This will happen for very productive firms or for firms coming from countries with cheaper or more reliable electricity provision (lower P_e^f). Whatever the case, the entry of new firms will expand the set of varieties available to consumers and, by increasing the mass of competing firms M, a more open environment will reduce the aggregate price H and the demand for all domestic varieties.

It follows that trade barriers are associated with greater aggregate prices and profits for domestic firms, while the productivity cut-off level falls:

$$\frac{\partial \pi}{\partial H} = (\sigma - 1)\alpha(1-\rho)Y[\frac{\varphi_j \rho}{P_e}]^{\sigma-1} H^{\sigma-2} > 0; \partial\varphi^*/\partial H < 0$$

The productivity needed to cover the fixed costs and to survive is greater in an open economy than in a protected economy, i.e. $\varphi_c^* < \varphi_o^*$. This replicates a result obtained in the literature on trade liberalization (e.g., Melitz (2003)) where an open environment forces firms at the bottom of the productivity distribution out of the market, raising the average productivity. Note that this would happen both when the generator is not available and in the situation where all firms adopt. This finding underlines the importance for domestic firms of well-functioning input markets. In such settings, the impact of foreign competition will depend mostly on the price of electricity as follows: first, the relative efficiency of the domestic country at producing electricity, i.e. whether $c \geq c^f$. Second, on the regulatory process that determines P_e relative to P_e^f. It follows that if $P_e = c = c^f$, then only very productive foreign firms will be able to sell their varieties and the impact on marginal firms in the domestic markets might be lower.

In terms of adoption of the technology, the condition represented in equation (11) shows that $\partial\Delta\pi/\partial H > 0$, implying that the marginal firm in the adoption decision has a greater productivity level in an open economy. This is explained by the fact that as the economy opens, a firm sells less units of output. If before, at a given level of productivity and P_e, there was just enough to cover the fixed cost of the generator, now firms need to be more productive to make up for the lower sales. Under the assumption of uniform productivity distribution, and considering that the change in the adoption margin is greater than the change in the survival margin, since $|\partial\hat{\varphi}/\partial H| = (\partial\varphi^*/\partial H)\ (\frac{G}{F})^{\frac{1}{\sigma-1}}[(\Theta(Pe))^{1-\sigma} - 1]^{-\frac{1}{\sigma-1}} > |\partial\varphi^*/\partial H|$ when $P_e < \hat{P}_e$, it follows that the proportion of firms adopting increases in more protected environments, i.e. $\partial A/\partial H > 0$. This stems from the fact that adopting the technology implies an extra fixed cost, meaning that adopting firms have to be proportionally more productive than non-adopting firms to compensate for reductions in sales after a fall in the aggregate price.

[4] $\dfrac{\Theta P_e}{\varphi^* \rho}$, if all firms adopt the generator

A similar point could be made regarding the entry fee, f_e, firms pay to participate in the market. Larger fees shift the FEC to the left and equilibrium happens at a lower φ^*, because firms need a greater probability of survival to compensate for the increase in fees. It follows that, using the same reasoning as with more protected markets, the proportion of adopting firms should increase, $\partial A/\partial f_e > 0$.

Borrowing constraints

An additional concern is the existence of imperfections in the credit markets that might induce borrowing constraints. As an illustration, assume a competitive financial sector, i.e. where banks meet a zero-profit constraint. In the case where adopters and non-adopters of the generator co-exist in the market, firms seek a loan L to buy the generator. Whenever a firm's productivity is observable and there are not incentives to default for operating firms[5], the bank will charge a gross interest rate r equal to the opportunity cost ξ. The fixed cost for the firm will be $G = Lr$, defining a productivity cut-off for the adoption of the generator $\hat{\varphi}$ such that $\Delta\pi(\hat{\varphi}) = 0$ as in equation (11). If banks cannot determine the productivity of a given firm and cannot recoup anything from a bad loan, their zero-profit condition requires that the expected value of the loan equals the opportunity cost, i.e. $p(\varphi \geq \varphi^*)Lr = L\xi$ or $r = \xi/(1-D(\varphi^*)) > \xi$. In the presence of information or enforcement problems, loans would be more expensive, which is equivalent to an increase in the fixed cost of the generator G that raises the adoption productivity cut-off. In the presence of credit market imperfections, more productive firms will still find it worthwhile to adopt, but firms on the margin of adoption will remain in the market, but will not use a captive generator, i.e. $\partial A/\partial G < 0$

Expenditure

Consumers derive their utility from consuming food and manufactures, and their shares in total consumption are captured in the model by α. When consumers change their preferences towards manufacturing goods (i.e. an increase in α), both the survival and the adoption margins are reduced. As the magnitude of the change is greater for adopting firms, then the ratio of adoption is greater, the greater the expenditure on manufacturing goods, i.e. $\partial A/\partial \alpha > 0$.

2.4 Upstream

This section of the model builds on Laffont-Tirole (1993) and analyses how the regulator of the electricity sector determines P_e. I assume that the electricity market is run by a state monopoly whose decisions are affected by the political process. Following India's example, the regulator can price discriminate between different types of consumers–agricultural and industrial–and that the farmer's lobby is such that an agricultural electricity tariff is always set equal to the marginal cost. The regula-

[5] Assume, for example, that for operating firms the probability of getting caught is equal to 1, and that cheating firms pay a hefty fine. However, firms not operating could "take the money and run," even though that is not a problem with full information.

tor is left with a Utilitarian Social Welfare function equal to the sum of industrial consumers and producer utilities in the electricity market (V and U, respectively):

$$W = V + U \tag{14}$$

Consumer surplus is weighted by a "sector-specific consumer bias" ($\lambda \in [0; 1]$) that captures the relative lobbying power of industrial consumers. The monopolist's utility is simply the revenue from selling to both sectors, less a separable cost function. The cost of producing a unit of electricity is $C = cq + F_M$. Combining firms' technological use of electricity, $e = \dfrac{q_t - l}{\varphi}$, and equations (2) and (5), an individual demand for electricity can be defined, as $e_j^d = \alpha Y \rho \dfrac{P_e^{-\sigma}}{(\rho H \varphi_j)^{1-\sigma}} - l/\varphi_j$. This expression shows that demand for electricity will depend on the level of productivity. Additionally, demand price elasticity of electricity is greater than 1.

The regulator can use transfers to expand the set of possible outcomes by taxing consumers and compensating the monopolist for low levels of prices that do not meet the participation constraint, namely $U \geq 0$. When such transfers are allowed, consumers are liable to be taxed in order to fund the transfer. I assume linear pricing and define $S(P_e; \varphi)$ as the net surplus obtained by an industrial consumer with productivity φ, where the surplus is 0 for the cut-off level of productivity φ^*, i.e. $S(P_e; \varphi^*) = 0$. Equation (15) defines the consumer surplus

$$V = \lambda \int_{\varphi^*}^{\Phi} S(P_e; \varphi) g(\varphi) d\varphi - (1 + \gamma)\tilde{t} \tag{15}$$

where $\tilde{t}$ is the gross transfer ($\tilde{t} \geq 0$) and γ the cost of transferring public funds. The monopolist's utility is $U = \tilde{t} + (P_e - c) \int_{\varphi} e(P_e; \varphi) g(\varphi) d\varphi - F_M$. By replacing $\tilde{t}$ in (15), adding up U, and replacing in (14), social welfare is:

$$\begin{aligned} W &= \lambda \int_{\varphi^*}^{\Phi} S(P_e; \varphi) g(\varphi) d\varphi + \\ &\quad (1 + \gamma)[(P_{e-}c) \int_{\varphi *}^{\Phi} e(P_e; \varphi) g(\varphi) d\varphi - F_M] - \gamma U \end{aligned} \tag{16}$$

The regulator chooses the price that maximizes (16) subject to the monopolist's participation constraint, $U \geq 0$. As the transfer of funds to the monopolist is socially costly, the utility of the monopolist will be kept at $U = 0$. The regulator also considers that the price set might affect the cut-off productivity, i.e. φ^* can be written as $\varphi^*(P_e)$.

The first order condition is

$$
\begin{aligned}
& -\lambda \int_{\varphi^*}^{\Phi} e(P_e;\varphi)g(\varphi)d\varphi + (1+\gamma)\int_{\varphi*}^{\Phi} e(P_e;\varphi)g(\varphi)d\varphi \\
& +(1+\gamma)(P_{e-}c)[\int_{\varphi*}^{\Phi} \frac{\partial e}{\partial P_e}(P_e;\varphi)g(\varphi)d\varphi - e(P_e;\varphi^*)g(\varphi^*)\frac{\partial \varphi^*}{\partial P_e}] \\
= & \; 0
\end{aligned} \tag{17}
$$

By defining $E(P_e;\varphi^*) = \int_{\varphi^*}^{\Phi} e(P_e;\varphi)g(\varphi)d\varphi$, the price elasticity of demand for a given cut-off level of productivity φ^* as η_d[6], and the price elasticity of participation $\eta_p = \frac{\partial \varphi^*}{\partial P_e}\frac{P_e}{\varphi^*}$, the Lerner index becomes

$$
\frac{P_e - c}{P_e} = \frac{1+\gamma-\lambda}{(1+\gamma)[\eta_d + \frac{e(P_e;\varphi^*)g(\varphi^*)}{E(P_e;\varphi^*)}\varphi^*\eta_P]} \tag{18}
$$

Condition (18) is a general expression for the Lerner index for cases with anti-consumer bias, consumer heterogeneity and transfer costs. When setting prices with consumer heterogeneity, the regulator has to include in the maximization programme the fact that price changes result in shifts for the marginal consumer; specifically by adding to the price elasticity of the demand (η_d), the sensitivity of the frontier (η_P) weighted by marginal consumer's relative importance in aggregate demand. In the absence of these three features, the price chosen by the regulator will be equal to marginal cost. Deviations from marginal cost pricing come from low levels of λ (i.e. industries' well-being in the electricity market does not enter fully in regulator's objective function), or from high levels of γ (i.e. as the cost of government transfers increases, it becomes optimal to recoup provision costs by charging electricity users more). As previously shown, in a closed economy the productivity of the marginal consumer is independent of the price of electricity ($\frac{\partial \varphi^*}{\partial P_e} = 0$). From (18), it follows that the regulator would set $P_e = \frac{c\eta_d}{\eta_d - 1 + \frac{\lambda}{1+\gamma}}$. There are two extreme cases: when the well being of consumers does not enter regulator's objective function ($\lambda = 0$), or when transfers are extremely expensive ($\gamma \to \infty$) such that the regulator sets the monopolist price, either because it would be simply maximizing the monopolist's profits or because avoiding costly transfers implies choosing the highest possible price.

Firms, industries and regulation

This result links to the firm and industry analysis in a very simple way: the parameters that determine the price level of electricity, namely c, γ and λ, will determine whether a firm adopts, as well as the composition of survival and adoption at the

[6] Where $\eta_d = -P_e \int_{\varphi*}^{\infty} \frac{\partial e}{\partial P_e}(P_e;\varphi)g(\varphi)d\varphi) / \int_{\varphi^*}^{\infty} e(P_e;\varphi)g(\varphi)d\varphi$

industry level. Everything else equal, the proportion of firms adopting will be greater in places where the monopolist is less efficient at producing electricity ($\partial A/\partial c > 0$) or the government is less efficient at taxing and redistributing ($\partial A/\partial \gamma > 0$) or where the regulator sets prices with less regard for the well-being of industrial producers ($\partial A/\partial \lambda < 0$). The introduction of the latter constitutes the most important mechanism in linking the political economy of regulation and industry outcomes. This relationship is explored further below, when applied to the Indian experience.

Quality

The discussion of prices could be extended to consider quality issues as well. In its simplest interpretation, and following the Laffont-Tirole framework (2003, see Section 2.5, Chapter 2), the results obtained above would remain the same when price and quality are perfect substitutes for consumers and the electricity producer. I could redefine P_e as the quality adjusted price such that $P_e = p_e - s$, where p_e is the actual tariff and s is quality (normalized to 0 for a standard service) and $c = c_t + s$, where c_t is the technological marginal cost. In that sense, predictions related to increases in the price of electricity and reductions in its quality should be the same. If quality is not verifiable, it provides the regulator with more freedom to set her preferred policies. For example, if the regulator has a big anti-industry bias ($\lambda = 0$) and no transfer costs in a closed economy, then the optimal price for the regulator would be the monopolistic price $P_e^M = \dfrac{c\eta_d}{\eta_d - 1}$. If additional constraints arise, such as a price cap $\bar{p}_e$ from the central government (or pressures for a maximum price from industrial producers, for example), the regulator would have to maximise $W = (p_e - c_t + s)Q(p_e - s; \varphi^*)$ subject to $p_e \leq \bar{p}_e$. By setting negative (i.e. below standard) quality $s = \bar{p}_e - P_e^M$, the regulator can avoid complying with the price cap and behave as if unconstrained.

2.5 Predictions in the Indian context

Electricity prices

The model predicts that regulatory outcomes are linked to industrial outcomes by means of the determinants of P_e. To test this in the context of Indian provision of electricity, it is important to understand the institutional framework. The Electricity Supply Act in 1948 created agencies like the Central Electricity Authority (CEA), in charge of formulating national policies and assessing the technical and economic viability of power projects, and the State Electricity Boards (SEB), whose board members are appointed by the state government (Chapter III, 5.2). The SEBs are fully vertically integrated, owning the four segments of the industry–generation, transmission, distribution and commercialization– and set their own pricing and investment policies.

In terms of linking the electricity tariffs to the government's anti-industry bias (λ) and inefficiency (γ), sectorial analysis for Indian SEBs deemed the energy provision as "more of a social service than a business. Prices do not reflect costs and state institutions are dependent on allocations from the public budget" (TERI (1999)). Also, "the SEBs became bastions of political patronage rather than true business enterprises (...) Reformers faced political opposition from farmers, who had come to rely on enormous quantities of low-cost electricity for pumping water" (Tongia (2003)). Overall, subsidies to farmers and domestic consumers by states via the electricity provision have been estimated to be in the order of 1 to 1.5% of India's GDP (World Bank (2000)). In all circumstances described by the previous model(e.g. availability of a generator, open economy, borrowing constraints), other than a closed economy, an increase in the price of electricity would induce the exit of firms at the margin ($\eta_P > 0$). The loss of consumers would reduce the monopolist's revenue regardless of the weight assigned to industrial consumers and would reduce the price set by the regulator. In all cases, states with more anti-industry bias and with less efficient governments should show higher electricity prices. Unfortunately, there is not enough information to test whether prices set by SEBs are sensitive to changes in the cut-off level for firms' survival.

The model predicts that cross-subsidization should be more prevalent in states with a stronger rural lobby. In particular, the measure of rural lobby I use reflects the adoption of high yield varieties (HYV) after the start of the Green Revolution. HYV seeds are known to be high-cost/high-yield because they multiply agricultural productivity if timely irrigation, among other inputs, is provided. The cheapest way for farmers to secure water is by means of electric pumpsets that suction water from the water table via tubewells. The importance of food production for reducing the possibility of famines gives farmers, in particular larger and richer ones, the upper hand. Dhanagare (1989) estimates that "the prosperity unleashed by the Green Revolution was distributed differentially, putting the small and marginal farmers at a relative disadvantage. The high cost/high yield technology called for capital investments beyond the means of a majority of small and marginal farmers." With a stronger economic position, rural rich farmers also developed political leverage that was translated into further subsidies. In particular, Gulati and Narayanan (2003) show how what they call "the subsidy syndrome in Indian agriculture" after the introduction of the new seeds in late 60s, became a fundamental instrument of economic policy that was mainly channelled through available and affordable fertilizers, irrigation and electricity. Dhanagare also points out that "only the needs of rich farmers were catered by the electricity boards," since while the unit price was heavily subsidized, connection charges were so expensive that only rich farmers could afford them. For example, in the case of Punjab, the state at the forefront of HYV adoption, Simms (1988) describes a situation in which "farmers are aware of the power they hold due to their strategic importance in the national economy (...) Political action has led to extensive changes in rural Indian Punjab." Describing a rally organized by one organization of farmers, Simms points out that "the state government was thrown off balance by their show of force and conceded many of their demands." This description of the Indian context combined with the upstream section of the model laid out earlier suggests that the power of rural lobbies and government's efficiency should be linked to the pricing strategy of the regulator, i.e. states with more adoption of HYV seeds and more budget deficits charge a higher price to industrial consumers of electricity (Prediction 1).

Adoption: individual characteristics

Poor regulatory decisions resulting in excessive prices or reduced quality necessarily increase the costs of industrial production and affect the competitiveness of firms, ultimately distorting their choice of technology or industry. As a consequence, firms set up their own electricity generator to hedge against power failures or voltage fluctuations to ensure the adequate quality or to reduce costs. This practice has increased over the years in India. As mentioned earlier, Biswas et al. (2004) point out that some industries like metal producers rely critically on the provision of energy and electricity is often a sizeable part of their total production cost. To ensure the quality of the provision and to remain competitive in the market, firms tend to install captive power plants. The installed captive capacity varies considerably across states and industries. An infrastructure report produced by Price Waterhouse Coopers for the government of Chhattisgarh shows that in 1998, the average captive capacity was around 17%, with significant variation. In some states–like Karnataka (30.5%) and Haryana (38%)–captive power is significant while in others–like Jammu & Kashmir and Himachal Pradesh– firms use exclusively SEB's electricity. Industry-wise, there is considerable variation as well, with industries like electronics producers using self-provision of energy just up to a 0.5% of total captive generation capacity, while engineering or metals and minerals industries surpass 20%.

The model predicts adoption of the captive generator according to a set of parameters that varies across firms. For example, as noted earlier, the electricity price P_e could be understood as a quality-adjusted tariff. In that case, some characteristics of the firms, such as their location (urban vs. rural), might be correlated with the quality of supply received and have an impact on their decision to adopt a generator. Additionally, measures that could be capturing an idiosyncratic productivity (φ) or access to finance (G)–such as whether a firm is public or multiproduct–should also be positively correlated with adoption. The model also predicts that if adopting firms coexist with non-adopting firms, measures of output and size (e.g., workers) should be greater for adopting firms. It follows that firm characteristics, including exposure to lower quality of electricity, greater productivity, access to credit and size are all correlated with more adoption of captive power (Prediction 2).

Adoption: state characteristics

As previously mentioned, regulatory outcomes vary only at the state level. As the model predicts that adoption of captive power increases with the price of electricity and decreases with quality, in-house generation of electricity should be more prevalent in states where industries are charged relatively more for electricity and where the quality of provision is poorer. Additionally, the model identifies variables that drive pricing policies. In particular, the lobbying power of farmers and government's inefficiency should be positively correlated with adoption. Finally, I use data on urbanization rates to proxy for the share of consumption in manufacturing goods (represented by α in the model) and test whether it is positively correlated with adoption. The incidence of adoption of captive power should be greater in states where the SEB charges higher electricity tariffs to industrial consumers or provides lower quality. Adoption should also be positively correlated with farmers' lobbying power and measures of government and SEB inefficiency (Prediction 3).

Adoption: industry characteristics

The impact of the regulatory context for the adoption decision in Indian industries can also be captured by some features of the model. In particular, adoption should be greater in sectors more protected from international competition via trade tariffs. This comes from the finding that in industries where some firms adopt and others do not, the margin for adopting firms is more sensitive to changes than the margin for surviving firms. Even though India considerably reduced its trade tariffs in 1991, there is significant variation in tariff levels across industries both before and after the reforms. Another widespread industrial policy in India after independence was the establishment of a licensing scheme that was dismantled progressively from 1985 onwards[7]. The license system can be understood in the framework of this model as the entry fee f_e firms have to pay before knowing whether they will survive or not. As with tariffs, greater fees should be correlated with a greater proportion of firms adopting the power generator. In short, the fourth prediction is that the incidence of adoption of captive power should be greater in industries that are protected by greater trade tariffs and subject to licenses (Prediction 4).

Productivity

The prediction regarding productivity is in line with the trade literature where protection allows for the survival of less productive firms. This paper also links productivity with the adoption of an in-house generator of electricity. In particular, firms which adopt are expected to be more productive and bigger, on average. The model also predicts that the margin of survival and adoption will be lower for more protected sectors. Industrial sectors that are more protected (whether by trade tariffs or licensing) should also produce less and be less productive, on average. Additionally, within an industry, the average productivity and output should be greater for firms adopting the captive generator (Prediction 5).

3 Data and Descriptive Statistics

To test the predictions laid out above, I use data on the adoption of captive power generators at the factory level. Tests on the effect of regulatory outcomes are done at the state level, while measures of openness vary at the industry level.

Factories: The dataset is a repeated cross-section of factories for the years 1990,

[7] For a information on the delicensing process and its effects, see Aghion et al. (2007)

1994 and 1997 collected by the Annual Survey of Industries, Department of Statistics, Government of India. The basic sample consists of more than 145,000 observations, but is lower when combined with state or industry measures. Since the sample includes firms in the "census sector" (i.e. with more than 100 workers) and firms that are sampled (the sampling design adopts 3-digit-industry groups per state as stratum and covers all the units in a span of three years), all regressions weigh units of observation accordingly. Table 1 provides some summary statistics, where it can be seen that around 1 in 3 firms have a captive generator of electricity. Some factory characteristics capture features of the model. For example, location (around 30% rural firms, 58% urban and the rest, in one of the metropolitan areas, i.e. cities with more than 1 million people as defined by the 1991 Indian census) might reveal information about the quality of the electricity that firms are exposed to (e.g. blackouts, pilferage, technical losses, power surges). Other characteristics might reveal idiosyncratic productivity, such as whether the factory produces more than one good (61.8% do) or size (25% are in the census sector). Finally, credit constraints might be captured by whether the firm has access to credit (a large number of firms–74%–have access to some kind of credit). Moreover, if firms are public (around 14% are), we should expect them to access formal (i.e. cheaper) sources of funds.

States: The variables capturing State Electricity Boards' regulatory outcomes include data on prices such as tariffs charged to industries and agricultural users, average tariffs (the sum of prices paid by industries, farmers, households and commercial users, weighted by their share in total sales). Quality measures include transmission and distribution losses (as a percentage of total electricity traded) and outages in thermal plants. Table 1 shows significant variation in both measures. Other relevant information related to SEBs efficiency is captured by variables such as a measure of network extension (i.e. the number of consumers connected to the electricity network), unit cost of electricity production, quantity of employees per Kwh produced and subsidies received from the central government. Other state-level variables, aimed at capturing the relative power of farming lobbies (λ), government efficiency (γ) and consumers' preference for manufacturing goods (α) are proxied by the incidence of the Green Revolution (the proportion of cultivated land cropped with HYV seeds), state governments' budget deficits and the proportion of urban population, respectively.

Industries: India-wide industrial policies are captured by measures of trade tariffs at the 3-digit industry level and by a dummy at the 4-digit industry level equal to one if firms require a license to enter that industry. The reduction process of barriers to entry for foreign products and new domestic producers started slowly in 1985 and accelerated after 1991. However, the process affected different industries at different points in time and in different degrees (in particular, in terms of trade tariffs reduction). Table 1 shows that factories were exposed to different degrees of protection. For example, around 76% of the firms in the sample were subject to a licensing process in 1990 while in 1994 and 1997, it was only around 37%. The mean imports tariff also dropped considerably, from around 1.3 in 1990 to 0.89 in 1994 and

0.47 in 1997.

4 Results

Pricing

The model predicts (Prediction 1) that in states where the anti-industry bias is stronger, the price for industrial consumers will be higher. The anecdotal evidence points to regulators having a pro-farmer bias and an anti-industry bias across the board in Indian states. However, the intensity of that bias could be associated with farmers' need for electricity. A measure of this can be obtained by looking at the adoption of an agricultural technology that is intensive in electricity. In particular, the use of high yield variety (HYV) seeds that were introduced with the Green Revolution required timely irrigation and electric pumpsets were the cheapest way of accessing groundwater.

Table 2 compares measures of relative prices and quality for states where HYV seed adoption was above the median [8], and the rest of the states. The first measure is the ratio between average tariff and unit cost, available from 1974 to 1997. Even though all SEBs struggled in that period to recoup their production costs, states intensive in HYV had a significantly lower proportion of their costs covered by sales revenue. All other measures are only available for the period 1990-1997, and show that states intensive in HYV charged higher tariffs for industrial producers, relative to the average tariff or the unit cost. Additionally, the tariff charged to farmers was much lower for both groups, relative to the average tariff or the industrial tariff respectively, but both ratios are significantly lower for states intensive in HYV. Table 2 suggests that states where farmers relied more on electricity tended to set pro-farmer pricing schemes in the electricity sector, and that industrial users tended to be charged more. However, measures of quality, such as thermal outages or transmission and distribution losses were similar, on average, for both groups of states.

To test whether this pricing policy started right at the beginning of the Green Revolution, I use data on the ratio of tariffs charged to industrial users of electricity over the tariff charged to farmers and a continuous measure of the proportion of land under HYV seeds for three years in the 70s (1973-1975). Column (1) in Table 3 shows that industries were charged relatively more, the greater the proportion of HYV seeds, even when controlling for other time varying state variables such as population, governments' real development expenditure and the party of the state Chief Minister. The model also predicts that electricity tariffs will be affected by governments' efficiency at transferring resources The intuition is that as governments become less efficient, the cost of transfers increases and the regulator has to rely on higher prices

[8] High HYV states are Andhra Pradesh, Bihar, Haryana, Kerala, Punjab, Tamil Nadu and Uttar Pradesh. These states were above the median of adoption both in 1974 (at least 27%) and in 1984 (at least 41%).

to recoup costs. Column (2) shows that states with higher budget deficits tended to charge higher prices to industrial producers, keeping HYV adoption fixed. One concern is that of reverse causality: i.e. because some states provided cheaper electricity, then HYV adoption follows. To mitigate this concern, in Column (3) I instrument HYV adoption with the proportion of districts with abundant groundwater, a geographical characteristic associated to the successful adoption of HYV (as in Rud (2009)), and find that results hold. Columns (4) to (6) use 11-year information for 15 states on average electricity tariff relative to average cost. Results show a similar pattern: states intensive in HYV seeds and with larger budget deficits tended to have less sustainable pricing policies. That suggests that even if industries were carrying the burden of pro-farmer pricing, SEBs had a harder time recouping electricity production costs. Column (6) uses the same instrument as in column (3), this time interacted with year dummies to capture divergence in HYV adoption across states. Overall, the data shows that Indian industries faced steeper prices in states with more powerful farming sectors and less efficient governments.

Adoption

The adoption of a captive generator in the model is driven by characteristics that can vary at the firm, industry and state level. In particular, the model predicts (Prediction 2) that factory characteristics that capture exposure to low quality of electricity, more access to credit and greater size and productivity are all associated with greater adoption of a generator. To look at firm level characteristics that capture each of these phenomena and see whether they are correlated with adoption, I run a linear probability model of the form

$$A_{fisy} = \alpha_{isy} + \boldsymbol{\beta}\mathbf{X}_f + \varepsilon_{fisy}$$

where $A = 1$ if factory f in industry i in state s in year y generates in-house some of the electricity it needs to produce and 0 otherwise. Individual characteristics are captured by X_f and state-industry-year fixed effects are captured by α. This means that the variation comes from firms producing in the same 3-digit NIC industry located in the same state and producing at a given point in time.

Anecdotal evidence shows that the supply of electricity in rural areas tends to be subject to more blackouts, power surges and erratic tension. Urban and metropolitan areas tend to suffer this problem less, in particular cities. This means that I should expect factories in rural areas to adopt more generators than those in urban and metropolitan areas. Column (1) in Table 4 shows that a rural firm is around 6% more likely to use a generator. Column (2) also includes a dummy for urban firms and shows that both rural and urban factories are respectively 11% and 6% more likely to own a generator than firms in metropolitan areas (defined as cities with a population of 1 million people or more).

The ownership structure of a firm can provide information on both its productivity and its access to external finance at a relatively cheap cost. Column (3) shows that factories belonging to a public company are around 24% more likely to adopt generators than firms that are privately (whether by individuals or societies) or state-owned. Another characteristic that might be linked to productivity is whether a factory produces many products or just one. Column (4) shows that the probability of owning a generator is around 9% greater for multiproduct factories. As predicted in the model, more productive firms tend to produce more. More productive firms, according to the model, should also be larger. To tell apart large and small firms, I use a dummy variable equal to 1 for factories that employ more than 100 employees (and are included in the census sector). Column (5) shows that the probability of owning a generator is 14% greater for those firms. The coefficient on public companies has dropped, suggesting that it was previously capturing some of the size effect, since around 60% of public firms are also in the census sector. Another measure of access to credit is also associated with more adoption of captive power. Column (6) shows that factories that have outstanding loans are 7% more likely to produce some of their consumed electricity. Finally, Column (7) shows that the larger the number of workers, the larger the rate of adoption even when controlling for whether a firm is in the census sector or not. In short, as predicted by the model, adoption of a captive generator of electricity is more likely for firms whose characteristics are associated with more exposure to lower electricity quality, greater productivity, larger size and access to credit.

An important feature of the model is the link between the upstream regulatory process and downstream behaviour, as reported by Prediction 3. The model predicts that a firm's decision to set up a captive power generator is positive in electricity prices and negative in quality. Table 5 presents results of the impact of State Electricity Boards' regulatory outcomes on the adoption decision, controlling for industry-year fixed effects and for all individual characteristics examined in Table 3. Column (1) shows that states that charge industries relatively more than other electricity consumers observe significantly greater levels of adoption. In terms of magnitudes, a standard deviation increase in the tariff charged to industries is associated with an increase in the probability of adoption of 4 percentage points. Column (2) finds a similar result using a measure of anti-industry bias relative to agricultural and domestic consumers only. Column (3) includes a measure of the average quality provided by the SEB, namely Transmission and Distribution losses as a proportion of total electricity sent into the network. The coefficient is positive and significant, meaning that a worse-performing electricity network is associated with more factories turning to self-provision of at least some of their electricity. Note that the coefficient on pricing remains similar, meaning that lower quality is not necessarily working through prices. Also note that among individual characteristics, there is a significant drop in the coefficients associated with rural and urban dummies only. When SEB quality provision is controlled for, the difference in adoption between metropolitan areas and rural and urban areas is smaller, suggesting that location was indeed picking up exposure to lower quality (unreported). Overall, the magnitude is also significant: an increase of one standard deviation in the measure of transmission and distribution losses is associated with additional 8 percentage points in the probability of adoption. Column (4) uses a more restrictive measure of quality (percentage of outages in thermal plants only) and again obtains a positive correlation between lower quality and adoption. Column (5) includes a measure of network extension that might be driving the ability to price or to provide good quality. More electricity connections per capita are negatively correlated with the adoption of captive power. The coefficient on prices is slightly larger and the coefficient on transmission and distribution losses drops slightly, and both remain strongly significant.

Column (6) includes the percentage of HYV adoption, which proxies for the anti-industry bias parameter in the regulator's objective function. Its coefficient is strong and positively correlated to adoption. The channel linking HYV to adoption of captive power through the electricity price seems to be at work since the coefficient on the electricity tariff charged to industries drops by almost 50% in column (6) with respect to column (5). With the thought that areas with a greater urban population might consume more manufacture–in turn affecting the margins for adoption and survival–Column (7) includes a measure of urban population at the state level and finds, as predicted by the model, that adoption increases with urbanization. The last column in Table 5 includes some measures of government and SEB efficiency that should affect adoption through price, according to the model. All variables remain significant and similar in magnitude, except the electricity tariff for industries, which drops in both. Factories in states with a greater budget deficit and with SEBs that require more subsidies from the state government tend to adopt generators more. Firms in states with larger electricity unit costs tend to adopt less, suggesting that is not the productive efficiency of the SEB that drives the results, but its anti-industry bias.

In the next set of regressions in Tables 6 and 7, I include an interaction between regulatory outcomes and firms characteristics, controlling for 3-digit industry-year fixed effects. If the predictions of the model are correct, then firms should react to bad regulatory outcomes when they are able to do so. Additionally, interactions can be used to identify who is most affected by regulatory outcomes. Table 6 looks at the two measures of pricing, namely the ratio between industrial and average tariffs and the burden on industries relative to the agricultural and domestic consumers. Columns (1) and (2) interact these measures with the dummies for urban and rural location. In both cases, the positive coefficients on the interaction terms suggest that adoption is more likely in rural and urban areas than in metropolitan factories, but only if the price is greater for industries. The negative coefficients on the rural and urban dummies suggest that if SEBs' pricing policy is not biased against them, then there is less adoption in those regions than in metropolitan areas, if any at all. Additionally, the negative and significant coefficients on the measure of pricing suggests that the larger the price, the lower the adoption in metropolitan areas. That suggests that pricing policies seem to influence the adoption decision only in non-metropolitan areas.

All interactions with other individual characteristics are not significant for the ratio of industrial tariff over average tariff (see, for example, Column (3)). However, in the remaining regressions shown in Columns (4) to (6), the interaction of individual characteristics with the measure of relative burden on industries vis-a-vis the domestic and agricultural sectors is positive and significant. Larger firms, multiproduct firms and firms with access to credit seem to be adopting more, the worse the anti-industry bias. This result suggests that factories' indicators of productivity and access to credit allow firms to react to bad regulatory outcomes, in line with Predictions 2 and 3. Note that as the generator take-up among public firms and census sector firms is very high (above 50%), there is not enough variation to obtain a significant coefficient in the interactions.

Table 7 looks at firms' characteristics interacted with measures of quality, i.e. transmission and distribution losses and outages in thermal plants. Columns (1) and (2) look at interactions with urban and rural dummies. With both measures of quality a similar pattern emerges: quality seems to matter more for metropolitan firms, since the coefficients on the quality measures are positive and significant. And even though rural and urban firms tend to adopt more captive generators, they adopt slightly less in areas with lower quality. As in Table 6, Columns (3) to (5) show that larger firms, multiproduct firms and those with access to credit tend to adopt more when the quality provided is lower, suggesting again that productivity and credit help firms deal with bad regulatory outcomes. Two patterns emerge from the last two tables: first, metropolitan firms react more to quality in the electricity supply and urban and rural firms react more to prices. Second, as predicted by the model, productivity, size and access to credit are positively correlated with adoption, especially when regulatory outcomes are more unfavourable.

To test Prediction 4–i.e. adoption increases with protection–I look at how the competitive environment affects the adoption decision by using a measure of whether the sector (at the 4-digit industry level) is licensed or not, and the average trade tariff (measured at the 3-digit industry level). In all cases, 2-digit industry-state-year fixed effects are included and all individual characteristics are controlled for. As predicted by the model, Column (1) and (2) in Table 8 show that adoption is more likely in more protected environments. The first column shows that firms in licensed sectors are 9% more likely to adopt. The coefficient drops to 7% when the trade tariff is included in the second column, but both measures are positive and significant. Column (3) controls for a measure of technological needs of electricity (at the 3-digit industry level), to check that results in previous columns are not capturing a correlation between protection and technology. The coefficient is positive and significant but barely affects the coefficients on license and tariffs. Columns (4) and (5) include some interactions with factory characteristics. Column (4) shows that the licensing scheme only affects non-metropolitan firms' decision to adopt. Rural and urban firms in non-licensed sectors are more likely to produce captive power than their metropolitan counterparts, but the probability is significantly higher in licensed industries. Column (5) finds that larger firms tend to adopt more in licensed industries. As predicted by the model, for a given characteristic such as size, adoption increases with protection.

To see how protection interacts with regulatory outcomes, I split the sample between licensed and delicensed sectors and run the linear probability model of adoption on price and quality measures, controlling for 3 digit industry-year fixed effects and individual characteristics. Table 9 shows that the effect of higher electricity prices and lower quality are very similar in magnitude and the statistical significance for both licensed and unlicensed industries.

Production and Productivity

The model predicts that average output and productivity of observed firms should be lower in more protected environments (Prediction 5). Column (1) in Table 10 shows that the log of real output is lower, on average, for firms in licensed sectors and in industries with greater trade tariffs, controlling for firms' characteristics. Column (2) isolates a rough measure of total factor productivity by controlling for the log of skilled and unskilled workers, the log of real fixed capital and the log of real materials consumed. Firms in licensed sectors tend to be less productive, even though the result loses significance for the measure of trade protection. Columns (3) and (4) include a dummy equal to 1 if the firm has a captive generator. The prediction of the model that firms which adopt are on average larger and more productive also holds. In Columns (5) and (6), I split the sample between firms with captive power and firms without and find that for both sets of firms, productivity tend to be lower in sectors that are licensed. The model also predicts that the average product and productivity of adopting firms should be greater in sectors that are more open to the entry of new firms. To test this idea, I split the sample between firms in licensed and unlicensed sectors. Columns (7) and (8) show that output is greater for adopters in both sectors. However, the difference between adopters and not adopters is significantly higher in unlicensed sectors. Columns (9) and (10) look at the effect on residual productivity and show that factories that have captive power are significantly more productive than non-adopting firms, but only in delicensed industries. This result suggests that protection reduces average productivity for adopters, as predicted by the model.

5 Conclusion

Developing countries aiming at increasing their industrial base have often disregarded the importance of infrastructure provision. By analysing how the regulation of a monopolistic supplier of a fundamental input in production affects producers of manufactures, this paper explores a specific mechanism that explains how firms react to the inadequate provision of infrastructure. This paper shows that only firms with high productivity and access to credit can actually reduce the negative effects of expensive and erratic electricity, by adopting a captive power generator. The Indian data also suggests a heterogeneous impact of regulation according to location. Firms in metropolitan areas appear to be more sensitive to quality while firms in rural and urban areas react more to prices and protection. On average, firms find it easier to cope in more protected environments–e.g. ones with high trade tariff and entry fees– where less competition raises their profits and makes the outside option affordable. Otherwise, in a more competitive environment, firms that could have survived with cheaper and better inputs will exit the market, while firms that were better prepared to cope with provision failure by adopting a captive generator will not be able to afford it any more. It follows that countries undergoing a process of opening to foreign competition and deregulation should pay particular attention to the negative impact of low quality and biased pricing policies in the provision of infrastructure goods and to the distributional effects that follow.

Appendix A Tables

Table 1: Summary Statistics

Variables	Mean	Std. Dev.	Min	Max
Adoption of Captive Generator	30.5%	0.46	0	1
Rural	30.6%	0.46	0	1
Urban	57.8%	0.49	0	1
Public Company	14.1%	0.35	0	1
Multiproduct	61.8%	0.49	0	1
Census Sector	25.1%	0.43	0	1
Access to Credit	73.9%	0.44	0	1
Log Workers	3.63	1.35	0	10.75
Log Output	15.98	2.09	0.35	24.74
Ind. Tariff / Avg. Tariff	1.83	0.40	0.97	2.89
T&D Losses	20.8%	4.43	15.3	33.4
Licensed	48.7%	0.50	0	1
Trade Tariff	0.86	0.45	0	3.44

Table 2: Differences in Electricity Pricing Schemes According to Green Revolution intensity at the State Level

Incidence of Green Revolution	Avg. Tariff / Unit cost	Ind.Tariff / Avg. Tariff	Ind. Tariff / Unit Cost	Agr. Tariff / Avg. Tariff	Agr. Tariff / Ind. Tariff	Outages	T&D Losses
Low	0.76	1.46	1.05	0.28	0.24	15.5	24.7
High	0.71	1.80	1.28	0.17	0.09	18.4	22.7
Difference	0.05**	-0.34***	-0.23***	0.11**	0.15***	-2.9	2

Significance level of differences: * significant at 10%; ** at 5%; *** at 1%. Data for column (1) is for the period 1974-1997. All other columns use years 1990-1997. All tariffs and unit costs are in Paise (cents of rupee) per KWh. "T&D losses" are Transmission and Distribution losses as a % of total electricity traded. "Outages" are forced outages of thermal stations (%). States with high incidence of Green Revolution: Andhra Pradesh, Bihar, Haryana, Punjab, Tamil Nadu, Uttar Pradesh.

Table 3: Electricity Pricing and Green Revolution

	(1)	(2)	(3)	(4)	(5)	(6)
	Ind Tariff / Agr Tariff			Avg Tariff / Unit Cost		
	OLS		IV	OLS		2SLS
HYV Adoption	0.85	1.21	0.66	-0.54	-0.73	-1.28
	(0.31)***	(0.35)***	(0.35)*	(0.11)***	(0.10)***	(0.15)***
Budget Deficit		82.1	59.5		-122.1	-159.1
		(36.7)**	(28.3)**		(17.2)***	(19.1)***
Observations	45	45	45	165	165	165
Adj. R square	0.66	0.71	0.69	0.54	0.62	0.55
F-test P-value			<1%			<1%
Over-id test P-value						0.31

Robust standard errors in parentheses, * significant at 10%; ** at 5%; *** at 1%. All tariffs and unit costs are in Paise (cents of rupee) per KWh. "HYV Adoption" is the net proportion of cropped area under High Yield Variety seeds. "Budget deficit" is the deficit as a proportion of state s product. Column (3) uses the "proportion of districts with abundant groundwater" as an instrument and Column (6) uses the same instrument interacted with year dummies. Low F-Test P-values suggest a strong correlation between instruments(s) and instrumented variables. Low Over-id P-values suggest that the instruments are correctly excluded from the second stage. State controls include development expenditure, proportion of rural population, credit availability, proportion of votes to the Congress Party and the party of the Chief Minister. Columns (3)-(6) include year dummies.

Table 4: Firm Characteristics and Adoption of Captive Generator

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Adoption of Captive Generator						
Rural	0.06	0.11	0.09	0.09	0.09	0.09	0.07
	(0.006)***	(0.008)***	(0.008)***	(0.008)***	(0.008)***	(0.008)***	(0.008)***
Urban		0.06	0.05	0.05	0.05	0.05	0.04
		(0.006)***	(0.006)***	(0.006)***	(0.007)***	(0.007)***	(0.007)***
Public Company			0.24	0.23	0.18	0.19	0.12
			(0.007)***	(0.007)***	(0.007)***	(0.006)***	(0.007)***
Multiproduct				0.09	0.08	0.07	0.04
				(0.007)***	(0.006)***	(0.007)***	(0.006)***
Census Sector					0.14	0.14	0.07
					(0.007)***	(0.006)***	(0.006)***
Access to Credit						0.07	0.06
						(0.005)***	(0.005)***
Log Workers							0.08
							(0.003)***
Observations	146251	146251	146251	146251	146251	146251	143797
R-squared	0.35	0.35	0.37	0.38	0.38	0.39	0.42

Robust standard errors in parentheses clustered at the state-industry level, * significant at 10%; ** significant at 5%; *** significant at 1%. The regressions are linear probability model where the dependent variable "Adoption" is equal to 1 if the firms produces some of the electricity used in production. All variables are dummies, except "Log Workers." For location, the excluded category is "Metropolitan." "Multiproduct" is equal to 1 if the factory produces more than 1 product. "Census sector" includes factories with more than a 100 employees. The sample sector follows a sampling design adopting State- 3 digit industry group as stratum so as to cover all the units in a span of three years. "Log workers" refers to unskilled workers. State* 3-digit industry * year fixed effects are included in all cases.

Table 5: Regulatory Outcomes at the State Level and Adoption of Captive Power

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Adoption of Captive Generator							
Ind. Tariff / Avg. Tariff	0.095		0.094	0.121	0.116	0.067	0.069	0.018
	(0.016)***		(0.014)***	(0.016)***	(0.014)***	(0.012)***	(0.012)***	(0.012)
Relative Burden on Industries		0.20						
		(0.014)***						
T&D Losses			0.017		0.012	0.008	0.010	0.015
			(0.002)***		(0.001)***	(0.001)***	(0.001)***	(0.001)***
Outages				0.010				
				(0.001)***				
Electricity Connections					-0.039	-0.045	-0.051	-0.078
					(0.004)***	(0.003)***	(0.004)***	(0.005)***
HYV Adoption						0.67	0.68	0.63
						(0.04)***	(0.04)***	(0.03)***
Urban Population							0.23	0.84
							(0.12)*	(0.13)***
Budget Balance								-0.91
								(0.17)***
Unit Cost								-0.02
								(0.002)***
Net Subsidies								0.02
								(0.002)***
Firm Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	133186	133186	133186	127940	133186	133186	133186	133186
R-squared	0.22	0.25	0.24	0.24	0.26	0.30	0.31	0.32

Robust standard errors in parentheses, clustered at the state-industry level. * significant at 10%; ** at 5%; *** at 1%. The regressions are a linear probability model where the dependent variable "Adoption" is equal to 1 if the firms produces some of the electricity used in production and includes 3-digit industry * year fixed effects. All tariffs and unit costs are in Paise (cents of rupee) per KWh. "Relative Burden on Industries" is percentage sales revenue to percentage sales for industries relative to agriculture and domestic sectors only. "T&D Losses" are Transmission and Distribution losses as a % of total electricity traded. "Outages" are forced outages of thermal stations (%). "Electricity Connections" are per capita. "HYV Adoption" is the net proportion of cropped area under High Yield Variety seeds. "Urban Population" is % of total population. "Budget Balance" is the budget superavit as a proportion of a state s product". "Net Subsidy" is the percentage of subsidies from State Government over revenues.

Table 6: Interactions Between SEB Pricing Policies and Firm Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
	Adoption of Captive Generator					
Ind. Tariff / Avg. Tariff (IT/AT)	-0.062 (0.03)**		0.075 (0.02)***			
Relative Burden on Industries (RBI)		-0.67 (0.11)***		0.11 (0.02)***	0.14 (0.01)***	0.14 (0.02)***
T&D Losses	0.016 (0.002)***	0.10 (0.001)***	0.017 (0.002)***	0.10 (0.001)***	0.10 (0.001)***	0.10 (0.001)***
Rural	-0.14 (0.05)	-1.27 (0.18)***	0.12 (0.01)***	0.12 (0.01)***	0.12 (0.01)***	0.12 (0.01)***
IT/AT * Rural	0.16 (0.03)***					
RBI * Rural		0.82 (0.11)***				
Urban	-0.19 (0.05)***	-1.35 (0.18)***	0.09 (0.01)***	0.09 (0.01)***	0.09 (0.01)***	0.09 (0.01)***
IT/AT * Urban	0.17 (0.03)***					
RBI * Urban		0.85 (0.11)***				
Log Workers	0.07 (0.01)***	0.07 (0.01)***	0.06 (0.01)***	0.04 (0.01)***	0.07 (0.01)***	0.07 (0.01)***
IT/AT * Log Workers			0.01 (0.01)			
RBI * Log Workers				0.015 (0.006)**		
Multiproduct	0.05 (0.01)***	0.04 (0.01)***	0.05 (0.01)***	0.04 (0.01)***	-0.04 (0.03)	0.04 (0.01)***
RBI * Multiproduct					0.04 (0.01)***	
Access to Credit	0.06 (0.01)***	0.04 (0.01)***	0.05 (0.01)***	0.04 (0.01)***	0.04 (0.01)***	-0.02 (0.03)
RBI* Access to Credit						0.03 (0.015)**
Public Company	0.13 (0.01)***	0.14 (0.01)***	0.14 (0.01)***	0.14 (0.01)***	0.14 (0.01)***	0.14 (0.01)***
Census Sector	0.06 (0.01)***	0.07 (0.01)***	0.07 (0.01)***	0.07 (0.01)***	0.07 (0.01)***	0.07 (0.01)***
Observations	133186	133186	133186	133186	133186	133186
R-squared	0.26	0.26	0.24	0.26	0.26	0.26

Robust standard errors in parentheses, clustered at the state-industry level. * significant at 10%; ** at 5%; *** at 1%. The regressions are a linear probability model where the dependent variable "Adoption" is equal to 1 if the firms produces some of the electricity used in production and includes 3-digit industry * year fixed effects. All tariffs and unit costs are in Paise (cents of rupee) per KWh. "Relative Burden on Industries" is percentage sales revenue to percentage sales for industries relative to agriculture and domestic sectors only. "T&D Losses" are Transmission and Distribution losses as a % of total electricity traded.

Table 7: Interactions Between SEB Quality Provison and Firm Characteristics

	(1)	(2)	(3)	(4)	(5)
	Adoption of Captive Generator				
Ind. Tariff / Avg. Tariff	0.11	0.13	0.09	0.09	0.09
	(0.01)***	(0.02)***	(0.01)***	(0.01)***	(0.01)***
T&D Losses	0.05		0.01	0.01	0.01
	(0.002)***		(0.003)***	(0.001)***	(0.001)***
Outages		0.03			
		(0.002)***			
Rural	0.79	0.37	0.12	0.12	0.12
	(0.06)***	(0.03)***	(0.01)***	(0.01)***	(0.01)***
T&DL * Rural	-0.04				
	(0.003)***				
Outages * Rural		-0.02			
		(0.001)***			
Urban	0.69	0.31	0.09	0.09	0.09
	(0.06)***	(0.03)***	(0.01)***	(0.01)***	(0.01)***
T&DL * Urban	-0.034				
	(0.002)***				
Outage * Urban		-0.014			
		(0.002)***			
Log Workers	0.07	0.07	0.03	0.07	0.07
	(0.01)***	(0.01)***	(0.02)*	(0.01)***	(0.01)***
T&DL * Log Workers			0.002		
			(0.0001)**		
Multiproduct	0.05	0.04	0.04	-0.05	0.04
	(0.01)***	(0.01)***	(0.01)***	(0.04)	(0.01)***
T&D L * Multiproduct				0.004	
				(0.001)***	
Access to credit	0.05	0.05	0.05	0.04	-0.14
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.03)***
T&DL * Access to Credit					0.009
					(0.001)***
Public Company	0.14	0.14	0.14	0.14	0.14
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Census Sector	0.07	0.07	0.07	0.07	0.07
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Observations	133186	127940	133186	133186	133186
R-squared	0.25	0.25	0.26	0.26	0.26

Robust standard errors in parentheses, clustered at the state-industry level. * significant at 10%; ** at 5%; *** at 1%. The regressions are a linear probability model where the dependent variable "Adoption" is equal to 1 if the firms produces some of the electricity used in production and includes 3-digit industry * year fixed effects. All tariffs and unit costs are in Paise (cents of rupee) per KWh. "T&D Losses" are Transmission and Distribution losses as a % of total electricity traded. "Outages" is forced outages of thermal stations (%).

Table 8: Competitive Environment and Adoption of Captive Power

	(1)	(2)	(3)	(4)	(5)
	Adoption of Captive Generator				
Licensed	0.09	0.07	0.07	0.02	0.01
	(0.01)***	(0.02)***	(0.01)***	(0.01)	(0.01)
Trade tariff		0.07	0.06	0.06	0.06
		(0.02)***	(0.02)***	(0.02)***	(0.02)***
Electricity intensity			0.005	0.005	0.005
			(0.003)*	(0.003)*	(0.003)*
Rural	0.08	0.08	0.08	0.04	0.08
	(0.01)***	(0.01)***	(0.01)***	(0.015)**	(0.01)***
Licensed * Rural				0.09	
				(0.02)***	
Urban	0.05	0.05	0.05	0.03	0.05
	(0.01)***	(0.01)***	(0.01)***	(0.01)**	(0.01)***
Licensed * Urban				0.04	
				(0.01)***	
Log workers	0.08	0.08	0.08	0.08	0.07
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Licensed * Log workers					0.02
					(0.006)***
Public Company	0.16	0.17	0.17	0.17	0.17
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Multiproduct	0.05	0.05	0.05	0.05	0.05
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Census Sector	0.07	0.07	0.07	0.07	0.07
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Access to Credit	0.07	0.07	0.07	0.07	0.07
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Observations	119054	119054	119054	119054	119054
R-squared	0.35	0.36	0.36	0.36	0.36

Robust standard errors in parentheses, clustered at the state-industry level. * significant at 10%; ** at 5%; *** at 1%. The regressions are a linear probability model where the dependent variable "Adoption" is equal to 1 if the firms produces some of the electricity used in production and include state * 2-digit industry * year fixed effects. "Licensed" is a dummy equalt to 1 if the 4-digit industry is licensed. "Trade tariff" is the ad-valorem import tariff (%). "Electricity intensity" is a measure of electricity needs of a 3-digit industry, as a proportion of total inputs.

Table 9: Effect of SEB Regulatory Outcomes in Licensed and Unlicensed Industries.

	(1)	(2)	(3)	(4)
	Adoption of Captive Generator			
	if Licensed = 0		if Licensed = 1	
Ind. Tariff / Avg. Tariff	0.097	0.093	0.093	0.094
	(0.02)***	(0.02)***	(0.02)***	(0.02)***
T&D Losses		0.018		0.016
		(0.002)***		(0.002)***
Observations	67745	67745	65441	65441
R-squared	0.17	0.20	0.21	0.26

Robust standard errors in parentheses, clustered at the state-industry level. * significant at 10%; ** at 5%; *** at 1%. The regressions are linear probability model where the dependent variable "Adoption" is equal to 1 if the firm produces some of the electricity used in production and includes 3-digit industry * year fixed effects. All tariffs and unit costs are in Paise (cents of rupee) per KWh."T&D Losses" are Transmission and Distribution losses as a % of total electricity traded.

Table 10: Product and Productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Log Real Output									
					if A=0	if A=1	if L=0	if L=1	if L=0	if L=1
Licensed (L)	-0.11	-0.07	-0.17	-0.07	-0.07	-0.07				
	(0.04)**	(0.02)***	(0.04)***	(0.02)***	(0.02)***	(0.02)***				
Trade Tariff	-0.32	-0.01	-0.38	-0.01	0.01	-0.01				
	(0.10)***	(0.03)	(0.10)***	(0.03)	(0.03)	(0.03)				
Adoption of Captive Generator (A)			0.98	0.04			0.97	0.86	0.05	0.01
			(0.03)***	(0.01)***			(0.03)***	(0.03)***	(0.01)***	(0.01)
Log Unskilled Workers		0.14		0.14	0.16	0.09			0.12	0.09
		(0.01)***		(0.01)***	(0.01)***	(0.01)***			(0.01)***	(0.01)***
Log Skilled Workers		0.10		0.10	0.11	0.09			0.12	0.09
		(0.01)***		(0.01)***	(0.01)***	(0.01)***			(0.01)***	(0.01)***
Log Fixed Capital		0.04		0.04	0.04	0.04			0.04	0.02
		(0.004)***		(0.004)***	(0.004)***	(0.004)***			(0.004)***	(0.004)***
Log Materials		0.77		0.77	0.75	0.83			0.78	0.84
		(0.01)***		(0.01)***	(0.01)***	(0.01)***			(0.01)***	(0.01)***
Individual Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	96448	96448	96448	96448	62678	33770	62674	53547	59725	51689
R-squared	0.44	0.90	0.44	0.90	0.89	0.90	0.51	0.53	0.92	0.92

Robust standard errors in parentheses, clustered at the state-industry level. * significant at 10%; ** at 5%; *** at 1%. "Adoption" is equal to 1 if the firms produces some of the electricity used in production. columns (1)-(6) include state * 2-digit industry * year fixed effects and Columns (7)-(10), state * 3-digit industry * year fixed effects. "Licensed" is a dummy equalt to 1 if the 4-digit industry is licensed. "Trade tariff" is the ad-valorem import tariff (%). Individual controls are the same as used in all other tables.

References

[1] Aghion, P., Burgess R., Redding, S. and Zilibotti, F. (2004), Entry Liberalization and Inequality in Economic Performance, mimeo, London School of Economics.

[2] Aghion, P., Burgess R., Redding, S. and Zilibotti, F. (2008), The Unequal Effects of Liberalization: Evidence from Dismantling the License Raj in India, American Economic Review, 98 (4)

[3] Ahluwalia, S. and Bhatiani (2000), Tariff Setting in the Electric Power Sector, mimeo, TERI.

[4] Arnold, J.M., Mattoo, A. and Narciso, G. (2008), Service Inputs and Firm Productivity in Sub-Saharan Africa: Evidence from Firm-Level Data, Journal of African Economies, forthcoming.

[5] Arrow, K. J. (1975), Vertical Integration and Communication, The Bell Journal of Economics, Vol. 6(1), 173-183.

[6] Asian Development Bank and The World Bank Group (2002), ICS - Investment Climate Surveys, mimeo.

[7] Baron, D. and Myerson, R. (1982), Regulating a Monopolist with Unknown Costs, Econometrica, Vol. 50, No. 4, 911-930.

[8] Bernard, A. , Redding, S. and Schott, P. (2006), Multi-Product Firms and Trade Liberalization, CEP Discussion Paper 769, London School of Economics.

[9] Besley, T (2003), Elected versus Appointed Regulators, published in the Encyclopaedia of Public Choice, Charles Rowley ed., Kluwer Academic Publishers

[10] Besley, T. and Burgess R. (2004), Can Labor Regulation Hinder Economic Performance? Evidence from India, Quarterly Journal of Economics, 119(1), 91-134.

[11] Biswas, D., Heller, T, Nag, T., Shukla, P.R., Victor, D.and Yajnik, A (2004), Captive Power Plants: Case Study of Gujarat, India, WP 22, Program on Energy and Sustainable Development, Stanford University.

[12] Carlton, D. (1979), Vertical Integration in Competitive Markets Under Uncertainty, The Journal of Industrial Economics, Vol.27(3), 189-209

[13] Caves, R. and Bradburd, R. (1987), The Empirical Determinants of Vertical Integration, Journal of Economic Behaviour and Organization, Vol. 9, 265-279.

[14] Dhanagare, D.N. (1989), The Green Revolution and Social Inequalities in Rural India, in Green Revolution and Social Change, edited by Sharma and Dak, Ajanta Publications, Delhi.

[15] Dixit, A. and Stiglitz, J. (1977), Monopolistic Competition and Optimum Price Diversity", American Economic Review, Vol. 67, 297-308.

[16] Dollar, D., Iarossi, G. and Mengistae, T. (2002). Investment Climate and Economic Performance: Some Firm Level Evidence from India , WP No. 143, Center for Research on Economic Development and Policy Reform, Stanford University.

[17] Dollar, D., Hallward-Driemeier, M. and Mengistae, T (2003). Investment Climate and Firm Performance in Developing Economies, mimeo, The World Bank.

[18] Estache, A. (2004), Emerging Infrastructure Policy Issues in Developing Countries: A Survey of the Recent Economic Literature, INFVP, The World Bank

[19] Fujita, M., Krugman, P. and Venables, A. (1999), The Spatial Economy, Cities, Region and International Trade, , MIT Press.

[20] Gonzalez. J., Guasch, J. L. Serebrisky, T. (2007), Latin America: High Logistics Costs and Poor Infrastructure for Merchandise Transportation, World Bank, mimeo.

[21] Green, J. (1974), Vertical Integration and Assurance of Markets, in J.E. Stiglitz and F. Mathewson (eds.), New Developments in the Theory of Market Structure, MIT Press, Cambridge, 177-210.

[22] Grossman, S. and Hart, O. (1986), The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration, The Journal of Political Economy, Vol. 94, No.4, 691-719.

[23] Guasch, J.L., Laffont, J-J and Straub, S. (2003), Renegotiation of Concession Contracts in Latin America, Policy Research Working Paper Series 3011, The World Bank.

[24] Gulati, A. and Narayanan, S. (2003), The Subsidy Syndrome in Indian Agriculture, Oxford University Press.

[25] Joskow, P. (2004), Vertical Integration, in C. Ménard and M. Shirley (eds.), Handbook of New Institutional Economics, Springer.

[26] Klein, P. (2004), The Make or Buy Decision: Lessons from Empirical Studies, in C. Ménard and M. Shirley (eds.), Handbook of New Institutional Economics, Springer.

[27] Laffont, J-J (2005), Regulation and Development, Federico Caffe Lectures, Cambridge University Press.

[28] Laffont, J-J and Tirole, J. (1986). Using Cost Observation to Regulate Firms, The Journal of Political Economy, Vol. 94(3), 614-641.

[29] Laffont, J-J and Tirole, J. (1993), A Theory of Incentives in Procurement and Regulation, MIT Press, Cambridge.

[30] Lieberman, M. (1991), Determinants of Vertical Integration: an Empirical Test, The Journal of Industrial Economics, Vol.39(5), 451-466.

[31] Malmgren, H.B. (1961), Information, Expectations and the Theory of the Firm, The Quarterly Journal of Economics, Vol. 75(3), 399-421.

[32] Mas-Colell, A., Whinston, M. and Green, J.R. (1995), Microeconomic Theory, Oxford University Press.

[33] Maskin, E. and Riley, J. (1984), Monopoly with Incomplete Information, The RAND Journal of Economics, Vol. 15(2), 171-196.

[34] Melitz, M. (2003), The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity, Econometrica 71 (6), 1695-1725.

[35] Ministry of Industry, Government of India (1993), Handbook of industrial statistics.

[36] Ministry of Power, Government of India (2001), Blueprint for Power Sector Development, mimeo.

[37] Rud, JP (2009), Electricity Provision and Industrial Development: Evidence from India, London School of economics, mimeo.

[38] Sibley, D. (1989), Asymmetric Information, Incentives and Price-Cap Regulation, The RAND Journal of Economics, Vol. 20(3), 392-404.

[39] Sims, H. (1988), Political Regimes, Public Policy and Economic Development: Agricultural Performance and Rural Changes in Two Punjabs, Sage Publications, New Delhi.

[40] TERI (1999), Indian Power Sector: change of gear, mimeo.

[41] Tongia, R. (2003), The Political Economy of Indian Power Sector Reforms, WP 4, Program on Energy and Sustainable Development, Stanford University.

[42] Williamson, O. (1971), The Vertical Integration of Production: Market Failure Considerations, American Economic Review, Vol. 61(2), 112-123.

[43] World Bank (2000), India: Policies to Reduce Poverty and Accelerate Sustainable Development, World Bank.

[44] World Bank (2005), Infrastructure and the World Bank: A Progress Report, World Bank.

[45] World Bank (2006), Infrastructure: Lessons From the Last Two Decades of World Bank Engagement, World Bank.

[46] World Bank (2007), World Development Report 2008: Agriculture for Development, World Bank.