Development and the Environment: The Implications of Agricultural Electricity Subsidies in India*

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Abstract

In India, the government provides agricultural electricity subsidies amounting to 85% of the average cost of supply to encourage agricultural production and economic growth, especially among the rural poor. However, these agricultural input subsidies may compromise environmental quality and have the potential to reduce agricultural output in the long-run. This article provides an overview of these subsidies in India, detailing the rationale behind their introduction and their evolution over time. It then examines the benefits of the subsidies, notably a rise in agricultural productivity and an increase in rural incomes. In addition, it considers the environmental and economic costs of this policy: accelerated groundwater extraction, increased electricity usage and in turn greenhouse gas emissions, a contribution to the intermittent and low quality electricity service characteristic of India, and potential impacts on industrial growth. We then broaden the lessons learned from electricity subsidies in India to other countries and contextualize these findings within the discussion on environment and development.

Biographical Sketches

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Introduction

In India, climate change is predicted to sizably reduce agricultural yields and profits. Yields are expected to fall by 4.5 to 9 percent in the medium-run and 25 percent in the long-run (Guiteras, 2009), and losses may amount to 10% of agricultural profits (Singh, Mendelsohn, and Dinar, 1998). Given the central role agriculture plays in the Indian economy - employing 54% of the workforce, contributing 16% of GDP, and disproportionately supporting poorer individuals – the economic effects of climate change will be felt throughout economy, most acutely among the rural poor (FAO, 2010).

Economists have advocated for a carbon tax as a policy to mitigate climate change (Nordhaus, 2007). This tax would establish a price for carbon emissions, thereby requiring emitters to internalize the marginal damage generated from their behavior. Despite the forecasted costs of climate change, and in contrast to the proposed carbon tax, many developing countries are subsidizing energy use in an attempt to encourage economic growth and accelerate the pace of poverty reduction. These subsidies are large in magnitude, totaling at over $220 billion for the 20 largest non-OECD countries (UNEP, 2008).

The 5th largest energy subsidies in the world in terms of expenditure are found in India – in 2005, the country spent an estimated $US 20 billion subsidizing oil products, natural gas, and electricity (UNEP, 2008). Nearly half of these subsidies are allocated to household and agricultural consumers, primarily as electricity subsidies. These subsidies were introduced in an effort to accelerate economic growth, increase food security, expand access to electricity, and lower the costs of irrigation. And, in fact, the evidence suggests that agricultural electricity subsidies have been effective in achieving some of these objectives. Previous work finds that these subsidies (through their impact on irrigation) increased agricultural production (Badiani and Jessoe, 2011), food security (Singh, 2000) and rural incomes (Briscoe and Malik, 2006).

However, these subsides are not without their costs. It is argued that they contribute to the financial insolvency of the current electricity system, as well as to the unreliable and intermittent electricity service it provides (World Bank, 2002). They have substantial opportunity costs since they limit the funding available for other social programs (Birner, Gupta, Sharma and Palaniswamy, 2007). In many states, the amount spent on subsidies is greater than that spent on education or health care (Birner et al., 2007).

These subsidies also have environmental costs, most notably increasing the rate of groundwater extraction for irrigation (Badiani and Jessoe, 2011). As India's dependence on groundwater irrigation increases, concerns over groundwater extraction have also grown, since increased extraction may compromise drinking water quality, the long-run availability of water for irrigation and ecosystem health (Gandhi and Namboodiri, 2009). An additional environmental consequence is the impact these subsidies have on greenhouse gas emissions since they increase electricity use, and the majority of electricity is produced using coal.

This article proceeds as follows: we first describe the historical background and political economy of electricity subsidies in India. We then examine the benefits of these subsidies, notably a rise in agricultural yields and the promotion of economic growth in rural areas. We also examine their costs, which include accelerated groundwater extraction that could potentially compromise the supply and quality of groundwater; increased electricity usage and in turn greenhouse gas emissions; and a role in the unreliable and intermittent electricity supply that is the status quo in India. We then broaden the lessons learned from electricity subsidies in India to other countries and frame the findings within the literature on environment and development.

Historical Background Electricity Sector and Subsidies

Energy policy in India was first formalized with the 1910 Electricity Act. This act opened electricity generation to public and private providers, allowing the market to determine efficient prices and levels of investment in new generation capacity. By 1947, approximately 80% of electricity in India was generated by private companies and local agencies (Dubash and Rajan, 2001). Upon independence in 1947, India enacted a series of policies to bring the economy under state control. These policies spread to the electricity sector, where the government sought to increase investment and organize small local generation into larger statewide systems. To this end, the government passed the Electricity Act of 1948, which transferred control of electricity generation, transmission and distribution from private ownership to public control. Under this act, each state formed a vertically integrated State Electricity Board (SEB) responsible for transmission, distribution and generation of electricity, as well as the setting and collection of tariffs (Tongia, 2003).

In the years following independence, most of India's population lived in rural areas and did not have access to power. In 1960, agriculture comprised approximately 43% of Indian GDP and employed 80% of the country's workforce (World Bank, 2010). Despite the size of the agricultural economy, agricultural yields were low and the country suffered from frequent food shortages (Tongia, 2003). Recognizing the poor state of the agricultural economy and its importance to the country's growth, the government enacted a series of policies to raise agricultural productivity, including subsidizing key agricultural inputs. These policies have been argued to have spurred the Green Revolution in the 1960s (Rosengrant and Evenson, 1992). High yielding varieties of seeds were introduced and fertilizer use substantially increased, transforming Indian agriculture and leading to an increase in food security and economic growth. Another key element to the Green Revolution was access to and control of irrigation, an essential input in agricultural production (Repetto, 1994). To encourage irrigation, and especially groundwater irrigation, the government and NGOs invested in developing and distributing affordable pumping technologies and provided electricity subsidies to farmers (Briscoe and Malik, 2006).[2]

In the 1970s, as agricultural profits increased, farmers increasingly recognized the need for a stable water supply and the benefits of agricultural input subsidies, and began to organize themselves into a powerful political coalition. Around the same time, political competition between state political parties was growing and it became increasingly important for politicians to gain the vote of the farming workforce. To attract this vote, politicians began to use electricity pricing as a campaign tool. While SEBs had the official authority to price electricity, in practice electricity pricing was determined by state politicians. To seek election or remain in power, politicians began to campaign on cheap electricity. The first evidence of a link between elections and electricity pricing was documented in Andhra Pradesh in 1977 when, for the first time, a political party campaigned on the ticket of free power for electricity users (Dubash and Rajan, 2001). By the 1980s, power subsidies had become routine political instruments, especially in agricultural states (Dubash, 2007) and the government was spending 25 percent of total expenditure on electricity subsidies (Dubash and Rajan, 2001).[3]

[2] Electricity and fertilizer subsidies were further increased in the 1970s to combat decreasing terms of trade for agricultural products, which had strained farmers' incomes and created political unrest (Birner et al., 2007).
[3] Outside of the electricity sector, a handful of empirical studies have investigated the relationship between elections and agricultural lending by publicly owned banks, expenditure on road construction and tax collection (Chaudhuri

As these subsidies endured and grew throughout the 1970s and 1980s, the financial burden they imposed was becoming increasingly apparent. Beginning in the 1990s, both state and national governments passed a series of electricity reforms aimed at introducing competition and reducing the role of the state in the electricity sector. In 1991 the national government opened up electricity generation (as part of the Electricity Laws Act of 1991) to Independent Private Providers (IPPs) in an effort to meet the shortfall in generation capacity (Lamb, 2006). Despite this policy, safeguards prevented the viable entry of IPPs and, as of 2003, IPPs accounted for just 13% of electricity generation (Lamb, 2006) and less than 16% in 2011.[4] Further, growth in generation capacity has been largely driven by the public sector, with growth in public sector capacity more than doubling that in the private sector (Tongia, 2003).

To reform electricity tariffs, the Chief Ministers agreed to a Minimum Action Plan in 1996 that called for the establishment of State Electricity Regulatory Commissions (SERCs) - independent agencies that would be responsible for setting electricity tariffs – and required that every user group pay at least 50% of the average cost of supply, with the exception of agriculture. Agricultural users would initially pay a price of 0.5 rupees/kWh, which would be incrementally raised to 50% of the average cost of supply over a three year period (Dubash and Rajan, 2001). Despite the actions set forth in this plan, implementation of these reforms has been limited. Few SERCs are functional, and in 2001 only 9 states had implemented the 0.5 rupees electricity tariff for agricultural users, and none had raised prices to 50% of the average cost (Dubash and Rajan, 2001).

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and Dasgupta, 2005; Cole, 2009; 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.

[4] In 2003, the central government controlled approximately one third of electricity provision with the remainder coming from the SEBs (Lamb, 2006). In 2011, the central government and states each controlled approximately 42 percent of electricity provision, with the remained coming from IPPs and the private utility sector.

In addition to national legislation, several states including Orissa, Haryana, Karnataka, Uttar Pradesh, Andhra Pradesh and Punjab have passed reform acts aimed at improving electricity service.[5,6] The impacts of these reforms have been mixed. Some claim that, despite an increase in tariffs, the quality of electricity service remains low (Dubash and Rajan, 2001), while others argue that the quality and availability of power to sectors aside from agriculture improved after a reduction in the agricultural electricity subsidy (Kundu and Mishra, 2011).

Despite reforms, electricity pricing remains a powerful political tool - Indian politics is often said to come down to *bijli, sadak, pani (electricity, roads, water),* an observation that has been corroborated in household data (Min, 2010; Besley et al., 2004). In Tamil Nadu, electricity has been provided free to farmers since 1991 and continues to be free in 2011. As recently as 2004, the Congress Party of Andhra Pradesh campaigned on free power for farmers (Dubash, 2007).[7] Politicians may also be able to manipulate other aspects of electricity delivery - Min (2010) uses temporal variations in nighttime light output at the time of the 2002 state election to show that electricity provision in Uttar Pradesh is manipulated to the interest of politicians. Furthermore, Min (2010) provides anecdotal evidence suggesting that politicians routinely

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[5] Electricity reforms were first implemented in Orissa in collaboration with the World Bank, beginning in 1995. Orissa is the only state with less than 4% of its GDP coming from the agricultural sector, and faced less political resistance, making it a prime candidate for reforms (Joseph, 2010). The reforms consisted of: separating the SEB into two generation companies, one transmission enterprise and four distribution companies; allowing private participation in electricity generation and transmission; establishing an autonomous regulatory agency; and reforming tariffs (World Bank, 1996).

[6] In 1999 Andhra Pradesh enacted the Andhra Pradesh Electricity Reform Act. Although the state remained active in generation and distribution, the act established an independent advisory committee who in 2000 issued an order to increase agricultural tariffs by 50% and offered incentives for farmers to switch from a fixed monthly electricity rate to a volumetric charge (World Bank, 2003, 2004). However, the proposed tariff increases were met with strong opposition, leading the advisory committee to cease the tariff hike (Birner et al., 2011).

[7] The Congress Party ran on a platform of free electricity in the 2004 election, which it implemented shortly after its victory. At the same time, it also introduced electricity reform policies to direct electricity subsidies to the poor and exclude large landed farmers and those earning non-farm incomes from subsidies (Birner et al., 2011). Additionally, the Congress Party attempted to address growing concerns over groundwater depletion by calling for large investments in surface water irrigation and increasing the monitoring of groundwater usage (Birner et al., 2011). Despite these reforms, Andhra Pradesh still continued to provide free electricity to farmers and in many districts groundwater extraction is increasingly exceeding the replenishable supply of water (Kondepati, 2011).

interfere in the operation of the SEBs, from patronage transfers of employees, interventions in the selection of villages for electrification projects, and the assertion of influence on when, where, and how power cuts are timed and distributed.

The Benefits of Electricity Subsidies to the Agricultural Sector

Prior to the introduction of agricultural electricity subsidies, agriculture's share in total electricity use amounted to just 3 percent. Once the government began subsidizing electricity prices, this share more than quadrupled to 14 percent in 1978, with most of the increase coming from agricultural pumping rather than domestic use (Pachauri, 1982). By 2000 the agricultural sector accounted for 30 percent of total electricity usage (Tongia, 2003), although in 2011 this has declined to approximately 20 percent of total electricity usage on average. In combination with irrigation technology, electricity subsidies have played a critical role in the expansion of irrigation, especially groundwater irrigation. Following the introduction of agricultural electricity subsidies, the net irrigated land more than doubled from 21 million hectares in 1950-51 to 56 million hectares in 2001-02 (Gandhi and Namboodiri, 2009). The majority of this increase was in groundwater irrigation. Between 1950 and 2000, the share of irrigated land fed by groundwater grew from 28% to 62% (Gandhi and Namboodiri, 2009) and during the Green Revolution groundwater irrigation contributed 60 to 70 percent of the increase in net irrigated area (Repetto, 1994). Electricity has also played a critical role in irrigating areas where the aquifer is too deep for the use of dug wells or where groundwater tables are declining. As a share of irrigated land, electric-powered tube well irrigation increased from 0% in 1950 to 40% in 2001 and constituted the majority of growth in groundwater irrigation (Gandhi and Namboodiri, 2009).

The transformation from rain-fed farming to irrigation has been credited with helping India to increase its agricultural output (Repetto, 1994; Murgai 2001) and to achieve food self-sufficiency (Singh, 2000).[8] Earlier work attributes the increase in agricultural yields in the 1960s and 70s to an increase in fertilizer inputs and groundwater irrigation, and highlights that the prices of these inputs, largely driven by subsidies, had also declined since the beginning of the Green Revolution (Murgai, 2001). Subsidies that encourage the use of inputs are no less important today. Using district-level panel data between 1995 and 2004, Badiani and Jessoe (2011) exploit year-to-year variation in state electricity prices across districts that differ in their hydrogeological characteristics to isolate the impact of electricity prices on groundwater extraction and agricultural productivity. They find that a 10% decrease in the electricity subsidy (which amounts to over a two-thirds increase in electricity prices) would reduce groundwater extraction by 4.3% and lead to a 13% decrease in agricultural output. This decline reflects a decrease in crop yields as well as a decrease in the share of land devoted to water intensive crops. Others suggest that the benefits of groundwater irrigation extend beyond food security and agricultural productivity, and find that groundwater irrigation, and the Green Revolution more generally, led to an increase in industrial employment (Rud, 2011) and agricultural wages (Foster and Rosenzweig, 2003).

Who actually accrues the benefits from the expansion of groundwater irrigation is less certain. In rural areas, agricultural laborers, landless households and marginal farmers are relatively worse off and are more likely to be poor than medium and large farmers (World Bank, 2011). Compared to land ownership, the distribution of dug and shallow tube well ownership is more equitable and skewed towards small and marginal farmers, although medium and large

[8] Singh (2000) argues that, by increasing both area of production and the intensity of production, irrigation (as part of the greater Green Revolution) helped India to achieve food self-sufficiency.

farmers are more likely than smaller farmers to own deep tube wells (Gandhi and Namboodiri, 2009).[9] However, even if the majority of wells are owned by larger farmers, it has been argued that the benefits from irrigation are likely to extend to smaller farmers via groundwater markets (Bardhan, Mookherjee and Kumar, 2011) and to agricultural laborers via labor markets (Chambers, 1998; Foster and Rosenzweig, 2003).

Measuring the Costs of Electricity Subsidies

Despite the tangible benefits from these subsidies, they are not without their costs. A long literature has discussed the unreliable and unpredictable electricity supply in India, citing agricultural electricity subsidies as one reason for the poor service (World Bank, 2001). Studies have also made the case that these subsidies, due to their magnitude, come at the cost of other social programs (Birner et al., 2007). More recently, attention has focused on the industrial and environmental implications of these subsidies, namely their drag on industrial growth and the country's increased and perhaps unsustainable dependence on groundwater extraction for agriculture. A less explored, but nonetheless important cost, is the effect these subsidies have on greenhouse gas emissions. We now explore in detail these costs.

As part of the State Electricity Act of 1948, SEBs are required to generate a 3 percent annual return on capital. Despite this requirement, electricity boards operate at an annual loss (Dubash and Rajan, 2001). For example, in 2001 the financial losses to the SEBs totaled at nearly US$6 billion or -39.5% of revenues (Lamb, 2006). This financial insolvency is largely

[9] Gandhi and Namboodiri (2009) support their arguments using descriptive statistics published by the Ministry of Water Resources and Ministry of Agriculture, among other sources. Marginal and small farmers owned 67 percent of the dug wells and shallow wells, while they operate 34 percent of land. The evidence presented suggests that the average yield on plots irrigated with private wells is higher than that on plots irrigated by canal, public tube well, or purchased from a tubewell for wheat, cotton, and rice. Research by Shah (1993) argues that this is due to the increased reliability and availability of water from privately owned wells.

attributed to agricultural electricity subsidies. In 2000, agricultural users consumed 32.5% of electricity but contributed only 3.4% of revenues (Tongia, 2003). The revenue losses incurred by SEBs are the single largest drain on state spending and limit the funding available for education, health care or drinking water (Tongia, 2003). Agricultural electricity subsidies comprise 25% of India's fiscal deficit and the government spends twice as much on these subsidies as it does on health or rural development (Monari, 2002).

Some argue that these subsidies have contributed to the intermittent, unpredictable, and low quality electricity service that characterizes the electricity sector in much of India (Lamb, 2006; Tongia, 2003). The low price of electricity has increased demand such that there is a shortage of electricity – official publications estimate that approximately 12.5% of demand was not met (Tongia, 2003). This shortfall has led to frequent black outs and load shedding, and forced the government to introduce electricity cuts of up to four hours per day in urban areas and twelve hours per day in rural areas (Min, 2010). These electricity cuts themselves exacerbate electricity demand – for example, to irrigate their crops farmers leave pumps on overnight due to unscheduled blackouts throughout the day (Tongia, 2003).[10]

Agricultural electricity subsidies also impose costs on the industrial and commercial sectors, since users in these sectors cross-subsidize agricultural and household users. Data from the Planning Commission of India suggest that industrial users pay an electricity price that exceeds the average cost of supply - in 2001, the average cost of electricity amounted to 3.49 rupees/kWh though industrial and commercial users were charged 3.79 and 4.26 rupees/kWh, respectively.[11]

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[10] This behavior also has environmental implications, such as water-logging and salinity (Tongia, 2003).
[11] The data on average costs and tariffs are from "The Annual Report on the Working of State Electricity Boards and Electricity Departments" (Government of India, 2002b). Unfortunately, the report only publishes data on the average cost of electricity provision, rather than the preferred marginal cost. The average unit cost of electricity provision is

The costs of agricultural electricity subsidies on the industrial and commercial sectors are likely to vary by state, since there is substantial variation in both the magnitude of subsidies and in the extent of cross-subsidization across states. Figure 1 shows the price of electricity faced by household, agricultural, industrial and commercial users of electricity and the average cost of electricity production in three states in 2002 - Gujarat, Madhya Pradesh and Karnataka. In Madhya Pradesh, the average tariff faced by agricultural users is 0.07 (2002) Rupees per kWh - 3 percent of the average unit cost of electricity while in Gujarat agricultural users pay 0.62 Rupees, 17 percent of the average cost. Similarly, electricity to households is heavily subsidized and the subsidy varies across states – households pay just over 2.5 Rupees per kWh in Gujarat and Karnataka (approximately 75 percent of the average cost of electricity), while they pay 1.6 Rupees (49 percent of the average cost) in Madhya Pradesh. In all three states, the commercial and industrial sectors pay average tariffs that are 30 to 50 percent greater than the average cost of electricity – in Karnataka, the commercial sector pays 5.7 Rupees per kWh (153% of the average cost), while in Gujarat the industrial sector pays 4.8 Rupees per kWh (130% of the average cost).

[Insert figure 1 near here.]

Despite the high relative costs of electricity to the industrial and commercial sectors, these users face an unreliable and inconsistent electricity supply (Bhattacharya and Patel, 2008). This has induced industrial and commercial users to invest in private generation, thereby eroding the base of revenues collected by the SEBs. An estimated 69% of firms have their own generators, despite the fact that the cost of this private electricity is 24% higher than the electricity provided by SEBs (Bhattacharya and Patel, 2008). Firms are willing to incur these costs to guarantee high quality electricity service.

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calculated as the total cost of electricity (revenue expenditure plus depreciation and interest due) divided by total electricity sold. The average electricity tariff faced in a sector is defined as the revenue from sales divided by the number of units of electricity sold.

This combination of high electricity tariffs and an unreliable electricity supply has been hypothesized to have strained industrial growth. According to the World Bank, "the poor quality of electricity has been the single greatest deterrent to India's economic growth and development" (US Department of Energy, 2003). Enterprises in India echo this concern; in a 2006 survey of Indian businesses, more firms reported access to reliable electricity as the primary obstacle facing their business (35%) than any other obstacle, including taxes and corruption (Min, 2010). The same study estimates a 6.6% loss of sales due to power outages.

Recent attention has focused on the environmental implications of agricultural electricity subsidies, namely groundwater extraction (Strand, 2010). Partly driven by these subsidies, India has increasingly relied on groundwater for agriculture and is currently the largest extractor of groundwater in the world, consuming 150 cubic km of groundwater annually (Shah et al., 2003).[12] Though on average groundwater extraction amounts to only 57 percent of the replenishable supply, data collected from district level groundwater assessments conducted by the Central Groundwater Board (CGWB) of India suggest that there is substantial variation in patterns of groundwater extraction across districts and over time.[13] Between 1995 and 2004, these data suggest that groundwater extraction increased by 23 percent.[14] In addition, the frequency of groundwater exploitation has increased over time: the number of exploited districts - those in which annual demand exceeds annual recharge - grew by 29 percent or 4 percentage points between 1995 and 2004.

[12] Until recently, the government placed no limits on groundwater extraction. However, in response to growing concerns, the national government implemented the National Water Policy, legislation targeting the management of groundwater resources (Government of India, 2002). This legislation has had limited success, largely because enforcement mechanisms are inadequate.

[13] Data on groundwater comes from district level groundwater assessments carried out by the Central Groundwater Board of India. Groundwater assessments are difficult and expensive to conduct and are therefore only conducted periodically by the CGWB. We collected an unbalanced panel of groundwater data for 344 districts using groundwater data from 326 districts in 1995, 19 districts in 1997, 31 districts in 1998, 245 districts in 2002 and 344 districts in 2004. In total, we have observations covering 965 district-years in 15 states.

[14] This statistic is calculated for the 226 districts for which we have a balanced panel of data at the district level.

Though groundwater exploitation is increasing over time, to what extent is this increase in groundwater extraction driven by electricity subsidies? Badiani and Jessoe (2011) use variation in district level hydrogeological characteristics to provide evidence that electricity subsidies are partly driving groundwater extraction, finding that that a 10% decrease in electricity subsidies would reduce groundwater extraction by 4.4 percent.[15] These subsidies have led to a shift towards water intensive crops, which has contributed to the increase in groundwater extraction. While this work does not find a statistically significant link between electricity subsidies and groundwater over-exploitation, it demonstrates that electricity subsidies have indeed increased groundwater extraction.

Another environmental consequence of these subsidies is their potential impact on greenhouse gas emissions. India relies heavily on fossil fuels to produce electricity. In 2011, coal accounted for 55% of India's electricity, followed by hydroelectric sources, renewable sources (such as biomass, wind, and solar), natural gas, and nuclear generation (Figure 2, Central Electricity Authority, 2011).

[Insert figure 2 near here]

And despite national policies to promote the development of renewable energy and an increase in clean energy investments (Bloomberg, 2011), there appears to be no slowdown in India's dependence on coal.[16] Recent trends show that the share of renewables and hydropower in

[15] The hydrogeological characteristics examined are the mean minimum and maximum aquifer depth within a district, which varies substantially within and across states. The water resources literature uses the interaction of electricity prices and minimum well depth to the measure the price of groundwater extraction (Domenico et al., 1968; Martin and Archer, 1971). Badiani and Jessoe (2011) draw upon this literature to identify the response of groundwater extraction to year-to-year variation in state electricity prices across districts that differ in their hydrogeological characteristics.

[16] The country has been promoting renewable energy through the Ministry of New and Renewable Energy since the 1980s (Deshmukh, 2011). Both the 2003 Electricity Act and 2006 National Tariff Policy give preferential feed-in-tariffs for renewable technologies, including wind and solar (Deshmukh, 2011). In the 2011 fiscal year, central government subsidies to clean energy were estimated at US$ 51 million (Bloomberg 2011). These subsidies have been fairly successful, and Bloomberg reported that clean energy investments in India reached $10.3 billion in 2011,

electricity production has fallen in the past 10 years, and has been outpaced by growth in coal-fired sources (Lamb, 2006).

[Insert figure 3 near here]

Given that India's power predominantly comes from coal-fired power plants - the dirtiest generation method in terms of greenhouse gas emissions (Gagnon, Belanger and Uchiyama, 2002)[17] – it is not surprising that electricity generation is the primary contributor to greenhouse gas emissions in the country. Electricity generation is responsible for 48 percent of India's greenhouse gas emissions (Ministry of Environment and Forests, 2010) and greenhouse gas emissions from this sector have more than doubled between 1994 and 2007 (Ministry of Environment and Forests, 2010), suggesting that this sector's role in greenhouse gas emissions has only increased over time. Given the magnitude of greenhouse gas emissions released from India – currently India is the 4th largest producer of greenhouse gases globally – policies that promote additional electricity generation may non-negligibly impact greenhouse gas emissions (and in turn climate change).

Lessons learned: placing India's experience in a broader context

Lessons learned from India's experience with agricultural electricity subsidies extend to other countries and beyond the electricity sector. First, agricultural electricity subsidies have been linked to an increase in groundwater extraction in other countries. Second, electricity

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a 52% increase over 2010. Several states are also beginning modest programs to subsidize clean energy, such as Uttar Pradesh, which gives villages willing to invest in solar power plants a 50 percent subsidy (Times of India 2011). Although these programs provide evidence of an emphasis on clean energy generation, the subsidies amount to only a small fraction of those given to agricultural and domestic users. An increase in the use of clean energy sources would reduce some of the environmental costs associated with agricultural electricity subsidies, although a move to clean energy sources will not necessarily reduce the over-exploitation of groundwater.

[17] Gagnon, Belanger, and Uchiyama (2002) use life-cycle assessments to compare the environmental impacts of electricity generation systems and find that coal-fired power plants emit far more greenhouse gases than any other form of generation.

subsidies can be placed more broadly in the literature examining the environmental implications of development policies. Lastly, electricity subsidies can be framed within the literature on the low-level equilibrium trap and lessons learned from other sectors may be applicable to the electricity sector in India.

Electricity subsidies to agricultural users have been linked to groundwater depletion across the world, in developed as well as developing countries. For example, in Mexico a similar linkage exists between electricity subsidies for agricultural irrigation and groundwater extraction.[18] Just as is the case in India, these subsidies have been credited with increasing agricultural productivity through the use of irrigation, which in turn has decreased rural poverty (De Janvry and Sadoulet, 2000)[19]. These subsidies have also been linked to increased groundwater over-extraction, though in Mexico over-extraction may be more severe.[20] Similar examples of subsidies and groundwater depletion can be found in developed country contexts. In California, for example, the Central Valley Project uses taxpayer funds to support irrigation for farmers, most often for large agri-businesses.[21] These subsidies persist despite frequent droughts that lead to water shortages across the state.[22]

India's experience with agricultural electricity subsidies also provides policy makers with another data point about the relationship between development policies aimed at increasing incomes and environmental quality. The government of India provides many subsidies, including

[18] In 2004, agricultural users in Mexico benefitted from a 73% electricity subsidy (Center for Energy Economics, 2006).

[19] De Janvry and Sadoulet (2000) use household-level data from 1997 to regress farm income on land holdings, household assets and characteristics, and other variables to show that irrigated land increases farm income more than five times as much as rain fed land.

[20] Mexico uses twice as much groundwater per irrigated hectare than India (Scott and Shah, 2007) and over half of Mexico's most important aquifers are over-drafted (Diario Oficial de la Federacion, 2003). One study estimates that reducing this subsidy by 50% would bring more than half of the overexploited aquifers to a more sustainable state (Guevara-Sanginés, 2006).

[21] These farms pay only 1 cent per kWh for irrigation power, which is 10 to 15% lower than other electricity users (Sharp and Walker, 2007).

[22] Further, in response to drought shortages farmers increase their reliance on groundwater (Zilberman et al., 2011), thereby consuming more when the resource is most scarce.

irrigation subsidies, electricity subsidies and drinking water subsidies, to raise living standards and promote rural economic growth. Yet the environmental implications of these subsidies remain open to debate. A long literature has evaluated the link between environmental quality and development, debating whether the Environmental Kuznets curve – the hypothesis that environmental quality will first degrade and then improve with rising per capita income – holds in practice (Arrow et al., 1995; Grossman and Krueger, 1991; Grossman and Krueger, 1995; Stern, 2004). In the case of India, while agricultural electricity subsidies are linked to an increase in agricultural revenues and groundwater extraction, it remains an unanswered question whether they result in unsustainable groundwater usage (Badiani and Jessoe, 2011).

For the most part, a low equilibrium trap (Briscoe, 1999; Nelson, 1956; Singh et al., 1993) describes electricity markets in India - customers refuse to pay high prices due to poor service but poor service is attributable to low revenues. The low equilibrium trap is most frequently used to describe the persistence of low quality and low priced drinking water supplies in developing countries (Brook and Smith, 2001; Singh et al., 1993). Lessons learned from successful reforms in the drinking water sector could be applied to electricity markets in India. Previous work in Thailand suggests that customers are willing to pay higher prices for drinking water conditional on high quality provision of this service (World Bank, 1992). The same may hold true for electricity, if electricity could be unbundled from political capture.[23]

Conclusion and Future Directions for Reform

Agricultural electricity subsidies in India have generated significant benefits including an increase in agricultural output and food security. At the same time, these subsidies are costly. They have induced farmers to increase groundwater extraction, perhaps to unsustainable levels;

[23] Previous research argues that when politicians have the power to determine prices, electricity and water service will be provided cheaply but the quality of these services will remain low since politicians have an incentive to provide these services at low prices (Briscoe and Malik, 2006).

contributed to the provision of an unreliable, intermittent and low quality electricity supply; come at the cost of expenditure on other social programs such as education or health; imposed an added cost on industrial and commercial users; and increased greenhouse gas emissions via an increase in electricity usage. Despite these costs, agricultural subsidies persist. One possible explanation for the continuation of these subsidies is political capture - politicians use electricity pricing as a campaign tool to attract the rural vote.

India's experience underscores the difficult balance surrounding agricultural development policies that affect the environment. Agricultural electricity subsidies are partly responsible for an increase in groundwater irrigation and in turn agricultural yields and food security. At the same time, as India's dependence on groundwater increases, these benefits may come at the cost of groundwater availability for future generations. Nowhere is the difficult tradeoff between development and environment more apparent than in discussions on climate change. In the near term, agricultural electricity subsidies have increased yields, and potentially accelerated the pace of economic growth, especially among the rural poor. However, in the long-term, climate change is predicted to reduce agricultural yields in India by 9 to 25 percent. While reducing electricity usage in India will not curtail climate change, policies aimed at increasing electricity usage and in turn fossil fuels will only exacerbate the problem.

We have highlighted the problems endemic to agricultural electricity subsidies in India. We now offer some future directions for reform. In particular, we focus on policies that would curtail the overuse of groundwater. First, increasing the agricultural electricity tariff to better reflect the average cost of supply would reduce groundwater extraction and at the same time increase the revenues collected by SEBs, thereby improving electricity service. While this reform would be met with strong opposition among agricultural users (as past experience suggests), if the government could guarantee an improvement in service, this would likely weaken the resistance to increased tariffs. In combination with a price increase, state governments need to improve electricity metering so that they can accurately monitor electricity usage and engage in policies to reduce electricity theft (World Bank, 2002). If the government is simply concerned with groundwater management rather that the provision of electricity, it may be more desirable to restrict the development of new wells (as was done by the National Bank of Agriculture and Rural Development), invest in the public provision of groundwater for irrigation in an attempt to crowd out the private construction of wells (Sekhri, 2011) and create and enforce groundwater markets (Foster and Sekhri, 2008).

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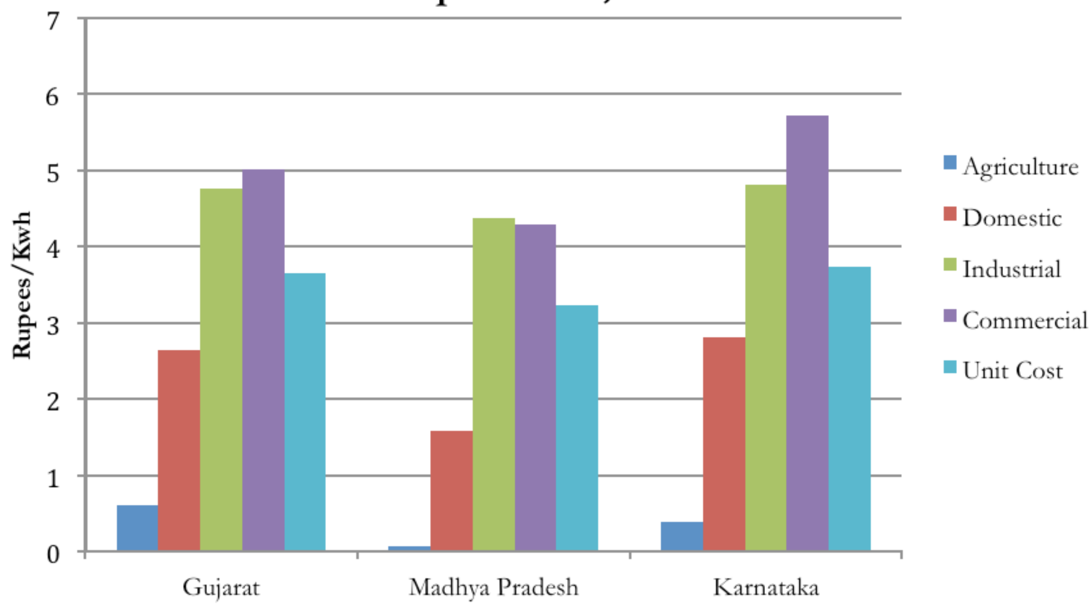
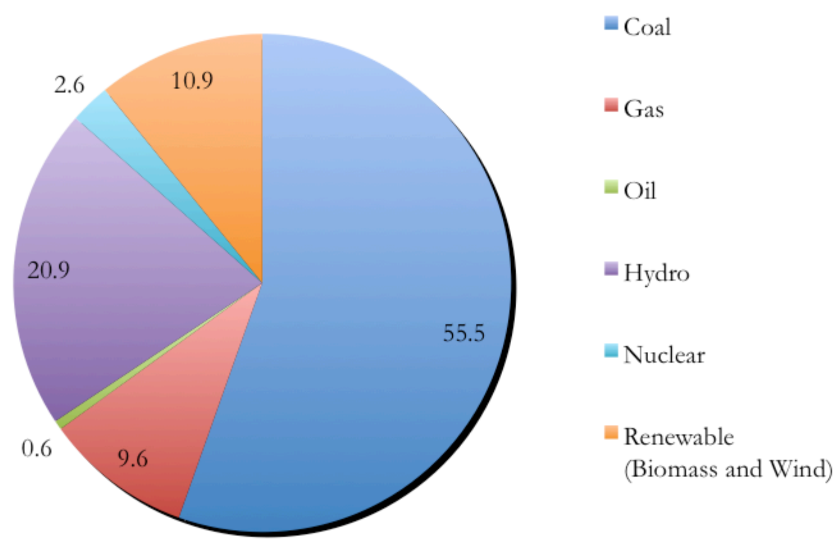
Figure 1: Average Cost and Electricity Tariff by User Group in India, 2001-02



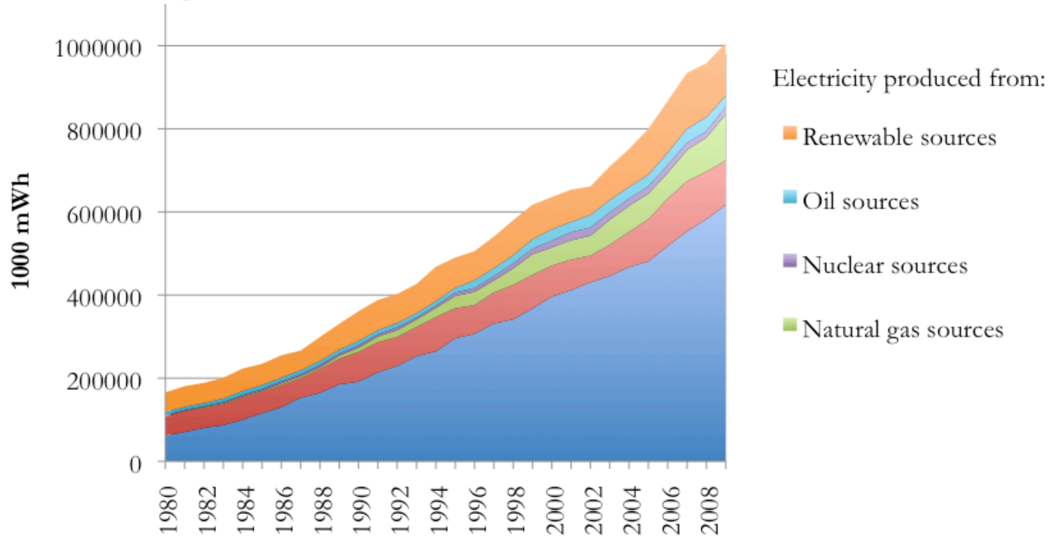
Prices are in 2002 Rupees, there are approximately 40 Rupees to the dollar. Source: Gov of India, 2002b.

Figure 2: Indian Electricity Sources, 2010-2011



Source: Central Electricity Authority, 2011

Figure 3: Sources of Electricity Production



Source: Central Electricity Authority, 2011