

Electricity Provision and Industrial Development: Evidence from India

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Abstract

This paper analyses the provision of electricity in Indian states and its effect on industrial outcomes between 1965 and 1984. The introduction and the differential adoption across states of a new agricultural technology intensive in irrigation (the Green Revolution) is exploited as a natural experiment to understand why some states invested more in expanding their electricity network, considering that irrigation water could be pumped from the water table using electric pumpsets. In particular, geographic characteristics and initial conditions that determined the successful adoption of new seeds are used in an instrumental variables strategy to address the endogenous investment on infrastructure. Estimates show that the uneven electrification process that followed the Green Revolution can explain between 10 and 15 percentage points of the difference in industrial output across states in India.

1 Introduction

The adequate supply of infrastructure goods is increasingly acknowledged as one key factor in generating a proper environment for industrial development. The World Bank Report on Infrastructure (2006) shows how infrastructure regained a central role on the Bank's agenda in 2003, when

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there was a "renewed appreciation - both inside and outside the Bank - of the importance of infrastructure in enabling growth and poverty reduction". From a theoretical perspective, Murphy et al. (1989b) show that infrastructure goods can be an important component of a "big push" industrialization process, where the expansion of one sector contributes to the development of other markets, by helping to overcome coordination problems.

This paper investigates the effect of electricity infrastructure in industrial development, by looking at a panel of Indian states between 1965 and 1984. The attention is drawn to India for two main reasons. First, because its particular political configuration gives each state the full responsibility in creating, expanding and administrating the electricity network, from upstream to downstream, with full freedom to set their pricing policies and their investment plans. That provides significant variation in performance and outcomes that can be exploited across regions over time. It also means that within the same country it can be tested whether the gap in infrastructure provision is associated with unequal industrialization levels, i.e. states' specific "big push". The second reason why the electricity supply in India deserves a lot of attention is because there is a general consensus that the sector as a whole is underperforming, unreliable and has been acting as a major constraint for industrial development (World Bank (2000), US DoE (2003)).

As it happens with all set of institutions and policies, assessing and quantifying the actual impact of investment in infrastructure on economic outcomes in the long run is a difficult task. Infrastructure and industrial development are so closely related that is very difficult to determine the underlying driving force. The resulting problem of endogeneity and omitted variables in econometric analysis might explain why an issue deemed so important has attracted so few development economists, relatively to issues such as institutions, credit markets or human capital. The problem arises because observable or unobservable state characteristics, such as level of income or the business climate, might explain why some states are better prepared to provide a better electricity network than others. To overcome this problem, the analysis delves into the circumstances that led some states to invest more than others in expanding the reach of electricity. This paper claims that the differential pace of expansion of the electricity network across Indian states was driven by the differential electricity needs in the agricultural sector, generated by the introduction of scientifically modified seeds that initiated the phenomenon known as Green Revolution. These high yielding variety (HYV) seeds are known to be high-cost/high-yield because they could potentially multiply agricultural productivity if timely irrigation

and an intensive use of fertilizers and pesticides are provided. The cheapest way of securing the water supply needed is by means of electric pumpsets that suction water from the water table via tubewells.

The empirical strategy will concentrate on using states' geographical characteristics that determined the feasibility of adopting the new HYV seeds as an instrument for understanding their diffusion and the subsequent rural electrification. The link between geography, adoption of HYV seeds and the electricity provision across states, that goes beyond states' wealth and their capacity to afford the provision of infrastructure, will help to overcome the endogeneity concern in the econometric estimation and will provide the exogenous variation needed to measure the effect of electricity provision in India on industrial indicators. The Green Revolution will be used as a quasi-natural experiment with respect to Indian states to understand the differential expansion of the electricity infrastructure. Because the "treatment" (adoption of HYV seeds) was not randomly allocated across states, I follow the literature (e.g. Foster and Rosenzweig (1996)) and argue that selection was on geographical variables and conditions directly uncorrelated with industrial development that could be used as an instrument. The empirical strategy consists on finding appropriate instruments for the expansion of the electricity network in order to consistently estimate its impact on industrial development in a two-stage least squares strategy, that can be summarised as follows

Geography \implies HYV Adoption \implies Electrification \implies Industrial Development

I first investigate what characteristics have driven the successful adoption and diffusion of HYV seeds and provide some tests on their power and suitability to instrument a measure of electrification in rural areas. Subsequently, I carry out an instrumental variables estimation of electricity indicators on manufacturing output and other outcomes. The main concern in my empirical strategy is related to the exclusion restriction. To alleviate concerns regarding the validity of the instruments and the mechanisms I propose I carry out a series of robustness checks and falsification exercises, aiming at ruling out alternative channels that could induce a spurious correlation in my results. Results in this paper suggest that a standard deviation difference in grid reach explains around 13% percentage points difference in industrial output, a substantial magnitude that underlines the importance of investing in infrastructure.

The paper is organised as follows. Section 2 provides an overview of the electricity sector in India and its relation to the Green Revolution. Section 3 develops the empirical strategy and results and Section 4 presents some

robustness checks. Section 5 delves into the political economy of electricity supply in India and Section 6 concludes.

2 Background and data

2.1 The power sector in India.

The Indian Constitution establishes in a handful of articles the distribution of legislative powers between the Central Government and the States, specifying a Concurrent List of activities where both levels of government have the power to intervene. These shared competencies include non economic legislation (e.g., criminal law) and economic regulation (e.g., labour markets or price controls). The electricity sector falls in this last category. The Electricity Supply Act created in 1948 agencies like the Central Electricity Authority (CEA)¹, in charge of formulating national policies and assessing the technical and economic viability of power projects, and the State Electricity Boards (SEB), in charge of coordinating the electricity generation, transmission and distribution and pricing at a state level. Board members are appointed by the state government (Chapter III, 5.2). The SEBs are fully vertically integrated, owning the four segments of the industry: generation, transmission, distribution and commercialization. In the 60s five not interconnected Regional Electricity Boards (REB), subordinate to the CEA, were created to integrate the operation of states under the same grid to improve the utilization of power resources in each region. In 2001, according to the Ministry of Power's Blueprint for Power Sector Development, the States were in control of 60% of India's generation capacity, 70% of the transmission network and a 100% of the distribution system. By 2002 links between regions were built after the creation of Powergrid Co., a national corporation responsible for up to 40% of total transmission.

A World Bank report stated in 2000 that "the fundamental of India's slow export growth lie in the lack of further tariff reform, high infrastructure and transaction costs (...) that reduce India's comparative advantage in labour intensive products". The situation in the energy sector fits into this general concern about India's future development and its aptitude to exploit its productive potential. It is generally acknowledged by both public agencies and private consultants that the performance of the electricity

¹The current national authority is the Ministry of Power, created in 1992, preceded by the Ministry of Energy comprising the Departments of Power, Coal and Non-Conventional Energy Sources. The CEA is now part of it. For most years included in this paper, the CEA was part of the Ministry of Irrigation and Power, Government of India.

sector affects heavily the growth and development possibilities of the Indian economy. The US Department of Energy published that "the poor quality and arbitrary pricing of electricity has been the single greatest deterrent to India's economic growth and development". To take an example, subsidies to farmers and domestic consumers by states via the electricity provision have been estimated to be in the order of 1 to 1.5% of India's GDP. These concerns are investigated and quantified by Dollar et al. (2002, 2003), showing that productivity, return and investment rates are lower in Indian states where the business climate is worse, using indicators on cost and reliability of the electricity supply among others.

The inadequate investment in maintenance and modernisation of the infrastructure and huge and avoidable energy losses topped with persistent cross-subsidy to agricultural and/or domestic consumers at the expense of industrial producers and/or commercial users explains the generalized poor state of SEBs' financial health. The quality considerations of the electricity provision are related to power cuts and voltage inadequacy mainly coming from infrastructure underinvestment (e.g. generation capacity, transmission and distribution networks maintenance, grid coverage) and regulatory concerns (e.g. inefficient use of available capacity, uneconomical pricing schemes, large scale theft). On the pricing side, the average ratio of tariff to cost fluctuated between 75% and 85% between the early 70s and the late 90s, with average tariff for industrial sectors as large as 10 times the tariffs for agriculture and domestic sectors. As a result of this, SEBs have shown commercial losses and consistently required subsidies from the state governments. Even though the 1948's Electricity Supply Act has an article requiring SEBs to earn a rate of return of at least 3%, most SEBs have never complied with it².

At the root of the problem are the preferences revealed by the regulator in the regulatory process. Sectorial analyses deemed the energy provision as "more of a social service than a business. Prices do not reflect costs and state institutions are dependent on allocations from the public budget". (TERI (1999)) and that "the SEBs became bastions of political patronage

²The problems were well acknowledged and by the late 90s some states began reforms to make tariff setting processes more transparent, balanced and faster and SEBs finances more sustainable. Additionally, in 1998, the Parliament passed the Electricity Regulatory Commissions Act, creating a Central Electricity Regulatory Commission and State Electricity Regulatory Commissions, aiming at rationalizing electricity tariffs, promoting transparent policies regarding subsidies and efficient and environmentally benign policies. These reforms are not exploited empirically in this paper since all attempts to redress SEB problems fall outside the time span of the data.

rather than true business enterprises (...) Reformers faced political opposition from farmers, who had come to rely on enormous quantities of low-cost electricity for pumping water and labour unions that represented electricity workers who feared losing their job if the bloated SEBs were privatized" (Tongia (2003)). This anecdotal characterisation of the political economy of electricity provision in some Indian states may explain the claim in this paper that after the Green Revolution states followed either a path of relative network expansion or a path of relative disregard for the rural provision of electricity. As a matter of fact, the pricing distortions seem to be more conspicuous in states where adoption of HYV seeds has been deeper³.

This paper will exploit these cross-state differences in infrastructure investment, underlining the importance of network extension over other indicators of regulation or performance. The idea is that having access to the grid, however imperfect and unreliable, opens the production possibilities inducing entry of new firms and improving the productivity of existing ones by turning production more capital intensive. Figure 1 shows that the above-mentioned dichotomy between agricultural and industrial consumers of electricity loses ground when looking at the number of connections for 16 states, between 1958 and 1984. The evolution of both variables shows a significant variation across states and a very similar pattern within states. The most spectacular evolution in electricity network expansion in Figure 1 is observed in Punjab, Haryana and Tamil Nadu. As it will be shown below, the first two states were at the forefront of the Green Revolution in India.

[Figure 1]

2.2 Green Revolution: irrigation and electricity

Food shortages were a persistent problem in newly independent India. The farming activity was mainly for subsistence, characterized by the use of primitive techniques and rainfed (Chakravarti (1972)). The Third Five Year Plan laid by the Planning Commission, covering the years from 1961-2 to 1965-6, set ambitious targets in terms of agricultural production, e.g. foodgrains should grow by 30%, other products like jute, by 55% in the belief that "with the achievement of these targets, the economy will become self-sufficient in the supply of foodgrains". To meet the Plan's ends, some programmes such as the Intensive Agricultural District Programme (IADP) and the Intensive Agricultural Areas Programme (IAAP) were introduced in selected districts

³Some states, like Haryana, have shown ratios of average tariff over unit cost as low as 40% and consistently below 60% for many years.

in selected states⁴, that could guarantee water supply and well developed village institutions while being free from floods or drainage and conservation problems⁵. The results were not as expected, mainly because the crops used had low response to fertilizers, but also because selected areas did not match the mentioned criteria. In 1966-7 the introduction of the High Yielding Variety Seed Programme provided the expected breakthrough, by providing farmers with hybrid seeds scientifically adapted to India's domestic conditions. These seeds were more responsive to fertilizers, had higher yields, were more resistant to adverse conditions such as droughts and more vulnerable to pests and weeds, and had a significantly shorter growing time. Five types were introduced: bajra, jowar, maize, rice and wheat, the best performer of all. The Green Revolution, in order to become a revolution, depended on a series of factors such as the use of fertilizers and pesticides and the adequate and timely supply of water. These requirements became a constraint to the spread of the new seeds. Even though the Fertilizer Corporation of India was created to supply farmers with fertilizers at a subsidised price, the problem of irrigation would prove decisive. In 1961, only around 20% of the total cropped area was under some form of irrigation. The increase in irrigated areas for the following twenty years was more than 50% with a very uneven distribution across regions. In the period under consideration, Haryana and Punjab, the two states at the forefront of the Green Revolution, achieved a share of irrigated area around 60% and 90% respectively, while other relatively rich states like Gujarat and West Bengal were around the 25% mark.

The nature and the depth of the irrigation development constitutes the fundamental argument in the empirical strategy. Its expansion goes hand in hand with HYV seeds adoption, meaning that states that were trying harder to introduce the new technology were creating a demand for irrigation that at the same time would increase the potential return from doing it. The nature of the irrigation expansion is linked to the use of canals supplying water from a dam or reservoir or to the installation of deep or shallow tubewells. Bharadway (1990) on a study on irrigation in India notes that "the rate of increase of irrigation by wells/tubewells was higher than that by canals and accelerated remarkably during the period 1969-1980 when there was a spurt in private tubewells, especially in the late sixties". McGuirk and Mundlak (1991) emphasize further this point by showing that in Punjab government

⁴ Andhra Pradesh, Bihar, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh.

⁵ Sharma and Dak (1989) provide a good account of the circumstances that led to the introduction of the new seeds.

provided canal irrigation dominated only until 1968; afterwards private wells and tanks became more important in terms of land coverage. As a matter of fact, this acceleration in the usage of tubewells is closely related to the availability of electricity in rural areas. As Bharadway explains, "a tubewell uses diesel or electricity operated pumps to lift the water (from the water table) and can manage greater depths and irrigate bigger commands (than dug wells)". Considering their high cost of operation, installation and maintenance a State Tubewell Corporation was set up to fund big, mainly state-owned, undertakings, through government backed banking loans. Private undertakings consisted generally on shallow tubewells and were funded by financial institutions, meaning that only well-off farmers that could provide a collateral had access to this form of irrigation. Poorer farmers had to rely on publicly provided sources of irrigation or simply buy from private tubewells' owners. As mentioned before, the efficient utilization of the tubewells was conditional on electricity or diesel availability. Again, this suggests that the success in the cultivation of new seeds became somehow conditional on the availability of electricity. It follows that states that were to deepen the Green Revolution had to expand their electricity network simultaneously. Kohlui and Singh (1997) analyse the experience in Punjab emphasizing that one of the main drivers in Punjab's HYV success was the development of infrastructure. In particular, they draw the attention to a phenomenon that is central for the empirical strategy undertaken in this paper, by pointing out that "since 1960-1, per capita power has been the greatest in Punjab among all the states. The high consumption could reflect greater availability." McGuirk and Mundlak back up this idea by showing that "from 1965/6 to 1979/80, power generation in Punjab increased by over 240% and by 1976 all villages had access to electricity. (...) The fastest-growing source of demand for electricity during this period was agriculture. A large part of this increase (from 14.5% in 1960/1 to 47% in 1979/80 of the total available electricity) was as a source of power for the growing numbers of tubewells"

Figure 2 shows the evolution for 15 states of HYV intensity (share cropped with HYV seeds as a proportion of total cultivated area) and number of farmers connected to the network per capita. It is striking to observe that the intensity of the change is similar for both variables in most of the states.

[Figure 2]

2.3 Data and related literature

This investigation covers fifteen Indian states⁶ over the period 1965-1984 using state varying indicators of manufacturing performance, electricity availability, adoption of HYV seeds and other demographic, political, economic and geographical variables. All electricity indicators are taken from "Public Electricity Supply - All India Statistics", published annually by the Central Electricity Authority between 1957 and 1985. These include the number of consumers, electricity consumed and connected load, all disaggregated per type of consumer (households, commercial, agricultural and industrial and other minor groups), generating capacity and electricity generated.

Data for industrial development and performance indicators include real per capita manufacturing output, stock of fixed capital, number of factories and investment. All these variables are taken from different publications published by the Department of Statistics, Ministry of Planning, and Ministry of Labour, Government of India, including the "Estimates of State Domestic Product", "Annual Survey of Industries" and "Indian Labour Year Book", respectively. State controls are taken from different sources: data on expenditure on health, education and development come from a Ministry of Finance, Government of India publication, "Public Finance Statistics". Political outcomes per state were compiled by Butler, Lahiri and Roy in their "India Decides: Elections 1952-1995". Banking data, including number of bank branches and total credit, come from "Statistical Tables relating to Banks in India", Reserve Bank of India. Price indices, used to deflate variables, and climatic and demographic variables are taken from "A Database on Poverty and Growth in India", prepared by Ozler, Datt and Ravallion (1996). Data on soil characteristics and cropped area under HYV seeds come from the "India Agriculture and Climate Dataset", compiled by Sanghi, Kumar, McKinsey, Jr. (1998).

[Insert Table1 : Descriptive statistics]

Descriptive statistics are presented for all main variables used in the regression analysis. In particular, I focus on the number of agricultural units connected to the network, manufacturing output and the incidence of HYV at the state level. Table 1 shows a significant variation in all three of them, with high values of standard deviations relative to the mean and substantial differences between minimum and maximum. Of particular interest is the number of agricultural connections to the electricity network, whose mean

⁶Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal.

increases tenfold during the period analysed. Additionally, states show substantial variation in geographic characteristics and initial conditions, a fact that will be exploited in the next section.

This paper adds to the literature investigating the sources of variation of economic performance across Indian states. Bandyopadhyay (2003) shows the existence of two income convergence clubs explained by the difference in infrastructure provision and electricity in particular. Sachs et al. (2002) carry out a simple analysis of convergence patterns, without distinguishing sectorial evolution. They also find divergence rather than convergence in Indian states' income per capita and refer to many studies that suggest that there has been a steady increase in the inter-state inequality of income and a clear dichotomy between "forward" and "backward" states. The former having higher levels of per capita income, better infrastructure and better social and demographic indicators. They suggest some explanatory factors to understand differential growth rates across states that are in line with this paper. First, states at the forefront of the Green Revolution have grown more in the 80s. Second, to explain Rajasthan's relative improvement in the 80s, the authors point out that this might be due, among other factors, to the rapid electrification of the state in that decade. Ravallion and Datt (1999) find that states with initial lower farm productivity and lower literacy experienced less poverty reducing growth, using household surveys for 15 states over the period 1960-94, .

Changes induced by policy have also been subject to scrutiny and used to understand Indian regional disparities. Besley and Burgess (1999, 2004) have exploited the relative independence that states have in India to set their policies to analyse the evolution of output and poverty. In Besley and Burgess (1999) they show that states that introduced more land reforms observed a substantial reduction in poverty and more growth. In their 2004 paper, they look at the effect of labour regulation on industrial outcomes. By coding amendments to labour laws as "pro-worker", "pro-employer" or "neutral" they find that the power balance of industrial relations can explain some of the long run industrial evolution across states. In particular, pro-worker regulations were shown to reduce industrial output and employment in the registered manufacturing sector while increasing output in the informal sector. Burgess and Pande (2005) also look at cross-state effects after a policy change. The introduction of a formal rural banking programme in India in 1977 is associated with greater output and less poverty. This paper will pay especial attention to the empirical strategy used to identify trend breaks.

The variation in manufacturing output across states is shown in Figure 3,

joint with the evolution of agricultural electricity connections to the network. Both variables move together in most of the states, irrespective of the level of manufacturing output. The evolution of a relatively more industrialised state like West Bengal, and others less developed, like Orissa or Bihar, are very similar. An interesting fact that stems from looking at Figure 3 is that the intensity of the change is also very similar for both variables: states that developed slightly but positively their electricity network also show a slightly but positive change in their industrial output, like Karnataka or Madhya Pradesh.

[Figure 3]

3 Identification Strategy

The main objective of this paper is to quantify the effect of electricity provision on industrial outcomes using a panel of Indian states from 1965 to 1984, by obtaining a consistent estimate of λ in equation (1), where an indicator of industrial performance (y_{st}) is expressed as a function of an indicator of electricity supply (e_{st}). The regression includes time varying state controls (X_{st}), state fixed effects, included to control for persistent and constant features within states, and year fixed effects to control for shocks common to all states.

$$y_{st} = \alpha_{0s} + \alpha_{1t} + \lambda e_{st} + \alpha_3 \mathbf{X}_{st} + \mu_{st} \quad (1)$$

The explained variable, y_{st} , captures industrial development or performance per state and year, using measures such as the log of real output per capita in the manufacturing sector or fixed capital per capita. Different variables are represented by e_{st} to capture the reach and network development in states' electricity supply at a point in time. The total number of consumers per type (farmers and factories) connected to the network relative to the state population and the average connected load (i.e. the maximum electrical power consumption per user) measure the depth of the network.

To control for demographic features and human capital I include the log of population density, and the proportion of rural and literate population. In order to investigate whether the infrastructure variable is actually picking up the effect of more credit availability that allows more manufacturing firms to start up, I control for financial development by including indicators such as the log of real per capita total credit. As noted by Lafort (2005), government's inefficiencies and corruption increase the marginal cost of raising funds and constraints the ability of the executive to invest

in infrastructure. It follows that the indicators of electricity network development might actually be capturing these political economy variables that would drive both dependent and independent variables. To address this concern, state controls include political party outcomes (party allegiance of the Chief Minister and votes for the Congress Party in parliamentary elections) and real per capita expenditure on development sectors, such as health and education. The latter is not only aimed at capturing states' investment on human capital but also the ability and/or willingness of the state government to enhance the economic environment. All regressions have their standard errors clustered at a state level to deal with serial correlation.

In the estimation of the coefficient of interest, λ , endogeneity is a major concern for quantifying the effect of infrastructure on output. The presence of correlation between the error term and the explanatory variable could be explained by reverse causality (i.e., more industrialized states can afford investments in expanding the electricity network) or omitted variables (e.g., unobservable changes in the institutional environment that drive both industrialization and electrification) and it would introduce a bias to the estimation. At this point, I am agnostic about the sign of the bias, since alternative stories could explain a positive correlation with both the outcome and the explanatory variable (e.g., a pro-business environment) or a positive correlation with either of them and a negative correlation with the other (e.g., the formation of a strong pro rural electrification lobby, clashing with urban industrialists).

The challenge is to find a set of instruments that can explain the differential pattern of investment in infrastructure that is not correlated with industrial output by other means. I argue in this paper that the introduction of High Yielding Varieties (HYV) in Indian agriculture in the mid-60s is at the root of the dissimilar development of the electricity network across states, without being related to contemporaneous or potential industrial development. HYV seeds need reliable irrigation and access to electricity was a fundamental input for farmers to pump water⁷. Because some concerns towards the endogeneity of HYV adoption remain, I will first investigate how geo-climatic characteristics and some initial conditions, such as groundwater availability and irrigation prior to the Green Revolution, respectively, have affected the diffusion of the new agricultural technology⁸. Subsequently, by

⁷It was also the cheapest option for farmers: the National Commission on Agriculture, Ministry of Agriculture and Irrigation of India (1976), estimated that operating diesel pumpsets was two times more expensive.

⁸A similar idea was already discussed by Evenson and Mckinsey (1999) where the authors analyse the viability of HYV seeds as a function of the interaction between climatic

exploiting the fact that states followed either a path of adoption of the new agricultural technology, creating a demand for rural electricity, either a path of traditional farming without creating the need for expansion of the electricity network, I will explore whether the proposed instruments satisfy the assumptions that validate the IV strategy. That is, I will investigate whether the state specific introduction of new seeds starting in 1966 is correlated to the development of the electricity network (power of the instruments) and whether this relation can be used to assess the differential impact in manufacturing outcomes (validity of the instruments). The underlying idea is that as the electricity network expanded to satisfy farmers' needs, industrial producers have benefited. In short, the empirical strategy will investigate each of the connecting arrows in the following schedule:

Geography \implies HYV Adoption \implies Electrification \implies Industrial Development

3.1 Instruments

The adoption of HYV seeds in rural India has been subject to a number of studies. As noted by Sharma and Dak (1989) or Kohli and Sing (1997) among others, there are many institutional factors that were required for the adoption of the new technology to be successful. Credit availability to buy the new seeds, fertilizers, pesticides or new machinery was deemed fundamental, as were price incentives, via subsidies or tax credits. Other characteristics like land titling, distribution and size also played a part, not just in terms of allowing access to credit via collateralization of the property, but also in terms of whether fixed costs, such as investment and maintenance of irrigation or machinery, could be recouped. Additionally, human capital (education, literacy) would determine whether farmers were aware of the potential benefits and its viability and prepared to change their production methods. Foster and Rosenzweig (1996) have shown that better educated people (at the primary school level) have benefited most from the introduction of the new technology and that initial levels of education would matter for growth after the introduction of the new technology. However, they point out that the technological change could be considered exogenous, given the fact that the innovation industries were different from the beneficiaries of the new seeds and that "a feature of the Green Revolution in India is that the ability to exploit the new seeds profitably was substantially different across India because of exogenous differentials in local soil and weather and technological (e.g., infrastructure) variables.

ditions". On a similar note, Evenson and Mc Kinsey Jr. (1999) show that climatic and edaphic endowments, when combined with basic investments in infrastructure, result in the diffusion of HYV seeds. In this section I will investigate further these claims, by looking at the evolution of HYV adoption as a function of initial conditions, soil and climate characteristics and the interaction of both.

3.1.1 Unveiling HYV adoption drivers: Geography and initial characteristics

Before the Green Revolution started all agriculture was rainfed and farmers in dryer states had to rely on irrigation, like canals or pumpsets. This initial "curse" that induced a state to look for alternative sources of water might have been the reason why some states, who were better prepared to reliably irrigate their crops, ended up introducing these new high yielding but sensitively water-dependant seeds. Sharma and Dak (1989) sustain that "HYV was directed towards areas that were irrigated and not areas that relied on rainfall. The rainfed areas comprising 70% as against 30% of irrigated areas remained outside the fold of green revolution. The new technology was tilted towards areas with better quality lands, assured irrigation facilities and more developed infrastructure". Chakravarti (1972) agrees by stating that "farmers under HYV cannot afford to take chances with erratic rainfall, but 70% of the cropped area in India has rainfall too low or too unreliable to permit their use even during the main cropping season and only 20% of the area is irrigated. Even where the annual rainfall is heavy, the available moisture is insufficient for crop production during winter and premonsoonic seasons. The HYV has been adopted mainly in areas with well developed irrigation facilities." This section will look more in detail at those claims.

The first step is to check whether areas that had to rely on some form of irrigation years before the Green Revolution started ended up successfully adopting the new technology. To this end, a regression that investigates whether states' initial infrastructure have experienced a different evolution in their HYV adoption is run in the following form,

$$HYV_{st} = \beta_{0s} + \beta_{1t} + \sum_{k=1966}^{1984} \gamma_t(IC_{s59} * T_k) + \sum_{k=1966}^{1984} \delta_t(X_{s59} * T_k) + \epsilon_{st} \quad (2)$$

where HYV_{st} is the gross proportion of cultivated land with HYV seeds in state s at time t , IC_{s59} is the state proportion of irrigated land in 1959 and T_k is a year dummy equal to 1 whenever $k = t$. State controls, X_{s59} ,

are included to control for the above mentioned characteristics suspected to be correlated with the diffusion of HYV seeds, such as proportion of literate population, log of real per capita development expenditure, population density and log of real per capita income, all measured in 1959. Additionally, state and time fixed effects are included and errors are clustered at the state level. In an alternative specification IC_{s59} takes the form of 1959's level of agricultural electricity connections per capita. The coefficients of interest in equation (2) are γ_t , where positive and significant values would indicate that states with greater initial levels of irrigation or agricultural connections to the electricity grid have adopted a greater proportion of HYV seeds. Increasing values of γ_t would also indicate that the difference is growing over time.

In the next regression, I investigate whether soil or climate characteristics can be linked to the adoption of the new agricultural technology from 1966 onwards. The variable S_s in equation (3) captures these characteristics identified by the literature as relevant (e.g., Evenson and Mc Kinsey Jr. (1999)) and is interacted with year dummies to follow the importance of S_s on HYV adoption over time. State controls (\mathbf{X}_{st}) are the same as described for equation (1).

$$HYV_{st} = \beta_{0s} + \beta_{1t} + \sum_{k=1966}^{1984} \gamma_t(S_s * T_k) + \delta_t \mathbf{X}_{st} + \epsilon_{st} \quad (3)$$

Three different state characteristics are used for S_s : to account for the availability of abundant groundwater that could be used to provide timely and adequate irrigation, I use the proportion of districts at the state level that have an aquifer thicker than 150 metres. To account for the quality of the land, I use the proportion of districts per state with a topsoil depth of at least 3 metres. Finally, to account for aridness, I use the average annual rainfall at the state level. As mentioned above, if irrigation was more prevalent in dryer areas, the HYV should have been directed towards those areas, leaving states with abundant rainfall to specialise relatively on rainfed crops. The main distinction in the specification of equations (2) and (3) is related to the introduction of state controls. In the former case, as I am testing the effect of initial conditions such as irrigation, I am concerned that variation across states in the initial values of other characteristics are driving the results. For example, it might be the case that what mattered for HYV adoption was the initial level of human capital (e.g., literacy). In the latter regression, I am focusing on time invariant characteristics, so I want to control for changes in potentially relevant variables.

Finally, I run a third specification similar to equation (2) where I include a triple interaction ($S_s * IC_{s59} * T_k$, i.e. geo-climatic characteristics times initial conditions times year dummies) to investigate whether there is a differential adoption pattern in areas with better initial infrastructure and better soil and climate conditions. As all lower levels of interactions are included, values of γ_t would represent the marginal levels of adoption for these states whose more appropriate geographical characteristics for HYV diffusion were complemented with better initial infrastructure.

[Insert Figure 4]

Results are shown in Figure 4 where the estimated γ_t are plotted by year for three specifications. For equation (2) only results using initial levels of irrigation are shown, even though the same pattern holds when using initial incidence of electricity in rural areas. For equation (3), the estimation shows coefficients for the proportion of thick aquifers (i.e. groundwater availability) interacted with time dummies. Results, in magnitude and significance, hold for the other two variables (topsoil depth and average rainfall⁹). Finally, I also include results for equation (2) when using the interaction of year dummies with initial irrigation and groundwater availability. All estimated coefficients after 1966 are significant at the 1% level and show that states with initial irrigation and states with better access to groundwater have become relatively more intensive on HYV seeds. An additional effect for states with more thick aquifers that had greater initial investment on infrastructure is also present. This is consistent with the idea that a combination of good geo-climatic conditions and investment in infrastructure fosters the adoption of technological change in the agricultural sector. Additionally, the difference increases over time, suggesting that initial conditions determined the fate of states at the start and then the process reinforced itself.

The depth in the diffusion of the Green Revolution can be, in part, attributed to initial conditions and geographic characteristics. From now on, I will always use the measure of abundant groundwater as a proxy for geographical characteristics (S_s) and the net proportion of irrigated area in 1959 as the measure for initial conditions (IC_{s59}). This exogenous variation will be later used in an instrumental variables strategy to address endogenous agricultural technological adoption and expansion of the electricity network.

⁹For "average rainfall", coefficients are negative, sustaining the previous point that arid areas, because they had invested more on irrigation, were better prepared to take on HYV seeds.

3.1.2 Instruments power

The empirical strategy will exploit the differential adoption and success of this new agricultural technology in Indian states as a shock to their decision to expand their electricity grid, exogenous to the needs or the performance of their industrial sector. If the instrument is not perfectly uncorrelated with the error term, the consistency of the IV estimator relative to OLS hinges on the power of the instrument, i.e. on how important is the correlation between the instruments, HYV adoption (HYV_{st}) or interactions explored in the previous section ($IC_{s59} * T_k$; $S_s * T_k$, $IC_{s59} * S_s * T_k$), and the instrumented variable, electricity provision (e_{st}). To test the power of the instrument I exploit the time dimension of the panel to test whether the timing at which some states have improved significantly their electricity reach coincides with the start of the Green Revolution.

A first test consists on analysing if the progress of the electricity network has shown a similar pattern of divergence as the one observed for the HYV adoption results in the previous section. To test for this, I follow a similar methodology as in equations (2) and (3), but I use instead the number of agricultural producers' electricity connections per 1000 people as the explained variable and the same measures of geographical characteristics (i.e., the access to abundant groundwater) and initial conditions (i.e., irrigated area in 1959).

Figure 5 shows that states with greater initial irrigation and abundant groundwater have developed more their electricity network. Significance levels have dropped but they still remain always within the 95% confidence interval. and the point estimates suggest that the pattern of divergence observed for HYV diffusion holds for the measure of rural electricity. These findings provide the first piece of evidence towards establishing a link between characteristics that determined the innovation process in the agricultural sector and the subsequent evolution of the electricity supply network.

[Insert Figure 5]

The second test consists on a difference-in-difference regression to see whether states with high levels of IC_{s59} or S_s have observed a differential expansion of their electricity network after the Green Revolution started in 1966, this time using electricity data that starts in 1958. The regression is of the form

$$e_{st} = \beta_{0s} + \beta_{1t} + \gamma(H_s * P_{66}) + \zeta \mathbf{X}_{st} + \varepsilon_{st} \quad (4)$$

where H_s is either IC_{s59} or S_s and P_{66} is a dummy equal to 1 for all years after 1966. Time varying state controls (X_{st}) are included. A positive

and significant coefficient for the interaction term $H_s * P_{66}$, would mean that states whose characteristics are associated with greater HYV adoption have also observed a differential expansion of their electricity network after 1966.

Additionally, a specification of the form

$$e_{st} = \beta_H H_s + \beta_P P_{66} + \gamma(H_s * P_{66}) + \zeta \mathbf{X}_{st} + \varepsilon_{st} \quad (5)$$

would add some relevant information to the picture of the electricity expansion across states. The coefficient β_H represents the difference across groups before the Green Revolution started. A result where the coefficient is not significantly different from zero would suggest that electricity availability was not statistically different across states before the introduction of the new seeds. The coefficient β_P captures how states with relatively lower values of H_s have performed after the start of the Green Revolution. A positive and significant coefficient would mean that these states have significantly expanded their network on average after 1966.

[Insert Table 2]

Results are shown in columns (1) to (3) in Table 2. In line with the idea that states with more suitable geographical characteristics or better initial conditions have developed relatively more their electricity reach with the start of the Green Revolution, the estimated coefficients for the interaction terms are all positive and significant. Again, results are shown for values of groundwater thickness and initial irrigation, but the pattern of results holds for different measures of IC_{s59} and S_s and for different measures of electricity expansion e_{st} . Results in column (3) refer to equation (5), where state and time fixed effects are dropped and estimates of the coefficients for H_s and P_s can be obtained. Both coefficients are insignificantly different from zero. Regarding β_H , this suggests that the mean agricultural reach of the electricity network was not substantially different across states in the years before the Green Revolution. With respect to β_P , the result suggests that the mean agricultural connections to the grid for the states with lower values of H_s has not changed after the Green Revolution. This result can probably be explained by the great variation across states with low initial irrigation or without thick aquifers that drive standard errors up.

To see whether this wedge in the evolution of electrification according to states' groundwater availability and initial irrigation also holds for the variable of interest in the second stage, i.e. industrialization, columns (4) to (6) in Table 2 show results for a difference in difference regression where manufacturing output is the explained variable. In all cases states with characteristics shown relevant for HYV adoption observe a differential increase

in industrial output. It is also interesting to see in column (6) that before the Green Revolution, these states were relatively less industrialized as the negative coefficient on groundwater availability shows.

A third specification looks at the time dimension only and tests whether there is a structural change in the provision of electricity with the start of the Green Revolution. To do this, I run

$$e_{st} = \beta_{0s} + \theta_1(t - 1958) + \theta_2(t - 1966) + \zeta \mathbf{X}_{st} + \varepsilon_{st} \quad (6)$$

where the estimated θ_1 and θ_2 provide information on whether the evolution of the electricity provision before and after 1966, respectively, increases significantly. Additionally, I introduce an additional test to the power of the instruments by interacting them with the time terms as follows

$$e_{st} = \beta_{0s} + \beta_{1t} + \theta_1(t - 1958) * H_s + \theta_2(t - 1966) * H_s + \zeta \mathbf{X}_{st} + \varepsilon_{st} \quad (7)$$

As in the case of the difference-in-difference specification, the same regressions are run using the log of manufacturing output per capita on the left hand side. Table 3 shows results for all four regressions. In column (1), there is no apparent change in electrification between 1958 and 1966. A different pattern emerges after 1966 where the number of agricultural connections increases with time. Column (2) shows that states with more abundant groundwater were under a slightly different evolution before the Green Revolution but the gap widened both in magnitude and significance afterwards. When analysing changes in industrial output, columns (3) and (4) show interesting results. There is no apparent change before and after the Green Revolution when all states are put together, as in column (3). However, in column (4) it becomes apparent that the industrial output in states with thick aquifers was falling behind before 1958, but this trend turned over with the Green Revolution. Once again when states are divided along the dimension of groundwater availability a wedge in both electrification and industrialization emerges, adding confidence to the suitability and power of the chosen instruments.

[Insert Table 3]

This section has shown that the period that followed the introduction of HYV seeds in 1966 is contemporaneous with a divergence in the electricity supply across states, in particular when states are divided along dimensions that determined HYV suitability. Additionally, a similar pattern emerges for a set of reduced form regressions of the outcome of interest, manufacturing output, on the same characteristics, adding confidence to the instrumental strategy. The next section will build on these findings in a two-stage least

square (2SLS) strategy to obtain an estimate of the impact of electrification on measures of industrial development.

3.2 Two-stage least squares results

In this section I present estimates of λ in equation (1) where e_{st} is replaced by $\hat{e}_{st} = f(S_s * T; IC_{59s} * T)$. That is, I instrument the electricity indicator using the geographical characteristics and initial conditions that, interacted with year dummies, have shown explanatory power with respect to states' divergence in both HYV diffusion and electricity expansion. Additionally, since the adoption of HYV is the channel I claim is at work I also instrument e_{st} with $\hat{e}_{st} = f(H\hat{Y}V_{st}(S_s * T; IC_{59s} * T))$, where $H\hat{Y}V_{st}$ is a generated instrument. Basically, I use the cross state variation in S_s and IC_{59s} , interacted with year dummies, to predict the value of $H\hat{Y}V_{st}$ and use these state and time varying predicted values ($H\hat{Y}V_{st}$) as an instrument for the electricity indicator.

Results are presented in Table 4. In all specifications the log of real manufacturing output per capita is run on the number of farms connected to the electricity network per 1000 people. Column (1) shows OLS results and finds, as expected, a positive and significant correlation between electrification and industrialization. In column (2), the number of agricultural connections is instrumented with the net proportion of area cropped with HYV seeds. There is a small drop in the magnitude and in the significance of the estimated coefficient. However, these results have to be taken with extreme care, since different sources of bias are most likely at work. As mentioned before a source of positive bias could be the presence of reverse causality or unobservable state characteristics, such as the business environment, that are positively correlated with both industrial outputs and infrastructure provision. Sources of bias towards zero could be any unobserved process driving positively rural electrification but at the expense of industrial producers (such as skewed electricity pricing policies) or the presence of attenuation bias because of measurement error in the electricity indicator (produced by illegal connections, theft of electricity, etc. that tend to be widespread in rural areas).

[Insert Table 4 2SLS]

Columns (3) to (7) present results for the instrumental variables strategy that produce more reliable results. In Column (3) the number of agricultural electricity connections is instrumented by the interactions between year dummies and the measure of abundant groundwater availability. Column (7) reproduces it without any state control. Column (4) uses the triple

interaction, adding the proportion of net irrigated area before the Green Revolution. Columns (5) and (6) use the same instruments to predict the values of HYV adoption, that are used as a generated instrument. Across specifications estimated values of λ are positive, significant at the 1% level and slightly lower than the OLS estimate. All first stage F-tests pass comfortably, in line with results in the previous section where I found a strong relationship between states' time invariant geographical characteristics and subsequent expansion of the electricity network. Additionally, in columns (3), (4) and (7) I can carry out overidentification tests of the instruments, that pass with a great margin in all cases. This suggests that instruments are uncorrelated with the error term and correctly excluded from the second stage.

The estimates of λ also suggest that the impact of electrification is substantial: an increase in 1 standard deviation in the number of rural connections implies an increase in 13.5% in manufacturing output. It is important to note that, given the great variation in electricity provision across states, a state at the mean of the distribution would need to double its electricity reach to observe an increase of 13.5 percentage points in the manufacturing outcome. For example, Bihar in 1984 had a real manufacturing output per capita of Rs 1206 and 2.64 farms connected to the network per 1000 people, while Haryana had Rs 2694 and 19.45 connections, respectively. If Haryana's network depth was reproduced in Bihar, the model predicts that the gap in manufacturing output between these two states would be reduced by almost 75 percentage points¹⁰. Bihar's network incidence covered only near 200,000 farms in 1984 and reaching Haryana's level would imply taking the number of total agricultural connections to more than 1,200,000. Even though serving an additional million farming units would be very expensive, the potential expected benefit derived only from the increase in the industrial output per year would be around 45 billion Rupees¹¹. This would constitute an increase of around 7.8% of Bihar's total product per year.

Table 5 show results for other industrial outcomes and when other measures of electricity are instrumented. In column (1) I use the number of factories per capita as the explained variable, in columns (2) to (4) I look at variables for small firms, as classified in the Factory Sector in the Annual Survey of Industries of India and excluded from the Census Sector, i.e. firms

¹⁰Haryana's manufacturing output would be 1.5 times Bihar's, rather than the observed factor of 2.25.

¹¹This is obtained by multiplying the estimated increase in real manufacturing output per capita times total population in Bihar in 1984 (around 74 million people). The value is in 1974 Rupees.

with less than 50 workers (and firms with more than 50 and less than 100 workers that do not use power). In particular, I use information on fixed capital, value added and investment. The idea behind these regressions is that we should expect the expansion of the network in rural areas to create and enhance performance of small factories. As there are not direct measures of rural industries available, I check whether the expected results hold for small industries without distinction of their location. Column (5) looks at the effect of electrification on registered manufactures, i.e. firms with 10 or more employees that use power (or firms with 20 or more that don't use power). In all specifications I run two-stage least squares regressions using the interaction between groundwater availability and year dummies and the variables of interest are positively and significantly affected by the expansion of the electricity network.

[Insert Table 5]

In columns (6), (7) and (8) I use the same procedure running different indicators of electricity availability on manufacturing output. I use the total connected load in Kw per million people (i.e., maximum power available), the number of factories connected to the network and the number of factories using low and medium voltage only, respectively. In all three cases, the pattern of results hold as do magnitudes: a change in one standard deviation in the electricity indicator explains between 11% and 15% difference in manufacturing output.

4 Robustness checks

4.1 Alternative channels

The main concern with respect to the identification strategy is related to the exclusion restriction. If the measure of rural electrification is strongly correlated with other rural outcomes that are actually driving the industrialization process, then the results obtained in the previous section would be spurious. In this section I will explore whether the variation used to identify the effect of electrification can also be used to explain alternative channels for the observed divergence in industrial development. There are many stories in the literature as to why shocks to agricultural productivity would spill over the manufacturing sector. Johnson (1997) points out that rapid increases in agricultural productivity was at the heart of the Industrial Revolution, by releasing (cheap) labour for the manufacturing sector and by creating the agricultural surplus needed to feed the growing population. This argument could be linked to a process of urbanization as

the agricultural sector lays workers off. Matsuyama (1992) formalizes those mechanisms in a model where both sectors compete for labour and where exogenous increases in agricultural productivity benefit the manufacturing sector. This mechanism only works in closed economies, since comparative advantages in the agricultural sector might deprive industries from labour in open economies. In that case, effects on industrialization could go either way¹². Murphy et al. (1989a) propose a mechanism where industrialization happens because positive shocks to agricultural productivity boost rural income and, subsequently, the demand for manufactures. An important point for the proposed mechanism to work, is that benefits from agricultural productivity increases are fairly distributed if they are to sustain a sizeable demand to the manufacturing sector¹³. Additionally, the increase in rural incomes might affect saving rates in rural areas and, subsequently, credit availability.

In short, the shock to agricultural productivity introduced by the Green Revolution might have affected industrial outcomes in different ways. In all cases, the instruments would be correlated with error of the baseline regression and the instrumental strategy would lose validity. It follows that, if these alternative channels are operating, variables that determined the feasibility of HYV seeds (e.g., groundwater availability) could also be used as instruments in a similar strategy to the one I used to identify λ in equation (1).

To test whether the results obtained for electrification hold for urbanization rates, changes in the demand for manufacturing goods or in funds available to invest via credit I reproduce the same steps as before, i.e. check whether instruments remain powerful and valid. The dependent variables used are the proportion of rural population, the average per capita monthly expenditure in rural areas and real per capita non-agricultural rural credit.

[Insert Table 6]

Columns (1) to (3) in Table 6 take a look at the first stage and test whether the variation in $H\hat{Y}V_{st}$ (predicted value of HYV adoption estimated using year and groundwater availability interactions) can explain variation in urbanization rates, non agricultural rural credit and expenditure. In all three cases, results suggest that variation in HYV adoption is not signifi-

¹²India, being a very large federal country could be thought as a collection of open economies. In that case, the mechanisms described by Matsuyama could be present.

¹³This could undermine the argument when applied to India, since it is well documented (see for example, Dhanagare(1989)) that the Green Revolution has increased the rift between poor and rich farmers and, in some cases, has not even increased poor peasants' real incomes.

cantly linked to either of the three variables. The pattern of results holds for different specifications, e.g. using the actual values of HYV adoption or when running a set of regressions similar to equation (3) using variables for the three alternative mechanisms on the left hand side. It has to be noted that these results do not mean that the Green Revolution had no impact whatsoever on rural incomes or on urbanisation rates. As a matter of fact, the opposite is true. This can be observed in the mean levels captured by state dummies and not in the variation in the adoption of HYV seeds. For example, the mean rural expenditure per capita in Punjab and Haryana is between 2 and 2.5 standard deviations greater and the proportion of rural population is between 5 and 11 percentage points lower than in Bihar. This shows that, conditional on states' mean, the variation exploited as an instrument has no effect on the variables of interest for alternative explanations. In the first stage at least there is a sharp contrast with the power the same instruments had with the measure of electrification.

Columns (3) to (7) look at the second stage using different specifications. Columns (3), (4) and (5) show that a two-stage least squares strategy similar to the one used with electrification would not provide the expected results as the variable of interest is never significantly different from zero. Column (6) drops state controls and finds no change in the significance of rural expenditure, reduces first stage significance and does not pass the overidentification test, i.e. instruments are correlated with the error and should not be excluded. This can also be compared with column (7) in Table 4 where dropping state controls did not weaken the 2SLS strategy on the electrification measure. Finally, column (7) instruments mean rural expenditure using \widehat{HYV}_{st} and again finds no effect on industrialization and has very weak first stage. Unreported results show that this results are reproduced when using rural population and non agricultural credit as the instrumented variable.

The importance of the information provided in Table 6 lies in ruling out alternative explanations to electrification in the empirical strategy. As mentioned before these results are not telling that these other variables are unimportant or did not reflect differences across states, but simply that the variation used to instrument for the measure of electrification can not be used to explain variation in urbanization rates, credit availability or expenditure in rural households. The use of state fixed effects in all specifications means that I exploit within state variation as well as cross state and only in the case of the electricity measure this variation shows explanatory power to understand states' divergence in industrial development.

4.2 District level analysis

The analysis presented so far looks at variation within states across time only. A good reason for focusing on states' variation is that each state has its own electricity network, run at the state level by the State Electricity Board. An implication of the story portrayed in this paper is that the expansion of the network aims at reaching areas intensive in HYV seeds, but given the network characteristic of electricity provision, intensity in HYV is not necessary. For example, a district whose soil or climatic characteristics are not suitable for HYV seeds might still benefit from this process of electrification if surrounded by districts intensive in HYV seeds. Unfortunately, I could not find information on electricity supply at the district level over time. However, some progress can be made using the district level data available from the World Bank's "Agricultural and Climate Dataset", gathering information on agricultural outcomes, geographical characteristics and input availability for 271 districts across 13 Indian states from 1956 to 1987.

As a first step, I check the robustness of the first stage to add confidence to the use of the Green Revolution as a natural experiment. In particular, I run a similar set of regressions as in Section 3.1 where the level of HYV adoption is explained by the interaction of time invariant state characteristics (e.g., abundant groundwater or initial irrigation) and year dummies. Exploiting within district variation using district fixed effects I use the following specifications

$$HYV_{dst} = \beta_{0ds} + \beta_{1t} + \sum_{k=1966}^{1984} \gamma_t(S_{ds} * T_k) + \delta_t \mathbf{X}_{dst} + \epsilon_{st} \quad (8)$$

and

$$HYV_{dst} = \beta_{0ds} + \beta_{1t} + \sum_{k=1966}^{1984} \gamma_t(IC_{ds59} * T_k) + \sum_{k=1966}^{1984} \delta_t(X_{ds59} * T_k) + \epsilon_{st} \quad (9)$$

As in the analysis for the state level, S_{ds} is a measure of groundwater availability (a dummy that equals 1 if the district has aquifers thicker than 150 metres and 0 otherwise) and IC_{ds59} the proportion of irrigated land before the start of the Green Revolution. A third specification is introduced, where I replace the explained variable in equation (8) by a constructed measure of electrification. As mentioned before, there is no information on availability of electricity at the district level. Using state level data on

electricity, I generate a variable that takes the number of agricultural electricity connections and multiplies it by the rural population in the district divided by the rural population in the state and by the total cropped area as a proportion of total area at the district level. This measure is somehow a conservative estimate of farm electrification since it allocates state connections according to the proportion of rural population and cropped area without weighting districts according to their intensity in the introduction of HYV seeds or in their agricultural productivity, phenomena that would be associated with more demand for electricity connections.

Figure 6 plots the estimated γ_t for the three specifications. As shown for the state level regressions, districts with greater groundwater abundance and more initial irrigation are associated with a greater and increasing proportion of adoption of HYV seeds. Estimates for the interaction terms are positive, significant and increasing, meaning that there is a positive marginal effect for districts with adequate geographical characteristics and for districts with better initial infrastructure. These results hold for other geographic characteristics, such as topsoil depth. Finally, there is a positive gap for districts with more abundant groundwater in the measure of agricultural connections. This set of results are consistent with the findings at the state level and provide more evidence that validate the choice of instruments.

[Insert Figure 6]

Now I turn to the analysis of whether electrification is a result of the Green Revolution or not. An alternative story with respect to the placement of the electricity network might be that what actually matters is groundwater availability and not HYV adoption, because households or rural industries pump groundwater for their consumption for example. To test this I run a difference-in-difference estimation for a cross section of districts in 1974 where I use a measure of rural power availability at the district level¹⁴ as the explained variable and the interaction between the measure of groundwater availability and adoption of HYV seeds. A setback to my story would be to find that power availability is not driven by the Green Revolution but by the thickness of the watertable. Column (1) in Table 7 shows that this alternative explanation does not hold. The coefficient on groundwater availability is negative, suggesting that districts with thick watertable that are not intensive in HYV have on average less rural power. This undermines the argument that what mattered for the placement of electricity connections was exclusively water availability. Furthermore, the coefficient on HYV is

¹⁴Collected and published only for 1 year by the National Commission on Agriculture, Ministry Of Agriculture and Irrigation of India.

positive, showing a positive correlation between HYV adoption and power in districts without a watertable thicker than 150 metres¹⁵. Finally, the coefficient for the interaction term is positive, significant and greater in magnitude than the estimates for each of the levels. That shows that districts adopting HYV and with thicker watertables were those with greater rural power availability. Overall, total effects of HYV adoption and groundwater are positive, as expected. This result provides evidence in favour of the second link of my empirical strategy (i.e., from Green Revolution to electrification).

[Insert Table 7]

Finally, I use a similar procedure to test the channel going from electrification to industrial outcomes. To this purpose I use census data at the district level on employment in the rural manufacturing sector for every 10 years from 1961 to 1991. I generate a dummy variable equal to 1 for districts with power availability in the top 25% of the distribution and I interact it with the measure of HYV adoption. As previously mentioned districts that have not intensively adopted HYV seeds might benefit from accessing to an electricity network that has expanded to serve those areas intensive in HYV. The difference-in-difference estimation will show whether rural manufacturing employment is linked to HYV adoption (irrespective of power availability), to power availability (irrespective of HYV adoption) or to the interaction of both. Column (2) in Table 7 finds that only the measure of electrification is positively and significantly correlated with the proportion of the rural population working in the manufacturing sector. The sign of HYV adoption is negative, even though not significant. This suggests that districts intensive in HYV with low levels of electrification have less people working in the manufacturing sector. The interaction term is positive, but insignificant. Column (3) uses a measure of the proportion of rural workers employed in the manufacturing sector. The three coefficients have the same signs but now are all significant. Again, HYV adoption without electrification is linked to less employment in the rural manufacturing sector. The interaction is positive, meaning that districts intensive in HYV and rural power have more manufacturing workers. Overall, the effect of HYV is slightly positive. The overall effect of rural electrification in the proportion of rural workers is again positive and significant, irrespective of whether the district is intensive on HYV seeds or not. These results adds confidence to the claim that rural electrification can be linked to an increase in the importance of the manufacturing sector and reduces concerns regarding the exclusion restriction by suggesting that HYV adoption affects outcomes in

¹⁵Of course water can be obtained from shallower watertables.

the rural manufacturing sector only by means of electrification.

5 Discussion

A natural question to ask is why the evolution of states seems very much determined by circumstances in the initial stages of the Green Revolution. What was impeding underperforming states, aware of their neighbours successful experience, to catch up with them or to attempt an overhaul of their agricultural sector? Results suggested that initial output per capita or initial levels of industrialization didn't explain why some states succeeded in introducing the new seeds or in developing their electricity sector. As an example, Punjab and Haryana whose manufacturing output was around 66% of West Bengal's in 1966, caught up to the same levels in less than 20 years after the Green Revolution started.

The first circumstance that seems important to note is that expanding the production possibilities in the agricultural sector was deemed fundamental and "increasing food shortages and mounting concern for immediate gain in production led to the shift in developmental priorities. Consequently, agriculture was given top priority in rural development and efforts were concentrated since early sixties in selected areas with high production potential (...) The change in strategy is accompanied by drastic changes in the developmental organisation,...., credit and input supply infrastructure". (Sharma and Dak, (1989)). As it was mentioned in the previous sections, the achievements associated with the Green Revolution depended on a set of circumstances that went from the having the right institutions to adequate soil conditions and financial help for farmers (subsidies, controlled prices). That means that introducing HYV seeds and obtaining quick and sizeable results implied shifting significant amounts of state resources towards the agricultural sector. One explanation why that might have been difficult to execute has to do with the endogenous formation of lobbies. Sharma and Dak (1989) document that government loans and subsidies were directed towards large landlords, increasing the rift between rich and poor farmers and, as a consequence, social tensions in rural areas. Richer landlords were also better prepared to exploit the potential gains: more educated, better access to credit via collateral and with better political connections. Dhanagare (1989) estimates that "the prosperity unleashed by the Green Revolution was distributed differentially, putting the small and marginal farmers at a relative disadvantage. The high cost/high yield technology called for capital investments beyond the means of a majority of small and marginal farmers."

Simple estimations show more than a 20% correlation between HYV adoption and inequality in rural areas. With a stronger economic position, rural rich farmers also developed a political leverage that was translated into further subsidies. In particular, Gulati and Narayanan (2003) show how what they call "the subsidy syndrome in Indian agriculture" after the introduction of the new seeds in late 60s became a fundamental instrument of economic policy that was mainly channelled through available and affordable fertilizers, irrigation and electricity. Concerning the latter, the State Electricity Boards were in charge of supplying and pricing electricity and their subsidies constituted more than 40% of total subsidies on average. Dhanagare also points out that "only the needs of rich farmers were catered by the electricity boards", since while the unit price was heavily subsidized, connection charges were so expensive that only rich farmers could afford them. The formation of a powerful farming lobby, or the lack of one, might explain the uneven development of the Green Revolution across states.

The importance of lobbies in shaping the Indian electricity sector policies is mentioned in Rud (2006), where the pricing policy of a regulator is determined by the weight given to a particular lobby in the welfare function. The leverage of the farmer's lobby is denoted by λ_A , a coefficient between 0 and 1 where 1 means that the regulator fully accounts for farmers' surplus in the objective function. The optimal price in the simplest case with just one lobby and full information, would be $p = \frac{c\eta}{\eta - 1 + \lambda_A}$ where c is the marginal cost of producing electricity and η is the demand elasticity. If the ability to lobby in this case is proxied by the level of HYV adoption, then a lower price of electricity should be observed in states more intensive in HYV seeds. This idea seems to be confirmed by the data. Figure 7 shows the correlation between HYV intensity and the ratio average tariff/unit cost of electricity for the years 1974-1984. States that have been heavily subsidising agriculture have done so at the expense of huge deficits in the operating balances of the State Electricity Boards, consistently bailed out by the central or state governments. It is widely accepted that the pricing policy is at the heart of those deficits (Tongia, 2003). The correlation is around -50%, showing that the Green Revolution has indeed been accompanied by heavy power subsidies at the state level and that pattern holds even when excluding states more intensive in HYV such as Haryana and Punjab from the sample.

[Insert Figure 7: HYV and Pricing Policy]

All this suggests that the lobby of rich agricultural producers has gained a lot of power in states where the Green Revolution succeeded. The farmer

sector in the remaining states might have remained weaker, at least relatively to other lobbies like unionised workers or urban industrial producers. Besley and Burgess (2004) show that unions gained a lot of power in states like West Bengal or Maharashtra, where since the 70s many "pro-worker" amendments to labour regulation have been introduced. In their state-wise classification, Haryana and Punjab, the two frontrunners in the expansion of HYV seed adoption, remain neutral, meaning that they can't be classified as "pro-worker" or "pro-employer". This would be consistent with the suggestion that the lobby that "captured" state's government attention was precisely a third one, the farming lobby. In the case of Punjab, Simms (1988) describes a situation in which "farmers are aware of the power they hold due to their strategic importance in the national economy (...) Political action has led to extensive changes in rural Indian Punjab". Describing a rally organized by one organization of farmers, Simms points out that "the state government was thrown off balance by their show of force and conceded many of their demands". Tongia (2003) stresses that reforms to the State Electricity Boards towards a rational pricing policy faced opposition from farmers who relied on cheap electricity and from some politicians who used the electricity supply for political patronage. Similarly, rural electrification "has swayed in strong political winds".

There are many hints insinuating that the formation of strong lobbies in the agricultural sector shaped the evolution of economic policy in Indian states. This paper suggests that industrial producers have indirectly benefited from an agricultural-led expansion of the electricity network. However, despite their impressive growth, agriculture persists as the main economic activity in this period: in 1984 the agricultural sector in Punjab and Haryana was almost 50% of total output. It still remains to be seen what the evolution of those states's industrial sector would have been if cross-subsidies in electricity pricing or other pro-farmer and anti-industrial policies demanded by their strong farming lobby were not implemented. Similarly, there is an unanswered question regarding the evolution of non-HYV states and why their industrial sector never picked up or remained virtually unchanged (e.g., West Bengal had a steady level of manufacturing output in the period analysed in this paper.) All this calls for more research focused on the political economy of lobby formation at a state level and their influence on state and central policy in India. Investigating economic causes and consequences of the rise and actions of political power groups might help to understand the different paths followed by Indian states since independence and could shed light on similar circumstances occurring in other developing countries with large regional variation.

6 Conclusion

The idea that infrastructure is a motor for economic change, expanding and diversifying production possibilities to, ultimately, reduce poverty is not new. In the years following the Second World War, the World Bank directed a large proportion of its government loans towards infrastructure projects in underdeveloped regions. At least two thirds at its peak, but not below 40% at its lowest, infrastructure lending remained, until the 90s, the heart of World Bank's activity (World Bank (2006)). The interest in publicly provided infrastructure declined in the 90s, mainly because the increasing involvement of the private sector. In recent years, the development agenda has gradually focused again in the power of infrastructure in improving economic conditions.

Despite this renewed interest the literature has not provided a substantial amount of empirical investigations aiming at quantifying the effects of infrastructure provision on output and at understanding the circumstances under which governments invest in infrastructure. The latter becomes important if the empirical strategy is to overcome the estimation challenges of endogeneity and omitted variables. This paper suggests that the dissimilar evolution of electricity provision in Indian states can be understood by looking at the exogenous determinants of the introduction of a new agricultural technology, intensive in irrigation, in the late 60s. The need for timely irrigation, that can be supplied by pumping water from the water table using electrified pumpsets, generated a growing demand for electricity and subsequent expansion of the electricity grid in some states. This paper also investigates why some states adopted the new technology while others did not. Two-stage least squares estimations show that between 10 and 15% of the differential level in manufacturing output can be explained by the adequacy of the electricity provision across Indian states. These findings go hand in hand with the idea that investment in infrastructure might contribute to a "big push", by allowing industrial producers to blossom.

There is a some preliminary evidence in the analysis that opens a whole new line of research into the mechanism that ensures that the infrastructure needs of a group will be satisfied by the government. Anecdotal evidence and some raw numbers suggest that the role of politically and economically strong interest groups might not only explain why some sectors are preferentially catered for but also why these groups gather power in the first place. In the case of India, but not exclusively, the investigation of endogenous lobby formation would allow a better understanding of the nature of regional disparities in infrastructure provision and economic outcomes.

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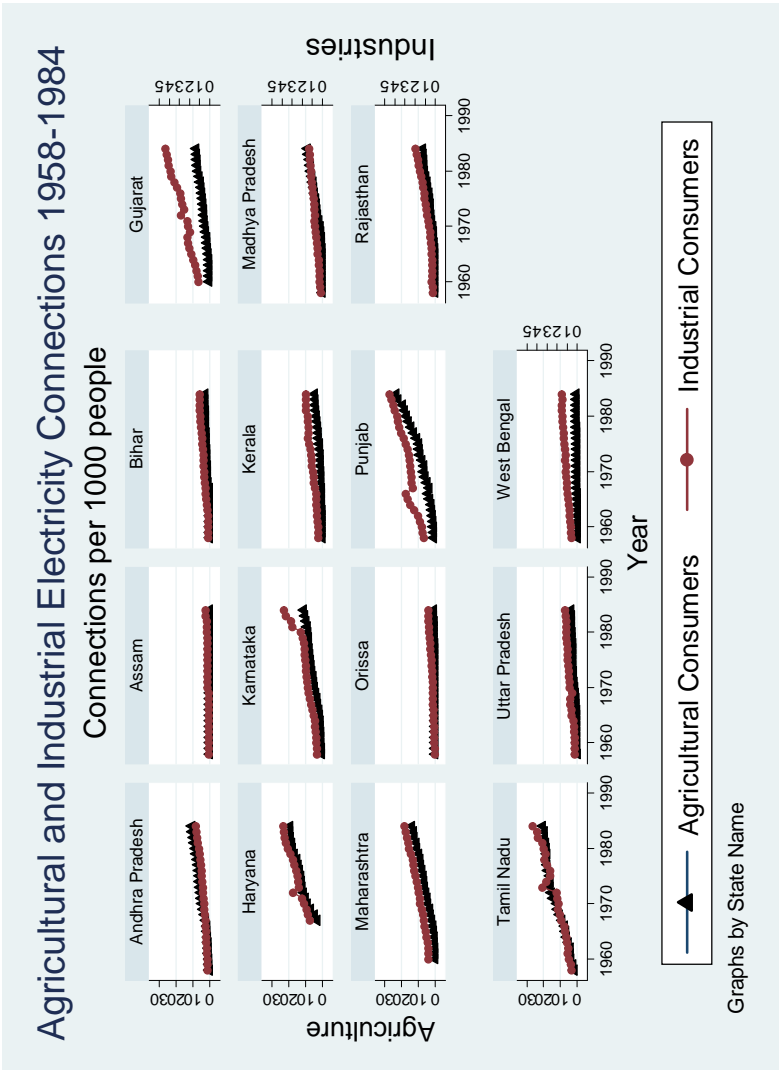


Figure 1: Electricity connections by consumer type

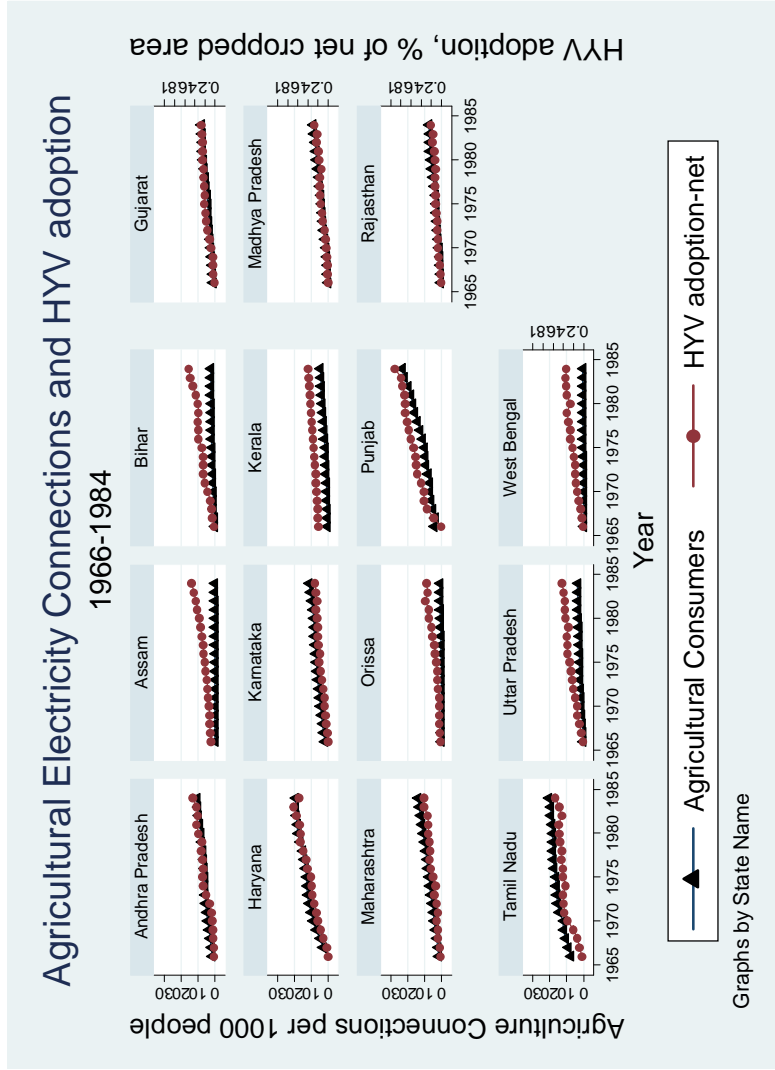


Figure 2: Agricultural Electricity Connections and HYV adoption. Data on HYV not available for Jammu & Kashmir.

Variables	Mean	Std. Dev.	Min	Max
<i>Agricultural Connections (per 1000 people)</i>	4.04	5.18	0	23.24
<i>HYV adoption (% from 1966)</i>	0.23	0.17	0	0.92
<i>Log Manufacturing Output per capita</i>	7.00	0.55	5.98	8.30
Geographic Variables				
<i>Abundant Groundwater (% of Districts)</i>	0.11	0.19	0	0.6
<i>Top Soil (% of Districts)</i>	0.48	0.35	0	1
<i>Average Rainfall (mm, annual)</i>	292.5	137.4	66.3	557.7
Initial Conditions (year 1960)				
<i>Irrigated Area (%)</i>	0.19	0.14	0.06	0.54
<i>Agricultural Connections (per 1000 people)</i>	0.46	0.89	0	3.54
Controls				
<i>Population Density</i>	0.23	0.15	0.02	0.68
<i>Literate Population (%)</i>	0.37	0.13	0.13	0.82
<i>Log Total Credit per capita</i>	4.70	0.98	2.49	6.76
<i>Congress Party Vote (%)</i>	39.72	10.78	8.8	56.3
<i>Log Development Expenditure per capita</i>	-6.16	0.76	-8.05	-4.62

Table 1: Descriptive Statistics

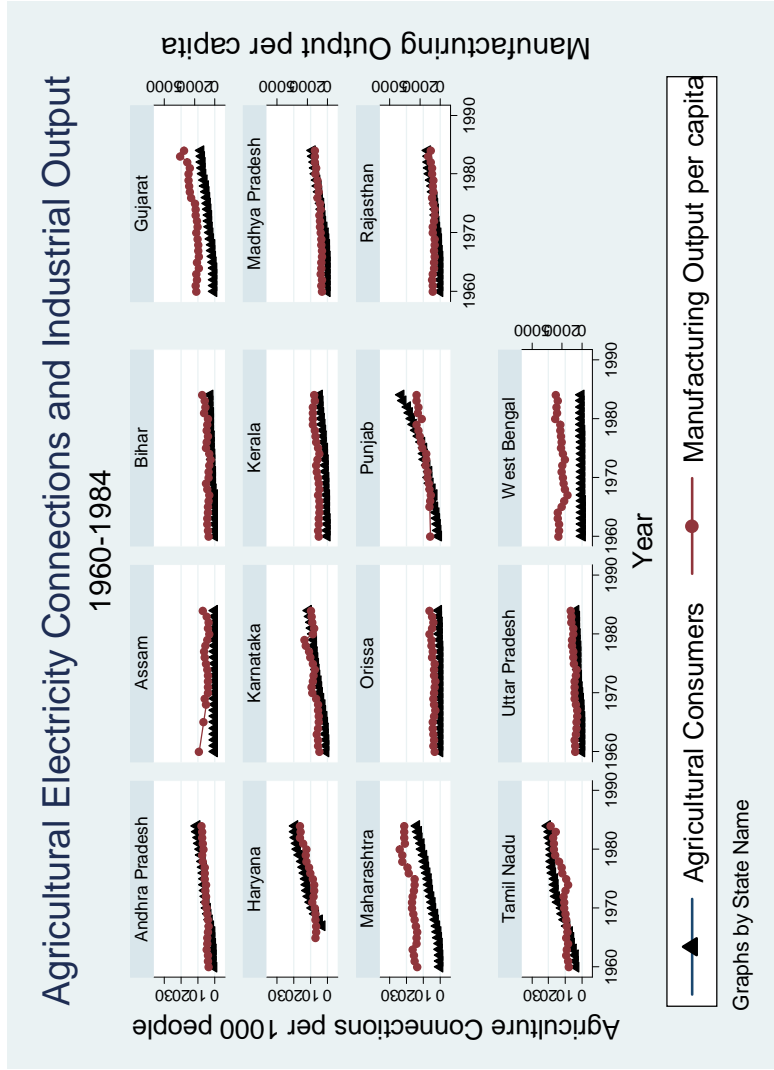


Figure 3: Agricultural Connections and industrial Output

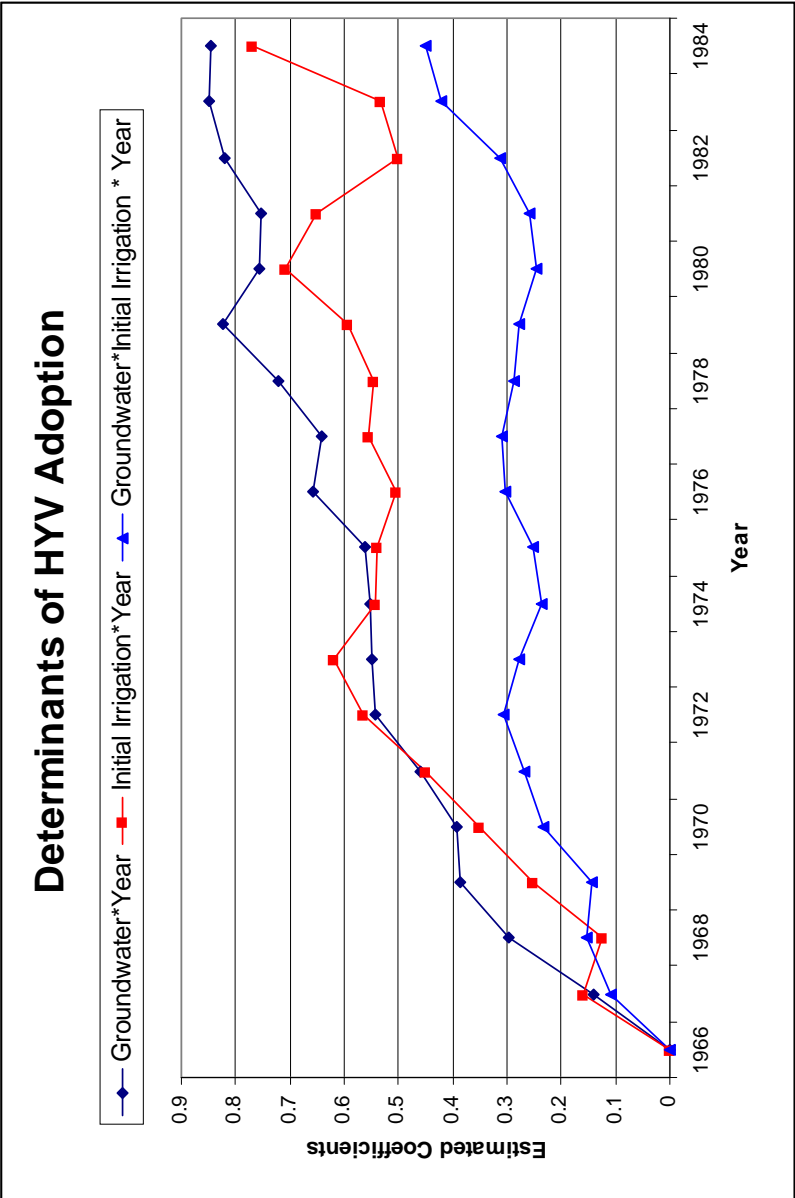


Figure 4: Drivers of HYV. Plot of estimated coefficients γ_t : Diffusion of HYV as a function of groundwater availability and initial irrigation

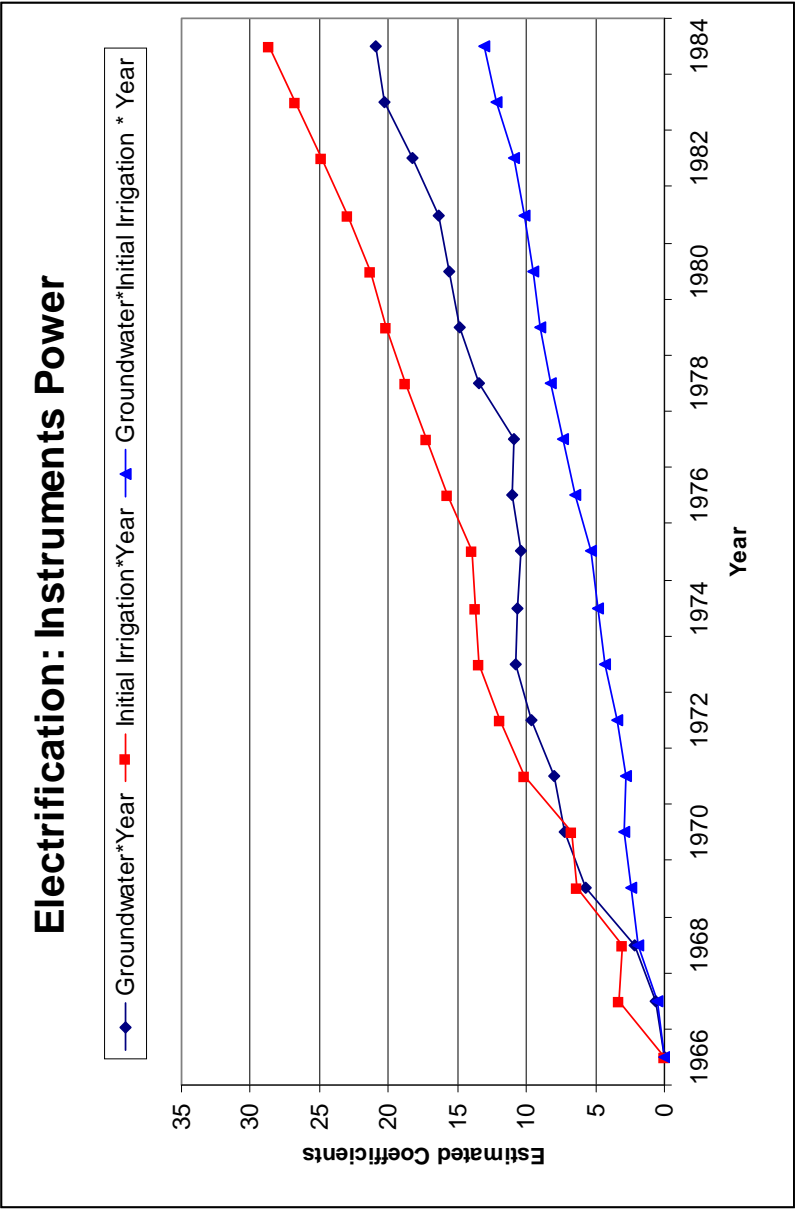


Figure 5: Instruments Power. Plot of estimated coefficients γ_t for agricultural electricity connections as a function of groundwater availability and initial irrigation

	(1)	(2)	(3)	(4)	(5)	(6)
	Agricultural Connections			Log Manufacturing Output		
Groundwater * Post 66	11.12 (1.53)***		11.75 (4.30)**	0.77 (0.19)***		0.83 (0.25)***
Initial Irrigation * Post 66		14.89 (2.21)***			0.83 (0.33)**	
Groundwater			0.48 (4.26)			-0.80 (0.36)**
Post 66			0.13 (1.05)			-0.13 (0.08)
State Fixed Effects	Yes	Yes	No	Yes	Yes	No
Year Fixed Effects	Yes	Yes	No	Yes	Yes	No
State Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	405	405	405	375	375	375
Adjusted R-sq	0.90	0.90	0.67	0.93	0.93	0.80

Robust standard errors in parentheses, clustered at the state level. * significant at 10%; ** significant at 5%; *** significant at 1%.
 "Agricultural Connections" is the number of agricultural units connected to the electricity network per 1000 people (data: 1958-1984). "Log Manufacturing Output" is the log of real per capita manufacturing output (data:1960-1984). "Post 66" is a dummy equal to 1 for all years from 1966. "Groundwater" is the proportion of districts per state with aquifers thicker than 150 mfs. "Initial Irrigation" is the proportion of cropped area irrigated in 1959. Controls are: population density, literacy, log of total credit pc, log of development expenditure pc, Congress Party vote, party of the Chief Minister.

Table 2. Difference in difference estimates of agricultural connections and manufacturing output in states with characteristics suitable for HYV seeds after the start of the Green Revolution.

	(1)	(2)	(3)	(4)
	Agricultural Connections		Log Manufacturing Output	
Year-1958	0.05 (.052)	-0.04 (0.35)	0.06 (0.09)	0.014 (0.007)*
Year-1966	0.47 (0.10)***	0.47 (.09)***	-0.001 (0.016)	-0.006 (0.013)
Groundwater * (Year-1958)		0.39 (0.19)*		-0.09 (0.02)***
Groundwater * (Year-1966)		1.09 (0.13)***		0.03 (0.01)**
State Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	No	No	No	No
State Controls	Yes	Yes	Yes	Yes
Observations	405	405	375	375
Adjusted R-sq	0.90	0.90	0.93	0.93

Robust standard errors in parentheses, clustered at the state level. * significant at 10%; ** significant at 5%; *** significant at 1%.
 "Agricultural Connections" is the number of agricultural units connected to the electricity network per 1000 people (data: 1958-1984). "Log Manufacturing Output" is the log of real per capita manufacturing output (data:1960-1984). "Year-1958" is equal to the number of years after 1958, measured every year until 1966. "Year-1966" is the number of years after 1966. "Groundwater" is the proportion of districts per state with aquifers thicker than 150 mts. Controls are: population density, literacy, log of total credit pc, log of development expenditure pc, Congress Party vote, party of the Chief Minister.

Table 3: Time breaks in agricultural connections and manufacturing output

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Log Manufacturing Output						
	Instrumental Variables						
	OLS						
Agricultural Connections	0.026 (0.007)***	0.024 (0.010)**	0.023 (0.007)***	0.021 (0.005)***	0.024 (0.006)***	0.024 (0.006)***	0.041 (0.006)***
Instruments	n/a	HYV	Groundwater * Year	Groundwater *Initial Irrigation* Year	Gen HYV Groundwater * Year	Gen HYV Groundwater* Initial Irrigation* Year	Groundwater * Year
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes	Yes	Yes	No
Observations	300	300	300	300	300	300	300
Over-identified P-value	n/a	n/a	0.82	0.89	n/a	n/a	0.89
First Stage F-Test P-value	n/a	<1%	<1%	<1%	<1%	<1%	<1%

Robust standard errors in parentheses, clustered at the state level. * significant at 10%; ** significant at 5%; *** significant at 1%. "Agricultural Connections" is the number of agricultural units connected to the electricity network per 1000 people. "Log Manufacturing Output" is the log of real per capita manufacturing output. "Groundwater" is the proportion of districts per state with aquifers thicker than 150 mts. "Initial Irrigation" is the proportion of cropped area irrigated in 1959. "HYV" is the net proportion of area cropped with HYV seeds. Controls are: population density, literacy, log of total credit pc, log of development expenditure pc, Congress Party vote, party of the Chief Minister. The First Stage F-Test is a test of the power of the instruments, sustained when null is rejected (low P-value). Over-identification tests instruments validity, where not rejecting the null (high P-value) suggests that instruments are correctly excluded and uncorrelated with the error. All data are from 1965 to 1984.

Table 4: 2SLS results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Proportion of rural population	Rural non agricultural credit	Mean rural expenditure per capita			Manufacturing Output		
Generated HYV	0.0005 (0.0005)	31.30 (77.7)	4.95 (13.4)					
Proportion of rural population				14.46 (9.55)				
Rural non agricultural credit				0.002 (0.002)				
Mean rural expenditure per capita				-0.004 (0.004)		0.006 (0.005)		0.19 (0.30)
Instruments	Groundwater * Year	Groundwater * Year	Groundwater * Year	Groundwater * Year	Groundwater * Year	Groundwater * Year	Groundwater * Year	Gen HYV Groundwater * Year
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Controls	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Observations	300	300	300	300	300	300	300	300
Over-identified P-value	n/a	n/a	n/a	0.46	0.20	0.58	0.06	n/a
First Stage F-Test P-value	n/a	n/a	n/a	0.83	0.99	<1%	0.12	0.53

Robust standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. "Agricultural Connections" is the number of agricultural units connected to the electricity network per 1000 people. "Log Manufacturing Output" is the log of real per capita manufacturing output. "Groundwater" is the proportion of districts per state with aquifers thicker than 150 mts. "HYV" is the net proportion of area cropped with HYV seeds. Controls are: population density, literacy, log of total credit pc, log of development expenditure pc, Congress Party vote, party of the Chief Minister. The First Stage F-Test is a test of the power of the instruments, sustained when null is rejected (low P-value). Over-identification tests instruments validity, where not rejecting the null (high P-value) suggests that instruments are correctly excluded and uncorrelated with the error.

Table 6: Exclusion restriction. Testing alternative mechanisms.

HYV Adoption and Electricity (Indian Districts)

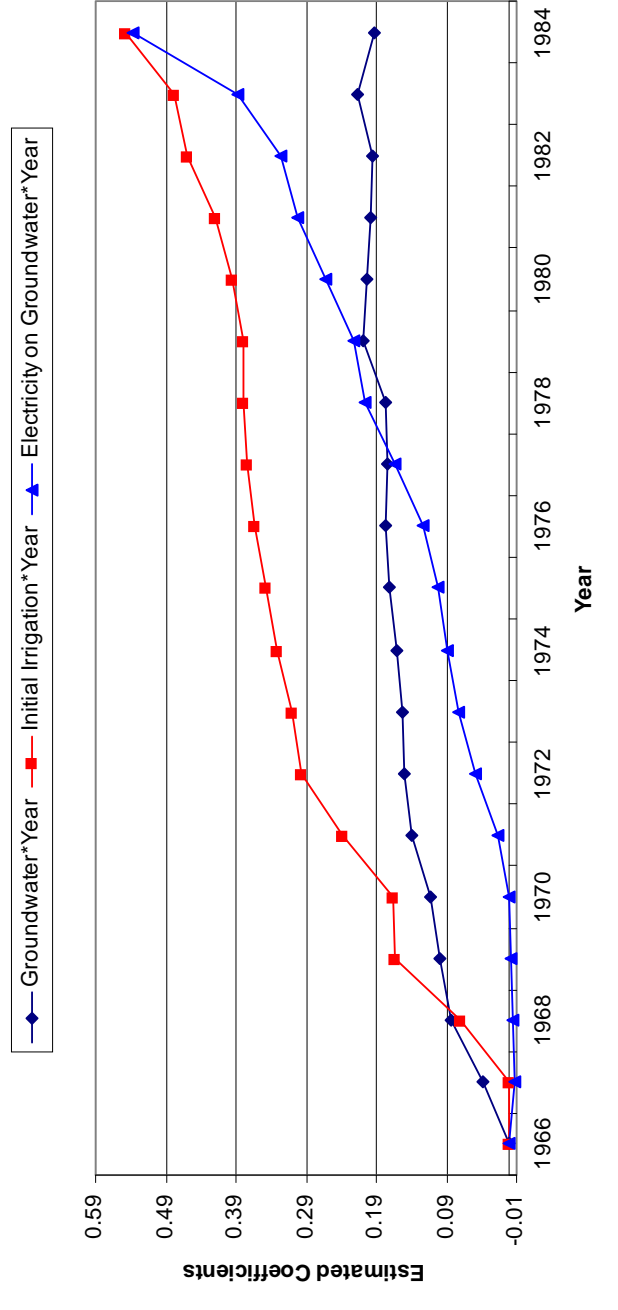


Figure 6: Plot of estimated coefficients γ_t : Diffusion of HYV and electricity as a function of groundwater availability and initial irrigation using data at the district level.

	(1)	(2)	(3)
	Power Availability	% Rural Population	% Rural Workers
Groundwater	-0.25 (.066)***	0.06 (0.09)	
Groundwater * HYV	1.27 (0.26)***		
HYV	0.52 (0.13)***	-0.004 (0.003)	-0.013 (0.007)*
Power Availability		0.024 (0.0009)***	0.005 (0.002)**
Power Availability * HYV		0.003 (0.002)	0.015 (0.007)**
Observations	271	763	763
Adjusted R-sq	0.40	0.58	0.62

Robust standard errors in parentheses, clustered at the state level. * significant at 10%; ** significant at 5%; *** significant at 1%. "Power availability" is a measure, in horses per hectare, of power in rural areas. "Groundwater" is a dummy equal to 1 if the district has aquifers thicker than 150 mts. "HYV" is the net proportion of area cropped with HYV seeds. Controls are: population density, literacy, roads and bullock per hectare. Column (1) uses data for 1974. Columns (2) and (3) use Census data for 1961, 1971, 1981 and 1991.

Table 7: Difference-in-difference analysis at the district level.

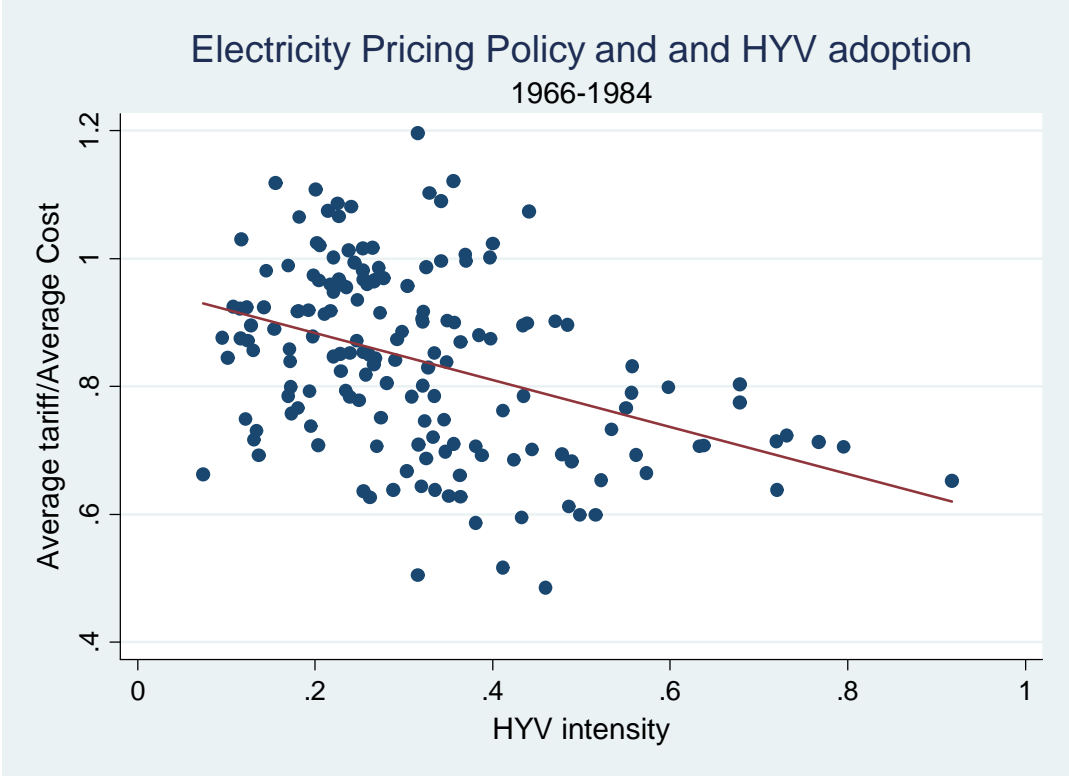


Figure 7: Intensity in HYV is correlated with less sustainable pricing levels across and within state over time