Elections at what cost? The impact of electricity subsidies on groundwater extraction and agricultural production
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Abstract

In India, electric utilities are owned and operated by the government. This paper explores whether these utilities have functioned to maximize social welfare and whether electricity pricing, through the provision of agricultural subsidies, has been manipulated for political purposes. We first explore the benefits of electricity subsidies to the agricultural sector between 1995 and 2004. A simple model predicts that electricity subsidies lower the price of groundwater extraction and, in turn, increase agricultural revenues. To isolate the impact of electricity prices on groundwater extraction and revenues, we exploit year-to-year variation in state electricity prices across districts that differ in hydrogeological characteristics. We find that a 10 percent decrease in subsidies would reduce groundwater extraction by 5.4 percent, costing farmers 12 percent in agricultural revenues. Despite the gains in agricultural revenue, the short-run costs of these subsidies exceed the short-run benefits six-fold, suggesting another rationale for the subsidies. Political capture partly explains the persistence of these subsidies, which have historically increased by 10% in the year preceding an election.

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1 Introduction

As environmental and energy infrastructure in developing countries expands, governments need to consider how to best regulate markets characterized as natural monopolies such as the supply of clean water, sanitation and electricity. With natural monopolies, governments face a dilemma - how to supply a good at least cost while avoiding monopoly pricing? In the U.S., the government has taken a variety of regulatory approaches. It has allowed private firms the opportunity to bid on the rights to the monopoly, regulated the return that a natural monopoly can make on capital, or provided the good itself through an enterprise owned and operated by the government. In the U.S., electricity - the good of interest in this study - is most often privately provided. By contrast in India, the setting for this research, electricity is provided by public enterprise in the form of State Electricity Boards. Public provision of electricity may better achieve the objective of social welfare maximization as compared to a private firm that seeks to maximize profits. However, it is susceptible to political capture (Vickers and Yarrow 1991) since the managers of the State Electricity Boards are accountable to state elected officials who are in turn accountable to voters. This paper tests the compatibility of public enterprise as an approach to manage the provision of electricity in developing countries, examining the extent to which current agricultural electricity markets in India function to maximize social welfare and whether they are susceptible to political pressure.

Previous literature has evaluated the comparative performance of public and private enterprise in developed (Vickers and Yarrow 1991) and developing countries (Estache and Wren-Lewis 2009), finding mixed evidence as to whether the privatization of natural monopolies improved efficiency. In developed countries, the lack of consensus in these studies can be largely explained by differences in regulatory policy. In developing countries, regulatory policy and the institutional framework, rather than the form of ownership, largely determine the relative performance of private and public enterprise (Estache and Wren-Lewis 2009). These findings are primarily theoretical or anecdotal, and when empirical have focused on water utilities (Clarke et al. 2009, Estache and Rossi 2002, Galiani et al. 2005, Kirkpatrick et al. 2006).[1] With a few exceptions (Cubbin and Stern 2006, Hawdon 1996, Zhang et al. 2008), little attention has been paid to the electricity sector. Electricity in India provides an ideal setting to measure the benefits from the public provision of electricity and to test if this market is captured by political interests.

In India, many attribute the poor and unreliable electricity service supplied by the State

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[1] A literature exists on telecommunications privatization, though our focus of this study is on energy and environmental infrastructure.

Electricity Boards (SEBs) to electricity subsidies for agriculture. Subsidies to the agricultural sector are large - Birner et al (2007) present evidence suggesting that the amount spent on agricultural electricity subsidies exceeds state spending on health or education if two states in India. The long-run costs of electricity subsidies have been widely documented, and the need for an overhaul and restructuring of the state electricity boards has been advocated by the Indian government itself (Dubash and Rajan 2001, Dubash 2007). The annual commercial losses from SEBs are large in magnitude and growing - in 2001 the SEBs' rate of return on capital amounted to -39.5% (Tongia, 2003). This negative profit was largely fueled by increased expenditure on agricultural electricity subsidies and a decline in the cross-subsidies provided by the commercial and industrial sectors.[2] Though SEBs have been operating at a loss and the quality of electricity continues to worsen, these subsidies remain in-tact. This paper examines the rationale behind this persistence by first investigating the agricultural benefits from these subsidies to determine if the short-run benefits of these subsidies dominate the short-run costs. It then evaluates the political capture attained by these subsidies.

Anecdotal evidence suggests that these subsidies are not without their benefits. The expansion and uptake of tube wells for irrigation was largely expedited by subsidized electricity prices, which reduced the price of groundwater extraction. In turn, this growth in irrigation increased agricultural yields, lowered food prices, increased demand for agricultural labor and disproportionately benefited landless farmers (Briscoe and Malik 2006, Modi 2005). However, these benefits may have come at the cost of groundwater exploitation (Strand 2010). India has increasingly relied on groundwater extraction for agriculture and is currently the largest extractor of groundwater, consuming 250 cubic km of groundwater annually. As demand for groundwater increases, extraction in some districts has begun to exceed the replenishable supply. Between 2002 and 2004, the percentage of districts reporting exploited groundwater resources increased from 8% to 17%.[3]

In this paper, we examine the impact of agricultural electricity subsidies on groundwater usage and exploitation, and the subsequent effect of these subsidies on agricultural production, using panel data from 350 districts (the U.S. equivalent of a county) between 1995 and 2004. We exploit variation in electricity prices over time and across states (the U.S. equivalent of a state). In India, state governments are authorized to set electricity prices, therefore electricity prices vary across states. There is also substantial heterogeneity in prices

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[2] To fund these subsidies, states charged higher prices to the industrial and commercial sectors, where the prices charged often exceeded the marginal cost of supply. This increase in production costs, encouraged the use of captive power plants by commercial and industry sectors, thereby lowering the base from which the SEBs funded these subsidies.

[3] According to the Central Ground Water Board of India, mining/over-extraction occurs when annual extraction of groundwater exceeds annual recharge.

across time; this occurs because states respond to economic and political pressures by changing agricultural electricity subsidies. In our empirical model, we use within state variation in electricity prices between 1995 and 2004 to estimate the short-run effect of agricultural electricity subsidies on district groundwater extraction and agricultural output. Preliminary results from an OLS model with district fixed effects suggest that electricity subsidies led to an increase in groundwater extraction and an increase in crop revenues.

Since electricity prices are likely to be correlated with unobservables such as the political party in power or the relative importance of the agricultural sector, we are concerned that exploiting variation of electricity prices across states and time will yield biased estimates. To isolate the effect of electricity prices on groundwater extraction and agricultural output, we turn to hydrology literature to construct a measure for the effective price of groundwater (Domenico et al. 1968, Martin and Archer 1971).

Our identification strategy isolates the differential effect of electricity subsidies on districts characterized by different effective groundwater prices. To measure the price of groundwater, we use two fixed district hydrological characteristics - the minimum and maximum depth to the aquifer. This strategy allows us to estimate a model that controls for both district unobservables (soil type) and time-variant state unobservables (other agricultural subsidies). While this model does not quantify the direct effect of state electricity prices on groundwater extraction, it estimates the effect of a related price, the interaction of aquifer depth and electricity price, on groundwater extraction. In the hydrology literature, the price of groundwater extraction is measured as this interaction term.

Consistent with the predictions from our theoretical model, our results indicate that electricity subsidies increased groundwater extraction and agricultural revenues. We find that a 25 percent increase in electricity prices generates a 2.2 percent decrease in groundwater extraction and a 4.9 percent reduction in agricultural revenues, where this reduction in revenues is not driven by changes in crop price, but by changes in the quantity produced.

Though electricity subsidies increased agricultural revenues, we find that the short-run costs of these subsidies exceed the annual benefits. If we reduced the average subsidy by 10 percent, we predict that district agricultural revenues would decrease by 33.5 million Rupees annually. However, average government expenditure on district subsidies would reduce by 185 Rs annually. A simple back of the envelope calculation reveals that the short-run costs of these subsidies outweigh the benefits by more than six-fold. Further, the cost of these subsidies would likely increase if we considered the linkages between these subsidies and the future costs of groundwater exploitation.

Despite the cost of these subsidies, they endure. We now explore the political economy behind the persistence of these subsidies. In particular, do state politicians manipulate agricultural electricity prices to gain electoral votes? A suite of studies has empirically examined the relationship between elections and agricultural lending by publicly owned banks, expenditure on road construction and tax collection in India to investigate hypotheses about the political capture of publicly owned goods (Cole 2009, Chaudhuri and Dasgupta 2005, Ghosh 2006, Khemani 2004). These studies find that funding for road construction and agricultural loans provided by publicly owned banks increased during election years, suggesting that political capture partly explains the provision of these goods. Our research contributes to this literature, finding that politicians may be trying to gain votes by manipulating electricity prices. In the year preceding a pre-scheduled election, electricity prices reduce by roughly 1.4 paise or 10%, controlling for district and year unobservables.[4] This is a substantial decrease, given that the mean electricity price is 14 paise per kWh over this period. We posit that electricity subsidies provide substantial gains to politicians, since they give politicians a means to increase rural incomes, and hence support, during elections.

2 Background to the Electricity Sector and Subsidies

Prior to 1948, private entities and local authorities generated approximately 80 percent of electricity in India (Dubash and Rajan 2001). With the Electricity Supply Act of 1948, states gained control over electricity generation and each state organized a vertically integrated State Electricity Board (SEB). Though jurisdiction over electricity is shared between the central and state governments, SEBs function as autonomous institutions. They have the authority to set and collect electricity tariffs, and are responsible for the three core elements of electricity provision - generation, transmission and distribution. While SEBs have the authority to price electricity, electricity pricing has often been at the discretion of the state government and politicians rather than the SEBs (Gulati and Narayanan, 2003).

Electricity pricing, or lack thereof, emerged as a powerful political tool in the late 1970s during the post green revolution period. As agricultural profits and the need for a stable water supply increased during the green revolution, the farming workforce organized into a powerful political coalition. The trend between elections and electricity pricing began in Andhra Pradesh in 1977, when the Congress party was the first in India to campaign on the basis of free power. By 1989, the government was spending 25 percent of total expenditure on agricultural electricity subsidies, and politicians were required to maintain these subsidies to either gain election or remain in power (Dubash and Rajan 2001). For example in 2004, the Congress Party on Andhra Pradesh campaigned on free power (Dubash 2007).[5]

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[4] One hundred paise equal one Rupee.

[5] In states where the commercial and industrial sectors comprise the influential and dominant political lob-

The electricity pricing strategies of SEBs have been linked to a number of negative features of the electricity sector. Many SEBs were not reimbursed by the state for the agricultural subsidies. Second, SEBs engaged in a system of cross-subsidization, whereby commercial and industrial users were charged high rates partly to cover the losses. Despite raising tariffs for these users, SEBs faced growing theft and financial losses which has been argued to have contributed to low frequency, brownouts and blackouts (Dubash and Rajan 2004; McKenzie and Ray 2004).

Beginning in the early 1990s, state governments passed a series of electricity reforms intended to introduce competition and to reduce the role of the state in the electricity sector. On the distribution side, these reforms however have had limited, if any, success during the time period examined in this paper, 1995 to 2004. Although the government implemented multiple reforms during this period that were aimed at increasing competition in the electricity sector, these bills had relatively little impact on distribution and tariff setting in the electricity sector.

By contrast, there has been greater progress in opening up generation and transmission to private sector competition. At the national level, the earliest attempts to reform the sector focused on meeting the shortfall in generating capacity. The Electricity Laws (Amendment) Act of 1991 changed the 1948 Electricity (Supply) Act to allow private generators into the market with their tariffs regulated by the government. This reform was largely unsuccessful in attracting new entrants, due in part to strong safeguard policies. Since the passage of this act, growth in public sector capacity has been more than double generation growth in the private sector (Tongia, 2004).

State governments, in collaboration with the World Bank, also introduced legislation that aimed to separate the vertically integrated SEBs into generation, distribution and transmission companies. These reforms were first implemented, in collaboration with the World Bank, in the state of Orissa beginning in 1996. By 1998, the reforms had separated the Orissa State Electricity Board into two generation companies, one transmission enterprise and four distribution companies. Part of the agreement with the World Bank included the reform of tariffs to allow suppliers to become financially solvent. However, the government slowed down the rise in tariffs through negotiations with the Orissa Electricity Regulatory Commission (Toniga, 2004).

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bies, politicians follow a reverse campaign strategy. Politicians promise to reduce or eliminate the electricity subsidies provided to farmers.

3 Theoretical Model

This section presents an agricultural production model, which draws heavily on Provencher and Burt (1993). The economy examined is a rural economy with many identical farmers, who choose water inputs and the fraction of their land to plant with water intensive crops. The farmers draw water using electric pumps from a common stock of replenishable groundwater. The model makes predictions on how variation in electricity subsidy feeds through to the price of electricity facing farmers, thus affecting groundwater usage and the water intensity of crop choice.

3.1 Groundwater

The economy consists of N identical farmers who have access to the groundwater stock in district d. The total groundwater stock at the end of time t is given by x_{dt}. In every time period, the groundwater resource is recharged r units. An individual farmer chooses to consume u_t units of groundwater. We assume that irrigation water does not leak back into the groundwater resources. Since farmers are identical, their groundwater use in every period is the same. Therefore, the stock of groundwater available for use in period $t + 1$ is given by:

$$x_{t+1} = x_t - Nu_t + r \tag{1}$$

3.2 Farmer - Individual Profit Maximization

Each of the N identical farmers is endowed with A units of land. The agricultural sector uses two inputs in production - land and water - to produce two crops, crop 1 and crop 2. Land and water are complements in production. Production of both crops is modeled using a Cobb-Douglas technology, which is increasing and concave in all inputs and the crops vary in the output shares of inputs. Therefore when faced with the same vector of input prices, the optimal input choices for the two crops will differ.

The cost of extracting groundwater, conditional upon each farmer owning a well, reflects multiple factors. First, electricity is used to pump water from the groundwater stock. The marginal cost of a unit of electricity is given by p_w. The farmer faces a subsidized groundwater price, $\tilde{p_w}$, where $\tilde{p_w} = p_w - s$. Furthermore, the per unit cost of extracting electricity - $c(x_t)$ - is convex in the stock of groundwater. The greater the stock, the lower the cost of pumping groundwater: $\partial c/\partial x < 0$. Conceptually, a decline in the stock of groundwater in a given groundwater basin will result in a decline in the water table as well as a decline in water pressure, raising the cost of pumping water.

Landowners choose the fraction of land and water inputs they will devote to each crop in order to maximize profits, given the input and output prices they face:

$$\begin{aligned} \Pi(A) &= \max_{A_1,w_1,w_2} \quad p_1F_1(u_t\xi, A_1) &+& \quad p_2F_2(u_t(1-\xi), A-A_1) &-& \quad \tilde{p_w}c(x_t)u_t \\ &= \quad p_1(u_t\xi)^\alpha A_1^\beta &+& \quad p_2u_t(1-\xi)^\gamma(A-A_1)^\delta &-& \quad \tilde{p_w}c(x_t)u_t \end{aligned}$$

Crop 1 is more water-intensive than crop 2: $\alpha > \gamma$, and $\alpha+\beta \leq 1$, $\delta+\gamma \leq 1$. In addition, assume for simplicity that $\alpha + \beta = \delta + \gamma$.

Since drawing water in period t will affect the stock of water available to be drawn in period $t+1$, the farmer faces the following dynamic problem:

$$\begin{aligned} v(x_t) &= max_{u_t,\xi,A_1}[p_1(u_t\xi)^\alpha A_1^\beta + p_2(u_t(1-\xi))^\gamma(A-A_1)^\delta - \tilde{p_w}c(x_t)u_t \\ &\qquad +\beta v(x_t-(N-1)u^*(x_t)-u_t+r)] \\ &\quad s.t. \quad x_t-(N-1)u^*(x_t)-u_t \geq 0 \end{aligned} \tag{2}$$

where β represents the discount factor and $v(x_t)$ is the present value from agricultural production over an infinite planning horizon when the initial state is x_t. The dynamic problem is subject to an inequality constraint, which restricts the farmers groundwater consumption in the current period to less than or equal to the total groundwater stock available today.

The corresponding Lagrangian expression to the maximization above is given by:

$$\begin{aligned} v(x_t) &= max_{u_t,\xi,A_1}[p_1(u_t\xi)^\alpha A_1^\beta + p_2(u_t(1-\xi))^\gamma(A-A_1)^\delta - \tilde{p_w}c(x_t)u_t \\ &\qquad +\beta v(x_t-(N-1)u^*(x_t)-u_t+r)] \\ &\qquad + \quad \lambda_t(x_t-(N-1)u^*(x_t)-u_t) \end{aligned} \tag{3}$$

Maximizing the equation above with respect to u_t yields the following first order conditions:

$$\frac{\partial F_1}{\partial u_t} + \frac{\partial F_2}{\partial u_t} - c(x_t)\tilde{p_w} - \lambda_t = \beta\frac{\partial v_{t+1}}{\partial x_{t+1}} \tag{4}$$

$$\lambda_t(x_t-(N-1)u_t^*(x_t)-u_t) = 0 \tag{5}$$

The final term, $\beta\frac{\partial v_{t+1}}{\partial x_{t+1}}$ represents the private opportunity cost of current groundwater extraction, since consuming water in the current period reduces the groundwater stock available for future consumption. Therefore the marginal product of water lies above the current marginal cost of water due to the private inter-temporal opportunity cost.

The farmer chooses to allocate water across crops by equating the marginal product of water across crops:

$$\frac{\partial F_1}{\partial \xi} = \frac{\partial F_2}{\partial \xi} \tag{6}$$

Finally, the farmer chooses the amount of land to devote to each crop in order to equalize the marginal product of land:

$$\begin{aligned}\frac{\partial F_1}{\partial A_1} &= \frac{\partial F_2}{\partial A_1}\\ \frac{A_1^{\beta-1}}{(A-A_1)^{\delta-1}} &= \frac{\delta p_2 u_t^{\gamma-\alpha}(1-\xi)^{\gamma}}{\beta p_1 \xi^{\alpha}}\end{aligned}$$

Note that water consumption is greater when farmers are individually optimizing than when optimization occurs at the community level. This is because users only take into account the private costs associated with groundwater pumping. However, the individual fails to consider the costs of their private groundwater consumption on the community. The first arises because groundwater consumption in period t makes the stock constraint more costly in period $t+1$. The second arises because groundwater consumption in period t increases the cost of pumping water in period $t+1$, since it increases the depth from which groundwater must be pumped. Therefore the socially optimal individual groundwater use is less than the privately optimal groundwater use. These results are discussed in greater depth in Provencher and Burt (1993).

3.3 Testable Predictions

1. The total water used increases as the price of groundwater decreases, i.e. as the groundwater subsidy increases:.

2.1 The fraction of land and water devoted to the water intensive crop increases as the price of water decreases, i.e. as the subsidy increases: since $\alpha > \gamma$, $\frac{\partial A_1}{\partial p_w} < 0$ and $\frac{\partial \xi}{\partial p_w} < 0$, while $\frac{\partial (A-A_1)}{\partial p_w} > 0$ and $\frac{\partial (1-\xi)}{\partial p_w} > 0$

2.2 Total agricultural production increases as the subsidy increases, i.e. as the effective price of groundwater decreases. Production of the water intensive crop increases by more than production of the non-water intensive crop.

3. Increasing total water consumption beyond the replenishable recharge reduces the groundwater stock available for future use and decreases future profits, through increas-

ing the cost of groundwater extraction as well as reducing water inputs.

4 Estimation strategy

In this section, we put forward a strategy used to test the predictions of the model. In this draft of the paper, we focus on the static predictions of the model. Future drafts of the paper will examine both the static and dynamic predictions of the model.

Prediction 1 states that the total groundwater consumed rises as the price of electricity falls. A first strategy is to estimate this using a simple OLS model:

$$Q^d_{it} = \beta_0 + \beta_1 R_{it} + \beta_2 p^E_{jt} + \beta_3 X_{it} + \lambda_t + \gamma_j + u_{it}. \tag{7}$$

Groundwater consumption, Q^d_{it}, is a continuous variable defined as the quantity (million cubic meters (mcm)) of groundwater extracted in district i and year t. We control for groundwater capacity by including the annual replenishable supply of groundwater in district i and year t, R_{it}, where the replenishable supply varies annually depending on rainfall. Since our measure of capacity is restricted to the replenishable quantity of groundwater, it is exogenous to annual groundwater demand.

The price of electricity in state j and year t is denoted by p^E_{jt}. The amount of rainfall in district i and year t and whether rainfall is reported is captured in X_{it}. Year dummies control for any trend in groundwater extraction over time. The error structure includes γ_j, a district fixed effect, and u_{it}, an idiosyncratic error term. Standard errors are clustered at the district level.

Since, at any given electricity price, the quantity of electricity supplied is often constrained below demand in India, this implies that the price of electricity may not be a sufficient statistic to capture how subsidies affect groundwater demand. The state governments may also alter electricity provision through other channels, such as via increasing generation (the average load factor in India in 2001 was 72%) or via turning a blind eye to thefts.

We therefore estimate the effect of other electricity measures that may affect groundwater extraction including generation and transmission and distribution losses. Identification of the effect of these other electricity measures on district groundwater demand comes from state-year variation in electricity prices controlling for time-invariant district unobservables and year shocks. Since all districts in a state face the same electricity prices, electricity prices will not differ across districts within a state. The same does not hold true for the other electricity measures. Capacity, generation, and transmission and distribution losses may differ across districts within a state if politicians or the state electricity boards selectively allocate these subsidies to preferred or disadvantaged districts. Because of this, coefficient estimates on generation, capacity, and transmission and distribution losses may suffer from omitted variables bias.

In a final specification for groundwater demand, we estimate equation (7) conditional on generation, capacity, and transmission and distribution, allowing us to test whether the effect of electricity prices on groundwater demand is robust to the inclusion of other subsidies.

To test the effect of electricity subsidies on agricultural production and crops sown, we estimate a variation of equation 7,

$$V_{it} = \beta_0 + \beta_1 R_{it} + \beta_2 p^E_{jt} + \beta_3 X_{it} + \lambda_t + \gamma_j + u_{it}. \tag{8}$$

In a first model, V_{it} denotes the value of agricultural output, measured as the sum over all crops in a district-year of crop-specific revenues. In other models, the dependent variable reflects the district market price of a crop grown in year t. The crops used in the analysis include cotton, rice, sugar, wheat, sorghum and millet, where the first three crops describe water intensive crops and the latter three crops describe non-water intensive crops.

4.1 Incorporating hydrology

Our current specification will generate biased coefficient estimates of the effect of electricity prices on groundwater extraction, β_2, since electricity prices are likely to be correlated with unobservables such as the political party in power, the state's agricultural economy and the weight placed on agricultural welfare in the social planner's utility function. To identify the effect of electricity subsidies on groundwater extraction, we turn to the water resources literature to construct a measure for the price of groundwater extraction.

The price of groundwater extraction depends on electricity prices, the depth to the aquifer and the interaction of these two variables. The water resources literature uses the latter variable, the interaction of electricity prices and depth to the water table, to measure the price of groundwater (Domenico et al. 1968, Miller and Archer 1971). Borrowing from this literature, we estimate a variation of equation 7 in which we interact electricity prices with groundwater characteristics:

$$Q^d_{it} = \alpha_0 + \alpha_1 R_{it} + \alpha_2 R_{it} p^E_{jt} + \alpha_3 p^{GWmin}_i p^E_{jt} + \alpha_4 p^{GWmax}_i p^E_{jt} + \alpha_5 X_{it} + \lambda_{jt} + \gamma_i + u_{it}. \tag{9}$$

The variables p^{GWmin} and p^{GWmax} describe fixed district hydrological characteristics that measure the price to access a unit of groundwater. The first variable measures the minimum depth one would need to drill to reach the aquifer. This variable does not describe the depth to the water table; rather it captures the hydrogeology of the district. Regardless of whether the water table increases or decreases, one would need to drill to this minimum depth to reach the aquifer. The second hydrological characteristic p^{GWmax} describes the maximum depth of the aquifer. When combined with minimum well depth, this variable measures the size of the aquifer (i.e. how much the aquifer can hold). If we think about p^{GWmin} as the depth to the aquifer and p^{GWmax} as the size of the aquifer, then we can characterize R_{it} as the quantity of water that replenishes or fills this aquifer annually. We include interactions of electricity prices and each groundwater variable in our estimating equation.

In this model, we continue to control for the replenishable supply of groundwater, rainfall and time invariant district unobservables. We also include state-year fixed effects that control for shocks common to all districts within a state such as electricity prices or state government elections.

The coefficient of interest, α_3, will capture the differential effect of changes in electricity prices in a single state year on two districts which differ in their aquifer depths, controlling for fixed district characteristics. We predict that an increase in electricity prices should decrease demand for groundwater relatively more in districts with deeper minimum well depths (i.e. higher groundwater prices). This identification strategy assumes that the differential effect of a change in electricity prices across two districts with different hydrological characteristics will be uncorrelated with district unobservables that vary over time, such as development assistance programs. We test for the robustness of our results to these channels.

5 Data

This paper uses four main sources of data: district groundwater data collected by the Central Groundwater Board, state assembly election data compiled by the Election Commission of India, annual state electricity price and generation data collected by the Power and Energy Division of the Planning Commission and agricultural data compiled by the Directorate of Economics and Statistics within the Indian Ministry of Agriculture.

5.1 Groundwater Data

District groundwater data (where the U.S. equivalent of a district is a county) on extraction and recharge from 2004 were provided for 350 districts from 15 states. Obtaining data on groundwater has been our greatest constraint - groundwater assessments are expensive and difficult to undertake and are therefore rarely conducted. We form an unbalanced panel of groundwater data for these districts using groundwater data from 331 districts in 1995, 19 districts in 1997, 31 districts in 1998, 197 districts in 2002 and 350 districts in 2004. Summary statistics on groundwater demand, the replenishable supply, groundwater development and exploitation are provided in Table 1.

In 1998, average district consumption in Madhya Pradesh accounts for 60 percent of the annual replenishable supply and over-exploitation of groundwater occurs in 23 percent of the state's districts.[6] In 2002, average district consumption amounted to 59 percent of the annual replenishable groundwater supply. In 38 percent of the 170 districts, groundwater consumption exceeds the replenishable supply. In the 2004 data, average district consumption amounts to 64 percent of the replenishable groundwater supply and 17 percent of the 204 districts are classified as "over-exploited". Between 2002 and 2004, groundwater development increased by 15 percent and the number of exploited districts grew by 10 percent (panel data is available for 169 districts).

Data collected in 2002 by the Central Groundwater Board of India (CGWB) spatially characterize fixed hydrogeological characteristics in the states of Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, Tamil Nadu and Rajasthan. Variation in groundwater characteristics is at the district level, where the minimum and maximum depth to the aquifer are calculated as the district mean.

5.2 Election Data

Data on elections were gathered from the Election Commission of India. There are two types of state elections in India, midterm and scheduled elections. Constitutionally scheduled elections are held every 5 years after the last election. Midterm elections occur when the lower parliament declares the state government incapable of ruling its constituent. Since the frequency and timing of midterm elections varies by state, there is substantial variation in pre-scheduled electoral cycles by state. We observe that the majority of midterm elections occurred during the politically turbulent 1970s. The fraction of states holding an election in 1995, 1997, 2002 and 2004 is shown in Table 2. In these years, the majority of elections were scheduled elections.

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[6] The annual replenishable groundwater resource is calculated as the sum of monsoon and non-monsoon recharge.

5.3 Electricity data

Electricity data were gathered from three primary sources: “The Annual Report on the Working of State Electricity Boards and Electricity Departments” published by the Power and Energy Division of the Planning Commission between 1992 and 2002, multiple volumes of “Average Electric Rates and Duties in India” published by the Central Electricity Authority and multiple volumes of “Energy”, a publication by the Center for Monitoring the Indian Economy in India.

Data on states’ electricity prices, measured in 1986 paise per kilowatt hour (paise/kWh), were collected for the period 1986-2004. The electricity prices captured are average tariffs, measured as the revenues from sale to particular sectors divided by the units sold. Trends in agricultural electricity prices are displayed in Figures 1 and 2. Figure 1 illustrates mean electricity prices over time, showing that between 1995 and 2004 prices have ranged from 9.6 to 20.6 paise. In addition to variation in electricity prices over time, electricity prices also vary across states. The mean electricity price in each state significantly differs from mean electricity prices in at least two other states. In Figure 2, electricity prices are disaggregated by state for a subsample of states. With the exception of Tamil Nadu, prices significantly differ within a state over time. In India, electricity prices also vary by sector with industrial and commercial users paying higher fees. The mean electricity price for agriculture in our sample was 14.7 paise as compared to 103 paise for industrial users.

Table 3 presents descriptive statistics on electricity during the period. Generation and total capacity are captured at a state level and are measured in millions of kW hours. While both generation and capacity have increased substantially during the period, evidence suggests that generation has not increased in line with demand (Tongia, 2004). Transmissions and distribution losses, which reflect both losses due to both technical reasons and theft, have risen substantially over the period examined.

The unit cost to supply electricity represents the cost incurred by the utility to supply a unit of electricity to consumers. The components considered for calculations include the cost of fuel, operations and maintenance expenditure, establishment and administration cost, interest payment liability, depreciation and the cost of power purchase. The subsidy to agricultural users can be backed out by examining the difference between unit costs and the tariff paid by agricultural users. The subsidy to the agricultural sector increases over the period, from approximately 60 paise per kilowatt hour, to over 80 paise. The subsidy account for approximately 87% of the cost of electricity - on average, the price faced by agricultural users is 13% of the cost of electricity.

5.4 Agricultural production data

District-year level data on agricultural yields comes from two publications at the Ministry of Agriculture - the “Agricultural Situation in India” and the “Area and Production of Principal Crops in India”. In order to decouple the effects of price changes from output changes, we create a Lespeyres volume index of total, water and non-water intensive output using average 1995 prices. Prices were taken from “Agricultural Prices in India”.

Agricultural data include agricultural production in a district-year and whether or not a crop is grown in a district-year. Data are available for 1995, 1997, 2002 and 2004. Total agricultural production is measured as the sum of production in wheat, rice, cotton, sugar, sorghum, and millet, weighted by the average 1995 market price of these crops. These six crops were chosen due to the widespread availability of data on these crops during the period examined and their prevalence across India. Water-intensive output is measured as the weighted sum of production in sugar, rice and cotton. Rice is grown in 76 percent of the district-years, sugar is grown in 63 percent of the district-years while cotton is grown in 48 percent of the district-years. Sorghum, wheat and millet are defined as non-water intensive crops. Wheat, sorghum and millet were grown in 55, 40 and 38% percent of districts in 1995, respectively. The water intensity of these crops was defined according to their relative levels of water usage, as defined by the FAO. In 1995, 61% of total production was attributable to water intensive crops.

6 Results

Table 4 reports results from the estimation of equation 7, an OLS model of demand for groundwater. Identification in the model comes from state-year shocks in electricity prices, generation, capacity and, transmission and distribution losses, controlling for fixed district unobservables. We report results for the effect of electricity prices on groundwater extraction in column 1. Results for the impact of generation, capacity and T&D losses on groundwater extraction are presented in columns 2-4, though we are cautious in interpreting these results due to omitted variables bias.[7]. We also look at the effect of electricity prices on groundwater extraction conditional on generation, capacity and transmission and distribution losses (column 5).

We find that on average district demand for groundwater decreases by 3.3 million cubic meters with with a 1 paise increase in the price of electricity. Our results suggest that a 25 percent increase in the agricultural price of electricity, where the mean price of electricity is

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[7] We are currently investigating whether district year data on generation, capacity and transmission and distribution losses exists.

12.16 paise/kWh, will reduce mean groundwater demand by 10 mcm or roughly 1.9 percent. If electricity subsidies were reduced by 10%, where the average subsidy over the duration of the study amounted to 85 paise/kWh, demand for groundwater would decrease by 4.7 percent. It should be noted that while these results suggest a price inelastic demand for groundwater, the source of variation exploited imply that the estimates capture only a short-run elasticity of demand. In the long-term as the area and the crops cultivated responds to changes in the price of groundwater, the demand response is likely to be greater.

When we estimate the effect of one type of electricity subsidy on groundwater extraction, our results suggest that capacity, generation and electricity prices are each significant in explaining district demand for groundwater. Once we condition each electricity subsidy on the other electricity subsidies, electricity price is the only subsidy that significantly impacts groundwater extraction. Conditional on other electricity subsidies, a 1 paise increase in electricity prices is predicted to decrease groundwater extraction by 3.5 million cubic meters. This result mirrors that reported in column 1, suggesting that our results are robust to the inclusion of other subsidies.

In Table 4 coefficient estimates on electricity prices may be downward biased since unobservables - the political party in power or the size of a state's agricultural economy - that may increase groundwater extraction may also be negatively correlated with electricity prices.

To identify the effect of electricity prices on groundwater extraction, we estimate equation 9, a district fixed effects model in which we interact groundwater characteristics with agricultural electricity prices and control for state-year shocks; results are reported in Table 5. In this model we are unable to measure the direct effect of electricity prices on demand for groundwater. Rather we estimate the differential effect of electricity prices on districts with different minimum well depths within a state-year. We find evidence that an increase in electricity prices reduces groundwater extraction relatively more in districts with deeper wells (higher priced groundwater sources). For a district with the mean tube well depth (57 m), we find that a 25 percent increase in the agricultural price of electricity reduces groundwater extraction by 11.65 mcm or 2.2 percent. Our results suggest that a 10% decrease in the average electricity would reduce district groundwater extraction by 5.4 percent.

6.1 Agricultural production

We have demonstrated that electricity subsidies induced an increase in groundwater extraction. Assuming that electricity subsidies affected agricultural production through the channel of groundwater extraction, we now present results for the subsequent effect of these subsidies on agricultural production - prediction 2. Table 6 presents results. Column 1 reports results from the estimation of equation 8, an OLS model of the value of agricultural output on electricity prices. This model estimates the effect of state-year electricity prices on agricultural revenues within a district, controlling for year shocks. Our results suggest that a 1 paise increase in electricity prices, which approximates an 8.25 percent price increase, induces a 5.2 percent reduction in agricultural revenues. This finding is both economically and statistically significant, and suggests a large reduction in annual revenues should electricity subsidies be reduced. For examples, a 25 percent increase in electricity prices would reduce revenues by 15.8 percent and a 10 percent reduction in subsidies would lower revenues by more than one-third.

The magnitude of the estimated impact of electricity prices on agricultural revenues suggests that unobservables that are positively correlated with groundwater extraction may also systematically increase agricultural revenues. For example, fertilizer subsidies, the other dominant agricultural subsidy in India, will likely lead to an increase in groundwater extraction and agricultural output. To isolate the effect of electricity subsidies (via the channel of groundwater extraction) on agricultural output, we estimate equation 9, an OLS model in which we interact electricity prices with minimum well depth, except now importantly the dependent variable is agricultural revenues.

Column 2 reports results. Consistent with the predictions in our theoretical model, we find that electricity subsidies led to a significant increase in agricultural revenues. Our results suggest that a 1 paise increase in the price of electricity would cause a 1.5% decrease in agricultural revenues. Compared to column 1, electricity prices have a less substantial impact on agricultural revenues; a 25 percent increase in electricity prices is predicted to reduce agricultural revenues by 4.7 percent. A 10% reduction in the subsidy would lower agricultural revenues by 11 percent. This evidence suggests that electricity subsidies in India benefited farmers, when benefits are measured as agricultural revenues. However, if we simply estimate the effect of electricity subsidies on agricultural outputs the stimulus provided by these subsidies will be largely overstated. In fact, the predicted impacts of electricity subsidies in the interaction model are less than one-third those reported in the simple OLS model.

If we breakdown agricultural revenues by water intensive and non-water intensive crops, we observe significant changes in water intensive crop revenues in response to a change in electricity prices (col. 3). All things equal, we would expect water intensive crop revenues to be more responsive to electricity prices, since these crops use more water and hence electricity. Indeed, consistent with our theoretical predictions, we find that revenues from water intensive crops are sensitive to price changes, reducing by approximately 3.4 percent with a 1 Rs increase in electricity prices (col 3). By contrast, we observe no change in non-water intensive crops in response to a change in electricity prices (col. 4).

The government introduced agricultural subsidies to lower average food prices and to increase agricultural revenues. We have already shown that these subsidies increased agricultural revenues. We now evaluate whether they reduced the price of crops. We estimate equation 8 and equation 9 where the dependent variables are crop price. Table 7 reports results. We find no significant impact of electricity subsidies on the price of cotton in the simple OLS model (column 1) or in the interaction model (column 2-5). Our results suggest that in the short-run electricity subsidies did not significantly impact the price of food crops, where our results apply to cotton (col. 2) jowar (col. 3), wheat (col. 4) and sugar (col. 5). These results are, however, unsurprising given the heavy involvement of the state in price setting for agricultural products (Gulati and Narayan 2003).

7 Measuring the short-run net benefits

In India, electricity subsidies for agriculture were introduced as a poverty alleviation tool. Advocates of these subsidies argued that they would increase agricultural productivity, reduce food prices and increase the incomes of the rural poor. Indeed, we find evidence that subsidized electricity prices, which lowered the price to access groundwater, led to an increase in agricultural revenues. However, these agricultural benefits are not without their costs. In this section, we conduct a back-of-the envelope cost-benefit analysis to evaluate the short-run net benefits of electricity subsidies.

A comprehensive cost-benefit analysis would include all the benefits and costs associated with electricity subsidies. We restrict our measure of benefits to agricultural revenues, though electricity subsidies most likely generated other benefits such as an increased food supply. We also underreport the costs of these subsidies. Costs estimates are confined to the direct cost of the subsidy, defined as the difference between the unit cost to supply electricity and the price paid by agricultural users to consume electricity. Cost estimates would increase if we considered the linkages between these subsidies and groundwater exploitation. In the case that groundwater is over-exploited, cost estimates must reflect the scarcity value of the resource - the fact that the consumption of a unit of groundwater today prevents the future consumption of that unit.

A second limitation of the cost-benefit analysis is that we cannot compare the costs of switching from a policy in which electricity is priced at the marginal cost to one in which electricity is priced at the status-quo. Rather this cost-benefit analysis predicts the change in benefits and costs if there was a 10% reduction in the subsidy. We calculate the net benefits of a 10 percent reduction rather than a complete removal of the subsidy due to concerns about out of sample predictions. In our sample, the average per unit cost of electricity is 85 paise per kWh, though farmers on average only pay 12.16 paise per kWh. There is no overlap between agricultural prices and the unit cost of supply; electricity prices for agriculture range between 0 and 39 paise whereas the unit cost of supply ranges between 57 and 119 paise. Since there are no observations in which the agricultural price equals the unit cost of electricity, we cannot reasonably predict the impact of unit cost pricing on agricultural revenues. By contrast if we reduce the subsidy by 10%, the calculated price of electricity overlaps with the observed price of electricity in all states in the study with the exception of two.

To measure the net benefits of these subsidies, we first perform a simple counterfactual and estimate what groundwater agricultural revenues would have been if the electricity subsidy was reduced by 10 percent. The difference between actual agricultural revenues and revenues under a 10 percent reduction in the subsidy reflects the net benefits of these subsidies, where we calculate net benefits annually. Coefficient estimates from the model in which minimum aquifer depth is interacted with electricity prices are used in the policy simulation. The average annual benefits conferred to district agricultural revenues from these subsidies amounted to \$33.5 million Rs.

To measure the annual cost of electricity subsidies, we first translate groundwater extraction into electricity usage using a methodology developed in Zhu et al.. The total energy in million watt hours (Mwh) necessary to pump Q mcm of water from an aquifer is given by,

$$E = \phi * W * h \tag{10}$$

where h measures average groundwater depth. We assume that h equals the minimum depth to the aquifer; this measure of groundwater depth provides a lower bound for the energy necessary to extract groundwater. The coefficient ϕ is defined as $\gamma * \rho * g/1000$ where ϕ denotes pumping efficiency which we take to be 0.55, ρ is the density of water (1000 kg/m^3) and g is the acceleration of gravity (9.8 m/s^2). Energy usage is calculated for each district-year. The annual of cost of electricity subsidies equals electricity usage multiplied by 10 percent of the agricultural subsidy. The annual costs of these subsidies are large, totaling at 185 million Rs per district.

A simple back of the envelope calculation reveals that the annual costs of a 10 subsidy reduction outweighed the benefits by more than a 150 million Rupees. If we calculate the net benefits of these subsidies using coefficient estimates from the OLS model with electricity prices (which predict a 33 percent reduction in revenues), we continue to find that the costs exceed the benefits by more than 80 million Rupees (roughly 2 million dollars). As mentioned earlier, this study likely understates the benefits of electricity subsidies. However, the benefits from agricultural electricity subsidies would need to increase more than 5-fold for the benefits of this policy to outweigh the costs. Cost estimates would also increase if we considered (1) the linkages between these subsidies and groundwater exploitation and (2) the negative externality imposed by emissions.

8 Political capture

In India electricity shortages are pervasive with many individuals receiving electricity for only a portion of the day. Over time, the provision of reliable electricity services has only worsened as industrial users begin to build their own capacity, thereby reducing the base of users that pay the marginal cost for electricity. These shortages are partly attributable to electricity subsidies, since SEBs are operating at a loss and do not have the capital to repair existing generation sources or construct additional capital. Even if we ignore the long-term impact of subsidized agricultural electricity, this paper shows that in the short-run, the annual cost of electricity subsidies outweighs the benefits six-fold. We now explore one possible explanation for the continued use of these subsidies. This section investigates the linkages between state elections and agricultural electricity prices to discern whether electricity subsidies partly function as a state political tool to gain rural votes.

8.1 State elections

In India, members of the SEBs are appointed by elected state officials who hold office in the legislative assembly. These state legislative assemblies, referred to as Vidhan Sabhas, are directly elected bodies whose size varies according to the population. As stated in the constitution, state legislative assembly elections are scheduled every five years. However if the lower parliament finds the state government unfit to rule, the government can issue an election, referred to as a midterm election, prior to the end of the five year term. Recently state midterm elections have become more common, though the frequency of midterm elections varies by state (NIC 2009). If a midterm election occurs, a constitutionally scheduled election will occur five years later. Due to midterm elections, there is substantial variation in electoral cycles across states.

8.2 The impact of state elections on electricity prices

It is important to distinguish between the anticipated impacts of midterm elections and pre-scheduled elections on electricity pricing. Since midterm elections occur if the central government views the state government as incapable, these elections are likely to be strongly correlated with the political climate of a state, the relationship between the federal and state political parties in office and the economic climate. A simple OLS model that estimates the effect of all lead elections years on electricity prices might be biased, since elections may capture the effect of political unrest or a weak economy on electricity prices.

By contrast, scheduled constitutional elections occur every five years independent of the political climate, the relationship between political parties and voter preferences. Our identification strategy exploits this exogenous variation in pre-scheduled elections to test for the presence of electoral cycles in electricity pricing. Other studies have employed a similar approach using pre-scheduled elections to estimate the effect of state elections on crime, road construction and revenue (Chaudhuri and Dasgupta 2005, Cole 2009, Ghosh 2006, Khemani 2004).

In Figure 3, we illustrate the rationale for this approach. For the state of Rajasthan, we graph electricity prices between 1996 and 2005 and indicate the years, 1997 and 2002, that precede a pre-scheduled election. Graphically, we observe a decrease in electricity prices prior to pre-scheduled election years.

We estimate an OLS model with district and year fixed effects,

$$p_{jt}^{E} = \beta_0 + \beta_1 elec_{jt} + \beta_2 X_{it} + \lambda_t + \gamma_i + u_{it} \tag{11}$$

The dependent variable p_{jt}^{E} measures the annual price of electricity in a state. The variable of interest $elec_{jt}$is an indicator variable set equal to one if a pre-scheduled election occurs in state j in year $t+1$. We choose to use lead election year since politicians campaign in the year preceding an election. We control for annual rainfall and whether rainfall is reported X_{it}, year fixed effects and district fixed effects. Standard errors are clustered at the district.

Since political campaigns occur in the year preceding an election, we predict that politicians will increase agricultural subsidies in the year prior to an election to secure the agricultural sector's vote.

Results from an OLS model of agricultural electricity prices on pre-scheduled elections are presented in Table 8. As shown in column 1, we find on average a 1.4 paise decrease in the price of electricity in the year preceding a pre-scheduled election. Since electricity prices in our sample range between 0 and 55 paise per kWh, with a mean price of 12.16 paise, our results suggest that politicians reduce electricity prices on average by 10 percent in the year preceding an election.

To test whether the relationship between electricity prices and elections is spurious, we estimate the effect of lagged pre-scheduled elections on electricity prices. As reported in column 2, we find that in the year following a pre-scheduled election, electricity prices on average increase. Lastly, we estimate the effect of midterm and pre-scheduled elections on electricity prices, where we include two indicator variables that are each set equal to 1 in the year preceding a midterm and pre-scheduled election, respectively. Conditional on midterm elections, electricity prices continue to decrease in the year preceding a scheduled election.

Our work fits within a growing literature that provides evidence of electoral cycles in crimes, revenues and public infrastructure (Chaudhuri and Dasgupta 2005, Cole 2009, Ghosh 2006, Khemani 2004). Similar to these studies, our results suggest that political capture partly explains the persistence of agricultural electricity subsidies. In the years preceding a scheduled state election, the price of electricity significantly drops, even after controlling for annual shocks and fixed district unobservables. Though state electricity boards operate at a loss and these subsidies only induce small increases in agricultural revenues, these subsidies provide a strong political tool for politicians. More generally, we find that public ownership of electric utilities provides managers with an incentive to maintain or even increase electricity subsidies in politically sensitive years.

9 Conclusion

We motivate this paper by asking if the public provision of electricity in rural India maximized social welfare and was captured by voting interests. In rural India, agricultural electricity prices are heavily subsidized, and we explore whether these subsidies correct an existing market failure, thereby increasing total welfare. We measure the benefits of this policy as the change in agricultural output from these subsidies. We find that a 1 paise increase in electricity prices raises agricultural output by 1.6 percent. However this comes at a cost. A 10% reduction in the subsidy would reduce government costs by \$185 million Rs in each district. We estimate that the costs of the subsidy are five times larger than the benefits. Though restrictive in the benefits and costs considered, our cost-benefit analysis reveals that state ownership of electricity did not lead to a maximization of social welfare. If electricity in India were privatized and subject to appropriate regulation, we anticipate that the annual losses from electricity provision would decrease.

Our research suggests that political capture offers one explanation for the persistence of these subsidies. To maintain their political position, state politicians have an incentive to price electricity below its efficient price, especially during politically sensitive periods. We find evidence for this behavior. First agricultural electricity prices are priced below the efficient price - the price agricultural users pay for electricity equals 13 percent of the unit cost of supply. Second, agricultural prices are manipulated during politically sensitive periods. Our research suggests that the price of electricity decreases in the year preceding an election.

While many are skeptical about the privatization of utilities in developing countries, our research shows that public ownership of electricity does not necessarily increase social welfare and is captured by the interest of voters. In light of this, privatization of electricity, with appropriate regulation, may improve social welfare in developing countries.

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Table 1: Summary Statistics on Supply and Demand for Groundwater

District variable	Year	Obs	Mean	Std. Dev.	Min	Max
Aggregate demand	1995	331	510	404	11	3075.3
Available gw supply	1995	331	953	786	31	8549
GW development	1995	331	0.59	0.35	0.033	2.38
Percent exploited	1995	331	0.105	0.31	0	1
Aggregate demand	1997	19	511	317	74	1419
Available gw supply	1997	19	676	277	72	1111
GW development	1997	19	0.75	0.37	0.01	1.65
Percent exploited	1997	19	0.16	0.37	0	1
Aggregate demand	1998	31	337	208	16	898
Available gw supply	1998	31	692	295	112	1136
GW development	1998	31	0.60	0.46	0.02	5.32
Percent exploited	1998	31	0.23	0.43	0	1
Aggregate demand	2002	197	586	472	4.66	2481
Available gw supply	2002	197	1049	628	53	4080
GW development	2002	197	0.59	0.38	0.03	2.74
Percent exploited	2002	197	0.112	0.33	0	1
Aggregate demand	2004	350	642	599	4.58	4177
Available gw supply	2004	350	1144	722	52.4	4644
GW development	2004	350	0.648	0.417	0.0160	2.24
Percent exploited	2004	350	0.169	0.374	0	1

Notes: Data from Central Groundwater Board. The unit of observation is a district.
Aggregate demand and available groundwater supply are measured in million cubic meters (mcm).
GW development is defined as the ratio of groundwater demanded over the the annual replenishable supply. The annual replenishable groundwater resource is calculated as the sum of monsoon and non-monsoon recharge. A district is defined as exploited if groundwater development is greater than 1.

Table 2: Summary Statistics on Supply and Demand for Groundwater

Variable	Year	States	Districts	Mean	Std. Dev.	Min	Max
Election (Any)	1995	14	331	0.35	0.49	0	1
Midterm Election	1995	14	331	0.07	0.26	0	1
Prescheduled Election	1995	14	331	0.29	0.47	0	1
Election (Any)	1997	1	19	1	-	1	1
Midterm Election	1997	1	19	1	-	1	1
Prescheduled Election	1997	1	19	0	-	0	0
Election (Any)	1997	1	31	0	-	0	0
Midterm Election	1997	1	31	0	-	0	0
Prescheduled Election	1997	1	31	0	-	0	0
Election (Any)	2002	9	197	0.22	0.44	0	1
Midterm Election	2002	9	197	0	-	0	0
Prescheduled Election	2002	9	197	0.22	0.44	0	1
Election (Any)	2004	15	350	0.07	0.26	0	1
Midterm Election	2004	15	350	0.07	-	0	0
Prescheduled Election	2004	15	350	0	0.46	0	1

Notes: The unit of observation is a state, the number of districts examined is given in column 4. Scheduled elections refer to constitutionally prescheduled elections, where elections are scheduled to occur 5 years after the previous election. Midterm elections refer to elections occuring in the intermittent time period due to a lack of confidence in parliament.

Table 3: Summary Statistics on Electricity Prices and Capacity

District variable	Year	States	Districts	Mean	Std. Dev.	Min	Max
Agricultural Electricity Price	1995	14	331	9.41	404	0	22.13
Industrial Electricity Price	1995	14	331	87.32	786	31	112.71
Generation	1995	14	331	14082	1952	2340	35335
Subsidy	1995	14	331	60.05	12.59	35.39	90.68
Agricultural Electricity Price	1997	1	19	7.43	-	-	-
Industrial Electricity Price	1997	1	19	107.01	-	-	-
Generation	1997	1	19	21303	-	-	-
Subsidy	1997	1	19	67.75	-	-	-
Agricultural Electricity Price	1998	1	31	2.09	-	-	-
Industrial Electricity Price	1998	1	31	126.25	-	-	-
Generation	1998	1	31	17057	-	-	-
Subsidy	1997	1	19	73.95	-	-	-
Agricultural Electricity Price	2002	9	197	10.91	13.14	0	3075.3
Industrial Electricity Price	2002	9	197	99.57	47.67	0	8549
Generation	2002	9	197	18552	12309	2608	2.38
Subsidy	2002	9	197	88.95	15.51	57.24	112.61

Notes: The unit of observation is a state, the number of districts examined is given in column 4. Electricity prices and subsidies are measured in 1986 paise. Electricity generation are measured in million kilowatt hours. Electricity subsidies are measured as the difference between the electricity price and the unit cost.

Table 4: OLS models of demand for groundwater

Demand Groundwater	(1)	(2)	(3)	(4)	(5)
Replenishable supply	0.255**	0.259**	0.260**	0.257**	0.256*
	(0.128)	(0.131)	(0.128)	(0.129)	(0.131)
Rural electricity price	-3.298**				-3.499**
	(1.546)				(1.487)
Generation		-0.00610***			-0.00529
		(0.00168)			(0.00503)
Capacity			-0.0213**		-0.00588
			(0.00993)		(0.0259)
T&D losses				-2.769	-0.425
				(1.747)	(2.062)
Log rain	-25.09	-31.58	-22.40	-27.66	-28.30
	(26.89)	(32.42)	(27.03)	(26.82)	(33.81)
Fixed effects	district	district	district	district	district
	year	year	year	year	year
Observations	928	912	928	928	912
R-squared	0.863	0.863	0.862	0.861	0.865

Notes: The dependent variable is the quantity in million cubic meters of groundwater extraction by district year. Columns 1-5 report results from an OLS model with standard errors in parentheses. Asterisks denote significance; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: OLS model of demand for groundwater with interaction

Groundwater	extraction	exploited	exploited -150%
Replenishable gw supply	0.305**	-7.70e-05	-4.01e-05**
	(0.141)	(4.54e-05)	(1.74e-05)
Elec price * gw supply	-0.000679	1.49e-06	1.46e-06*
	(0.00467)	(1.20e-06)	(7.22e-07)
Elec price*min well depth	-0.0655***	-1.32e-05	2.95e-05
	(0.0218)	(4.09e-05)	(3.01e-05)
Log rain	-3.029	-0.0100	0.00357
	(10.27)	(0.0136)	(0.00379)
Fixed effects	district state*year	district state*year	district state*year
Observations	468	468	468
R-squared	0.913	0.656	0.374

Notes: The dependent variable is the quantity in million cubic meters of groundwater extraction by a district in a year. Columns 1-5 report results from an OLS model with standard errors. Regression includes dummy for rain reported and avg max well depth*electricity price. in parentheses. Asterisks denote significance; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6: OLS model of agricultural production

Value agricultural product	(1) All crops	(2) All crops	(3) H20 intensive crops	(4) Non-H20 intensive crops
Replenishable gw supply	-6.43e-05	-0.000342	-0.000339	-0.000208
	(0.000186)	(0.000845)	(0.000852)	(0.000595)
Elec price	-0.0521***			
	(0.00783)			
Elec price * gw supply		3.71e-06	2.82e-06	-2.33e-05
		(2.17e-05)	(2.17e-05)	(2.82e-05)
Elec price*min well depth		-0.000261***	-0.000191***	-0.000277
		(5.50e-05)	(5.41e-05)	(0.000183)
Log rain	-0.0252	0.142	0.155	0.179
	(0.120)	(0.0901)	(0.0926)	(0.148)
Fixed effects	district	district	district	district
	year	state*year	state*year	state*year
Observations	663	335	335	335
R-squared	0.904	0.895	0.915	0.944

Notes: The dependent variable is the log of agricultural revenue in
a district in a year. Columns 1-5 report results from an OLS model with standard errors.
Regression includes dummy for rain reported and avg max well depth*electricity price.
in parentheses. Asterisks denote significance; *** p<0.01, ** p<0.05, * p<0.1

Table 7: OLS model of crop prices

Price	Cotton	Cotton	Sugar	Jowar	Wheat
Replenishable gw supply	-0.00825	0.0120	0.00652	-0.000489	-0.00189
	(0.00976)	(0.0128)	(0.00544)	(0.00370)	(0.00140)
Elec price ag	-0.299				
	(1.145)				
Elec price*min well depth		-0.0334*	-0.0165	-0.00520	-0.00717
		(0.0174)	(0.0102)	(0.00396)	(0.00541)
Fixed effects	district state*year	district state*year	distric state*year	district state*year	district state*year
Observations	1519	767	767	767	767
R-squared	0.760	0.790	0.777	0.781	0.790

Notes: The dependent variable is the real price in kg of each crop
a district in a year. Columns 1-5 report results from an OLS model with standard errors.
Regression includes dummy for rain reported, log rain and avg max well depth*electricity price.
in parentheses. Asterisks denote significance; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: OLS model of electricity prices

	Electricity prices	Electricity prices	Electricity prices
Pre-scheduled election	-1.408***		-1.340***
	(0.355)		(0.342)
Replenishable supply	0.000576	0.00112*	0.000708
	(0.000600)	(0.000595)	(0.000609)
Log rain	0.267	0.361	0.0228
	(0.317)	(0.294)	(0.292)
Pre-scheduled election lag		5.300***	
		(0.712)	
Midterm election			-4.224***
			(0.228)
Fixed effects	district year	district year	district yearr
Observations	1646	1646	1646
R^2	0.367	0.403	0.382

Notes: The dependent variable is the price for a kWhr of electricity in a district-year.
Pre-scheduled election is an indicator variable for whether there was a
prescheduled election in year $t+1$. Asterisks denote significance; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

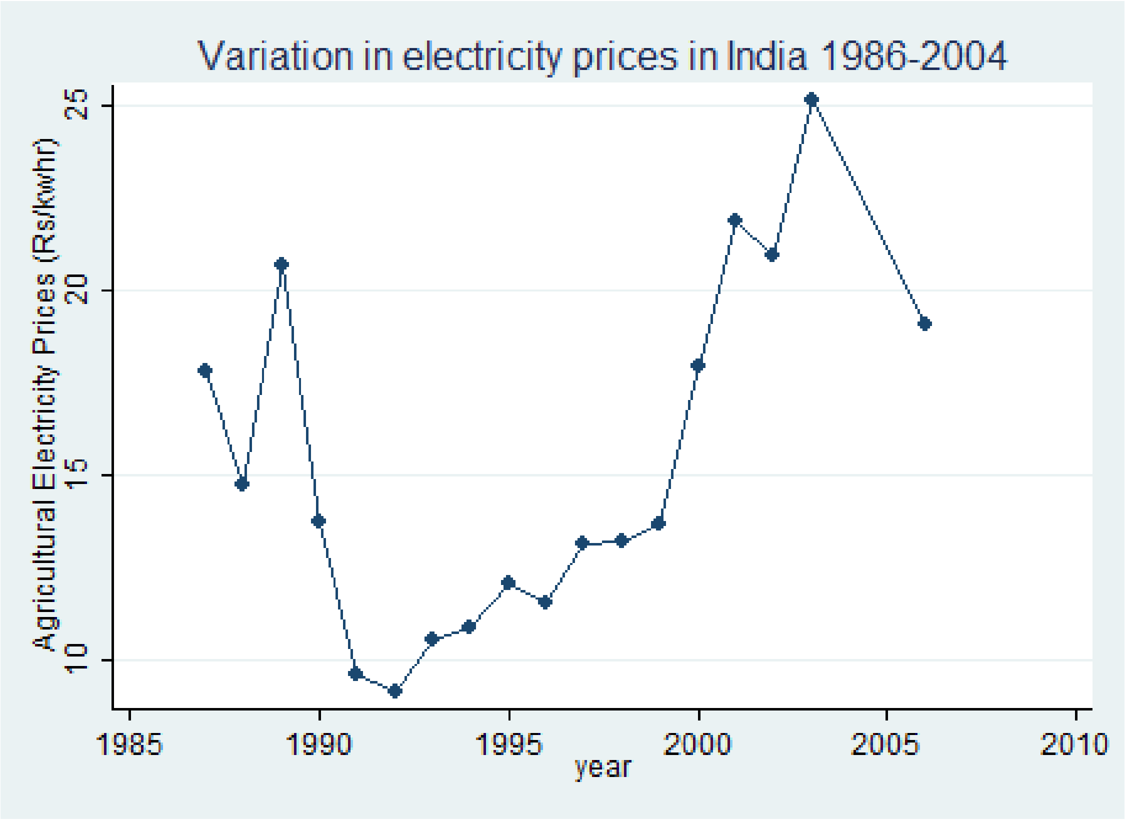

Figure 1: Electricity prices in India 1988-2005

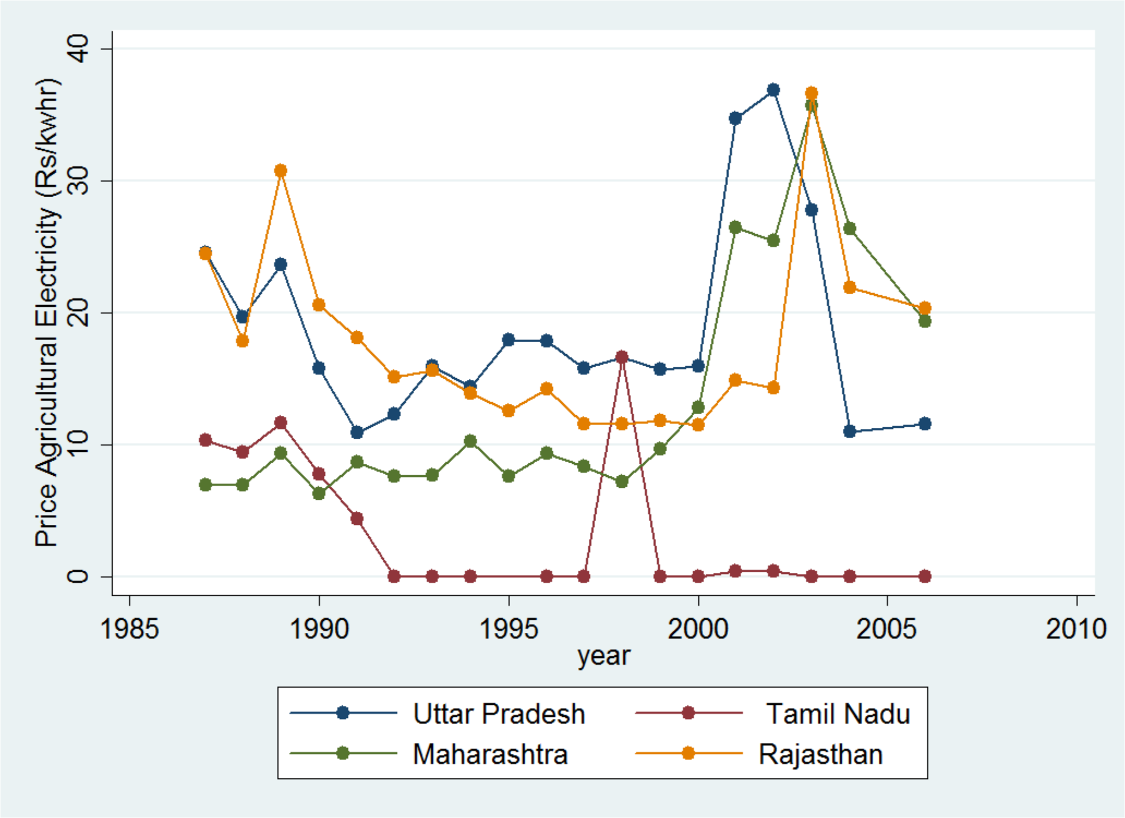

Figure 2: Electricity prices by state in India 1988-2005

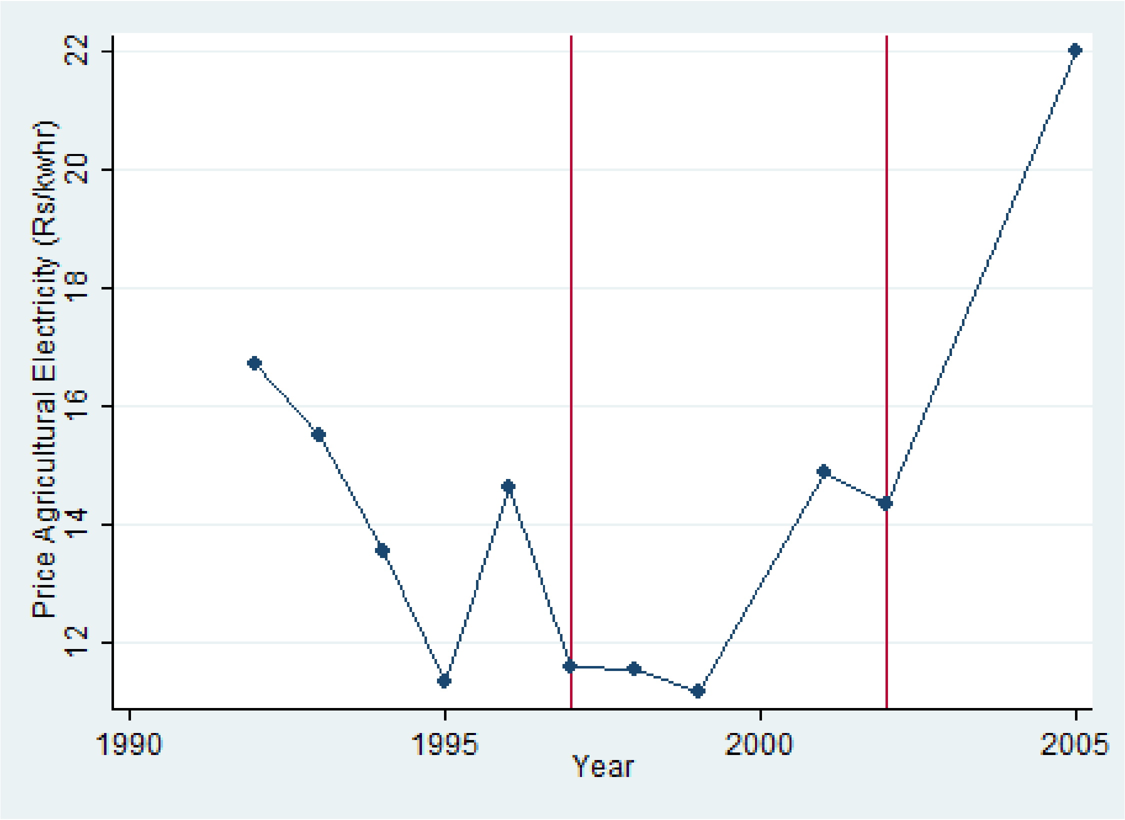

Figure 3: Electricity prices and elections in Rajasthan1995-2005