Impact of Farm Electricity Supply Management on Farm Households in Gujarat, India

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Abstract

This paper studies the impact of farm electricity supply management through feeder segregation initiated under "Jyotigram Yojana" (JGY) on farm households in Gujarat, India. By matching the exact village-level JGY rollout dates to the 2004-05 and 2011-12 India Human Development Survey (IHDS), we analyse the impact of rationed but high-quality farm electricity supply on net farm income and investments in fixed and variable inputs. Using a difference-in-differences framework, we find that, on average, JGY leads to a significant increase in net farm income per acre for all farmers. We observe a decrease in ownership of electric pumps across all farmers. Hired labor also reduces for farmers across land sizes. Medium-to-large farmers increase investment in diesel pumps and tractors. In addition, we find that access to groundwater and labor intensity of crops mediate impact on net farm income. Overall, farm electricity supply management increases welfare of farm households and brings about expected reallocation in fixed and variable farm inputs.

Keywords: farm electricity supply, farm profits, impact evaluation, difference-in-differences, India

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1. Introduction

Agriculture continues to occupy a centre-stage in the Indian economy employing about 56% of its labor force and contributing about 17.5% to the national GDP (Census of India, 2011; World Bank, 2016). The sector is critical in achieving national goals such as reducing poverty, providing food and nutritional security, supplying raw materials to major industries, and earning foreign exchange (Kalamkar, et al., 2015). A key input necessary to sustain agricultural growth is irrigation, which requires access to electricity on farms. For this reason, electricity to agricultural consumers continues to be heavily subsidized in India (World Bank, 2013). These subsidies impose two significant costs – financial and environmental.

Subsidies for farm electricity have a long history in India starting from the Green Revolution in the 1960s (Badiani, et al., 2012; Swain & Mehta, 2014). The high-yielding crop varieties depended on access to irrigation. However, availability of surface water irrigation was low and the focus therefore shifted to groundwater irrigation (World Bank, 2008). To enable farmers to extract groundwater, electricity was provided either free-of-cost or at very low flat tariffs. This was further justified by the need to promote rural livelihoods, food security, and overall rural development (Swain & Mehta, 2014). Owing largely to clientelism, there has been no reform in this subsidy policy over the years (Chindarkar, 2017). While the share of electricity consumed by agricultural consumers is nearly 23%, revenue realization from agricultural consumers is only about 9% (Power Finance Corporation, 2016). It is estimated that agricultural electricity subsidies are equivalent to about 25% of India's fiscal deficit, twice the annual public spending on health or rural development, and two and a half times the annual spending on developing surface water irrigation infrastructure (Monari, 2002). As consequence of this increased financial pressure on public utility companies has been poor transmission and distribution (T&D) in the form of interrupted and low-voltage electricity supply to agricultural as well as residential consumers (World Bank, 2013).

There is evidence supporting the positive correlation between subsidized electricity to farmers and increased productivity in agriculture and allied sectors (Badiani & Jessoe, 2014; Fan, et al., 2002; Kumar, 2005). However, this has come at the environmental cost of increasing groundwater extraction (Badiani, et al., 2012). More than 60% of irrigation in India depends on groundwater drawn using electric pumps (World Bank, 2012). Further, as surface water irrigation is low, farmers depend heavily on groundwater irrigation as a buffer against poor monsoons. It is also argued that as groundwater irrigation gives farmers greater control over when to irrigate and how much water to use, productivity of farms irrigated with groundwater is higher than those irrigated using surface water (World Bank, 2012). Farm electricity subsidies effectively shift the preferences of farmers towards increased use of groundwater irrigation as they lower the cost of extraction. This is further reinforced by poor monitoring and regulation of tube wells and borewells mostly due to clientelism (Birner, et al., 2007). It is estimated that about 29% of districts in India are either semi-critical, critical, or over-exploited in terms of groundwater extraction, which is largely attributable to electricity subsidies (Suhag, 2016).

Balancing the competing policy objectives of agricultural growth, financial viability of public utility companies, and environmental sustainability is challenging yet critical (Chindarkar, 2017). Several policy tools are available to policymakers to move towards achieving this balance. Among these are – tariff changes, direct regulation, technical innovation, and a mix of these tools (Badiani, et al., 2012; Mukherji, et al., 2010; Shah, et al., 2008; World Bank, 2013). Tariff changes in accordance with demand and cost of supply is expected to increase revenue generation for the utility companies and also likely to discourage over-extraction of groundwater (Badiani, et al., 2012). Direct regulation in the form of metering as well as controlling the number and depth of tube wells and borewells is also predicted to yield similar results. However, it is likely to impose significant administrative and monitoring costs (Mukherji, et al., 2010; Shah, et al., 2008). Technical innovation refers to changing the physical power supply infrastructure and segregating the non-agricultural and agricultural feeders, or in other words, separating the paid and non-paid (or nominally paid) loads (World Bank, 2013).

Implementing tariff increases for agricultural users and direct regulation continue to be plagued by political opposition, corruption, and non-compliance (Gronwall, 2014). These reforms therefore have had limited success in striking the sensitive balance. In contrast, feeder segregation has gained considerable traction among both policymakers and consumers (World Bank, 2013). While feeder segregation has been implemented or in-progress in several states in India and each has followed its own tailored approach, the state of Gujarat in particular, is seen as an example of successful feeder segregation (Shah, et al., 2008; World Bank, 2013). This is because Gujarat went beyond just physical segregation and combined it with intelligent supply management. This included – (i) enhancing the predictability of farm electricity supply, that is, the duration and timings when it would be available, (ii) improving quality and reliability, that is, uninterrupted and high voltage farm electricity supply, and (iii) matching the supply timings with peak periods of moisture stress (Shah, et al., 2008). However, this has not meant that the reform has been completely devoid of oppositions and criticisms. These include criticisms against rationing without taking into consideration land sizes and crop types. Further, feeder segregation was accompanied with direct regulation which entailed disconnecting unauthorized connections and imposing heavy fines for non-compliance, and this turned out to be unpopular with the opponents (Chindarkar, 2017).

While there is a general consensus that feeder segregation has been more effective than other reforms, there is as yet no study that has rigorously evaluated its impact on farm households. This paper fills this crucial gap and undertakes an econometric evaluation of Gujarat's feeder segregation program, known as "Jyotigram Yojana" (JGY) or lighted village, on farm households. The program was launched by the state government of Gujarat in October 2003 with an investment of US$290 million to separate agricultural and non-agricultural feeders against the backdrop of rapidly rising electricity demand, depleting ground water tables, and heavy losses to the state electricity board (Shah, et al., 2008). As previously mentioned, JGY not only physically segregated the loads but also enhanced the predictability and quality of electricity supply to rural agricultural and non-agricultural consumers. Under JGY, farms received 8 hours of high-quality electricity while non-agricultural users received 24 hours of high-quality electricity supply. There were no significant changes to the tariffs paid by agricultural consumers (Gujarat Urja Vikas Nigam Limited, 2010).

Our outcome variables of interest are net farm income per acre and farm investments in fixed and variable inputs. Our theoretical model adapted from (Barnum & Squire, 1979) implies that an exogenous shock to variable inputs such as electricity, and by implication, groundwater irrigation, is likely to result in reallocation of other factors of production. Thus, if the quantity and quality of farm electricity changes then farmers will change other factors to maximize their welfare. To examine this, we use data from Wave 1 (2004-2005) and Wave 2 (2011-2012) of the India Human Development Survey (IHDS) and match it with administrative data on exact village-level JGY rollout dates. Using a difference-in-differences framework, we find that, on average, JGY leads to a significant increase in net farm income per acre for all farmers. We observe a decrease in ownership of electric pumps across all farmers. Hired labor also reduces for farmers across land sizes. Medium-to-large farmers increase investment in diesel pumps and tractors. In addition, we find that access to groundwater and labor intensity of crops mediate impact on net farm income. Overall, farm electricity supply management increases welfare of farm households and brings about expected reallocation in fixed and variable farm inputs.

2. Background on Gujarat and JGY

Much of Gujarat falls under arid, semi-arid, and dry sub-humid climatic zones. The state receives average annual rainfall of about 1107 mm, however, the northern and north-western regions are distinctly semi-arid or arid receiving on average between 500-700 mm rainfall annually (Department of Agriculture & Cooperation, 2013). Due to low rainfall, the state relies heavily on groundwater for irrigation. Groundwater development (GWD), which is the ratio of the annual ground water extraction to the net annual ground water availability, was 30.81% in 1984 which significantly worsened to 75.57% in 1997 (UNDP, 2004)[1]. In 2004, it remained at 76%, however, 50% of the 223 sub-districts assessed were classified either as over-exploited (GWD>100%), critical (90-100% GWD), or semi-critical (70-90% GWD) (CGWB, 2004).

Since 1988, the state has implemented a flat tariff system based on motor capacity of the electric pumps for agricultural users. Clientelism made it infeasible to increase farm electricity tariffs. The only alternative available to the severely financially stressed state electricity board was therefore to reduce the quantity (number of hours) and quality (voltage) of farm as well as domestic electricity supply. This negatively affected both rural development and agricultural growth (Chindarkar, 2017). Against this backdrop, the state government of Gujarat launched JGY, a rural

[1] Groundwater development rate indicates the quantity of groundwater available for use. A higher ratio (or percentage) implies that extraction as a percentage of availability is higher and therefore reflects an unsustainable situation.

feeder separation program, which separated power loads of rural non-agricultural and agricultural consumers by connecting them to separate feeders. The program was first implemented in 8 districts in early-2003 and gradually covered the entire state by early-2008. In total, it covers more than 18,000 villages. Agriculture feeders provide 8 hours of high-quality electricity supply to farms while rural non-agricultural users receive 24 hours of high-quality supply.

JGY involved complete transformation of the electricity infrastructure landscape with installation of new Specially Designed Transformers (SDTs), high tension lines, low tension lines, electricity poles, electricity conductors, and PVC cables. Feeders were metered to improve the accuracy of energy accounting. Apart from the infrastructural changes, concerted efforts were taken to restructure the work culture within the distribution companies (DISCOMs). Figures (1a) and (1b) illustrate the physical infrastructural changes under JGY.

3. Electrification and farm households: A review of literature

Electrification affects farm households both through the intensive and extensive margins. Previous research shows that electrification can increase yields (intensive margin) and consequently farm incomes mainly through adoption of electric pumps for irrigation and other electric farm appliances (Barnes & Binswanger, 1986; Khandker, et al., 2013). It increases the value that the farmers can extract per drop of water as they can shift towards water-intensive, high value crops (Mukherji, et al., 2010). It also enables farmers to expand the land under cultivation (extensive margin) as they are no longer constrained by the capacities of manual and animal labor (Bhargava, 2014). Essentially, electricity is a labor-saving technology for farmers as it reduces their dependence and expenditure on hired labor (FAO, 2008).

Availability of farm electricity can have positive spillovers on forward linkages such as post-harvest sorting, storing, processing, and packaging (Grant Thornton & ASSOCHAM, 2017). This enables farmers to minimize wastage and increase marketed surplus. Access to electricity on the farm can interact with electricity access at home or in the village local government offices and lead to positive spillovers on backward linkages such as access to information related to agricultural best practices through television and mobile phones (Grant Thornton & ASSOCHAM, 2017). This is likely to encourage farmers to adopt practices that enhance productivity and profits. In addition, access to electronic portals usually placed in village local government offices can connect farmers to the wider market providing an avenue for extraction of better price for their yields (Shalendra & Jairath, 2016).

Evidence on impact of farm electricity supply management and quality of supply on farm households is very scarce and largely qualitative. A recent study looks at the impact of quality of electricity, measured as hours of supply, on rural non-farm income in India and finds that it increased non-agricultural income by 28.6% during 1994-2005 (Chakravorty, et al., 2014). Qualitative evidence on JGY finds that the program induced farmers to shift towards high value crops and efficient use of groundwater (Banerjee, et al., 2014; Gronwall, 2014; Mukherji, et al., 2010; Shah, et al., 2008). Overall, the literature suggests that quantity-quality trade-off due to JGY has not had negative consequences on farmers.

Drawing upon the literature, we posit that impact of JGY on farm households' net income and input decisions is an empirical question and depends on factors of production are simultaneously affected or change. This is because while JGY rationed farm electricity to 8 hours per day effectively restricting irrigation per day to a fixed duration, it brought about significant efficiency improvements as there was improvement in the quality of supply, enhanced predictability as farmers were provided a pre-determined schedule as to when the supply would be available, and lower rates of replacement of fixed inputs such as electric pumps as there were no sudden voltage fluctuations, power outages, fuse blackouts, and motor burns. As discussed above, there are also likely to be shifts in labor inputs and choice of crops.

4. Data and empirical strategy

4.1. Data

This paper uses Waves 1 and 2 of the India Human Development Survey (IHDS) conducted by the University of Maryland and the National Council of Applied Economic Research (NCAER). IHDS is a nationally representative, multi-topical survey of 41,554 households spread across 1503 villages and 971 urban neighbourhoods in India. IHDS key characteristics of rich contextual information, evidentially form the basis for the regression analysis. IHDS-1 is a nationally representative survey of 41,554 households conducted in 2004-2005 while IHDS-2 re-interviewed 83% of this original household sample in 2011-2012. Due to inherent demographic shifts and attrition, IHDS-2 interviewed an additional 2134 households, which form the replacement sample. The rural sample is drawn using stratified random sampling of villages and the urban sample is drawn using stratified sampling of towns and cities within states (or groups of states) selected by probability proportional to population (PPP).

We use only the rural sample and retain land-owning farm households in Gujarat and its neighboring state, Maharashtra, which yields an unbalanced panel of 3338 households. We match this with administrative data on village-level JGY implementation sourced from the four DISCOMs in Gujarat. These data suggest that JGY was implemented gradually between 2003 and 2008. The earliest implementation date is January 2003 and the latest is March 2008. As the IHDS Wave 1 interviews in Gujarat were fielded between January 2004 and October 2005, a concern might be that Wave 1 data does not truly reflect baseline or pre-JGY characteristics. Digging further into the administrative data we find that the percentage of villages electrified up until October 2005 is less than 1% in all districts except Ahmedabad, Jamnagar, and Surendranagar, where percentage of villages electrified was 1.36%, 1.84%, and 1.22% respectively (see Appendix 1). We argue that the percentage of villages covered under JGY over the duration of IHDS-1 in these two districts is small enough not to significantly bias our estimates. Further, impact of development programs such as electrification requires some time to manifest, which assuages concerns about bias. We conduct a series of robustness checks to rule out any potential bias in the baseline sample.

To conduct heterogeneity analysis, we source administrative data from the Central Ground Water Board of India (CGWB, 2004, 2011) to classify districts in Gujarat and Maharashtra into safe, semi-critical, critical, and over-exploited categories based on level of GWD. We source district-wise crop data from the Ministry of Agriculture, Government of India, and match them with reports from the World Wildlife Fund (2003) and the Federation of Indian Chambers of Commerce and Industry (FICCI)-KMPG (2015) to classify districts in Gujarat and Maharashtra as primarily growing water-intensive or non-water intensive crops. This is done because cropping pattern and crop yield data are not available in IHDS-2.

To control for geographic characteristics, data on annual groundwater depth, measured in meters, for districts in Gujarat for 2004-05 and 2011-12 are obtained from Water Resources Information System of India (WRIS). For Maharashtra, the district-wise annual groundwater depth data are obtained from the Centre for Technology Alternatives for Rural Areas (CTARA) at the Indian Institute of Technology, Bombay. It should be noted that WRIS sources data from CGWB while CTARA sources data from Groundwater Surveys and Development Agency (GDSA). District-level annual average rainfall data, measured in millimeters (mm), are sourced from National Oceanic and Atmospheric Administration (NOAA).

Additional district-level controls on percentage of villages in the district having commercial banks, cooperative banks, and credit societies, and land area irrigated by tube wells are sourced from the district census handbooks of 2001 and 2011.

4.2. Variables

Our outcome variables of interest are net farm income per acre and farm investments in fixed and variable inputs. Net farm income per acre is computed as gross crop income minus all expenditure on hired labor, seeds, fertilizer, pesticides, irrigation, hired equipment and animals, interest on loans, and other miscellaneous farm expenses, and converted to log form. It is possible for net farm income to be negative if investments or expenditures exceed revenue. To avoid computational issues, we add a constant value to each observation before the log transformation so that we have only non-negative values. Fixed inputs include ownership of tube wells, electric pumps, diesel pumps, and tractors. Variable inputs include log of expenditures on irrigation, fertilizers, pesticides, and number of hired labor days in the last 100 days. In addition, our farm investments analysis includes dummy variables indicating whether farmers irrigate with tube wells or other wells.

Our JGY treatment variable is an interaction variable between dummy indicating whether the farm household is in Gujarat (=1) or Maharashtra (=0) and dummy indicating whether the farm household is interviewed after JGY implementation (=1) or before (=0). Observations from IHDS-1 are considered pre-JGY implementation and those from IHDS-2 are considered post-JGY. We explain the econometric rationale underlying the treatment variable in further detail in the empirical strategy sub-section.

We include three sets of observed covariates to control for any confounding effects. First is household characteristics including age of household head, gender of household head, caste and religion of household head, household size and its quadratic form, dummy indicating whether household is below the poverty line, log of total outstanding debt, and log of land size. The second set includes district-level controls including percentage of villages having commercial banks, cooperative banks, and credit societies, log of average annual groundwater depth, log of average annual rainfall, and log of area irrigated using tube wells and other wells. And the last set are district dummies which control for district fixed effects or unobserved characteristics that do not vary for a given district over time. These might include cultural factors and administrative capacity that might be correlated with both implementation of JGY and the outcomes.

4.3. Empirical strategy

We examine the impact of JGY on farm households using a difference-in-differences approach, with the neighboring state of Maharashtra as the control group. In other words, we compare the changes in outcomes in Gujarat before and after JGY with the changes in Maharashtra over the same time period. We treat our unbalanced panel data as a repeated cross-section and estimate the following equation:

$$Y_{idt} = \alpha_0 + \alpha_1 P_t + \alpha_2 T_i * P_t + X_{it} + W_{dt} + D_d + \varepsilon_{idt} \quad (11)$$

where, Y_{idt} is the outcome for household i residing in district d at the year t. P_t is a dummy variable taking value 1 if the household is interviewed post-JGY implementation (IHDS-2) and 0 otherwise, and T_i is a dummy taking value 1 if the household resides in Gujarat and 0 if it is in Maharashtra. α_2 is the coefficient of interest, measuring the impact of JGY on the outcomes. The difference-in-differences identification assumption is that without JGY, Gujarat would have the same growth in farm income and farm investments as its neighbouring state Maharashtra, which is tested by use of parallel trends. X_{it} is a vector of time-varying household characteristics and W_{dt} is a vector of time-varying district-level characteristics. D_d are district dummies controlling for district fixed effects and ε_{idt} is the random error.

4.4. Parallel trends assumption

The identification assumption required to be satisfied for difference-in-differences estimates to have internal validity is parallel trends. This means that in the absence of the program, households in Gujarat and Maharashtra would have the followed the same trend in the outcomes. Therefore, any change in outcome is attributable only to the program and not to any differences in baseline trends. Essentially, we need to show that prior to implementation of JGY Gujarat and Maharashtra followed shared similar characteristics and differ only with respect to program implementation.

Maharashtra and Gujarat are two bordering states located in the western part of India. In 2003-2004, both states were classified as high-income with real per capita income of Gujarat at INR 16,779 and that of Maharashtra at INR 16,050 (Purfield, 2006). Over the period from 1995-2005, both states recorded less than 0.5% growth rate of net state domestic product (NSDP) in agriculture (Planning Commission, 2007).

The two states have different agro-climatic conditions with Gujarat being largely semi-arid and arid and Maharashtra having tropical wet and dry climate. Based on Köppen Climate Classification System, large part of Gujarat is covered by semi-arid and arid climatic zones while few districts that border Maharashtra have tropical wet and dry climate. Maharashtra on other hand has largely tropical wet and dry climate with few parts sharing semi-arid climate (Husain, 2015). There exists large spatial variation in rainfall in both the states. Both states have more than 50% cultivable area dependent on rainfall (Planning Commission, 2007). Due to different agro-climatic zones and geomorphic features, net annual groundwater availability varies between Gujarat (15.02 bcm) and Maharashtra (31.21 bcm), however, annual groundwater draft for irrigation does not differ significantly with Gujarat recording 10.49 bcm and Maharashtra recording 14.29 bcm extraction (CGWB, 2004).[2]

[2] bcm = billion cubic meter

We summarize a host of other baseline characteristics for the two states in Table 1 below. It is observed that prior to implementation of JGY, Gujarat and Maharashtra were largely similar except in the average daily earnings of women in agriculture and share of agriculture in total employment. Figures 2a – 2c present pre-JGY trends of average landholding size, gross area under cultivation, and electricity consumed for agriculture as a percentage of total. Again, it is observed that the two states follow similar trends. We therefore argue that Maharashtra makes for a valid counterfactual.

In our regression models, we explicitly control for observed covariates that may differ at the baseline such as district-level rainfall, groundwater availability, and credit availability. In addition, we conduct robustness checks using only those districts of Maharashtra that share a border with Gujarat to rule out potential bias arising due to differences in baseline characteristics.

5. Descriptive statistics

We present descriptive statistics of all variables in our regression models for both Gujarat and Maharashtra, pre- and post-JGY in Table 2. We observe that post-JGY, net farm income per acre increased by 76.81% in Gujarat and by 71.45% in Maharashtra. Cost of irrigation increased in Gujarat by 46.88% while it decreased by 33.33% in Maharashtra indicating that farm electricity supply management possibly made irrigation costly in Gujarat. Hired labour days reduced in Gujarat by 31.58% while they increased in Maharashtra by 50% indicating plausible efficiency gains in farming in Gujarat post-JGY. Number of electric pumps owned and proportion of farmers irrigating their farms with tube wells increased both in Gujarat and Maharashtra. Proportion of farmers who irrigated with tube wells increased marginally in Gujarat by 18.52% while in Maharashtra they increased significantly by 138.46%. Area irrigated by tube wells or other wells in hectares increased both in Gujarat and Maharashtra by 28.17% and 11.01% respectively. A greater increase in Gujarat is likely owing to electrification benefits at the extensive margin. Depth to groundwater (in billion cubic meters) improved both in Gujarat and Maharashtra by approximately 6% and 7% respectively. Total outstanding household debt in Gujarat increased by 12.16% while in Maharashtra it increased by 20.44%.

6. Results

6.1. Main results

We estimate the average treatment effect of JGY on net farm income per acre and farm investments in fixed and variable inputs using equation (11). We present the results in Table 3 for all farm households and separately for farm households with small and medium-to-large landholdings separately. The definitions of small, medium, and large farmers are as per the guidelines of Department of Land Resources, Government of India, where large farmer = landholding >5 hectares, medium farmer = landholding >2 hectares and <=5 hectares, and small farmer = landholding <=2 hectares. We find that farm electricity supply management initiated under JGY significantly increases net farm income per acre for all farmers in Gujarat by 14.3% and also for small and medium-to-large farmers by 12.6% and 15.7% respectively. Our findings are somewhat contradictory to the qualitative evidence on JGY which suggests that only medium and large farmers benefitted from JGY and small and marginal farmers were made worse-off (Gronwall, 2014; Mukherji, et al., 2010).

Next, we examine whether JGY has resulted in farm households altering their investments in fixed and variable inputs. Results are presented in Table 4. Our findings suggest that probability of irrigation with tube wells fell by 23.4 percentage points for medium-to-large farmers. However, there is no significant impact on small farmers. On the other hand, probability of irrigation with other wells increased significantly by 32.7 percentage points for all farmers and by 27.9 percentage points and 43.4 percentage points respectively for small and medium-to-large farmers. These findings allude to a substitution effect plausibly because of rationing of farm electricity to 8 hours thus inducing farmers to find alternative sources of irrigation. There is decrease in the number of tube wells owned for medium-to-large farmers by 0.866 units, however, there is a secular increase in the number of diesel pumps owned for all farmers. Again, these findings resonate with a possible substitution effect where in farmers need to compensate for the running pumps beyond the 8 hours. We also observe an increase in the number of tractors owned by medium-to-large farmers by 0.847 units, which are in line with theory and previous evidence that gains from farm electrification operate at the extensive margin. As it is the medium-to-large farmers who have scope for expanding land under cultivation, they are likely to invest more in fixed inputs that support the expansion. This result is consistent with qualitative evidence on JGY that is has mainly benefitted medium and large farmers (Gronwall, 2014; Mukherji, et al., 2010).

Consistent with theory and empirical evidence, we find that JGY results in reduction in hired labor days by 27.9% for all farmers and the decrease in hired labor for small farmers (32.2%) and medium-to-large farmers (13.3%) separately is also significant. We find an increase in irrigation costs across farmers of varying landholding sizes. On average, for all farmers, irrigation costs increase by 83.8% and for small and medium-to-large farmers they increase by 82.6% and 86.3%. This is likely due to the fact that farmers need to spend on alternative pumps and fuels during the hours without electricity. JGY has no impact on farm investments in fertilizers and pesticides.

6.2. Heterogeneous effects

To understand whether JGY affects farm incomes due to groundwater availability and cropping patterns, we disaggregate the impact on net farm income per acre by – (i) districts with safe levels of GWD or districts with exploited levels of GWD (ii) districts growing primarily water intensive or non-water intensive crops and (iii) districts growing primarily labor intensive or non-labor intensive crops.[3] Classification of districts based on level of GWD follows CGWB guidelines and categorize districts as safe, semi-critical, critical, or over-exploited (Appendix 2). We treat districts with semi-critical, critical, or over-exploited levels of GWD as groundwater stressed districts. Districts growing water intensive and non-water intensive, and labor intensive and non-labor intensive crops are identified based on data from the Ministry of Agriculture, Government of India; World Widlife Fund's "Thirsty Crops Report 2003"; and Federation of Indian Chambers of Commerce and Industry (FICCI)-KMPG 2015 joint report on "Labour in Indian Agriculture". We use >70% of cultivated land under water/labor intensive crops as our threshold (see Appendices 3 and 4).

Results in Table 5, panel A shows that net farm income of farmers in groundwater safe districts increases by 13.5%. The effect on small and medium-to-large farmers separately in groundwater safe districts is also positive. We find no impact on the net farm income of farmers in groundwater

[3] IHDS-2 does not provide data on cropping patterns and crop yields.

stressed districts. These findings underscore access to groundwater as a key channel through which JGY affects farm incomes. The insignificant impacts on farmers in groundwater stressed districts imply that preventing over-extraction of groundwater through the implementation of JGY might actually be effective although it may come at the cost of farmer welfare.

Further, from Table 5, panel B we observe that net farm income of farmers in districts growing non-water intensive crops increases significantly by 12.8% while there is no effect on farmers in districts growing water intensive crops. These findings corroborate with the earlier finding on groundwater stressed districts and reinforce access to groundwater as a significant mechanism affecting farm incomes.

Table 5, Panel C indicates that there is positive impact of JGY on farmers in districts growing non-labor intensive crops with their net farm income increasing by 21.7%. However, there is a welfare loss for farmers in districts growing labor intensive crops with their income decreasing by 59.4% on average. Interestingly, medium-to-large farmers in districts growing labor intensive crops benefit from JGY as their income increases by nearly 4 times. We investigate further by looking at the Ministry of Agriculture data and find that labor intensive districts (>70% cultivated land under labor intensive crops) are also those where most of the land is under high value crops such as cotton and sugarcane are grown. It is likely that farmers growing high value crops are more likely to be the ones with larger farm sizes. Therefore, they benefit from JGY as they can engage more machinery such as pumps and tractors, which we find in our earlier results.

6.3. Robustness checks

We conduct a series of robustness checks to test the validity of our results and present them in Table 6. First, to rule out potential bias arising out of districts that were nominally electrified in 2004-2005, we run the difference-in-differences regressions on net farm income per acre excluding households in districts where baseline JGY coverage exceeds 1% and 1.5%. Second, in the Maharashtra sample, we retain only those households that reside in districts sharing a border with Gujarat. The rationale here is that the characteristics of this sub-sample would be more similar on average to all farmers in Gujarat. Third, we retain only those farm households that were interviewed in both waves. Fourth, we retain only those farm households whose main source of agricultural income is cultivation. Fifth, we exclude households in the top/bottom 1% and 5% of the distribution according to groundwater depth to check sensitivity to extremely low or abundant groundwater availability. And last, we add interview year-month fixed effects to control for any unobserved factors that were common to farm households in a given year-month such as climate shocks. We find that our results are highly robust adding credibility to our identification strategy and regression specification.

7. Conclusion

This study fills a critical gap in the existing literature on farm electricity supply management on farm households. In particular, we evaluate the impact of JGY on farm households in the Indian state of Gujarat. The state government launched JGY to balance the competing policy objectives of agricultural growth, financial viability of public utility companies, and environmental sustainability (particularly groundwater extraction). Using data from IHDS Waves 1 and 2 and applying a difference-in-differences econometric framework, we examine the impact of JGY on net farm income and farm investments in fixed and variable inputs.

Contrary to qualitative evidence that JGY only benefits medium and large farmers, we find that the program leads to a significant increase in net farm income per acre for farmers across land sizes. Farmers across land sizes also decrease investment in electric pumps. Medium-to-large farmers seem to decrease their investment in tube wells but simultaneously increase investment in diesel pumps. They also increase their investment in tractors potentially due to gains at the extensive margin. Further, farmers across land sizes significantly reduce hired labour supporting both theory and literature that farm electricity is essentially a labor-saving technology and results in greater efficiency. Our findings thus suggest that, on average, farm electricity supply management increases farmers' welfare measured as net farm income per acre. Underlying reasons seem to be reallocation of investments in various fixed and variable farm inputs.

Other important insights emerging from our findings are that access to groundwater and labor intensity of crops mediate the impact on net farm income. In particular, farmers in districts with sufficient groundwater availability and those in districts growing non-water intensive and non-labor intensive crops benefit. On the plus side, these findings imply that the objective of groundwater sustainability might actually be achievable through farm electricity rationing in groundwater stressed districts. However, on the down side, it may come at the cost of reducing farmers' welfare.

Our findings have significant policy implications. First, we provide the first rigorous evidence of JGY on farm households, which is crucial to examine the effectiveness of innovative yet politically difficult reforms. Second, contrary to popular belief, we do not find evidence to support that the overall impact of rationing farm electricity on farmers is negative. Of course, this is partly because quality and predictability is ensured, but partly the effect also manifests through reallocation of investments in other farm inputs. And third, policymakers need to carefully assess the impact of rationing on farmers in groundwater stressed districts. Farmers in these districts may need to be provided alternative cropping technologies such as drip irrigation to compensate for reduced groundwater extraction or encouraged to shift towards non-water intensive crops. Thus, reforms such as JGY can be a solution for policymakers to balance the competing needs of the energy and agricultural sectors.

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9. Tables and figures

Table 1. Comparison of baseline characteristics of Gujarat and Maharashtra

Indicator	Gujarat	Maharashtra	Source of data
Average number of wage earners in agricultural labor (2004-05)	2.17	2.15	Rural Labour Enquiry, Labour Bureau, Government of India
Average daily earnings of men (in INR) of rural households in agricultural occupations (2004-05)	45.90	44.56	
Average daily earnings of women (in INR) of rural households in agricultural occupations (2004-05)	41.60	27.41	
Share of agriculture in total employment (2004-05)	62.10%	45.70%	Planning Commission, Government of India
Percentage of rural household electrification (2001)	72%	65%	Census 2001, Government of India
Overall transmission & distribution (T&D) losses as % of availability (2004-05)	34%	35%	Power & Energy Division, Planning Commission, Government of India
Tube wells and other wells as source of irrigation as % of total (2004)	78%	78%	Directorate of Economics & Statistics, Ministry of Agriculture, Government of India

Table 2. Descriptive statistics

Variable	Gujarat				Maharashtra			
	Pre-JGY		Post-JGY		Pre-JGY		Post-JGY	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Panel A: Farm income and investment in inputs								
Net farm income per acre (INR)	12949.30	47003.63	22895.14	58449.55	10874.12	33894.08	18644.19	44289.92
Irrigation cost per acre (‘000 INR)	0.64	1.39	0.94	2.88	0.12	0.52	0.08	0.37
Fertilizer cost per acre (‘000 INR)	1.72	2.51	2.08	3.42	1.00	1.37	1.71	2.09
Hired labour cost per acre (‘000 INR)	1.52	4.59	1.84	6.30	0.83	1.56	1.52	2.37
Hired labour days in 100 days	0.19	0.63	0.13	0.34	0.06	0.17	0.09	0.19
Pesticide cost per acre (‘000 INR)	0.87	1.52	0.82	1.15	0.35	1.35	0.70	1.01
Irrigated with tube wells	0.27	0.44	0.32	0.47	0.13	0.33	0.31	0.46
Irrigated with other wells	0.14	0.34	0.21	0.41	0.28	0.45	0.15	0.36
Number of tube wells	0.10	0.31	0.20	0.42	0.18	0.42	0.33	0.58
Number of electric pumps	0.06	0.25	0.14	0.38	0.40	0.54	0.48	0.63
Number of diesel pumps	0.08	0.30	0.14	0.35	0.04	0.21	0.07	0.28
Number of tractors	0.06	0.25	0.11	0.33	0.04	0.20	0.04	0.21
Panel B: Household socio-economic characteristics								
Household size	5.68	2.70	5.67	2.60	5.61	2.67	5.50	2.69
Household below poverty line (BPL)	0.08	0.28	0.10	0.31	0.17	0.37	0.20	0.40
Education of HH head	4.56	4.19	4.99	4.31	4.72	4.16	5.23	4.26
Gender of HH head	0.93	0.25	0.91	0.28	0.93	0.25	0.93	0.25
Age of HH head	48.30	12.99	52.25	12.20	51.44	13.47	55.33	13.06
Total household debt (INR)	30655.65	94447.31	34382.09	206292.70	33163.48	109110.49	39943.60	130510.54
Land size in acres	5.63	7.84	5.75	6.74	5.29	6.09	5.06	5.80
Panel C: District-level characteristics								
Rainfall (mm)	136.55	162.78	17.82	26.62	10.79	31.31	40.02	131.56

Depth to groundwater (meters)	14.91	13.37	14.03	22.28	9.08	2.83	8.43	1.34
% of villages having commercial banks	9.61	5.05	9.76	5.55	7.09	2.74	7.95	2.78
% of villages having cooperative banks	4.82	3.77	4.54	3.42	8.65	4.95	10.90	4.98
% of villages having an agricultural credit society	52.49	9.74	37.19	17.05	52.07	18.00	55.55	18.31
Area irrigated by wells/tube wells (hectares)	101861.50	57610.16	130559.80	75524.83	97789.38	70010.28	108553.80	75295.24
Observations	554		441		1296		1047	

Note: All monetary values have been adjusted to 2012 rupees.

Table 3. Impact of JGY on net farm income per acre

	Outcome = Log net farm income per acre								
	All farmers			**Small farmers**			**Medium-to-large farmers**		
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Gujarat*Post	0.087**	0.148***	0.143***	0.089**	0.129***	0.126***	0.053	0.156**	0.157***
	(0.039)	(0.047)	(0.048)	(0.042)	(0.044)	(0.045)	(0.055)	(0.058)	(0.050)
Post	0.135***	0.161***	0.164***	0.131***	0.196***	0.200***	0.147***	0.080*	0.074*
	(0.024)	(0.034)	(0.035)	(0.025)	(0.036)	(0.036)	(0.029)	(0.040)	(0.037)
HH size			0.005			-0.007			0.009
			(0.006)			(0.011)			(0.007)
Squared HH size			0.000			0.001			-0.000
			(0.000)			(0.001)			(0.000)
HH BPL			-0.004			0.004			-0.027**
			(0.016)			(0.019)			(0.013)
Education of HH head			0.004***			0.004**			0.004**
			(0.001)			(0.002)			(0.002)
Gender of HH head			0.012			0.008			0.019
			(0.013)			(0.019)			(0.031)
Age of HH head			0.000			-0.000			0.001
			(0.000)			(0.001)			(0.000)
Log total household debt			-0.004***			-0.003*			-0.004**
			(0.001)			(0.002)			(0.002)
Log land size			-0.017			-0.001			-0.049***
			(0.015)			(0.026)			(0.013)
Log area irrigated by wells or tube wells		-0.046	-0.053*		-0.056	-0.068**		-0.049	-0.051
		(0.032)	(0.030)		(0.035)	(0.032)		(0.051)	(0.044)
Log rainfall		-0.004	-0.003		-0.007	-0.006		-0.006	-0.005
		(0.009)	(0.008)		(0.011)	(0.010)		(0.010)	(0.009)

Log depth to groundwater		0.105	0.116*		0.132	0.126		0.055	0.077
		(0.072)	(0.069)		(0.083)	(0.081)		(0.081)	(0.081)
% of villages having commercial bank		-0.003	-0.004		-0.003	-0.003		-0.002	-0.004
		(0.005)	(0.005)		(0.006)	(0.006)		(0.003)	(0.003)
% of villages having cooperative bank		0.009	0.009		0.002	0.002		0.028***	0.029***
		(0.007)	(0.007)		(0.008)	(0.007)		(0.009)	(0.007)
% of villages having agricultural credit society		0.005***	0.004***		0.005***	0.005***		0.003**	0.003*
		(0.002)	(0.001)		(0.002)	(0.002)		(0.001)	(0.001)
Constant	10.785***	10.782***	10.819***	10.796***	10.870***	11.081***	10.777***	10.855***	10.830***
	(0.037)	(0.391)	(0.350)	(0.041)	(0.467)	(0.419)	(0.039)	(0.562)	(0.490)
District FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Caste & Religion FE			Y			Y			Y
Observations	3,338	3,338	3,338	2,028	2,028	2,028	1,310	1,310	1,310
Adjusted R-squared	0.130	0.132	0.150	0.118	0.118	0.130	0.265	0.272	0.306

Note: Difference-in-differences estimates from OLS regressions. Robust standard errors clustered at district-level in parentheses. $p<0.01$***, $p<0.05$**, $p<0.10$*.

Table 4. Impact of JGY on farm investments in fixed and variable inputs

	All farmers			Small farmers			Medium-to-large farmers		
Outcome variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Irrigated with tube wells*	-0.097	-0.112	-0.147	-0.113	-0.053	-0.081	-0.010	-0.191	-0.234**
	(0.083)	(0.101)	(0.093)	(0.088)	(0.100)	(0.102)	(0.093)	(0.122)	(0.112)
Irrigated with other wells*	0.051	0.350***	0.327***	0.063	0.279*	0.255*	0.045	0.433***	0.434***
	(0.082)	(0.116)	(0.109)	(0.082)	(0.144)	(0.133)	(0.111)	(0.116)	(0.115)
Number of tube wells+	-1.126***	-0.573	-0.585	-1.026**	-0.184	-0.143	-1.181***	-0.873**	-0.866**
	(0.372)	(0.389)	(0.367)	(0.483)	(0.421)	(0.469)	(0.415)	(0.440)	(0.431)
Number of electric pumps+	-2.498***	-1.893***	-1.802***	-2.574***	-1.562**	-1.385**	-2.479***	-2.017***	-1.952***
	(0.522)	(0.464)	(0.456)	(0.711)	(0.670)	(0.606)	(0.416)	(0.477)	(0.511)
Number of diesel pumps+	0.636**	1.255***	0.792*	0.833**	0.498	-0.112	0.494	1.407***	1.041**
	(0.324)	(0.456)	(0.417)	(0.398)	(0.812)	(0.816)	(0.458)	(0.520)	(0.477)
Number of tractors+	0.814**	0.725	0.338	0.833	-1.617	-1.679	0.977***	0.995**	0.847**
	(0.325)	(0.554)	(0.391)	(0.772)	(1.459)	(1.257)	(0.344)	(0.423)	(0.342)
Log Irrigation cost (‘000 INR)^	0.293***	0.857***	0.838***	0.284**	0.911***	0.826***	0.534***	0.768*	0.863**
	(0.085)	(0.224)	(0.231)	(0.132)	(0.230)	(0.213)	(0.196)	(0.419)	(0.411)
Log fertilizer cost (‘000 INR)^	0.026	0.068	0.071	0.117	0.238	0.187	-0.192	-0.215	-0.162
	(0.109)	(0.128)	(0.118)	(0.126)	(0.180)	(0.172)	(0.151)	(0.235)	(0.236)
Log pesticides cost (‘000 INR)^	-0.183*	-0.178	-0.185	-0.216*	-0.182	-0.237	-0.166	-0.172	-0.106
	(0.110)	(0.139)	(0.142)	(0.129)	(0.179)	(0.182)	(0.127)	(0.142)	(0.142)
Log hired labor in 100 days^	-0.220*	-0.263**	-0.279**	-0.196	-0.322**	-0.375***	-0.262**	-0.137**	-0.133**
	(0.126)	(0.115)	(0.116)	(0.139)	(0.138)	(0.132)	(0.107)	(0.068)	(0.065)
District FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Household controls		Y	Y		Y	Y		Y	Y
District controls			Y			Y			Y
Caste & Religion FE			Y			Y			Y
Observations	3338	3338	3338	2028	2028	2028	1310	1310	1310

Note: Difference-in-difference estimates: * OLS, + negative binomial, and ^ tobit regressions. Robust standard errors clustered at district-level in parentheses. p<0.01***, p<0.05**, p<0.10*.

Table 5. Heterogeneous effects of JGY on net farm income per acre

	Outcome variable: Net farm income per acre					
Panel A: Groundwater exploitation	**Groundwater stressed districts**			**Groundwater safe districts**		
	All farmers	**Small farmers**	**Medium-to-large farmers**	**All farmers**	**Small farmers**	**Medium-to-large farmers**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Gujarat*Post	-3.345	-8.425	-230.203	0.135**	0.120**	0.154**
	(2.939)	(5.440)	(.)	(0.054)	(0.054)	(0.074)
District FE	Y	Y	Y	Y	Y	Y
Household controls	Y	Y	Y	Y	Y	Y
District controls	Y	Y	Y	Y	Y	Y
Caste & Religion FE	Y	Y	Y	Y	Y	Y
Observations	732	404	328	2,606	1,624	982
Panel B: Crop water intensity	**Districts growing water intensive crops (>70% cultivated area under water intensive crops)**			**Districts growing non-water intensive crops(<=70% cultivated area under water intensive crops)**		
	All farmers	**Small farmers**	**Medium-to-large farmers**	**All farmers**	**Small farmers**	**Medium-to-large farmers**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Gujarat*Post	-0.275	1.642	-0.026	0.128**	0.053	0.136**
	(1.132)	(0.975)	(0.545)	(0.059)	(0.067)	(0.051)
District FE	Y	Y	Y	Y	Y	Y
Household controls	Y	Y	Y	Y	Y	Y
District controls	Y	Y	Y	Y	Y	Y
Caste & Religion FE	Y	Y	Y	Y	Y	Y
Observations	421	306	115	2,917	1,722	1,195
Panel C: Crop labor intensity	**Districts growing labor intensive crops(>70% cultivated area under labor intensive crops)**			**Districts growing non-labor intensive crops(<=70% cultivated area under labor intensive crops)**		
	All farmers	**Small farmers**	**Medium-to-large farmers**	**All farmers**	**Small farmers**	**Medium-to-large farmers**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Gujarat*Post	-0.594***	-1.460***	3.660**	0.217***	0.137*	0.232***
	(0.062)	(0.357)	(1.025)	(0.061)	(0.074)	(0.040)

District FE	Y	Y	Y	Y	Y	Y
Household controls	Y	Y	Y	Y	Y	Y
District controls	Y	Y	Y	Y	Y	Y
Caste & Religion FE	Y	Y	Y	Y	Y	Y
Observations	534	333	201	2,804	1,695	1,109

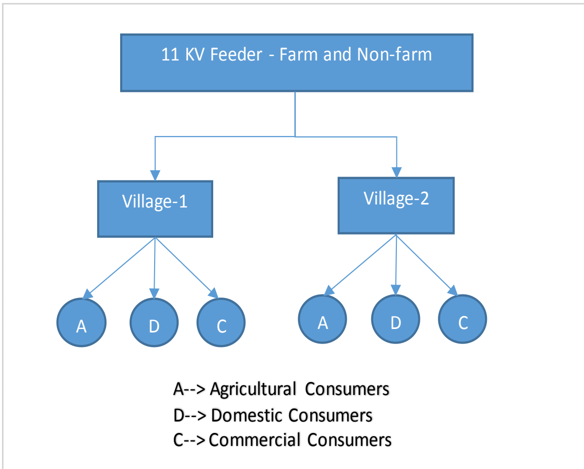
Note: Difference-in-differences OLS estimates. Robust standard errors clustered at district-level in parentheses. p<0.01***, p<0.05**, p<0.10*

Table 6. Robustness checks

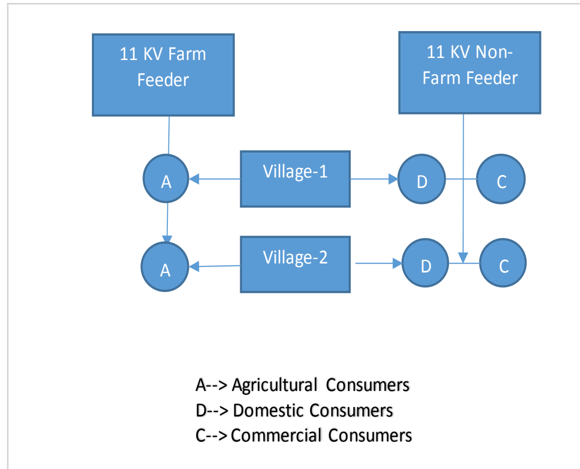
	Outcome variable: Net farm income per acre		
	(1)	**(2)**	**(3)**
	All farmers	**Small farmers**	**Medium-to-large farmers**
Base specification	0.143***	0.126***	0.157***
Excluding households in districts with >=1.5% villages electrified under JGY in 2004-2005	0.171***	0.141***	0.207***
Excluding households in districts with >=1% villages electrified under JGY in 2004-2005	0.184***	0.164**	0.188***
Only Maharashtra districts that are close to Gujarat border (arbitarily chosen)	0.129**	0.109**	0.128**
Only households that are interviewed in both waves	0.123**	0.088	0.160***
Only households whose main income comes from cultivation	0.171***	0.217**	0.178***
Excluding households that are in top/bottom 1% of the distribution according to groundwater depth	0.167***	0.134**	0.204***
Excluding households that are in top/bottom 5% of the distribution according to groundwater depth	0.176***	0.121**	0.213***
Adding interview year-month fixed effects	0.156**	0.155*	0.128**

Note: Difference-in-differences OLS estimates with full set of control variables. p<0.01***, p<0.05**, p<0.10*.

Figures 1a and 1b. Pre- and post-JGY feeder system



1a: Feeder system before JGY



1b: Feeder system after JGY

Source: Shah et al. (2008)

Figure 2a. Trend of average landholding size in hectares in Gujarat and Maharashtra

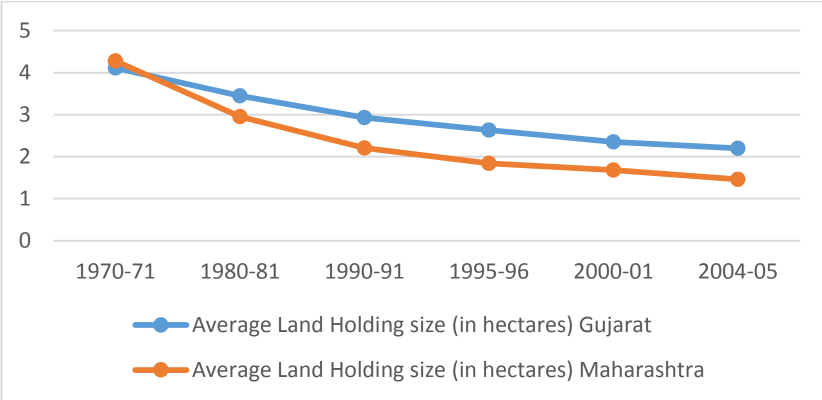


Figure 2b. Trend of gross area under irrigation in '000 hectares in Gujarat and Maharashtra

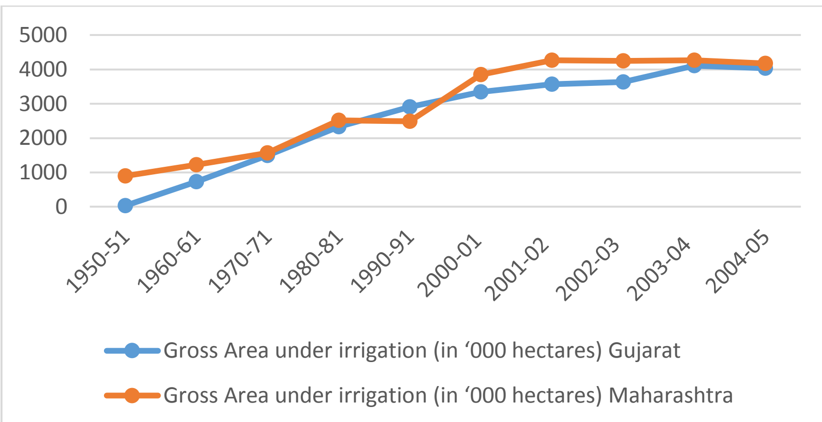
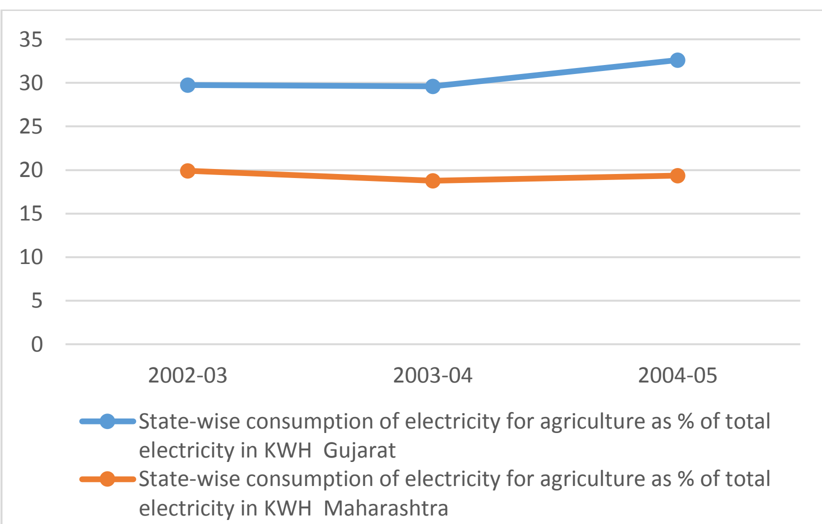
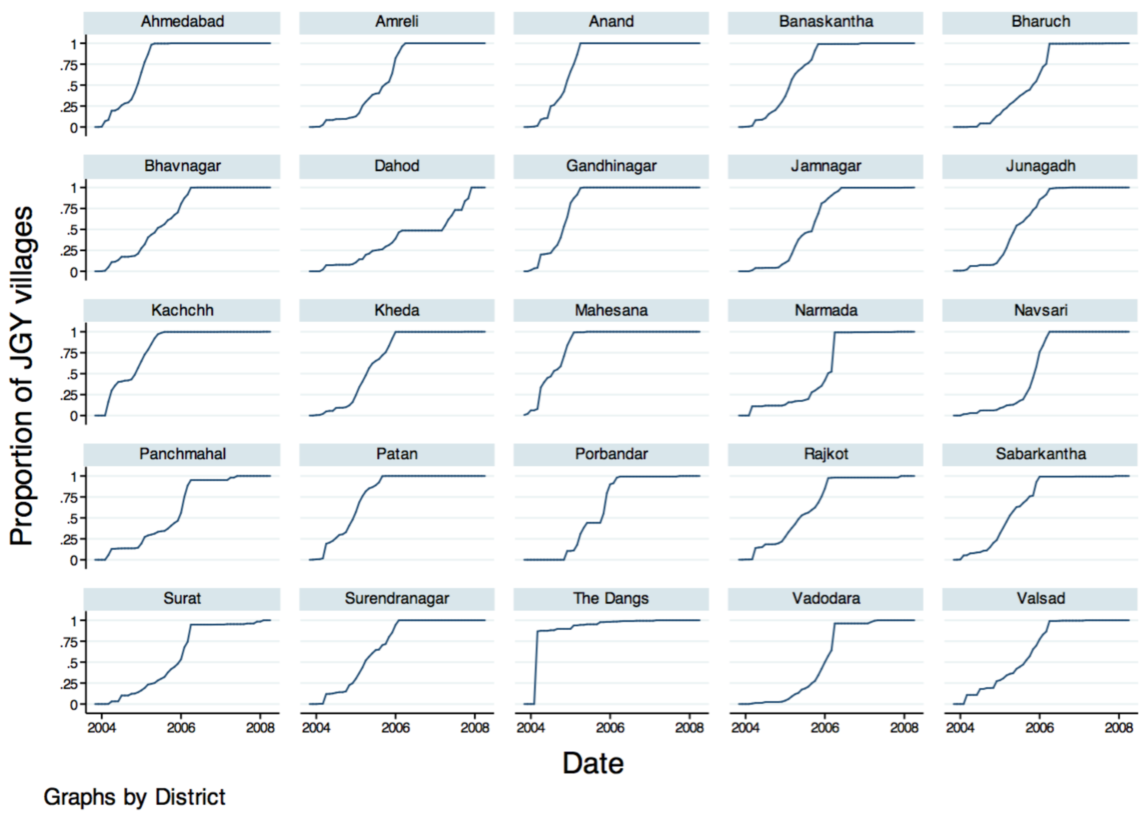


Figure 2c. Trend of consumption of electricity for agriculture as a % of total electricity consumption in Gujarat and Maharashtra



10. Appendices

Appendix 1. JGY program rollout by district



Source: Authors' calculations using administrative data on JGY program rollout collected from DISCOMs.

Appendix 2. Classification of districts based on groundwater exploitation

Districts are classified as safe, semi-critical, critical, and over-exploited based on level of groundwater development (GWD). GWD is calculated as ratio of annual groundwater draft to net annual groundwater availability. CGWB classifies districts as over-exploited if GWD>100%, critical if 90-100% GWD, or semi-critical if 70-90% GWD. Districts with lower than 70% GWD are classified as safe.

Appendix 3. Classification of districts into those growing water intensive or non-water intensive crops

District-level crop data is sourced from Ministry of Agriculture, Government of India (http://aps.dac.gov.in/Home.aspx). District-wise compilation includes number of hectares cultivated, number of tonnes produced, and yield for each crop grown in the district. World Wildlife Fund's "Thirsty Crops Report 2003" is used to classify crops into water intensive and non-water intensive. The report classifies cotton, maize, rice, sugarcane, soya, wheat, potatoes, and banana as water intensive.[4] Millets, oilseeds, and pulses are classified as non-water intensive. Other sources are used to classify crops not covered in the report such as – safflower[5], dry chillies[6], garlic[7], guar seed[8], onion[9] and tobacco[10]. Districts where >70% of cultivated land is under water intensive crops are classified as "growing water intensive crops" and classified as "growing non-water intensive crops" otherwise.

[4] https://www.firstclimate.com/water-services/water-projects/efficient-agriculture-india/
[5] http://www.agrifarming.in/safflower-cultivation/
[6] http://www.bbc.com/news/business-14847808
[7] http://www.bbc.com/news/business-14847808
[8] http://www.thehindubusinessline.com/economy/agri-business/guar-beckons-maharashtra-farmers/article4898686.ece
[9] http://www.bbc.com/news/business-14847808
[10] http://www.thehindu.com/todays-paper/tp-national/tp-andhrapradesh/tobacco-farmers-not-ready-to-switch-to-alternative-crops/article2649028.ece

Appendix 4. Classification of districts into those growing labour intensive or non- labour intensive crops

District-level crop data is sourced from Ministry of Agriculture, Government of India (http://aps.dac.gov.in/Home.aspx). District-wise compilation includes number of hectares cultivated, number of tonnes produced, and yield for each crop grown in the district. The joint 2015 report by Federation of Indian Chambers of Commerce and Industry (FICCI) and KPMG on "Labour in Indian Agriculture" is used to identify labor-intensive and non-labor intensive crops. The report classified labor intensity based on average man hour per hectare. Based on the report, paddy, wheat, sugarcane, cotton, and groundnut are classified as labor-intensive while all other crops are classified as non-labor intensive. Districts where >70% of cultivated land is under labor intensive crops are classified as "growing labor intensive crops" and classified as "growing non-labor intensive crops" otherwise.