ACCESS TO RELIABLE ELECTRICITY AND ITS IMPACT ON DEVELOPMENT

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by

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In the memory of Madhuri Bajpai, who was the most amazing human being, a fierce feminist and lucky for me, my Nani. She was capable of finding the best in people and making them feel loved even if they didn't see it in themselves.

Abstract

No developed country has low energy consumption. This observation has prompted developing countries to aspire to emulate developed countries into a growth path of high energy consumption through massive electricity access programmes. scholarships looking at causal relationships between energy consumption and development do not support a strong relationship, leading to confusion for policy makers about how to proceed with electricity expansion programmes. India has had the second most rapid electricity access expansion in this millennium, after China but has not achieved the same level of development as China. The electricity in India is decidedly of lower quality than other countries with power cuts being ever present. In the absence of concrete scholarship, electricity has been provided to households but there has been no assurance of hours per day, therefore seemingly being very successful but leading to concrete developmental outcomes. This thesis investigates this relationship with reliable, high quality electricity access and its impact on impacts socioeconomic development.

Chapter 1 investigates the spread of the grid itself and the factors that drove village connection. This paper tracks the rural electrification policy in India from 1947 to 2015 and evaluates the financial, political, and social drivers of the evolution of the electricity grid over time. It uses survival analysis with two survey data sets. In line with previous studies, the paper confirms that cost is an important consideration in the electrification process throughout this period: greater distance from the grid reduces the probability of the village getting electrified. However, it finds other factors are also in play, such as the caste composition of the village, and the caste and gender of the village head. Finally, the number of poor households in the village has a negative and significant effect on the probability of electrification, indicating that the incentives of the distribution company play into the electrification policy.

Chapter 2 examines data spanning two decades (1994-2015), over 41,000 households and nearly 150,000 individuals across 30 Indian states to understand whether the quality of electrification matters for development. The paper finds that good-quality electrification is crucial to increasing individual incomes and that only a sufficiently reliable electricity supply is able to secure these benefits for women in particular. Greater labour force participation and a shift from precarious to non-precarious work are identified as the likely mechanisms through which these gains accrue to individuals. The results suggest that policy targets should focus more explicitly on the quality

of electrification.
Chapter 3 uses data from two survey waves covering over 41,000 households and nearly 9000 children in India to examine the links between the reliability of electricity available to households in India and children's learning outcomes and the intervening mechanisms. The results show strong positive links between the reliability of electricity and the probability of children achieving higher maths, reading and writing scores. The two most plausible channels of transmission for these effects are found to be increased time spent on homework and fewer days missed at school. Both girls and boys benefit from more reliable electricity, with no systematic gender differences. These results hold using an alternative, more fine-grained classification of electricity reliability, and there is evidence for causal relationships. The results suggest that reliable electricity is an important component of reaching basic educational policy goals in a developing country context.
Chapter 4 offers an examination of the use of appliances in households with different levels of income and over different vintages of electricity connection. The paper finds that most households keep using very basic appliances even after 5-6 years of having an electricity connection. Most households use electric lighting, a charging point and a fan or TV. There is no significant 'appliance ladder' where households who are using electricity for a while begin using more sophisticated appliances: the data show that households do not in fact move to more and more sophisticated appliances. There is also continued use of kerosene, which previous literature shows has negative health effects. The data also show that appliances that may reduce unpaid household labour are taken up by very few households, implying that this lack of an appliance ladder is particularly serious for women.

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Introduction


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[1]This image has been generated using the AI DALLE by using keywords from the chapter in the style of the artist Henri Mattise and Andy Warhol's colours

Introduction

In a world that is increasingly interconnected and digital, a universal and functioning electricity sector is the lifeblood of modern functioning economies. There is no such thing as a low energy-consuming developed country: every country that has grown wealthy and is growing wealthy has used energy to get there. This strong relationship has launched aspirations for every developing or least developed country to increase the access to electricity to its citizens.

India recently declared 100% village electrification; it is the fastest pace of electrification by any country. According to the International Energy Agency, between 2015-2018, 80% of all households electrified were in India. This is quite impressive and these policies are being adopted by Kenya and Nigeria, for example, seemingly quite successfully. The 7th Sustainable Development Goal aims to electrify the world by 2030. With seven years to go, this is a good time to evaluate progress and impact and ask: does electricity access spur economic development?

Despite the rush to electrify across countries, scholars have reached no consensus on the impact of electricity access on people's well-being at a microeconomic level. The expectation has been that electricity access means that households will use it, change their time allocation and increase paid work and reduce non-paid work. In reality (as we show in Chapter 4), 30% of households that get a new connection in India get disconnected again from the grid, and on average households don't get electricity at all times.

This thesis tries to disentangle the links between electricity access and development through the lens of the quality and reliability of electricity. We analyse data at three levels – village, household and individual. We disaggregate individual-level data into adults and children and also look into gender differences within these two demographic groups.

This thesis is written in the form of four self-contained papers, linked under a common theme. There follows a brief outline of each chapter.

The spread of the grid

Chapter 1 tracks the rural electrification policy in India from 1947-2015, comparatively evaluating the financial, political, and social drivers of the evolution of the electricity grid over time. We use survival analysis with two survey datasets. We introduce caste groups and caste-based discrimination in India and then examine the rate of electrification of villages over time and the relevant importance of cost-based, identity-based and political parameters. While the non-parametric results indicate swifter electrification for the majority-Brahmin and slower electrification for the majority-Scheduled-Tribe villages, the parametric estimates suggest only that villages with a larger share of 'other backward classes' got electrified later. However, non-parametric results also suggest that caste-based differences have been disappearing in the most recent years. In line with previous studies, we confirm that cost is an important consideration in the electrification process throughout this period: greater distance from the grid reduces the probability of the village getting electrified. A village with a female head and a head from a lower caste gets electrified later. Finally, the number of poor households in the village has a negative and significant effect on the probability of electrification, indicating that the incentives of the distribution company play into the electrification policy.

Income and employment

Connecting every household to the grid is pointless if nobody gets any useful hours of electricity. Electrification is often seen as a silver bullet for economic development but little or no attention is paid at the policy level to the reliability of the electricity supply. In Chapter 2 we examine data at the household and individual levels. We use data spanning two decades (1994-2015) and over 41,000 households across 30 Indian states to understand whether the quality of electrification matters for development. Using three different types of instruments for the quality of electricity, we show that good-quality electrification is crucial to increasing individual incomes and that only a very reliable electricity supply is able to secure these benefits for women in particular. Greater labour force participation and a shift from precarious to non-precarious work are identified as likely mechanisms through which these gains accrue to individuals. Our results suggest that policy targets should focus more explicitly on the quality of electrification.

Education achievement

In Chapter 3, we further examine the individual-level data for children to analyse the links between the reliability of electricity available to households in India and children's learning outcomes, as well as the intervening mechanisms. This is an interesting outcome from the point of creating a long-term virtuous cycle and inter-generational impact of electricity. Our results show strong positive links between the reliability of electricity and the probability of children achieving higher maths, reading and writing scores. We also find that the two most plausible channels of transmission for these effects are increased time spent on homework and fewer days missed at school. Both girls and boys benefit from more reliable electricity, with no systematic gender differences. These results hold using an alternative, more fine-grained classification of electricity reliability, and we find evidence for causal relationships. The results suggest that reliable electricity is an important component of reaching basic educational policy goals in a developing country context.

Intensity of electricity use

Finally, in Chapter 4, we examine the use of electricity, in terms of the adoption of appliances. This paper sheds light on the relationship between electricity access and well-being in India through a detailed examination of the use of appliances in households with different levels of income and over different vintages of electricity connection. The paper finds that most households tend to use very basic appliances even after 5-6 years of having an electricity connection. The data show that there is a cycle of at least a decade and a half for households to get to a minimum basket of electrical appliances, which seems linked to both affordability and reliability challenges. The households take up to 3-4 years to transition across each step, and overall about 9 years to reach a bundle of appliances that is close to the average in urban areas. This cycle has to be reduced so that households can fully benefit from electricity. Most households use electric lighting, a charging point and a fan or TV. There is no significant 'appliance ladder' where households who are using electricity for a while using more sophisticated appliances: the data show that households do not in fact keep moving to more and more sophisticated appliances. There is continued use of kerosene, which previous literature shows has negative health effects. We also find that appliances that can reduce unpaid household labour are taken up by very few households and hence, this lack of an appliance ladder is particularly serious for women. Finally, we examine a dimension of electricity quality based on voltage fluctuations. The reliability of electricity has increased, with fewer power cuts over the years. However, the lower number of power cuts is not enough: the quality of electricity should be good so that households are able to run appliances without significant voltage fluctuations.

Chapter 1

What has driven electrification in India?

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1.1 Abstract

This paper tracks the rural electrification policy in India from 1947-2015 and evaluates the financial, political, and social drivers of the evolution of the electricity grid over time. We use a survival analysis with two survey datasets. While the non-parametric results indicate swifter electrification for majority Brahmin and slower electrification for majority Scheduled Tribe villages, the parametric estimates suggest only that villages with a larger share of other backward classes got electrified later. However, non-parametric results also suggest that the caste-based differences have been disappearing in the most recent years. In line with previous studies, we confirm that cost is an important consideration in the electrification process throughout this period: greater distance from the grid reduces the probability of the village getting electrified. Finally, the number of poor households in the village has a negative and significant effect on the probability of electrification, indicating that the incentives of the distribution company play into the electrification policy.

Keywords: Energy, electrification, survey, villages, India, survival analysis

1.2 Introduction

This paper tracks the rural electrification policy in India from 1947 − 2012 and evaluates the financial, political, and social drivers of the evolution of the electricity grid over time. Access to electricity or electrification is globally considered an important policy goal, exemplified by the aim of Sustainable Development Goal 7 for universal electrification by 2030, agreed and ratified by 193 countries including India United Nations 2015. By 2005, 55% of Indian villages were electrified, but electrification was uneven across different states Office of the Registrar General & Census Commissioner 2011 Therefore, the Government of India (GoI) introduced a village electrification policy making electrification the joint responsibility of the central and the state governments but primarily managed by the central government. This programme was named Rajeev Gandhi Grameen Vidyutikaran Yojana (RGGVY) after the sixth Prime Minister of India. This led to more rapid progress as the RGGVY was the first policy in India that had an explicit target for village and household electrification.

The RGGVY policy aimed at intensifying electrification efforts by allocating money to states that chose to participate in the scheme; all 27 Indian states participated in the scheme (the union territories had already achieved complete electrification). The policy provided a subsidy for poor households, but not for communities that have been historically discriminated against such as the so-called 'lower castes', recognised as the Scheduled Castes and the Scheduled Tribes under the Indian constitution. Modern Indian politics has always been influenced by the caste system (e.g., Sen 2012),[2] and years of discrimination

[2] The caste system is a complex hierarchical structure of endogamous groups, i.e. groups characterised by marriage within the same social group (Omvedt 2006). Even though the caste system is hierarchical, the political system need not be, as voters in the Indian democracy may vote into office candidates of their own caste to ensure they bring changes for them and their group. However, there is also evidence of significant political over-representation of the so-called upper caste (see e.g., Louis 2003) and therefore lower castes are often disadvantaged in a political quid pro quo.

have led to systematic under-provision of services to these communities. Special provisions are important to ensure they rapidly electrify. In the RGGVY policy, however, there is no set principle on how to prioritise or order the provision of electricity to different villages.

In the absence of any rules on the order of electrification, the logical step in theory is to begin where the costs are lower. Setting up an electricity grid is a cost intensive exercise. Distance from infrastructure for a village is important because of the nature of costs of electrification: there are economies of scale in electrification and the costs are significantly higher for the basic grid infrastructure and lines than for extending the lines into the villages (see Chakrabarti and Chakrabarti 2002).[3] If the progress of electrification were unbiased and based on cost consideration alone, then for every city/district, controlling for distance from large cities,[4] there should be equal probability of getting electrified. With other words, the probability of villages at the same distance from the nearest major city getting electrified should be equal. We test this basic hypothesis and examine whether instead villages with a higher population of disadvantaged groups are provided electricity later than villages with higher populations of advantaged groups. In an alternative specification, we also analyse whether results hold for the number of hours of electricity supplied.

We apply a time-to-event or survival analysis to examine the implementation of India's electrification policy, using cross-sectional data from the large Indian Human Development Survey (IHDS) and Access to Clean Cooking Energy and Electricity – Survey of States (ACCESS) dataset. The results show little or no effect on electrification for the so-called lower caste groups, i.e. the scheduled castes (SC), scheduled tribes (ST) and other backward classes (OTB). While the non-parametric results indicate swifter electrification for majority Brahmin and slower electrification for majority ST villages, the parametric estimates are only consistently significant for the OTBs, suggesting that villages with a larger share of OTBs got electrified later. It is important to note that while in the past there appears to have been some caste-based selection for electrification of villages, the non-parametric results also suggest that the caste-based differences have been disappearing in the most recent years, which would be in line with a successful RGGVY policy.

Results are much clearer for the cost measures: as in previous studies, we find that cost is an important consideration in the electrification process throughout this period. Greater distance from the grid, proxied by distance of the village from the nearest road and town, reduces the probability of the village getting electrified. Most interestingly, the number of poor households in the village has a negative and significant effect on the probability of electrification. This may be explained by the fact that the poorer households get electricity at a concession, which reduces the revenue expected from the electrified villages. At the same time, it may indicate that the targeting of poor households, which is a stated aim of the RGGVY policy, has been unsuccessful, though our datasets cover only the first seven years after the policy's implementation.

The rest of the paper is organised as follows: Section 2 reviews the literature on the drivers of electrification and Section 3 provides contextual background on the caste system in India and the electrification policies. Section 4 provides details of the dataset used in the analysis and Section 5 on the methodology. Section

[3]Another variable that factors into electrification costs in India is electricity theft. There is no official estimate but studies have estimated that 20% of electricity produced is lost due to theft or fraud Razavi and Fleury (2019) . In the official accounting these thefts are counted under the transmission and distribution losses and are borne by the State Electricity Boards (SEBs).

[4]There are certain priorities for policy makers, such as electrification of the capital city and major cities where electrification is required for strategic reasons or political functioning.

6 presents results and Section 7 concludes.

1.3 Literature Review

We contribute to two strands of literature. The first is the relatively small literature on electricity access and its drivers, which generally finds cost variables to be among the most significant factors. Kemmler (2007) uses data for 15 states in India and applies a discrete choice model to identify what variables lead to use of electricity in households and villages. The unit of analysis is at the state level. They test the hypothesis that electrification depends on three categories of variables. The first is the infrastructure and financial health of the State Electricity Board (SEBs) measured by the length of lines installed per unit of state area and the transmissions and distribution (T&D) losses incurred by the state. The second is the economic structure of the state, whether it depends on agriculture, industry or services. The third is the geographical endowment of the state measured by the density of villages in the state and difference in altitude within the states (to account for terrain). They find that the infrastructure variables are significant – length of lines is positively related and the T&D losses are negatively related to probability of village electrification. States that have large agricultural areas but where the economy does not depend solely on agriculture have the highest share of electrified villages in India. They identify state area and density of villages as the most significant factors. They conclude that the larger states, particularly large states with many small villages, become the most difficult to electrify.

Oda and Tsujita (2011) look at the Indian state of Bihar using survey data from 2008. Their unit of analysis is at village level. They use the same model as Kemmler (2007), and find that the location of the village, measured as distance from the state capital, is the most important determinant of electrification. They don't find occurrence of floods in the area as a significant variable, even though the state of Bihar is prone to flooding but they conclude it may be because of their weak proxy variable. They also find a difference in electrification in villages based on the majority religion of the village: villages with a Muslim majority are electrified faster because of more political activism or clout. Dugoua et al. (2017) use the ACCESS survey 2015 and 2011 census data to check for impact of cost and socioeconomic factors in determining the electrification of a village. They use cross sectional regressions to explain electrification rate using distance, caste composition and surface area of the village. They find that the variable for distance becomes insignificant in the 2015 survey data but find the caste variables to be significant in both the regressions. They conclude that distance and surface area of the village are no longer determinants of electrification but villages populated by lower castes are less electrified. They also show that within a village, lower caste households have 14-15% less electricity access than other castes.

The previous analysis covers small areas in the country, we use a nationally representative survey to evaluate electrification efforts at the village level all across the country and a second survey to zoom into the states that made the slowest progress into electrification. We expand on these contributions by applying a different methodology to two different survey data sets and focusing on an extensive set of socio-economic factors relevant for India, thereby adding to our understanding of which factors drive electrification in India and how robust previous findings are through a holistic evaluation.

Our paper also contributes more generally to the substantial literature on the provision of public goods in developing countries, which often finds that large infrastructure projects like roads in India (e.g., Asher and Novosad 2020) and electricity in Brazil (e.g., Lipscomb et al. 2013) improve village income and development, though the impact is not always very large. Asher and Novosad (2020) for example find that rural roads in India do not have a transformational effect on the village economy, though having a feeder road does increase the movement of workers out of agriculture.[5] Of particular relevance for our study is the subset of studies that look at how political factors influence public goods provision and development in general. Asher and Novosad (2017) analyse close margin elections at constituency level in India and found that in constituencies with close elections, the ones that had electors from the ruling party grew significantly faster than the others. They conclude that political favouritism impacts resource allocation and it is large enough to impact economic growth.[6] Closer to our study unit, Dutta (2012) in a comparative study of two *panchayat* elections, which are the local village elections in India, find that the village head or the *Pradhan* is influenced by dominant groups in the village in terms of class and caste. Bardhan et al. (2009) found that the villages in which the *Pradhan* and other members were a close ally to the party at the state level, the Communist Party of India (M), were the largest beneficiaries of any government scheme. This is because the village *Pradhan* signs off on the completion certificate of village schemes. What emerges from these studies is that caste and political affiliation continue to play an important role in many aspects of Indian society, which further justifies our focus on these factors for explaining electrification.

1.4 Background

1.4.1 The Indian caste system

The caste system is a complex set of hierarchical social groups that divide Indian society. It is commonly believed to have its basis in the Hindu religion, but many scholars disagree with that and suggest it was formed more recently. One of the most striking features of the system is endogamy (i.e. marrying only within the social group), but exogamy is possible for some groups (Omvedt 2006). The term 'caste' today is, technically speaking, social groups called 'varna'. There are four varna: in hierarchical order from the top, the Brahmin (the priests), Kshatriya (the warriors), the Vaishyas (traders) and the Shudras (the working class). The communities not covered under these terms were outcastes and were believed to not have any caste. The society is also divided into 'jati' that are a form of social groups that do not have any universally accepted definition. Some jati could identify themselves through a region, some through a common language or dialect, and some through a mixture of language, dialect and religion. Historically, these two societal structures could be seen as separate or as one system, based on the jati's own decisions, and the words were rather fluidly used. However, under British rule of India, the census system created a strict rule and people were to report their caste, which was then ascribed to them permanently Clark-Decès 2011. British society at the time was divided by class, and the British interpreted the existing

[5] This is important as for example Gollin et al. (2014) found that labour productivity in non-agricultural sectors in 151 countries is higher than in agricultural sectors, and point to transport bottlenecks as a reason.

[6] In a related contribution, Faccio (2007) found that in 74% of all countries in the world there were political connections in firms. Politicians try to seek rents, the most extreme example in the paper was Russia where politically connected forms had 87% of market capitalisation. Therefore, the implication is that the board members (politicians) would benefit from this form of corruption. Sukhantar 2012 found evidence of embezzlement in Maharashtra in India: in election years, politically controlled cane mills paid lower prices to cane farmers (note that sugar cane farmers have a higher income on average that the median voters).

societal structure through the lens of the class system. The system evolved to become a mixture of the varna, jati and the class system. The data used in this paper reports the jatis and categorises them into Varnas. We use the more popularly used terms "caste" (for Varna) and "sub-caste" (for jati) in this paper.

The constitution of India recognises this system of historical injustice and has made provisions for affirmative action in the form of reservation in government jobs and educational institutions. The constitution provides for a list or 'Schedule' where it covers different categories of castes:

- Scheduled castes (SCs): Under Article 341 of the Indian Constitution, the people who belong to the so-called outcastes or untouchables are covered in this category. This category covers primarily people who follow Hinduism, but people who converted to Sikhism or Buddhism (but not Christianity) to escape discrimination are also covered.
- Scheduled tribes (STs): Under Article 342, the aboriginal communities of India are covered under the ST schedule and get the same benefits as the SCs. The STs may not adhere or subscribe to Hinduism and could follow any religion.
- Other Backward Classes (OBCs): These are castes/groups that get a protection in the Indian constitution but were never the untouchables and are firmly within the Hindu religion. This category was created in 1992 as an amendment to the constitution due to political demands.

The constitutionally backed affirmative action was supposed to be a temporary measure until there has been a historical correction and the different caste groups are evenly placed. The GoI sets up commissions at different intervals to check if this has been achieved. In British India, some of the higher caste people were given reservations in the government and certain castes and tribes were deemed criminal just by birth. Hence, the system has long perpetuated wealth and income inequality in India (Louis 2003). An example of village-level discrimination is when some of the jatis, who had the task of cleaning and waste collection, were deemed as untouchables, and were treated literally so. This led to segregation of communal resources in the villages such as the village well, with the higher caste groups often owning these resources. There is evidence that this is practised with water resources (Omvedt 2006).[7] There is no literature that checks if this resource segregation extends to energy resources, especially electricity, which is difficult but not impossible to isolate. The lower castes could be spatially segregated and may live in separate villages or even in the outskirts of the same village.

1.4.2 A brief history of electrification in India

Electrification attempts in India have come in bursts or waves. There are three distinct periods of electrification efforts: 1900-1947, 1947-1990, and post 1991 (see Palit and Bandyopadhyay 2017). These periods are distinguished by ownership of resources and lack (or encouragement) of market mechanisms. The first period started by introducing basic regulations for safety and security of the grid network and establishing the laws based on which electrification would pan out. The second period was driven by state

[7] The impact of affirmative action in India is still unclear; many of the previously deemed untouchable jatis have stopped practising their traditional professions. However, many of the cleaning jobs today are still occupied by the people belonging to the untouchable jatis.

ownership and responsibility for generation, transmission and distribution of the power. The current period has seen steady liberalisation and allowing markets to develop. The consumer end, which is the distribution sector, is still largely state controlled. However, post 2015, the state is now encouraging entry of private players through distributed generation (such as mini-grid or solar rooftop-based generation). This summary focuses on the electricity distribution sector in India post-1947, i.e. the second and third phases.[8]

In the second, post-independence phase from 1947-1990, there was a recognition of the importance of electricity as a basic need. Policy makers strongly believed electricity was important for development and that it should be developed quickly and without focus on commercial profit (Palit and Bandyopadhyay 2017). In principle, the state and centre shared responsibility for electrification but in reality it was implemented by the states. The tax from electricity was a major part of the state revenue (Kale 2014). Each state or Province had its own State Electricity Board (SEB); these still exist today. The SEBs were large and vertically integrated monopolies and provided for generation, transmission, distribution of electricity. SEBs are also responsible for providing electricity access to everyone in their state. The aim was to create geographical coverage and to achieve 'industrialisation'.

In 1951, India started the system of five-year plans (FYP) under the Planning Commission of India. The first and the second FYPs (1951-56 and 1956-61) focused mostly on providing electricity to cities, towns and peri-urban areas, with special emphasis on industry. There was no explicit target for villages. The SEBs were free to set 'cost reflective' tariffs, which led to higher tariff in rural areas because of high demand and economies of scale in urban areas. This became a political problem and was seen as being against the spirit of the law. Therefore, the Electricity (Supply) Act was amended in 1958 and directed SEBs to take approval from the State government before setting the tariffs, and especially before making any capital expenditure. This created perverse incentives for state governments to politicise tariffs, and these were often used as a political tool in campaign promises (Kale 2014).

Around this time, India was also going through a period of food shortage and the focus of electricity provision in rural areas was shifted to irrigation to increase productivity of agriculture. Through the 1960s, the focus of rural electrification was towards pump-set electrification, and electrification of the households was a co-benefit. The focus on pump-set irrigation paid off and this was followed by the period of increased agricultural productivity popularly known as the 'green revolution', which saw a steady increase in economic growth and electrification. Since household electrification was not the focus, the definition of an electrified village was comprised of two factors: first, a village was deemed electrified if the grid had been extended to the village; and second, if one connection had been energised in the 'revenue area' of the village.

Throughout this period, the SEBs were mandated to ensure rural electrification beyond the productive needs of the agricultural sector. However, in practise, the pursuit of pump-set electrification with the goal of food security led to the SEBs' indebtedness, and the Boards started compromising on reliability. This led to either complete blackouts at select times or 'brownouts', where electricity was available but of low voltage and could not be used. The Boards were not able to price electricity at cost and often had to do

[8] We focus on post-1947 because it is the year of independence of India. At that time, only around 1500 of the then 560,000 villages in India were electrified, which was less than 0.3% of the total population (Palit and Bandyopadhyay 2017). Therefore, any electrification efforts pre-1947 were limited and not of great relevance for village electrification.

it well below costs.

To tackle these issues, in the third, post-1991 phase, India started the process of liberalisation, market reforms and reduction in the central state's interference in the market. In terms of the electricity sector, this meant building a national-level electricity market, breaking the vertical monopoly of the SEBs. However, the distribution sector was still largely held by the state. In 1997 the Ministry of Power declared that a village would be deemed electrified if electricity was used in the inhabited area of the village. Also, intervention by the judiciary established the Right to Electricity as a fundamental right under Article 21 of the Indian Constitution. This meant that both the state and central government became legally responsible for providing electricity (Palit and Bandyopadhyay 2017).

The electrification policy, RGGVY, aimed at complete village electrification of India by 2009 through the accelerated electrification of 100,000 villages and 10 million households. The scheme was not successful in completing electrification by 2009, but it did manage to build electricity infrastructure (Ministry of Power 2010). The scheme also lead to a comprehensive definition of electrification: 'A village will be deemed to be electrified if: basic infrastructure such as distribution transformers and distribution lines are provided within the inhabited locality; electricity is provided to public places like schools, panchayat offices, health centres, dispensaries, community centres etc. and *the number of households electrified should be at least 10% of the total number of households in the village* (emphasis added).'[9]

To summarise, the distribution of electricity in India today is still largely the responsibility of the state and is heavily regulated. The SEBs are responsible for electrification but are not allowed to increase tariffs to reflect increasing costs without consulting state government, who find increasing tariffs difficult to explain politically. The SEBs therefore end up compromising on the quality or quantity of electricity. Of note also is the fact that the definition of 'electrification' has evolved over time, and that village electrification was not a policy priority for a long time as most policies until quite recently targeted agricultural electrification. Pre-2005, a village was deemed electrified if electricity was being used anywhere in the village. Post-2005 policies (RGGVY and DDUGJY) define a village as electrified only if at least 10% of households have electricity.

1.5 Data

The paper uses two independent datasets for the analysis. The first dataset is the Indian Human Development Survey (Desai and Vanneman 2005), a cross-sectional dataset covering 1503 villages conducted in 2011-12 covering 31 out of 33 states of India (includes union territories). The dataset collects details on consumption expenditure, gender relations and other development related variables (see Table 1.1 for details). The second dataset is the Access to Clean Cooking energy and Electricity – Survey of States

[9] Post 2015, the Government of India has tried to improve upon the RGGVY policy. While RGGVY was widely seen as a success, there were still some challenges such as the need for rationalisation of tariff as the distribution sector was still under financial pressure and to ensure reduced wastage of electricity. This lead to the new scheme Deen Dayal Upadhyay Gramin Jyoti Yojna (DDUGJY), which subsumed RGGVY with the additional component of separation of domestic and agricultural feeders in rural areas. This would mean an accurate account of the consumption of electricity in rural households and farms separately. The dataset in this paper only covers the period 1947-2011 and does not cover the implementation of the DDUGJY.

Table 1.1: Summary statistics for IHDS 2012, village level

	Mean	SD	Min	Max	N
years since village has electricity	31.30	14.62	0.00	65.00	1369
electrified	0.97	0.17	0.00	1.00	1410
village income(log)	11.34	0.61	9.37	13.60	1408
distance from the nearest town	13.77	11.15	0.00	110.00	1398
number of BPL HHs in the village in the sample	0.19	0.19	0.00	1.00	1410
% SC in the village	20.38	17.67	0.00	100.00	1374
% ST in the village	12.18	25.06	0.00	100.00	1373
% brahmins in the village	5.18	11.82	0.00	100.00	1375
% OBC in the village	40.60	29.56	0.00	100.00	1374
same caste of Pradhan & MLA	0.45	0.50	0.00	1.00	1410
same caste of Pradhan& MP & MLA	0.43	0.50	0.00	1.00	1410
Proportion of village with majority ST	0.12	0.32	0.00	1.00	1410
Proportion of village with majority SC	0.08	0.27	0.00	1.00	1410
Proportion of village with majority OBC	0.40	0.49	0.00	1.00	1410
Proportion of village with majority Brahmin	0.04	0.20	0.00	1.00	1410
Proportion of village with majority Other majority	0.03	0.18	0.00	1.00	1410

(ACCESS) dataset (Aklin et al. 2016). This dataset is a special energy consumption survey covering 756 villages in six of the lowest income states in India for 2015. The ACCESS survey was focussed on assessing the quality and patterns of energy use in India. The dataset has variables at household level on income, expenditure, land holding patterns, level of education etc. The data also has village characteristics such as distance of the village from nearest town, road or capital city, size, caste composition, the year in which the village was electrified, when do the households need electricity and level of satisfaction with the quality of electricity (see Table 1.2 for details). This survey also makes a distinction between grid electricity and electricity from other sources such as micro grids etc and provides the coordinates of the villages. These characteristics are not available in the IHDS dataset.

For both datasets, the number of years electrified denotes the number of years the village has had access to electricity (based on answers given by the village Pradhan). Distance from the nearest town is given in kilometres; the selection of the town is decided by the village Pradhan and the (road-based) distance is checked by the surveyor. The distance of the village from the nearest (non-dirt) road (called *pucca* road) is a measure of how close the village is to other existing infrastructure; the setting-up of a grid is dependent on other infrastructure, as transmission lines run along main roads, because they need large trucks and other commercial vehicles for the construction and regular maintenance (Chakrabarti and Chakrabarti 2002).

The caste variables are some of our main variables of interest in this study. Percentage of a caste group in the village is included because some caste groups have been discriminated against historically, and they have an educational and social disadvantage. *Prima facie*, the advantageous castes such as Brahmin are expected to be favoured. Therefore, a village with higher percentage of Brahmins is expected to be electrified first. The Scheduled Castes (SC) and Scheduled Tribes (ST) are particularly disadvantaged groups and the relationship between the percentage of SC and of ST with the time to electrification/probability of electrification is expected to be negative.

Table 1.2: Summary statistics for ACCESS 2015, village level

	Mean	SD	Min	Max	N
How long ago village was electrified (years)	21.24	13.91	0.10	58.00	606
Grid electricity in revenue village (dummy)	1	0	0	1	714
village income (log)	9	0	8	9	714
distance from the nearest town	21	18	0	110	609
distance from the district HQ	39.00	24.52	0.00	130.00	625
percentage of village poor	0.22	0.21	0.00	1.00	269
percentage of SC households	0.18	0.18	0.00	0.92	713
percentage of ST households	0.10	0.21	0.00	1.00	713
percentage of OBC households	0.48	0.28	0.00	1.00	713
percentage of general households	0.24	0.23	0.00	1.00	713
Pradhan is male(=1)	0.92	0.26	0.00	1.00	714

Number of households below poverty line (BPL) (or village poor) is a nationally maintained poverty-line estimate; this estimate tries to reflect the World Bank's poverty line of people living on less than$2 per day. This definition is different for different states and is translated to expenditure in Rupees per month. These estimates are made by Committees that are appointed by the Parliament. The present analysis uses the Tendulkar committee estimate for poverty line, which was set up by the 16th Lok Sabha (Lower House) and has not been revised yet. This information is important in our context as the electrification policy makes a concession for people living below the poverty line, to ensure that these people get electrified as a priority. However, this adds a burden to the SEBs as the electricity provided to them is at a concessional rate. The expectation of the relationship between the share of poor households in a village and village electrification is not clear: it could be positive because of policy priority, or negative because of the inherent costs.

Political representation variables – beyond caste measures – could also play a role: specifically, there is a possibility of favouritism if the caste of the village head is the same as the caste of the representative for the village at the state level, the Member of the Legislative assembly (MLA), or of the representative at the federal level, the Member of Parliament (MP) representing the village's constituency. The analysis includes three dummy variables which count if the caste of the village head is the same as the caste of the MLA (state level), if the caste of the village head is the same as the caste of the Member of Parliament, and a third dummy if all three are in alignment. We do not have the party affiliation for the three leaders but we use caste as a proxy for their party affiliations.

We use controls for characteristics of the village Pradhan, as s/he has the highest level of decision making power in the village. Given the hierarchical nature of the caste system, a Brahmin village head may be able to better liaison with state officials and able to get his/her village electrified sooner. This can also be true for other characteristics such as gender and religion. The analysis includes dummy variables for gender, caste and religion of the village head. These variables (with the exception of gender) are only available for the IHDS dataset.

Table 2.6 gives an overview of the variables across the two datasets, pointing out which are in common and which are available only in one dataset. Since the efficiency of bureaucracy and the tax revenue available is different in different states, state dummies will be added to the analysis.

Table 1.3: Comparison of variables across IHDS and ACCESS datasets

Name	Measured	IHDS	ACCESS
Caste composition of the village	Fraction of population from different castes in the village	Y	Y
Average income of the village	Monthly expenditure per household	Y	Y
Distance from the nearest town	km	Y	N
Distance from the closest city	km	Y	Y
Distance from district capital	km	Y	Y
Level of Education	% of people who have passed 12 years of schooling	Y	Y
Size of the village	squared km	N	Y
Poverty	Count, percentage	Y	Y
Number of women headed households	Count	N	Y
How long ago was the village electrified	Number of years	Y	Y

1.6 Methodology

We examine the time to electrification for villages in India and test if it is dependent on socio-economic characteristics of the villages in addition to or instead of costs. Since electrification in India is policy driven, the data are not normally distributed but have a step-like characteristic with "bursts" of electrification in some years. The data are also skewed, as over time more and more villages have become electrified. These characteristics of data can be handled using survival or time-to-event models. The time-to-event models are able to analyse data with such a distribution and are also able to analyse the data for "incomplete" observations to describe the distribution of survival time and analyse the main factors affecting electrification of villages.

1.6.1 The model

Four concepts are important in survival models: the event itself, the time to event, censoring observations, and the survival function (Pocock et al. 2002, Kartsonaki 2016). For our datasets, the event is defined as electrification of the village. The starting period of the analysis was chosen to ensure that all the observations have the same baseline treatment. The starting period of the analysis is the year 1947, when the Republic of India was established and was able to implement its own policies.

The time to event is defined as the time it took for the village to get electrified since India's independence, based on survey information on years of electrification of a village. If the event did not occur during the observation period, data is considered to be truncated. If the event happened before the observation period, the data is censored. Depending on the application, censoring could be informative or non-informative, but has to be handled differently because the event time cannot be observed. For the model and application in the current paper (i.e. a proportional hazard model), censoring is non-informative. This means that for the villages that were electrified before the period of analysis, the time of censoring is assumed to be independent of the event time that would have otherwise been observed, given the explanatory variables, to ensure inference is unbiased.

The survival function measures the probability that an observation survives longer than time t, given that it has survived time periods t. In the paper, time is measured in years. In the context of this paper, we are interested in the probability that the village has not been electrified at time t, given that it has stayed un-electrified until that time. Therefore, in the context of the model, electrification of the village is defined as 'failure' because it fails to survive in the sample after we observe the event.

These terms are defined more formally as follows:

Survival function: Let $T \geq 0$ be a random variable representing the survival to electrification time. The survival function is defined as the probability that the village does not electrify beyond time t. It is related to the probability density function, which gives the frequency of electrification per year.

$$(S(t) = P(T > t)), 0 < t < \infty$$

This measures the likelihood that a village will survive (i.e. not get electrified) longer than t.

Hazard function: The hazard function describes the instantaneous rate at which a village is electrified for villages surviving at time t, given by

$$h(t) = \frac{P(T > t)}{\delta t}$$

The hazard function gives the conditional probability that the village will "fail" in the future given that it has survived up to the current time, i.e. the probability that the village can get electrified in the future. The cumulative hazard function is

$$H(t) = \int_0^t h(x)dx$$

The cumulative hazard function is related to the survival function as follows:

$$S(t) = e^{-H(t)}$$

which implies the higher the hazard, the lower the survival time, i.e. the faster the electrification.

There are several types of survival models (Allison 1984) that make different assumptions on the instantaneous hazard rate. The Cox proportional hazard (PH) model evaluates the effect of several factors on survival time: it is a semi parametric model and does not assume the data to be normally distributed. The model evaluates how the given covariates influence the rate of an event. The Cox model assumes the instantaneous hazard rate to be constant. This paper uses both the Cox PH model and the Weibull accelerated hazard model to allow for variable hazard rate, this allows us to contrast these and comment if there was different rates of electrification over time. These two models are briefly described below.

Cox proportional hazard model: The Cox model assumes that the hazard function consists of two parts, a baseline hazard and an exponential function. Formally,

$$h_0(t, x) = h(t)e^{BX}$$

Where, h_0 = baseline hazard rate and BX is the matrix of covariates and associated coefficients

$$h(t, x) = h0(t)e(B1X1 + B2X2 + B3X3 + B4X4 + B5X5)$$

Where,

h() = hazard function for villages
X1 = average income of the village
X2 = distance from the nearest town
X3 = percentage of scheduled caste in the village
X4 = percentage of people below poverty line
X5 = Dummy variable =1 if the caste of the village head, the Member of Legislative Assembly (state level) and Member of Parliament (federal level) is the same

The coefficients for the model give the relationship between the change in the covariates and the hazard function. A unit increase in a covariate leads to the hazard increasing by a multiple of e^{BX}.

Weibull Hazard model: Since electrification was initiated by multiple subsequent policies, the probability of electrification over time may increase. To account for this, we also estimate Weibull accelerated hazard model. The hazard function is

$$h(t, x) = \frac{p}{\delta}(\frac{t}{\delta})^{p-1}e^{BX}$$

where p is a shape parameter calculated from the data. $P > 1$ indicates that the failure rate or the rate of electrification increases over time. δ is the scale parameter and X denotes the vector of covariates. The model is estimated using the maximum likelihood procedure.

To select which model is more appropriate for the data, the assumption of the constant hazard ratio needs to be examined. The Cox model assumes that the ratio of hazard function to the baseline hazard is constant over time. This implies that the failure rate does not increase/decrease over time. For these data, this means that the conditional probability of a village getting electrified is constant over time. There is no clear theoretical answer to this question, as the hazard ratio could be constant or increasing over time. This is because as more and more villages get electrified, given a budget for the electrification programme, the pace of electrification may still not change. However, it is also possible that there are economies of scale in electrification, because the initial infrastructure is more costly to set up than subsequent branch lines (Chakrabarti and Chakrabarti 2002) and over time the pace of electrification or the probability of electrification – given that other villages have been electrified – increases. We therefore compare the results using the two models.

1.6.2 Variables in our survival models

The dependent variable in survival models is the survival time, which is calculated as following:

$$(Y = Y_e – Y_S), if event = 1 \quad (1.1)$$

$$(Y = Y_S – Y_L), if event = 0 \quad (1.2)$$

Where, Y_e is the time to event (i.e time to village getting electrified); Y_S is the start year (1947); and

Y_L is the last year in the analysis (2012 in the IHDS data set and 2015 in the ACCESS data set). If the village is electrified during the period of analysis (1947-2014), then Y is calculated by the year the village electrified minus 1947; if not, the data is censored and the village may become electrified after the last year. Therefore, the dependent variable is the time to electrification: as each village is electrified, it is marked as a 'failure' in the model.

The explanatory variables were chosen based on the literature available on the drivers for electrification. A positive coefficient for each covariate implies that the village is more likely to get electrified and a negative sign would imply it is less likely to become electrified.

The hazard ratios are defined as the risk of instantaneous exit, i.e. the instantaneous rate of electrification. A hazard rate is greater than 1 if the coefficient is positive, and the larger the ratio, the higher the probability of electrification.

1.7 Results

1.7.1 Non Parametric analysis

Within the dataset, the electrification starts in 1947 and extends up to 2012 for the IHDS dataset and 2015 for the access dataset, the end period of the data. The electrification is non uniform, that is, the number of villages electrified in a year changes rapidly. The level of analysis is at the village level. Figure 1.1 shows the frequency of electrification by year in the sample. The frequency histogram (top) shows that the rate of electrification has not been uniform: the frequency of electrification is highest in the year 1972. The survival curve in the bottom graph shows the proportion survived in the sample (i.e. did not get electrified) during the period of observation (1947-2012). The slope of the curve seems to be getting steeper over time, indicating that the proportion surviving decreases rapidly over time. 1.2 gives the same graph for ACCESS dataset. Comparing these figures we see that, the frequency distribution is different and the villages in the ACCESS dataset have been electrified for fewer years since they are electrified later. On average the IHDS village were electrified for 31 years and ACCESS for 21 years,a gap of 10 years. This shows just how slow the electrification in the states of Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengal were compared to the rest of the country, which is represented in the IHDS data.

We also draw the Kaplan Meier (KM) survival curve; this is a non-parametric method to estimate the survival function which does not make any assumptions on the underlying distribution of the data. It plots the estimated probability of survival against analysis time. Each event (i.e. electrification) appears as a step on the KM curve. Figure 1.3 plots the KM survival curve along with the hazard ratios over time. The hazard function here is a monotonically increasing function indicating that over time, the instantaneous rate of electrification of a village has been increasing. This means that over time, the probability of a village getting electrified increases, as expected. Comparing this to Figure 1.6 the ACCESS dataset seems to have a very sharp change in the slope in the hazard ratio, after starting flat. The KM curve shows a distinct change in pace at year 20 and 40.

The KM curve can also be used to compare the survival time of two groups of data within the sample or many groups. This will check whether a village gets electrified later if it has a higher fraction of a certain

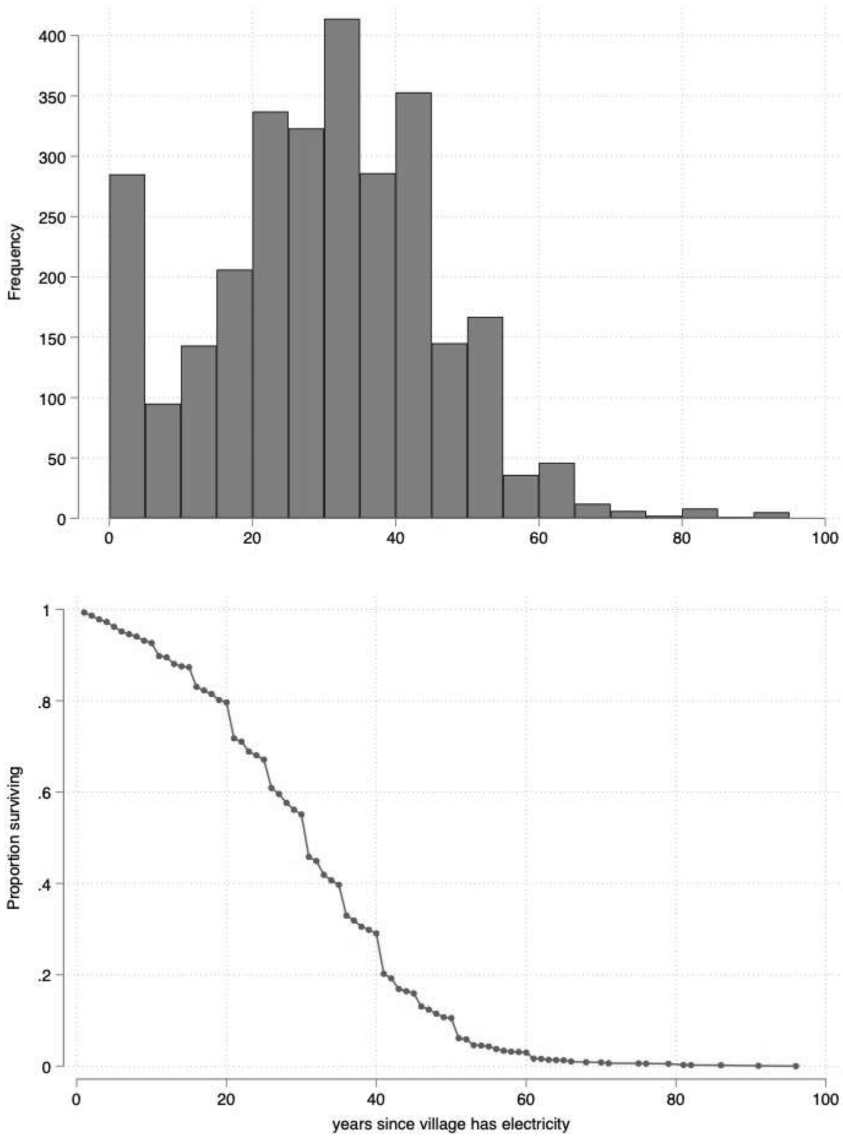


Figure 1.1: Top: Frequency distribution of number of years villages have been electrified, in the analysis we censor this at 1947 = 65 years. Bottom: the proportion of households not electrified (i.e. survived). Data is from IHDS

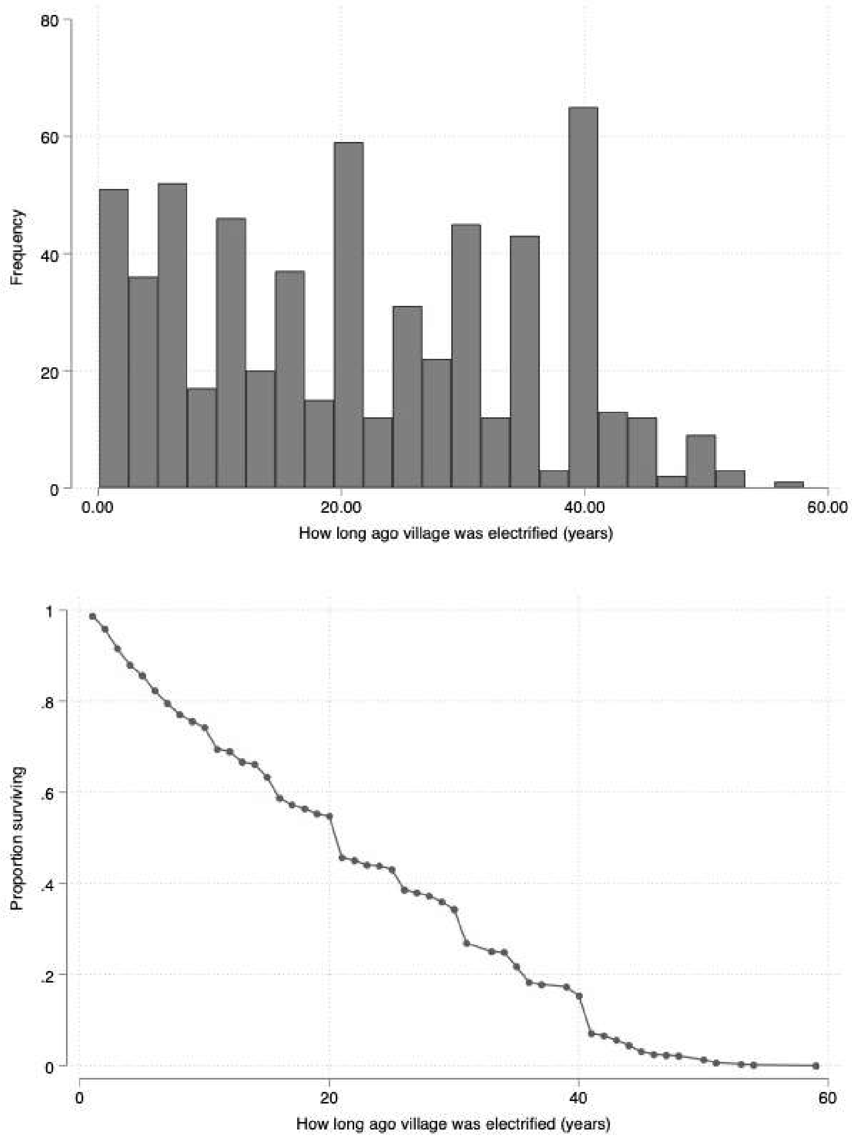
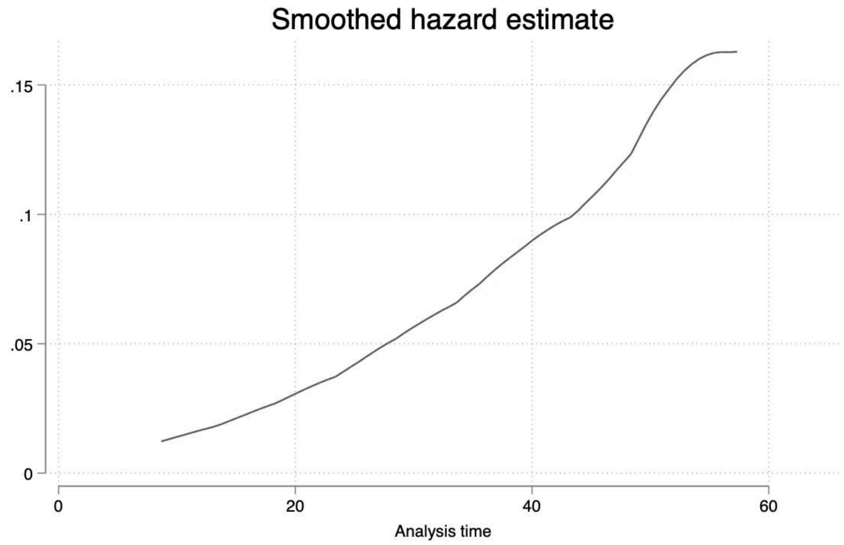


Figure 1.2: Top: Frequency distribution of number of years villages have been electrified, in the analysis here we dont censor but the villages started electrification very late. Bottom: the proportion of households not electrified (i.e. survived).Data is from ACCESS dataset



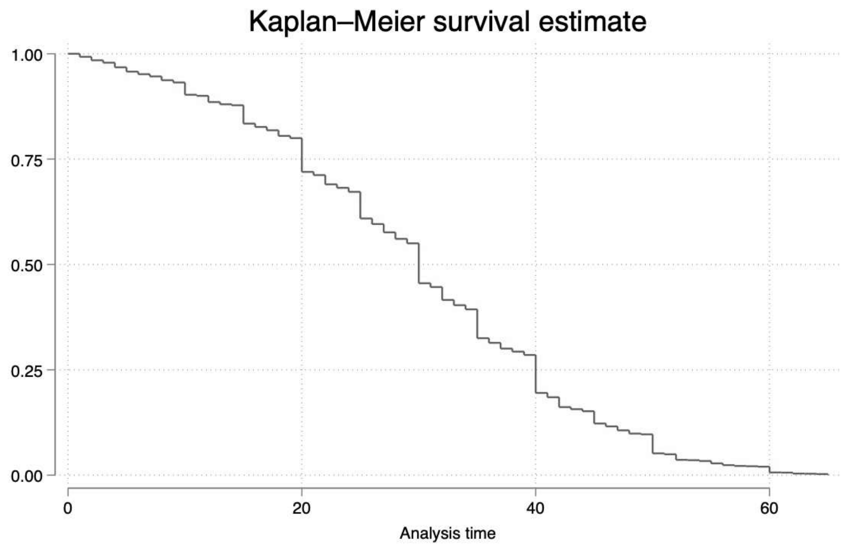


Figure 1.3: Hazard function (top) and KM curve (bottom) for survival analysis for the full IHDS data set.The figure for ACCESS dataset if given in Figure 1.6

caste in the population. Figure 1.4 shows the KM survival curve for the villages with different majority caste in the two datasets. The curve for villages with a ST majority is almost entirely below the curve for other groups. This can be interpreted as at any time period, for a village with a ST majority the probability of it remaining un-electrified (surviving) is higher than for other villages. The KM curves for other caste groups at year 55 seem to merge into one, perhaps indicating the acceleration of electrification under the RGGVY policy. The curve for majority Brahmin group intersects with majority OBC at time 35 and then spreads out later. The curve for villages where Other Backward Castes (OBCs) are in majority tends to move roughly in parallel with the other lower-caste majority villages but with a slight delay in electrification for the OBC majority villages. This may suggest that there is a non-linearity in the relationships and other factors may be important which the non-parametric analysis is unable to account for. The ACCESS data shows a similar result, with the ST group almost entirely behind all of the groups. A note of caution with the groups, the groups for ST, SC, and OBC are defined similarly in the dataset but the ACCESS dataset stays with the more legally defined "general" category, the IHDS tried to identify Brahmins specifically as the most advantageous group. Unfortunately since the jati data is not available, we cant construct the general category for IHDS data. We keep the two categories as it is with this caveat in mind.

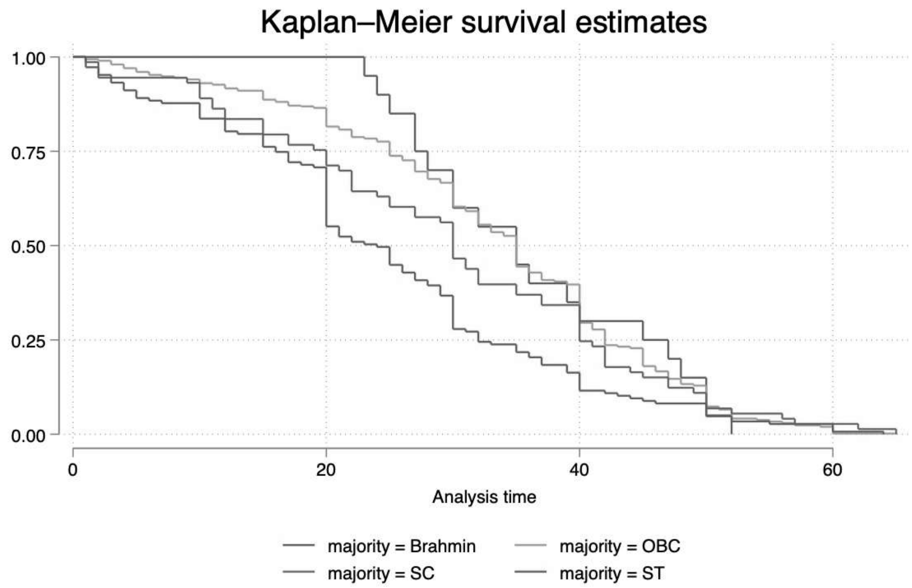
Next we look at differences in the KM curves by the gender of the Pradhan in Figure 1.6. [10] Interestingly, the gap in electrification for the female headed village is much more pronounced in the ACCESS dataset compared to the nationally representative IHDS dataset. It is quite a startling difference and is in line with the literature of gender norm differences in these states. These states have the highest level of gender inequality for example in schooling and the most skewed sex ratio at birth Rammohan and Vu (2018).

1.7.2 Parametric analysis

We next discuss results of the parametric analysis using both datasets. We present the results for the IHDS dataset using the accelerated hazard or Weibull model for village electrification in Table 1.4 and the Cox PH model in Table 1.5. Table 1.6 shows the results using both models for the smaller ACCESS dataset. The tables show unexponentiated coefficients.

Table 1.4 shows the accelerated hazard (Weibull) model results for the IHDS dataset. The coefficients are interpreted as the hazard of failure: a positive coefficient indicates a greater probability of electrification (i.e. 'failure'), and vice versa. In terms of village demographics, only the share of OBCs (other backward castes) in the village is linked to the time taken by the village to electrify: a larger share reduces the probability of electrification. This is interesting because OBCs are widely believed to be a very large and diverse group and hence no meaningful affirmative action is possible without further qualifying groups that are needed for help. The share of ST and SC in the village also lengthens time to electrification, but not significantly. Our most significant result is that if the village Pradhan is Brahmin, the time taken to electrify increases significantly, this is consistently negative and significant in every specification. For the political alignment variables, we find it only to be significant if all three the Pradhan, the Member of Parliament and the Member of the Legislative Assembly are in alignment. Here we define alignment as the castes of the members being same, in the absence of data on political party affiliation.

[10] The data only mentions male and female. It is not clear where the transgender Pradhans have been categorised but since we dont have access to the census identifiers, we cant get the legally declared gender of the Pradhan.



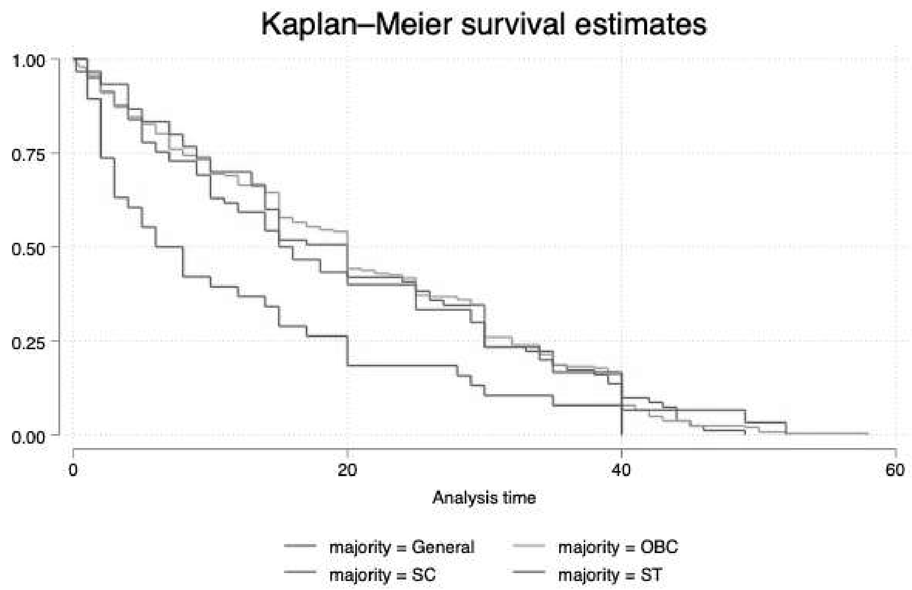


Figure 1.4: Top:KM curve for villages in the IHDS dataset with different majority caste living Bottom: KM curve for villages in the ACCESS dataset with different majority caste living.Caution: ACCESS data does not provide only Brahmins but groups all the forward castes together as general category

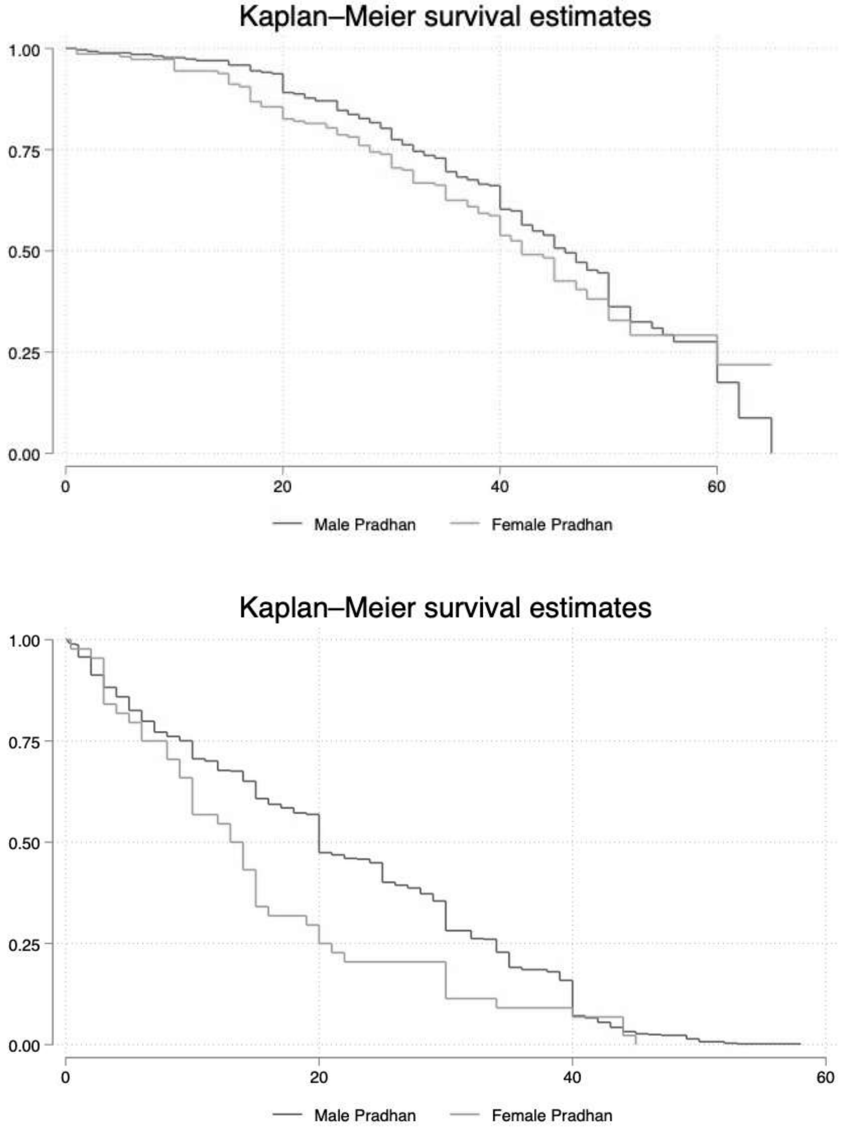


Figure 1.5: Top: Survival estimates for ACCESS data by gender of the Pradhan (village head) Bottom: Survival estimates for IHDS data by gender of Pradhan.

Table 1.4: Results from the accelerated hazard (Weibull) model for village electrification using the IHDS dataset

	(1)	(2)	(3)	(4)	(5)	(6)
village income(log)	0.0120	0.00836	0.00793	0.00133	0.0127	0.00912
	(0.0362)	(0.0371)	(0.0370)	(0.0371)	(0.0373)	(0.0370)
distance from the nearest town	-0.00171	-0.00184	-0.00185	-0.00210	-0.00205	-0.00217
	(0.00184)	(0.00183)	(0.00182)	(0.00179)	(0.00182)	(0.00182)
distance from the nearest pucca road	-0.00944	-0.00961*	-0.0105*	-0.00972*	-0.0101*	-0.00961*
	(0.00575)	(0.00575)	(0.00568)	(0.00565)	(0.00562)	(0.00562)
number of BPL HHs in the village	0.0203	0.0142	-0.00177	-0.00839	-0.00614	0.00171
	(0.125)	(0.129)	(0.128)	(0.127)	(0.128)	(0.128)
% SC in the village		-0.000279	-0.000426	-0.000410	-0.000487	-0.000471
		(0.000957)	(0.000963)	(0.000957)	(0.000960)	(0.000953)
% ST in the village		-0.00121	-0.00121	-0.00130	-0.00122	-0.00121
		(0.000939)	(0.000956)	(0.000954)	(0.000955)	(0.000952)
% Brahmins in the village		0.00177	0.00234	0.00219	0.00214	0.00205
		(0.00175)	(0.00178)	(0.00176)	(0.00178)	(0.00178)
% OBC in the village		-0.00142*	-0.00155*	-0.00162*	-0.00164*	-0.00159*
		(0.000851)	(0.000852)	(0.000844)	(0.000853)	(0.000847)
=1 if Pradhan is brahim			-0.207**	-0.226***	-0.231***	-0.222***
			(0.0807)	(0.0812)	(0.0818)	(0.0809)
=1 if Pradhan is Muslim			-0.00433	-0.00980	0.000600	0.0000848
			(0.0817)	(0.0813)	(0.0815)	(0.0812)
gender of Pradhan			0.0261	0.0276	0.0249	0.0251
			(0.0358)	(0.0356)	(0.0356)	(0.0356)
same caste of Pradhan & MLA				-0.0555		
				(0.0342)		
same caste of Pradhan & MP					-0.0567	
					(0.0356)	
same caste of Pradhan & MP & MLA						-0.0666*
						(0.0373)
Constant	8.232	8.123	8.145	8.250	8.116	8.146
	(203.4)	(166.6)	(165.2)	(164.4)	(164.2)	(164.8)
ln_p	1.201***	1.215***	1.223***	1.228***	1.226***	1.227***
	(0.0417)	(0.0426)	(0.0427)	(0.0428)	(0.0427)	(0.0427)
Observations	1271	1242	1242	1242	1242	1242

Note:Results from the accelerated hazard model show the association between village characteristics and probability of electrification. Pradhan is the village head, MLA is the member of legislative assembly, which is at the state level and MP is the member of parliment, which is at the federal government level. BPL means Below Poverty Line. State fixed effects not shown here for brevity. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

For the other variables, we find that village income and number of BPL households are not significantly related to the time taken to electrify a village. Only distance from the nearest pucca road is significant in most of the specifications. The coefficient indicates that the villages further away get electrified later, indicating that cost does play a role in electrification, as shown in previous studies. The state dummies (not shown) are significant, out of the 31 states, 13 state dummies are significant, which indicates that there is some state level characteristics that lead to electrification. Of these the positive signs are shown for the richer states and the negative for the poorer states, possibly indicating that there is a relationship between the state's revenue generating capabilities and the implementation of the electrification policy.

Table 1.5 shows the Cox PH results for the IHDS dataset. The coefficients are now interpreted as chance of survival, i.e. not being electrified: a positive coefficient indicates extended time until electrification ('survival), and vice versa. This is therefore the opposite of the Weibull model results and the coefficients should have the opposite sign to Cox model. [11]

The assumption here is that the efforts of electrification are uniform across the whole time period, i.e. the RGGVY policy did not increase the probability of a village being electrified during. Here we find that income of village is significant and reduces the survival rate (i.e reduces the time to electrification): richer villages get electrified sooner. Conversely, the number of households below poverty line significantly increase the time to electrify a village. Both the distance variables are significant and again in line with previous literature showing that cost is driving electrification, i.e. greater distance increases the time to electrify a village (i.e. increase the survival rate). For the Pradhan characteristics, Pradhan being a Brahmin dramatically increases the time to electrify. For this specification we don't find any significance for the political alignment variables. We note that the results for the two models using the IHDS dataset are very similar, with some small differences where significance is marginal

The first two columns in Table 1.6 show results for the Weibull model for the much smaller ACCESS dataset. As for the IHDS dataset, a larger share of OBCs (other backward castes) in the village increases the time taken by the village to electrify. We now see that a higher share of ST households also significantly increases time to electrification. We also see that a higher average village income significantly increases the time to electrification, while at the same time having more poor in the village also increases time to electrification. These results are puzzling and not in line with those from the IHDS dataset, though we note that the ACCESS dataset is much smaller and focuses on the poorest states. Columns 3-4 give the results for the Cox PH model. Village income is insignificant, but the percentage of village poor still has the same effect of increasing the time to electrification. The caste variables have hardly any effect anymore; only the share of ST households marginally increases time to electrification. Distance from the nearest town slightly increases time to electrification, which is similar to the IHDS results.

1.8 Conclusions

The aim of this paper was to assess the implementation of India's electrification policies from 1947-2012 with a focus on access for different social groups, comparing socio-economic (and especially caste) factors with cost-related ones. We applied a time-to-event or survival analysis with two different methods (Weibull

[11] The Weibull model shows the chance of failure and the Cox models shows the chance of survival, so the sign of the Cox model should be opposite to the sign of the Weibull model.

Table 1.5: Results from Cox PH model for village electrification using the IHDS dataset

	(1)	(2)	(3)	(4)	(5)	(6)
village income(log)	-0.161**	-0.141**	-0.137**	-0.136**	-0.144**	-0.142**
	(0.0628)	(0.0641)	(0.0645)	(0.0644)	(0.0648)	(0.0644)
distance from the nearest town	0.00831***	0.00802***	0.00805***	0.00824***	0.00822***	0.00835***
	(0.00273)	(0.00275)	(0.00276)	(0.00276)	(0.00277)	(0.00277)
distance from the nearest pucca road	0.0205**	0.0209**	0.0208**	0.0199**	0.0204**	0.0196**
	(0.00979)	(0.00990)	(0.00988)	(0.00988)	(0.00986)	(0.00985)
number of BPL HHs in the village	0.514***	0.439**	0.440**	0.418**	0.429**	0.410**
	(0.192)	(0.199)	(0.200)	(0.200)	(0.200)	(0.200)
% SC in the village		-0.00103	-0.00117	-0.00111	-0.00108	-0.000985
		(0.00201)	(0.00202)	(0.00202)	(0.00202)	(0.00202)
% ST in the village		0.00342*	0.00322*	0.00329*	0.00307*	0.00318*
		(0.00180)	(0.00181)	(0.00181)	(0.00182)	(0.00181)
% Brahmins in the village		-0.00128	-0.00351	-0.00343	-0.00328	-0.00323
		(0.00264)	(0.00285)	(0.00285)	(0.00286)	(0.00285)
% OBC in the village		0.000162	0.000238	0.000331	0.000342	0.000450
		(0.00145)	(0.00146)	(0.00146)	(0.00146)	(0.00147)
=1 if Pradhan is brahim			0.394**	0.424***	0.407**	0.413**
			(0.162)	(0.164)	(0.163)	(0.163)
=1 if Pradhan is Muslim			-0.00531	-0.0105	-0.00833	-0.0171
			(0.132)	(0.133)	(0.133)	(0.133)
gender of the head of the village			-0.0660	-0.0657	-0.0660	-0.0648
			(0.0614)	(0.0614)	(0.0613)	(0.0614)
same caste of Pradhan & MLA				0.0800		
				(0.0603)		
same caste of Pradhan & MP					0.0624	
					(0.0615)	
same caste of Pradhan & MP & MLA						0.103
						(0.0674)
Observations	1271	1242	1242	1242	1242	1242

Note: Pradhan is the village head, MLA is the member of legislative assembly, which is at the state level and MP is the member of parliament, which is at the federal government level. BPL means Below poverty line. State fixed effects not shown here for brevity. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 1.6: Results from the accelerated hazard (Weibull) model(1-2), Cox PH Model(3-4), village electrification for ACCESS dataset

	(1)	(2)	(3)	(4)
village income (log)	-0.718***	-0.722***	-0.223	-0.234
	(0.272)	(0.271)	(0.333)	(0.335)
distance from the nearest town	-0.00527	-0.00540	0.00833*	0.00836*
	(0.00408)	(0.00404)	(0.00442)	(0.00442)
distance from the district HQ	0.00167	0.00253	0.00664	0.00554
	(0.00326)	(0.00327)	(0.00406)	(0.00409)
percentage of village poor	-1.254***	-1.315***	1.789***	1.901***
	(0.411)	(0.411)	(0.455)	(0.460)
percentage of SC households	-0.244	-0.289	0.208	0.256
	(0.554)	(0.551)	(0.561)	(0.561)
percentage of ST households	-1.093**	-1.006**	0.934*	0.829
	(0.499)	(0.506)	(0.530)	(0.540)
percentage of OBC households	-0.931**	-0.928**	0.483	0.470
	(0.388)	(0.387)	(0.415)	(0.418)
Pradhan is male(=1)		0.712		-1.078**
		(0.468)		(0.500)
Constant	9.663***	8.981***		
	(2.381)	(2.414)		
Observations	172	172	172	172

Note: Pradhan is the village head, percentage of village poor is calculated using population of below poverty households (BPL). State fixed effects not shown here for brevity. This data set has villages from 6 states that were the worst performers in electrification. Model 1,2 report the survival and 3-4 report the hazard so the opposite signs have the same meaning. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

and Cox PH), using cross-sectional data from the Indian Human Development Survey (IHDS) and the smaller ACCESS dataset, in order to see how robust our results would be.

In general, we find some relatively small differences in the results between the datasets and between models used, but also a lot of commonalities. The parametric results suggest that cost related factors have been significantly driving electrification over this long time period, confirming previous studies. The distance of the village from the grid has been an important determinant for electrification of a village – the closer and cheaper to connect, the sooner electrification happened. An interesting result is that a greater share of poor households tends to delay electrification. One interpretation is that the policy making concessions for the poor households has possibly deterred SEBs from electrifying poorer villages: connecting more poor households that benefit from lower tariffs means lower income for SEBs. This would be in line with the results for our more direct cost proxies, the distance-to-grid measures.

In terms of caste groups, the parametric estimates show no strong and systematic differences between electrification of Scheduled Castes (SC) SC or Brahmins, though both datasets indicate that villages with larger shares of Other Backward Castes (OBC) increase the time to electrification in the Weibull estimations. However, the non-parametric findings suggest there were some systematic differences in electrification between villages with different caste makeups, with majority ST villages being electrified last. We also observe gender differences Interestingly though, these differences fade away in recent years, suggesting that the RGGV policy begun in 2005 has had the desired effects of more widespread electrification. Whether this holds for the most recent decade remains to be seen, as our datasets go only until 2015. We can also not draw any firm conclusions on causality, as this lies beyond the scope of our analysis. These interesting questions are left to future research.

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1.9 Appendix

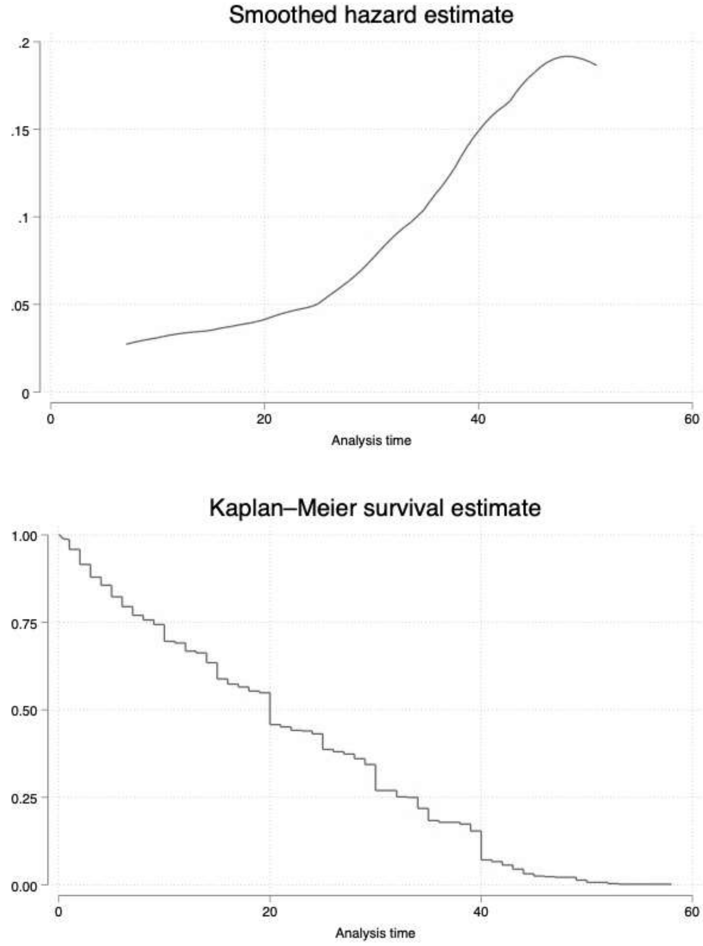
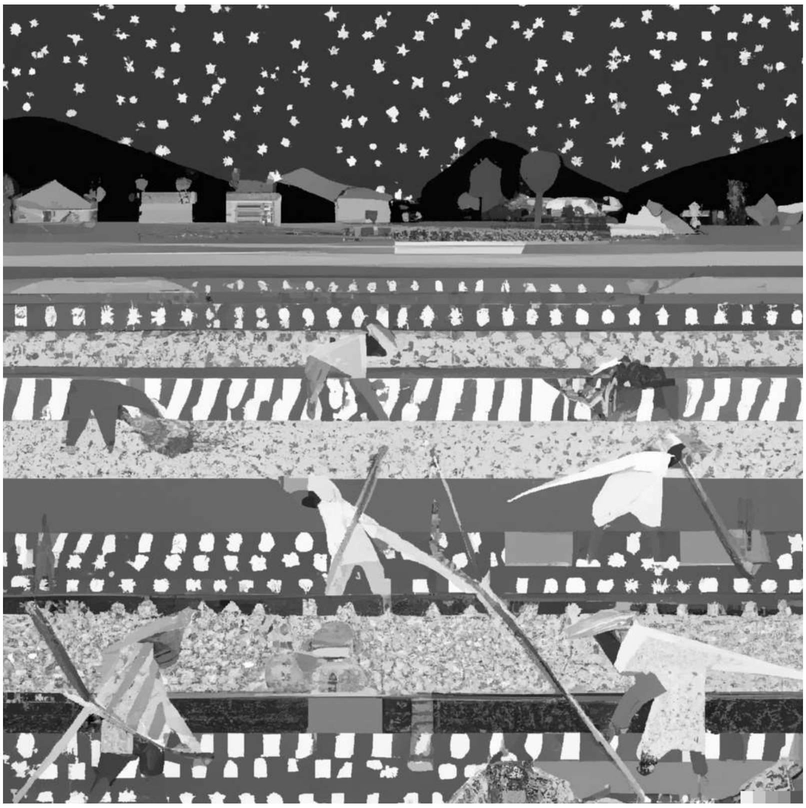


Figure 1.6: Top: Frequency distribution of number of years villages have been electrified, in the analysis. Bottom: the proportion of households not electrified (i.e. survived) for ACCESS dataset

Chapter 2

Reliable electricity, income and employment

 [1]

[1]This image has been generated using the AI DALLE by using keywords from the chapter in the style of the artist Henri Mattise and Andy Warhol's colours

2.1 Abstract

Electrification is often seen as a silver bullet for economic development but little or no attention is paid at the policy level to the reliability of the electricity supply. We use data spanning two decades (1994-2015) and over 41,000 households across 30 Indian states to understand whether the quality of electrification matters for development. We show that good-quality electrification is crucial to increasing individual incomes and that only a very reliable electricity supply is able to secure these benefits for women in particular. Greater labour force participation and a shift from precarious to non-precarious work are identified as likely mechanisms through which these gains accrue to individuals. Our results suggest that policy targets should focus more explicitly on the quality of electrification.

Keywords: Energy, Energy use, Survey, Households, India, Energy Transition

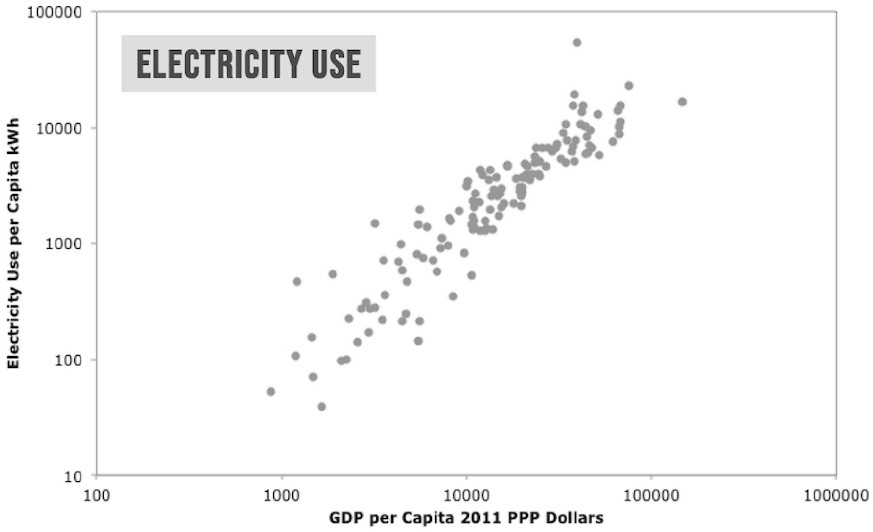
This is joint work with Prof. Corrado Di Maria and Dr Christa Brunnschweiler

2.2 Introduction

Access to abundant energy sources, and in particular to electricity, is tightly linked to economic development (see Figure 2.1). While there is little doubt that the ability to tap into vast resources of fossil fuels to produce energy has enabled the process of modern economic development (e.g. Wrigley, 2013), there still is substantial disagreement on the causal impact of investment in energy infrastructure. The causal link between electrification and income (and employment) has been strongly supported by some authors (e.g. Khandker et al., 2009; Dinkelman, 2011), while others found no significant effects (Lee et al., 2020; Burlig and Preonas, forthcoming). This uncertainty has led some to challenge the wisdom of the large investments being made to provide universal access to electricity, despite the provision of electricity networks being the cornerstone of development policies across much of the Global South. Burgess et al. (2020) , for example, question treating electricity as a right because to deliver this entitlement, power companies end up delivering the same (poor) quality of electricity to paying and non-paying customers alike, leading to a low-quality equilibrium. Given the salience of this debate, we look at the relationship between electricity consumption through a micro-economic lens.

In this paper, we contribute to this debate by focusing on an important issue that has received limited attention in the literature so far. Taking inspiration from the work of Chakravorty et al. (2014), we investigate the causal link between electrification and income while explicitly instrumenting for the *quality* of electricity supply. Within an instrumental variables framework, we quantify the impact that different levels of electricity supply have on income across a sample of 41,554 Indian households in 1,503 villages in 31 (of 33) Indian states, using three waves (1994, 2004, and 2015) of the Indian Human Development Survey (IHDS). The richness of the data allows us to estimate these impacts at the level of the household and to investigate the mechanisms behind the income changes. A reliable provision of electricity facilitates the adoption of technologies – for cooking, handicraft and small business alleviating the drudgery of firewood collection and poorly paid and unreliable manual work. This frees up time that may be devoted to working outside of the house and seeking better-paid opportunities, thus leading to higher income and improved quality of life. With this in mind, our focus is on testing whether (the quality of) electrification affects the labour force participation as well as the quantity and quality of the work supplied outside the

Figure 2.1: Per Capita Electricity Use and GDP for UN recognised 193 (logarithmic scale, 2014)



Source: Stern et al. (2019), p.40

household. Using the unique features of our data-set, we are also able to look at the problem from a gendered perspective, tracing the impacts to the individual members of the household and differentiating between the gains accruing to male and female respondents.

Our results show a strong positive effect of reliable electricity on individual incomes: going from no to low-quality electricity supply – i.e. under 18 hours per day – increases incomes by a factor of 3.6 on average, and having access to high-quality electricity – i.e. 18 hours per day or more – by a factor of 3. We also find a striking gender difference in outcomes as income is only shown to increase for the women in our sample when the electricity supply is very reliable, while men see a positive income effect already at low-quality electrification. Our analysis of the mechanisms through which these increases in income come about suggests that, both males and females achieve higher labour force participation, especially via the substitution of time spent in precarious work with hours worked in non-precarious occupations. We find less clear-cut evidence for the reduction of drudgery, proxied by time spent collecting firewood: though women spend less time on this once they gain access to low-quality electricity, men seem to spend more time on it.

Our contribution is three-fold. First, we complement the scant literature on the quality of electrification by offering a significantly longer perspective on the issue (1994-2015) and focusing on the mechanisms underlying the headline results. This is important because a connection to the grid does not guarantee predictable access to electricity, and both intermittence and outages may make significant differences to the benefits experienced by the households (Aklin et al., 2016; Aklin and Urpelainen, 2020), and because structural changes might take time to take hold. While a rich literature investigates the developmental benefits of electrification in a binary setting, only a handful of papers discuss the role of the quality of supply in this context.[2] The quality of electricity – or the 'usability' of electricity – may be proxied either in terms of voltage fluctuations or hours of electricity supply. Jacome et al. (2019) offer one of the few contributions to examine the impact of voltage variability. In their study, they combine data on physical systems with survey data from Tanzania to estimate the disruption due to voltage fluctuations. They find large swings in voltage, which can lead to people being unable to use electricity and to damage to appliances. As mentioned, Chakravorty et al. (2014) introduces the quality of electricity in terms of hours of access to the households. Their paper finds that the increased quality of electricity increases non-agricultural incomes in India by 9% during the survey. However, their paper assumes that the impact of changes in quality is the same irrespective of the initial level, and they do not discuss the channels leading to the increase in income. In this paper, instead, we focus on the threshold of 18 hours [3] of electricity access to households and estimate heterogeneous treatment impact across the main outcome variables and the channels.

Our second contribution is to offer a gendered perspective on these issues. In this respect, we follow Dinkelman (2011), who uses two different empirical approaches to examine the impact of electricity access on employment in post-apartheid South Africa. She finds that electrification increases female employment within five years. The paper shows that one channel of this employment is through the use of electric cook stoves and reduced time spent on looking for firewood; there is only evidence for the business-creating and migration channels. We take inspiration from this article and examine the time spent gathering firewood, labour force participation and job quality, but with a focus on the quality of electrification. Burlig and Preonas (forthcoming), using data from India, estimate the impact of village electrification on employment, income and asset ownership and find that these do not increase significantly, even in the medium run. Our work focuses on electrification quality and the household level, uncovering some interesting micro-level results.

Our final contribution lies in the combination of three different sets of instrumental variables to counter the endogeneity problems that are pervasive in this framework. Our identification strategy relies on infrastructure-related variables, geographic variables and weather-related variables to offer a cleaner estimation of the coefficient. Compared with other contributions in this literature, moreover, both the time horizon and the geographical coverage of the data are wider.

The rest of the article is organised as follows. Section 3.3 offers a brief background on electrification in India; the data are described in Section 4.4 and the methodology in Section 3.5; the main results are discussed in Section 3.6. Section 3.8 concludes.

2.3 Background

Electrification policy in India is divided into three main periods: 1900-1947 (pre-independence), 1947-1990, and post-1991, characterised by the different ownership of the resources and infrastructure and (lack of) encouragement of market mechanisms (Palit and Bandyopadhyay, 2017). Actual electrification in the first period remained very limited, though some basic laws and regulations for the grid network were introduced. The second period, following the Electricity (Supply) Act of 1948, was driven by state

[2]For a comprehensive review of the earlier literature, see van de Walle et al. (2017).

[3]selected to approximate the minimum hours of electricity that can be provided while covering evening hours

ownership of the generation, transmission and distribution of power. After the independence of India, the initial focus was to electrify cities and towns with no target for rural villages. The widespread food shortages in the 1960s shifted the focus of electricity provision in rural areas to powered irrigation to increase the productivity of agriculture; the electrification of rural villages and households was a potential co-benefit with no explicit target. Since household electrification was not the focus in this second period, the definition of an 'electrified village' was comprised of two factors: first, if the grid has been extended to the village; and second, if one connection has been electrified in the revenue area of the village (usually a farm). Mounting financial pressure on the State Electricity Boards in the latter half of this period led to the deteriorating reliability of electricity supply, with either complete blackouts at select times or 'brownouts' (i.e. electricity is available but of unusable low voltage).

India's energy markets have seen steady liberalisation and development in the period since 1991. The consumer end, i.e. the distribution sector, is still largely state controlled.[4] Importantly, in 1997 the Ministry of Power declared that a village was deemed electrified if electricity was used in the inhabited area of the village, while the enshrinement of the right to electricity as a fundamental right under Article 21 of the Indian constitution meant that both the state and central governments became legally responsible for providing electricity (Palit and Bandyopadhyay, 2017). Nevertheless, until 2005 the electrification of a village was largely the responsibility of the individual states and the electrification progress remained heterogeneous: 55% of households in villages were electrified by 2005, and electrification was uneven across states as well as within (electrified) villages (Office of the Registrar General and Census Commissioner, 2016). Outside of cities and large towns, the push for electrification had remained focussed on agriculture, as described above, and with the exception of the states of Uttar Pradesh (UP) and Bihar, most of the agrarian states progressed faster in providing electricity than non-agrarian ones.

The year 2005 marks the launch of a major new electrification policy called the Rajeev Gandhi Grameen Vidyutikaran Yojana (RGGVY), which made electrification the joint responsibility of the central and the state governments (though it was primarily managed by the central government). The RGGVY policy set the goal of complete village electrification by 2009 through the accelerated electrification of 100,000 villages and 10 million households, making it the first policy in India that had an explicit target for village *and* household electrification. The scheme introduced a new definition of electrification: 'A village will be deemed to be electrified if: basic infrastructure such as distribution transformers and distribution lines are provided within the inhabited locality; electricity is provided to public places like schools, *panchayat* offices, health centres, dispensaries, community centres etc., and the number of households electrified should be at least 10% of the total number of households in the village.'[5] The RGGVY scheme was not successful in terms of complete electrification by 2009, but progress was rapid and it did manage to electrify a large part of the country (Ministry of Power, 2010).

Our focus is on the reliability of the electrification of households and how this relates to income and labour market outcomes. Considered a co-benefit of agrarian-sector electrification policy before 2005, household-level electrification – or at least 10% of village households – only became an explicit target under the RGGVY policy. Technically, therefore, while there is an intention-to-treat with electricity access at the

[4] The state has been encouraging the entry of private players since 2015 through small-scale generation such as mini-grid or solar rooftop-based systems. This lies outside the scope of our analysis.

[5] In recent years, the policy focus has shifted more squarely towards electrifying all households, but this lies beyond our period of analysis.

household level at least in the last two periods of our analysis, there is no clear goal in terms of the quality, or reliability of electricity. We continue to use the threshold of 18 hours to signify low- and high-quality electricity as chosen in Chakravorty et al., 2014 for two reasons. First, one of the first uses of electricity is for lighting, which would be useful only in the evening. Selecting 18 hours ensures we have some hours of darkness out of the total 24 hours in a day. Ideally, we would need information on hours of electricity available in the evening, but this measure is missing in the current dataset. Second reason is since we expand the analysis from Chakravorty et al., 2014 , we can compare our results to get a sense of progress made with the addition of the new wave of data. In theory we can keep increasing this threshold to any number between 18-23 and it would still work, if we keep two types of electricity quality intact. However, from a policy perspective, the interesting question is – what the minimum level of hours electricity is to be supplied to make a significant impact on the outcome – i.e. a focus on the minimum. Therefore, we decided to keep the 18 hours threshold, even if it's an arbitrarily set. Note: Chakravorty et al., 2014 set the 18-hour threshold because it "approximates productive hours of a typical agricultural household" [page 232, footnote 8, section 3.1]

2.4 Methodology

Our main goal is to investigate the causal link between electrification and income in India; we use the panel dataset described in Section 4.4, which comprises information on Indian households and the individuals within each household. Letting y_{ht} be the level of income for household h at time t, E_{ht} is the treatment indicator, which measures the quality of the electricity supply available to the household – see Section 2.4 – and $\mathbf{X}_{ht}$ a vector of control variables, the baseline specification is given by,

$$y_{ht} = \alpha + \delta_h + \beta_1 E_{ht} + \beta_2 \mathbf{X}_{ht} + \epsilon_{ht}, \tag{2.1}$$

where δ_h and δ_t are household and wave fixed-effects, ϵ_{ht} is the error term, and our main focus is the coefficient of quality of supply, β_1.

The corresponding individual-level specification is then,

$$y_{iht} = \kappa + \sigma_i + \sigma_d + \gamma_1 E_{iht} + \gamma_2 \mathbf{X}_{ht} + \nu_{iht}, \tag{2.2}$$

The main concern in estimating (2.1) and (2.2) is the potential for endogeneity in our analyses. For example, if both income and reliability were driven by some external omitted factor, the reliability of power supply to the households might improve faster in wealthier districts and E_{ht} and ϵ_{ht} (E_{iht} and ν_{iht}, respectively) would be correlated.

To mitigate these endogeneity concerns, we resort to instrumenting the reliability indicator within a two-stage least square (2SLS) approach. We use three types of instruments: the density of transmission lines, the distance from power plants, and weather shocks (described below). The density of the transmission lines increases the probability of a network connection and limits power losses, thereby increasing reliability (see Chakravorty et al. 2014). Similarly, proximity to generation points increases the chance of receiving a higher-quality power supply. We use a set of two instruments based on the distance from coal power plants and distance from hydroelectric power plants (see e.g., van de Walle et al. 2017). Finally, severe weather shocks such as floods, heatwaves, etc. tend to have significant impacts on energy infrastructure, especially in lower-income countries, but arguably only temporary direct income effects. Note that the instruments are constructed at district level, which is the most disaggregated level available for these types of information.

We use the three instruments together to get the most robust value for quality of electricity. The aim is to get the best underlying variation with electricity quality. For households that are closest to the powerplant, have a dense transmission network and have network unaffected by small scale disasters have the highest quality of electricity available and hence should be able to impact quality of electricity. We believe that these instruments are exogenous, and we argue this in the following paragraphs.

To use instruments, we must be able to argue that the error term in the outcome regression must be conditionally independent of the instrument used. We use three sets of instruments in our analysis – and therefore must justify this for all the three instruments. In the first two cases i.e. cable density and distance from coal plants, we build on existing literature that uses these. For disasters, there is no direct literature using these as an IV for quality of electricity, but these are the easiest to prove to be exogenous. The distance from powerplants influences the probability of getting a connection, as it is roughly a proxy for costs of electrifying a household. However, the same distance can have different costs if not accounting for terrain and therefore we use a second IV i.e. the transmission cables.

For our second IV, we follow Chakravorty et al. 2014 and use density of transmission cables. The transmission network in India was not built to support household electrification but more for strategic industries, indeed household electrification has not been a goal until 2005 under the RGGVY. The exclusion restriction can be compromised if the dependent variable (income, employment, labour force participation etc.) is correlated with the grid density, to avoid this we use federally built grid lines which are not maintained by the state and have no state mandates on employment.

Even the most robust infrastructure in the world is influences by small scale climate disasters. We use small weather shocks as a third instrument. It can be argued that a disaster can be a negative shock to economic activity. Therefore, we use small scale disasters, lasting a couple of days (as opposed to large disasters) which are unlikely to be correlated to income and other dependent variables, an assumption critical to our estimation strategy. Therefore, we argue that Therefore, we argue that our instruments influence outcomes variables solely through the quality of electricity.

In the second part of our analysis, we investigate the potential channels linking energy reliability to income. In this context, we use the individual-level data at our disposal, to estimate

$$z_{iht} = \mu + \theta_d + \lambda_1 E_{iht} + \lambda_2 \mathbf{X}_{ht} + \zeta_{iht}, \tag{2.3}$$

where z_{iht} is, by turns, the labour force status of individual i, hours spent collecting firewood, and hours worked in precarious and non-precarious occupations. Once again, these regressions are estimated using instrumental variables to mitigate endogeneity concerns similar to the ones discussed above, using the same instruments. One final notice refers to labour force participation, which is a categorical variable. In this case, (2.3) is estimated as an ordered probit model, appropriately instrumented as needed.

2.5 Data

This paper uses the Indian Human Development Survey (IHDS) conducted in two waves by the University of Maryland and the National Council of Applied Economic Research (NCAER) India (see Desai and Vanneman 2005 and Desai and Vanneman 2012), alongside an earlier wave carried out in 1994, called the Human Development Profile of India (HDPI) and conducted only by the National Council of Applied Economic Research (NCAER) (National Council on Applied Economic Research, 1994).[6] The IHDS is a panel dataset collected in 2004-05 and 2011-12, respectively, covering 41,554 households and 1,503 villages in 31 out of 33 states of India.[7] The same households are targeted in the two surveys, making it a longitudinal study at the household level. The 1994 survey is more limited, covering a total of 33,000 households, only about 10,000 of which are repeated in the following two waves.[8] The dataset collects details on consumption expenditure, gender relations and other development-related variables. The survey was carried out in face-to-face interviews with the following modules: An interview with a knowledgeable informant — typically the head of the household — regarding the socio-economic condition of the household including income, employment, educational status and consumption expenditure; and an interview with a married woman aged 15-49 regarding health, education, fertility, family planning, marriage, and gender relations in the household and community. A final module looked at village-level characteristics, assessing employment opportunities and infrastructure facilities in the village.

Tables 2.5 and 2.5 give the summary statistics of the data for HDPI/IHDS in each of the two (for individual-level data) respectively three waves (for household-level data). The household size has been decreasing over the years, probably because of increased focus in India on the two-child norm. This can also be seen in the relatively sharp decrease in the number of children over the years compared to the number of adults. There is a steady increase in the amenities available to the households, such as piped water and indoor toilets.

Income. Household income is constructed by adding individual types of income streams in the household – agricultural, business, daily wage work from farms, daily wage income from other sources, salary income and other sources. The components of income are defined differently in the first from the subsequent two rounds of the survey. In the first round (1994) the income is reported by occupation groups: allied agricultural activities, artisans and independent work, petty trade or small business, organised trade or business, salaried employment, qualified profession, cattle tending, rents interests or dividends, and other sources and imputed income from agriculture. There are also constructed variables such as the annual income of the households from agriculture wage workers, the annual income of the households from non-agricultural wage workers, and finally total annual household income including wage income and income from agriculture. The second and third waves also include income from the government's new policy which guarantee employment to anyone who seeks it in the rural areas, National Rural Employment Guarantee scheme (NREGA); this income is not included in the analysis for all three waves for comparability.

[6] The IHDS survey was supposed to release its latest data in 2021 but it has been postponed to 2023 due to the COVID-19 pandemic.

[7] The exceptions are the two island territories of Andaman & Nicobar and Lakshadweep.

[8] For the purposes of this paper, we refer to the 1994 wave as the HDPI, keeping in mind that the quality of data differs between the HDPI and the subsequent two IHDS surveys. It is important to note that, because the data contains sensitive identifiable information, the data providers did not give us the necessary identifiers to link individuals in the first wave to the second and third ones. Therefore, whenever the analysis is done at the individual level, the data refer to only the years 2005 and 2012. The household data results cover all three waves.

To make income comparable across the survey years, the following categories are used: agricultural income, which includes income from crops and animal rearing; agricultural daily wage income which is income by individuals from sowing, harvesting etc. while working on farms; non-agriculture daily wage work; income from a business, salaried employment; and income from rents and dividends. It is worth noting that most households have one single source of income.

	IHDS I					IHDS II				
	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N
Log monthly income (INR 2005)	7.45	1.20	1.17	11.85	35524	7.58	1.30	1.76	12.21	47128
Status in the labour force	0.96	1.19	0.00	3.00	150988	1.18	1.19	0.00	3.00	150983
Non precarious jobs	394.42	825.74	0.00	6,250.00	150988	511.90	931.11	0.00	5,200.00	150983
Precarious jobs	277.99	675.15	0.00	6,640.00	150988	286.08	665.49	0.00	7,000.00	150983
Time collecting firewood (mins/week)	383.54	429.96	0.00	4620.00	84336	391.38	651.20	0.00	8610.00	51667
Controls										
Lives in rural area	0.70	0.46	0.00	1.00	150988	0.70	0.46	0.00	1.00	150983
Owns their house	0.94	0.24	0.00	1.00	150988	0.94	0.24	0.00	1.00	150983
Size of the household	6.50	3.11	1.00	29.00	150988	5.77	2.69	1.00	27.00	150983
Share of boys in hh	0.24	0.16	0.00	1.00	150988	0.20	0.16	0.00	1.00	150983
Share of girls in hh	0.22	0.17	0.00	1.00	150988	0.19	0.17	0.00	1.00	150983
Are they head of household	0.20	0.40	0.00	1.00	150988	0.26	0.44	0.00	1.00	150983
Owns livestock	0.51	0.50	0.00	1.00	150988	0.48	0.50	0.00	1.00	150983
Household is below poverty line	0.25	0.43	0.00	1.00	150846	0.19	0.39	0.00	1.00	150914
Age	27.27	18.89	0.00	105.00	150988	34.28	19.24	5.00	99.00	150983
years of completed education	4.29	4.55	0.00	15.00	150105	5.85	4.70	0.00	15.00	150860
Person's caste = SC	0.35	0.48	0.00	1.00	150988	0.34	0.47	0.00	1.00	150983
Person's caste = ST	0.21	0.41	0.00	1.00	150988	0.21	0.41	0.00	1.00	150983
Person's religion = Muslim	0.08	0.27	0.00	1.00	150988	0.08	0.27	0.00	1.00	150983
Person's is from other minority	0.13	0.33	0.00	1.00	150988	0.13	0.33	0.00	1.00	150983
Instruments										
Density of transmission lines	0.00	0.00	0.00	0.00	121434	0.00	0.00	0.00	0.02	121429
Distance from coal plant (km)	0.00	0.00	0.00	0.00	144129	0.00	0.00	0.00	0.00	144129
Distance from coal plant (km)	0.00	0.00	0.00	0.00	144129	0.00	0.00	0.00	0.00	144129
Days with heavy rain	2.32	5.52	0.00	40.00	150988	0.45	1.50	0.00	14.00	150983
Days with flood	0.25	1.41	0.00	15.00	150988	0.02	0.22	0.00	3.00	150983
Days with severe flood	5.96	13.30	0.00	56.00	150988	0.06	0.86	0.00	15.00	150983

Table 2.1: Summary statistics of IHDS I and IHDSII for the individual data

	HDPI					IHDS1					IHDS2				
	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N
Zero/low/high hours of electricity	0.63	0.66	0.00	2.00	15578	1.16	0.78	0.00	2.00	40842	1.28	0.68	0.00	2.00	39861
Log household income	7.41	0.87	3.88	10.97	15561	7.84	1.08	-0.29	13.21	38815	8.75	1.07	0.51	13.76	39245
Controls															
Owns their house	0.97	0.16	0.00	1.00	15578	0.94	0.24	0.00	1.00	41154	0.94	0.25	0.00	1.00	40018
Share of children in the household	0.36	0.21	0.00	1.00	15477	0.32	0.23	0.00	1.00	41111	0.26	0.23	0.00	1.00	39994
Owns livestock	1.00	0.02	0.00	1.00	15578	0.91	0.28	0.00	1.00	41154	0.44	0.50	0.00	1.00	40018
Household is below poverty line	0.37	0.48	0.00	1.00	15578	0.22	0.41	0.00	1.00	41154	0.17	0.37	0.00	1.00	40018
Size of the household	6.77	3.44	1.00	32.00	15578	5.80	3.02	1.00	38.00	41154	4.87	2.34	1.00	33.00	40018
Years of education of household head	.	.	.	.	0	7.37	5.03	0.00	15.00	41102	8.11	5.00	0.00	15.00	40007
SC	0.10	0.30	0.00	1.00	14646	0.21	0.41	0.00	1.00	41154	0.21	0.41	0.00	1.00	39997
ST	0.25	0.43	0.00	1.00	14646	0.08	0.28	0.00	1.00	41154	0.09	0.28	0.00	1.00	39997
Muslim	0.09	0.29	0.00	1.00	14646	0.11	0.32	0.00	1.00	41154	0.11	0.32	0.00	1.00	39997
Other minority	0.00	0.00	0.00	0.00	14646	0.03	0.17	0.00	1.00	41154	0.03	0.17	0.00	1.00	39997
Lives in rural area	1.00	0.00	1.00	1.00	15578	0.71	0.45	0.00	1.00	41154	0.68	0.47	0.00	1.00	40018
Instruments															
Density of transmission lines	0.00	0.00	0.00	0.00	11106	0.00	0.00	0.00	0.00	28769	0.00	0.00	0.00	0.02	27999
Distance from coal plant	0.00	0.00	0.00	0.00	15340	0.00	0.00	0.00	0.00	38439	0.00	0.00	0.00	0.00	37316
Distance from hydro plant	0.00	0.00	0.00	0.00	15340	0.00	0.00	0.00	0.00	38439	0.00	0.00	0.00	0.00	37316

Table 2.2: Summary statistics for households level for three survey waves

For individual income, the survey reports wage and salary workers in three categories: salaried, agricultural worker, and other workers. The difference is the frequency of the payout. Salaried workers are paid monthly or annually, agricultural workers are paid daily and report farm-related work, and other workers are also paid daily but they undertake other non-farm work. Individuals report work at every level but for a person to be considered working regularly in one occupation – e.g. animal rearing – they have to be occupied a minimum of 240 hours a year in that occupation category to classify as a worker in that category.

Table A.5 in the Appendix shows that the rate of growth of income is quite different between the periods: between 1994-2005 the household income increased from Rs 2332 to 3897, just shy of doubling in ten years. Contrast this to the income increase from 2005-2012: in seven years, it nearly tripled. All three incomes are measured in 2005 prices.

Labour force status. Labour force participation is a categorical variable which takes the value of 0 if the individual is not employed and not looking for employment. It is 1 if they are working, but for less than 10 days a year. It is 2 if they are working on a part-time contract with more than 10 days a year. Finally, it assumes a value of 3 for individuals working in full-time occupations. Participation in the labour force is crucial since a significant part of the income of households is dependent on being employed and very few households rely on rents, dividends etc.

Table 2.3 shows the labour force participation pattern over the last two waves, by gender for all adults in the sample. The level of unemployment is very high for both male and females but the female unemployment is clearly higher. Over the 6 years between the surveys, female unemployment decreased by 10 percentage points to 61% and male unemployment decreased by 14 percentage points from 46% to 32%. Full-time employment increased for both men and women but for women, the increase is marginal – only one percentage point.

Table 2.3: Labour force participation and degree of employment by gender

	2005		2012	
	Female	Male	Female	Male
Unemployment	71 %	46 %	61 %	32 %
Underemployed (<240 hours per year)	4 %	3 %	9 %	8 %
Part time	21 %	26 %	25 %	31 %
Full time	5 %	24 %	6 %	29 %

Hours worked across occupations. The surveys contain information on individuals' hours worked in the previous year and what type of work they did. We categorise this information based on the stated frequency of pay received by workers and the existence of a contract into two types of jobs: precarious[9] and non-precarious jobs. Precarious jobs are jobs without any verbal or written contract. People are hired for a daily rate, often on the day of the job, offered a pay called *dihari* and asked to work for that day. They are paid at the end of the day. In the data these are jobs on farms, such as tilling, irrigation, animal management. Non-precarious jobs are jobs where there is some form of (longer-term) contract, which could be written or verbal. If the job is in the formal sector, the contract is written but in the

[9]Precarious jobs are known in India as 'daily-wage' jobs.

informal sector it is often verbal. The data reports these jobs as agricultural work, construction and other hard manual work and salaried jobs.

Reliability of electricity. The survey asks households whether they have electricity access and for how many hours per day on average. Reliability is defined in terms of the hours of electricity the households receive every day: more average hours of electricity indicate more reliable electricity access. Reliability is defined as 0 if the household does not use any electricity (i.e. is not connected); 1 if the household receives less than 18 hours of electricity per day on average; and 2 if the household receives more than 18 hours of electricity per day on average. Therefore, letting h represent the hours of electricity available per day, we have:

$$E = \begin{cases} 0, & \text{if } h = 0 \\ 1, & \text{if } 0 < h < 18 \\ 2, & \text{if } h \geq 18 \end{cases} \tag{2.4}$$

Our three categories are inspired by the multi-tier framework of the Energy Sector Management Assistance Program (ESMAP).[10] The ESMAP framework is very detailed and looks at hours of access (duration) between day and night, voltage issues, affordability, having access to formal connection and health and safety aspects. However, in the absence of that detail we are making some approximations. Our category of 1, which is electricity for less than 18 hours a day, captures the tier 3 of electricity access according to ESMAP; our category 2, which is more than 18 hours, captures tiers 4 and 5 in ESMAP. 18 hours is the critical point where the household will get access to electricity in the evening or dusk hours; Chakravorty et al. (2014) for example also follow this approach. Figure 2.2 shows the values of reliability, averaged at the district level for presentation.

For the HDPI, the reporting is in terms of power outages per week. Our variable equals 2 if there were less than two outages per week, 1 if the households experience two or more outages and 0 if the household does not have access. This again follows the work of Chakravorty et al. (2014).

Table 2.6 shows the proportion of households that have a connection in the state over the three waves of data collection. There is a wide variation in the progress of states, even within a year. For example, Himachal Pradesh had 80% of the households connected in 1994 compared to 8% in Bihar.[11] Comparing Bihar and West Bengal, in 1994 both started at 8 and 10% respectively but West Bengal was at 76% while Bihar was only 41% in 2005. Bihar picked up pace after and reached 63%, while Bengal increased to 87%

Instruments. The summary statistics and figure of the instruments used are reported in Appendix 2.10. To calculate the density of transmission lines in each district, we need the length of transmission cables within each district and the area of the district. Chakravorty et al. (2014) kindly shared the data for 1994 and 2005 with us. For the cable length for 2012, we used maps available in pdf format for each state. We digitised the maps using QGIS and added the cables onto the map. After this, the district map of India was overlaid onto the cables. We then calculated the length of the cables within the district polygon. To keep it comparable with data received from Chakravorty et al. (2014), we used only the 440 kV lines,

[10]ESMAP is a partnership between the World Bank and 24 partners to help low and middle-income countries reduce poverty and boost growth through sustainable energy solutions.

[11]Bihar was a combined state of present Bihar and Jharkhand in 1994, we have made retrospective changes to be able to compare the progress at the district level

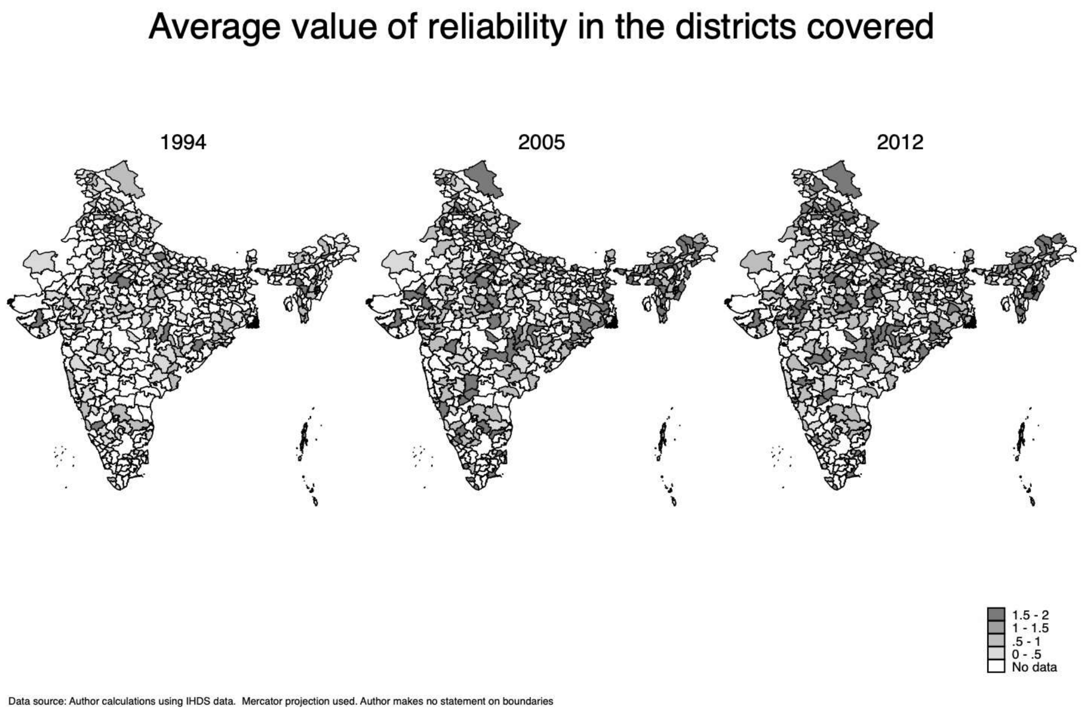


Figure 2.2: Map of India showing the average value of the treatment variable, reliability, in the three survey waves.Source: Author calculations from HDPI and IHDS data

which constitute the bulk of the transmission network [12].This data is not reported at the district level, so to check this, we added the length of lines to state level and used the data from CEA's Load Generation and Balancing report. Appendix 2.10 gives a detailed overview of the instruments.[13] For the area of the districts, we use the district boundaries as of 2005 and calculate the area inside the polygon.[14] Summary statistics for the density IV over the three survey periods are given in the Appendix Table 2.16.

The distance from power plants is constructed by using the coordinates of the power plants available from the Ministry of Power but compiled and publicly made available by KAPSARC (2023). This dataset includes the coordinates of the power plant, other information about capacity (MW), utilisation, and technology of the plant. This information is available and compiled for coal-based plants and hydro plants (small and large). The IHDS dataset does not give access to village or household geographical identification information, therefore the distance of the power plants is calculated from the centroid of the district polygon to the power plants. Appendix 2.10 reports maps and summary statistics for our two distance from power plant IVs for the three survey periods.

The disaster data set is available from the Indian meteorological organisation and is published every year. This information was digitised manually. From this data, we extracted precipitation-based disasters and the number of days these occur for each type of disaster. In the description, the districts report if the electricity supply was affected during the disaster. The latter is recorded as a dummy variable equal to one if there was any disruption. It is important to note this is not mandatory reporting and districts report this on their own discretion. To extract this information, we look for the keywords "power lines", "electricity poles", "power supply" and similar word combinations. We arrived at these keywords with a manual examination of the data. Crucially, since the surveys were conducted across two years, we add the data for 1993 and 1994 for the first wave, 2004 and 2005 for the second wave, and 2011 and 2012 for the third wave. The data are often reported at the sub-district (*tehsil*) level or sometimes non-official names of the areas are used. For example, the data might say the Bundelkhand area was affected but this spans some areas in two states (UP and MP) so we manually searched for the districts in these areas on the web. For the district names, similar to earlier, we first match the original names to the disaster in each year and then used Asher et al. (2021) to link them over time.

Control variables. We follow the literature for the list of controls to include, most closely, Khandker et al. (2009), Chakravorty et al. (2014), and van de Walle et al. (2017). For the household level regressions, the controls used are the gender composition of the household, the caste of the household, if the household is above the poverty line, if the household owns any livestock, and if the household is located in a rural area. The poverty line used is called the Tendulkar committee poverty line, Alagh (2010) set by each individual state based on a consumption-based formula. For the individual level regressions, in addition to these controls, we include the age of the individual, education levels, and relationship of each of the members of the household and if the individual is the head of the household.

[12]India only introduced higher than 440 kV lines in 2012 and these span a few hundred km

[13]We find some discrepancy in the state of Rajasthan, where the lines under construction seem to have been added to the total lines, for the relevance of our instrument we only use the existing lines, however its hard to check this for past data.

[14]A note on changing district boundaries over time. Indian states and districts have been breaking down, to balance administrative costs, language spoken in the district, and cultural identities. For the districts in 1994 and 2011, we use Asher et al. (2021) which provides a mapping of districts using a common identified to map the district to the 2005 and 1991 level.

2.6 Results

2.6.1 Main results

Our first step in this empirical investigation is to discuss the role of the quality of electricity supply on income. For ease of interpretation, we use log of income. We start by looking at the household level, where we look at log of household income. The first column in Table 2.4 presents the results from the OLS estimation of equation (2.1). The signs of the coefficients are as expected, and the quality of electricity is estimated to have effects that align with our theoretical priors: on average, for Indian households, some access to electricity is better than nothing in the sense that it correlates positively with a higher level of income; high-quality of supply, however, is even more strongly associated with income. Since we are conscious of the likely endogeneity of the electricity quality indicators, however, we move on and estimate the same relationship within an instrumental variable framework, as discussed in Section 2.4. The results from this procedure are reported in column (2). While the coefficients remain positive and significant, they exhibit a large increase in size, the coefficient for 'High-Quality Supply' jumps up by an order of magnitude, and the 'Low-Quality Supply' coefficient by a factor of thirty! However, for the model with household income(log) the instruments in the first stage are not significant (see Table 2.7), therefore we have little confidence in these results other than to note that there seems to be a significant underestimation of the impact of electricity in the OLS regression. This is consistent with a situation where both household income and quality of supply are increasing over time due to exogenous factors, e.g. increases in productivity from technology diffusion that raise wages and incomes, while, at the same time, making reliable electricity easier to provide. Instrumenting with reliability shifters, we are able to identify the (steeper) electrification-income schedule we are looking for.

The remaining columns in Table 2.4 replicate this exercise, this time using the (logarithm of) individual incomes, i.e. the sum of all the income that each individual respondent claims to be receiving. Focussing on columns (3) and (4), we can see that, qualitatively, the results are broadly consistent with the household ones. The quality of electrification drives increases in individual income at the aggregate level, and the OLS results significantly underestimate this effect. This time, the first stage is convincing, all the instruments are strongly significant and have the expected signs, overall the first stage has a strong F-statistic (we report the weak-instrument robust Cragg-Donald F-statistic throughout). Therefore, while the estimated coefficients for the IV are still significantly larger than the OLS ones, we have much more confidence in these results, which suggest that electrification has a strongly positive impact on the income of the respondents.[15] The results from column 4 suggest that going from no electricity to low-quality electricity increases individual incomes by a factor of 3.6 or over 260% on average, and going to high-quality electricity by a factor of 3 or over 200%.[16] For individuals in unelectrified households, the average income is INR 754, therefore this increase would imply individual income increases by 2735 on average for transitioning to low quality electricity from none. Similarly, going from low quality electricity to high quality electricity means an increase of INR 2261. These are very significant amounts for households.

[15] Note that, as discussed in Section 4.4, the sum of individual incomes falls short of the corresponding household income, possibly explaining part of the disparity in the size of the coefficients.

[16] The dependent variable is in natural logarithms (i.e. a log-level regression), so to get the impact for all individuals of going from no to low-quality electricity, for example, we take $exp^{1.29} = 3.63$, and in percent we get $100 * (exp^{1.29} - 1) = 263\%$.

Table 2.4: Impact of reliability of electricity on log income

	Household		All individuals		Only Male		Only Female	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Electricity supply:								
Low-quality supply (<18 hours/day)	0.35***	9.60***	0.17***	1.29***	0.22***	1.67***	0.12***	0.62
	(0.011)	(3.144)	(0.010)	(0.437)	(0.011)	(0.470)	(0.017)	(0.511)
High-quality supply (≥18 hours/day)	0.42***	5.88***	0.26***	1.11**	0.33***	0.99*	0.13***	1.37*
	(0.011)	(2.222)	(0.011)	(0.563)	(0.013)	(0.585)	(0.020)	(0.721)
Demographic variables:								
Lives in rural area	-0.34***	-0.11	-0.51***	-0.42***	-0.47***	-0.46***	-0.55***	-0.34***
	(0.009)	(0.457)	(0.010)	(0.111)	(0.011)	(0.120)	(0.020)	(0.128)
Age			0.05***	0.04***	0.08***	0.08***	0.07***	0.06***
			(0.002)	(0.005)	(0.002)	(0.007)	(0.003)	(0.007)
Age squared			-0.00***	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Education (years completed)	0.06***	-0.06*	0.08***	0.07***	0.06***	0.04***	0.08***	0.06***
	(0.001)	(0.033)	(0.001)	(0.008)	(0.001)	(0.007)	(0.002)	(0.013)
Head of household			0.58***	0.62***	0.06***	0.04	0.24***	0.27***
			(0.009)	(0.025)	(0.014)	(0.040)	(0.021)	(0.032)
Wealth:								
Owns their house	-0.02	-0.05	-0.11***	-0.03	-0.12***	-0.05	-0.20***	-0.12**
	(0.015)	(0.138)	(0.015)	(0.035)	(0.016)	(0.045)	(0.029)	(0.050)
Percentage of children in household	-0.33***	-0.11	-0.37***	-0.25***	-0.03	0.11	-0.11***	0.04
	(0.018)	(0.116)	(0.020)	(0.083)	(0.024)	(0.083)	(0.035)	(0.117)
Owns livestock	-0.40***	0.01	-0.37***	-0.29***	-0.38***	-0.32***	-0.42***	-0.30***
	(0.008)	(0.146)	(0.008)	(0.041)	(0.009)	(0.045)	(0.015)	(0.057)
Below poverty line	-0.34***	0.57**	-0.28***	-0.12**	-0.31***	-0.14**	-0.22***	-0.09
	(0.010)	(0.260)	(0.009)	(0.055)	(0.010)	(0.060)	(0.016)	(0.075)
Size of the household	0.08***	0.03	0.05***	0.04***	0.02***	-0.00	0.01***	-0.00
	(0.002)	(0.022)	(0.002)	(0.007)	(0.002)	(0.008)	(0.003)	(0.014)
Religion and caste:								
SC	0.07***	0.33***	-0.25***	-0.23***	-0.24***	-0.24***	-0.22***	-0.15**
	(0.009)	(0.125)	(0.011)	(0.042)	(0.012)	(0.044)	(0.022)	(0.060)
ST	0.06***	0.55**	-0.09***	-0.07*	-0.07***	-0.08*	-0.09***	-0.04
	(0.014)	(0.220)	(0.011)	(0.043)	(0.013)	(0.046)	(0.023)	(0.052)
Muslim	0.04***	-0.10	-0.28***	-0.27***	-0.31***	-0.32***	-0.14***	-0.07
	(0.012)	(0.152)	(0.014)	(0.085)	(0.017)	(0.091)	(0.026)	(0.092)
Other minority	0.19***	0.36**	-0.02	-0.02	-0.02	-0.07	-0.17***	-0.08
	(0.022)	(0.155)	(0.015)	(0.069)	(0.016)	(0.078)	(0.032)	(0.074)
Constant	7.77***		6.50***		6.34***		6.02***	
	(0.020)		(0.036)		(0.040)		(0.072)	
District Fixed Effects		Yes		Yes		Yes		Yes
C-D F-statistic for first stage		13.16		102.948		75.475		33.605
N	77,489	52,864	76,645	58,617	54,669	42,147	21,976	16,469

Notes: For the household specification Income is total household income and education is reported for the highest educated adult, for individuals is total individual income. Instruments used for all regressions are density of cables, distance to power plants and disasters as discussed in Section 4.4. Cragg-Donald F-statistic for weak-instrument robust inference shown for each IV specification. The first stage results are given in Table Table 2.7. *p <0.10, **p <0.05, ***p <0.01.

Overall, the sign of the remaining coefficients in these regressions align with our theoretical priors.

Columns (5)-(8) add a gendered perspective to this exercise. The first two columns present the OLS and IV results (respectively) for individuals within the household who identify themselves as male, and the last two present results for the female members of the household. Several points are worth noting. First of all, focussing on the IV results for females in column (8), the most striking aspect is that the coefficient for 'Low-Quality Supply' loses significance, and the 'High-Quality Supply', while significant at the 10%, is the largest coefficient among those estimated at the individual level. For males instead the low-quality electrification remains highly significant and the IV coefficient magnitude is very large (column 6). This analysis shows significant gender differences and the main message is that the benefits of electricity access only start accruing to women at very high levels of quality. Therefore, This increase is distributed disproportionately between men and women, for men going from no electricity to low quality means quadrupling of their income but for women it means an increase of 1.69 times. This means an income increase of INR for 2682 but only INR 269 for women. Going from low quality to high quality means an increase of 1674 for men but only 571 for women on average. These increase would be additional since the two measures are significantly different as confirmed by the t tests. We argue that the impact of increased quality of electricity is different on different sub-groups of interest working age men and women and there is heterogeneity in the impact of higher quality of electricity. Therefore, we believe that the estimates are the local average treatment effect (LATE). To the best of our knowledge, we are the first to provide empirical evidence on this point.

In the rest of this section, we investigate the potential mechanisms that might underpin these results, looking at the labour force participation and the hours worked in different occupations across genders.

2.6.2 Mechanism analysis

Underpinning our analysis is a conceptual framework *à la* Greenwood et al. (2005), within which as electricity becomes available, new technologies enter the production possibility set of the households, allowing household production to become more efficient and freeing up time to seek opportunities – such as paid employment – outside of the household. In this context, we would expect to see three patterns in the data. First, we would expect to see a decline in the time spent in the pursuit of those labour-intensive activities that are most likely to be supplanted by electricity-powered appliances. In the Indian context, this is likely to emerge in the form of a reduction in the time spent collecting firewood for cooking, for example. Second, once this reduction in drudgery takes place, we would expect a general increase in labour force participation, and more markedly among women, who ought to benefit the most from this aspect of electrification given that they traditionally carry most of the burden of these labour-intensive household chores. Finally, we would expect this increased participation in the labour market to translate, at least in part, into an increase in hours worked across a range of occupations, possibly starting with an increase in precarious ones but also in salaried, non-precarious ones.

Given these theoretical priors, we now turn first to an examination of the first channel, whereby electrification allows for a reduction in hours spent in unpaid occupations, such as firewood collection, for which we have information in our data. Panel A of Table 2.5 reports the results for hours spent collecting firewood. The first two columns refer to the aggregate results for all individuals in our sample and present first the results of the OLS, followed by the IV (2SLS) estimation, which uses the same set of

Table 2.5: Analysis of the mechanisms

	All individuals		Male		Female	
	(1)	(2)	(3)	(4)	(5)	(6)
A. Hours spent on collecting firewood (hours per week)						
Low-quality supply (<18 hours/day)	-55.29***	20.16	-3.71**	1052.39***	-4.20*	-518.88**
	(2.112)	(44.816)	(1.607)	(239.432)	(2.395)	(212.637)
High-quality supply (≥18 hours/day)	-45.26***	168.27***	-3.89**	319.69***	43.68***	17.72
	(2.336)	(16.878)	(1.915)	(36.244)	(2.852)	(30.133)
B. Labour force participation (0-3)						
Low-quality supply (<18 hours/day)	0.02	0.21**	0.04***	-0.10	0.05***	0.41***
	(0.010)	(0.103)	(0.012)	(0.120)	(0.015)	(0.142)
High-quality supply (≥18 hours/day)	-0.01	0.38***	0.14***	0.38***	-0.07***	0.63***
	(0.011)	(0.096)	(0.013)	(0.106)	(0.017)	(0.137)
C. Hours worked on precarious jobs (hours per year)						
Low-quality supply (<18 hours/day)	125.68***	-1481.44***	148.18***	-1394.75***	134.55***	-1179.64***
	(7.688)	(212.368)	(10.882)	(259.328)	(9.062)	(295.596)
High-quality supply (≥18 hours/day)	67.92***	-241.11***	96.27***	-197.55**	86.51***	-23.23
	(8.799)	(72.109)	(12.376)	(94.628)	(10.544)	(100.183)
D. Hours worked on non-precarious jobs(hours per year)						
Low-quality supply (<18 hours/day)	-16.75***	979.49***	-25.28***	1369.06***	6.67	690.18***
	(4.249)	(111.548)	(6.818)	(156.266)	(4.109)	(130.909)
High-quality supply (≥18 hours/day)	14.39***	709.60***	62.09***	1046.80***	-11.55**	413.60***
	(4.700)	(39.834)	(7.535)	(63.856)	(4.553)	(41.194)

Notes: The table presents the coefficients for the quality of electrification estimated for each mechanism. Columns (1), (3) and (5) show results for OLS, and columns (2), (4) and (6) for 2SLS. Control variables and a constant are included in all specifications and district fixed effects are included in the 2SLS. LFP is a categorical variable with 0= unemployed, 1 = underemployed, 2= part time job and 3 = full time job. Underemployed is defined as working less than 10 days a year. Standard errors are clustered at district level. The full results are available in Appendix 3.10, Tables 2.8-2.11. The corresponding first-stage results may be found in Tables 2.12-2.15. **p* <0.10, ***p* <0.05, ****p* <0.01.

instrumental variables as before (density, distance and disaster instruments). The following four columns replicate the same process on the gendered samples for males (columns 3-4) and females (columns 5-6). Overall the results point to a significant decrease in hours spent collecting firewood among the females in the sample when going from no to low-quality electrification, both in the OLS (column 5) and 2SLS (column 6) estimation. This result is supportive of the first channel discussed above. However, there is a marked increase in effort by males in the 2SLS results (column 4). However, there is a strong base effect applicable here since there is a very wide disparity in firewood collection times. The median time spent by women collecting firewood is 150 mins per week (nearly 2.5 hours) with median time spent by men being equal 13.8 mins per week. It is also possible that the increase in time for collecting firewood translates to income by men selling this firewood but unfortunately, we don't have relevant variables to check this in our dataset. In the aggregate, the 2SLS results are insignificant when the electricity supply is of low quality and positive and modest when electricity is supplied for more than 18 hours a day, and this does not seem a clear channel of transmission for our positive income effects for both genders in Table 2.4.

The second panel of Table 2.5 further traces the impacts of electrification in terms of labour force participation. The coefficients are presented in the same order as before, with the key difference that, since the dependent variable is ordinal, the regressions are ordered probits, instrumented in respective columns as above. The aggregate IV results – see column (2) – indicate a significant increase in labour force participation, which is larger when electricity is more reliable. The gendered results show that male participation does not respond to low-quality electrification, but it does when the quality of supply increases, whereas the participation rate increases significantly in both scenarios for females, becoming stronger as reliability improves. We think that these results have been shown here for the first time so starkly: these results strongly suggest that better-quality electrification increases income through increased labour force participation, particularly for women.

So far we have shown that electrification leads to an increase in labour supply. The final two panels of Table 2.5 help us understand the impact of electrification on job quality. Once again the first two columns present the aggregate results and the remaining four focus on the differential outcomes by gender. Focussing on the instrumented results for the sake of brevity, we immediately see a pattern emerging. Electrification leads to a decrease in hours worked in precarious jobs and an increase in hours spent in non-precarious occupations, for both genders. While the impact is strongest among males, there is a very significant impact on women as well; for both, the impact is largest when going from no to low-quality electrification.

2.7 Robustness check

We check for robustness of our results by varying the threshold to 16 and 20 hours. In table **??** we show a summary of this with second stage coefficients for the results, the first stage coefficients and the F stat. The detailed tables are in appendix 2.11

Comparing our results at 18 hours of threshold to 16 and 20 hours, there is no significant difference between the coefficients. As expected, the high-quality coefficient for 18 hours is more than the coefficient for 16 hours and less than 20 hours. The first stage coefficients are also similar, where density is positive for low quality hours of electricity and negative for high quality of electricity. The estimates for distance

16 hours threshold	All sample	Men	Women
Low quality	1.444***	1.685***	0.662***
	[0.0923]	[0.106]	[0.162]
High quality	1.029***	1.097***	0.842***
	[0.0801]	[0.0910]	[0.153]
First stage			
density	-10.22***	-8.139*	-17.15*
	[2.946]	[3.225]	[7.173]
coalkm	282.4***	333.7***	135.8*
	[30.22]	[34.06]	[65.87]
hydrokm	-165.7***	-137.7***	-244.1***
	[27.04]	[31.26]	[54.05]
daysd1	-0.0118***	-0.0128***	-0.00901***
	[0.000491]	[0.000568]	[0.000978]
daysd2	0.0171***	0.0183***	0.0124**
	[0.00218]	[0.00267]	[0.00381]
daysd3	-0.00216***	-0.00194***	-0.00293***
	[0.000213]	[0.000250]	[0.000410]
Check for weak instrument			
F stat	194.74	156.23	44.63

20 hours threshold	All sample	Men	Women
Low quality	0.166***	1.198***	1.530***
	[0.00934]	[0.0902]	[0.105]
High quality	0.304***	1.104***	1.088***
	[0.0115]	[0.0809]	[0.0919]
First stage			
density	-8.686**	-3.475	-30.19***
	[2.978]	[3.276]	[7.154]
coalkm	16.2	94.78**	-220.3***
	[30.55]	[34.59]	[65.69]
hydrokm	-163.3***	-140.2***	-220.2***
	[27.34]	[31.76]	[53.91]
daysd1	-0.00961***	-0.0110***	-0.00550***
	[0.000497]	[0.000577]	[0.000976]
daysd2	0.00814***	0.0106***	-0.000482
	[0.00220]	[0.00271]	[0.00380]
daysd3	-0.00283***	-0.00261***	-0.00365***
	[0.000215]	[0.000253]	[0.000409]
Test for weak instruments			
F stat	194.74	156.23	44.63

from coal plants are consistency of the opposite sign to the density coefficients.

2.8 Conclusion

Energy, and in particular electricity is often seen as the conduit of development. However, the focus has most often been on gaining access to electricity; only recently has a small literature started to emerge that looks at the effects of the quality of electrification, i.e. how reliable the access to electricity is. Our analysis focuses on the impact of the quality or reliability of electrification on household and individual income in India and also sheds light on the intervening mechanisms. We do this using data spanning over twenty years (1994-2015) and over 41,000 households and up to 270,000 individuals across the country, and employ both OLS and instrumental variables estimations for causal identification.

We find a strong positive effect of reliable electricity on individual incomes: going from no to low-quality electricity supply – i.e. under 18 hours per day – increases incomes by a factor of 3.6 on average, and having access to high-quality electricity – i.e. 18 hours per day or more – by a factor of 3. Yet, our work underlines a striking gender difference in outcomes as income is only shown to increase for the women in our sample when the electricity supply is very reliable, while men see a positive income effect already at low-quality electrification.

Our analysis of the mechanisms through which these increases in income come about suggests that, once time is made available to seek opportunities outside of the house, both males and females achieve higher labour force participation, especially via the substitution of time spent in precarious work with hours worked in non-precarious occupations, with obvious benefits to the household. We find less clear-cut evidence for the reduction of drudgery, proxied by time spent collecting firewood: though women spend less time on this once they gain access to low-quality electricity, men seem to spend more time. Even at low quality electricity, women enter the labour force and have a higher probability of taking up stable jobs, they reduce hours spent on precarious jobs and increase hours spent on non-precarious jobs. In other words, they get employed and this employment is at better conditions. There is a balancing of household chores, as seen by reduction in hours spent on collecting firewood by women and increase by men. However, Income benefits start accruing to women only at high quality electricity, as they continue to increase working on better jobs.

We hope that our results may inform the debate on electricity provision: the clear policy implication from our work is that a focus on reliable electricity is likely to be crucial to leverage the development gains linked to electrification. This is especially relevant as neither national policies nor the Sustainable Development Goals account for these aspects in their targets.

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Table 2.6: Percentage of connected households by state

	1994	2005	2012
Andhra Pradesh	59%	89%	98%
Assam	21%	62%	69%
Bihar	8%	41%	63%
Chhattisgarh	38%	73%	90%
Gujarat	73%	90%	96%
Haryana	81%	93%	97%
Himachal Pradesh	91%	98%	10%
Jharkhand	18%	69%	86%
Kerala	77%	92%	99%
Madhya	63%	75%	81%
Maharashtra	68%	85%	95%
Orissa	20%	45%	74%
Punjab	81%	97%	99%
Rajasthan	50%	66%	85%
TamilNadu	64%	90%	98%
Tripura	56%	82%	88%
Uttar	21%	47%	61%
Uttarakhand	33%	80%	95%
West	10%	59%	81%
Arunachal Pradesh	-	99%	99%
Chandigarh	-	100%	100%
DadraNagar Haveli	-	96%	100%
Daman Diu	-	100%	100%
Delhi	-	99%	100%
Goa	-	98%	99%
Jammu Kashmir	-	98%	100%
Karnataka	-	89%	94%
Manipur	-	97%	100%
Meghalaya	-	87%	99%
Mizoram	-	100%	100%
Nagaland	-	75%	99%
Pondicherry	-	91%	100%
Sikkim	-	100%	100%

Note: Some states were not covered in the 1994 wave of the survey

2.9 Appendix I: Additional Tables

Table 2.7: First stage regressions for Income

	HH low quality (1)	HH High quality (2)	All ind. low quality (3)	All ind. High quality (4)	Males low quality (5)	Males High quality (6)	Females low quality (7)	Females High quality (8)
density	-4.01	16.39	-17.87***	34.60***	-13.61***	30.54***	-32.87***	49.51***
	(20.779)	(19.730)	(3.105)	(2.772)	(3.428)	(3.101)	(7.290)	(6.283)
coalkm	306.48	-242.64	168.97***	-171.35***	244.39***	-237.59***	-68.92	31.22
	(220.439)	(211.464)	(31.186)	(27.836)	(35.114)	(31.764)	(68.191)	(58.770)
hydrokm	-1493.15	340.70	-213.17***	-368.78***	-185.74***	-418.29***	-284.92***	-226.38***
	(1970.507)	(1450.150)	(28.247)	(25.213)	(32.648)	(29.534)	(56.434)	(48.637)
heavy rain	0.00	-0.00	-0.01***	0.01***	-0.01***	0.02***	-0.01***	0.01***
	(0.005)	(0.004)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
flood	-0.00	-0.00	0.01***	-0.03***	0.02***	-0.03***	0.01	-0.03***
	(0.008)	(0.006)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)
severe flood	-0.00	-0.00*	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***	0.00
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
owns their house	0.02	-0.03*	0.02*	-0.03***	0.02*	-0.04***	0.02	-0.00
	(0.015)	(0.013)	(0.009)	(0.008)	(0.010)	(0.009)	(0.017)	(0.015)
share of children in hh	-0.02	-0.00	-0.01	-0.12***	-0.03*	-0.11***	-0.04*	-0.11***
	(0.011)	(0.010)	(0.011)	(0.010)	(0.014)	(0.013)	(0.020)	(0.017)
owns livestock	-0.04*	0.02	0.01*	-0.06***	0.01*	-0.07***	0.01	-0.06***
	(0.020)	(0.019)	(0.005)	(0.004)	(0.005)	(0.005)	(0.009)	(0.007)
household is below poverty line	-0.07***	-0.04***	-0.10***	-0.03***	-0.09***	-0.03***	-0.11***	-0.02**
	(0.010)	(0.008)	(0.005)	(0.005)	(0.006)	(0.005)	(0.009)	(0.008)
size of the household	0.01***	0.00	0.01***	0.00***	0.01***	0.00	0.01***	0.01***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
educ	0.01***	0.01***						
	(0.001)	(0.001)						
SC	-0.03**	-0.01	0.05***	-0.06***	0.05***	-0.06***	0.06***	-0.06***
	(0.010)	(0.008)	(0.006)	(0.005)	(0.007)	(0.006)	(0.013)	(0.011)
ST	-0.01	-0.07***	0.03***	-0.06***	0.02**	-0.05***	0.03	-0.05***
	(0.015)	(0.015)	(0.006)	(0.006)	(0.007)	(0.007)	(0.013)	(0.011)
muslim	0.01	-0.00	-0.01	-0.09***	-0.01	-0.08***	-0.01	-0.08***
	(0.017)	(0.014)	(0.008)	(0.007)	(0.010)	(0.009)	(0.015)	(0.013)
other minority	-0.04*	0.02	0.07***	-0.11***	0.07***	-0.11***	0.07***	-0.09***
	(0.018)	(0.017)	(0.008)	(0.007)	(0.009)	(0.008)	(0.018)	(0.016)
lives in rural area	0.11***	-0.22***	0.12***	-0.22***	0.12***	-0.22***	0.12***	-0.20***
	(0.027)	(0.025)	(0.006)	(0.005)	(0.006)	(0.006)	(0.012)	(0.010)
Age			-0.00	0.01***	-0.01***	0.01***	-0.00	0.01***
			(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Age squared			0.00	-0.00***	0.00***	-0.00***	0.00	-0.00***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
years of completed education			-0.00*	0.01***	0.00***	0.01***	-0.01***	0.02***
			(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
are they head of household			-0.01	-0.03***	0.04***	-0.06***	-0.01	-0.00
			(0.005)	(0.004)	(0.008)	(0.007)	(0.012)	(0.010)
C-D F-statistic for first stage	13	13	102.948	102.948	75.475	75.475	33.605	33.605
N	52,864	52,864	58,617	58,617	42,147	42,147	16,469	16,469

Notes: Results show first-stage results for household and individual income. The second stage results are given in Table 2.4. Columns 1-2 show results for household income for low and high quality electricity, respectively; columns 3-4 for all individual incomes for low and high quality electricity, respectively; columns 5-6 for males for low and high quality electricity, respectively; and columns 7-8 for females for low and high quality electricity, respectively. Cragg-Donald F-statistic for weak-instrument robust inference shown for each specification. *p <0.10, **p <0.05, ***p <0.01.

Table 2.8: Impact of reliability of electricity on firewood collection

	All individuals		Only Male		Only Female	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Low quality	-55.29***	20.16	-3.71**	1052.39***	-4.20*	-518.88**
	(2.112)	(44.816)	(1.607)	(239.432)	(2.395)	(212.637)
High quality	-45.26***	168.27***	-3.89**	319.69***	43.68***	17.72
	(2.336)	(16.878)	(1.915)	(36.244)	(2.852)	(30.133)
Demographic variables:						
owns their house	15.01***	18.06***	13.12***	-58.78***	25.20***	60.81***
	(3.214)	(3.841)	(4.719)	(21.499)	(6.947)	(17.428)
size of the household	0.18	-0.06	1.65***	-12.42***	0.90**	8.59***
	(0.278)	(0.635)	(0.243)	(3.506)	(0.362)	(3.135)
share of children in the household	48.47***	72.69***	-33.44***	60.97***	20.20***	-0.35
	(4.077)	(5.101)	(3.691)	(19.240)	(5.435)	(16.364)
Wealth:						
owns livestock	60.41***	72.53***	8.63***	38.55***	38.70***	27.67***
	(1.747)	(2.515)	(1.481)	(5.574)	(2.203)	(4.531)
household is below poverty line	63.53***	65.83***	23.03***	150.23***	24.25***	-48.31*
	(1.923)	(5.611)	(1.563)	(30.493)	(2.331)	(26.999)
is head of household	10.38***	16.92***	3.63*	17.74***	6.16**	3.81
	(2.066)	(2.320)	(1.871)	(5.223)	(2.785)	(4.279)
Age	0.83***	1.05***	0.26**	-0.93**	0.57***	1.51***
	(0.145)	(0.169)	(0.126)	(0.470)	(0.188)	(0.402)
Age squared	-0.02***	-0.03***	-0.01***	-0.00	-0.01***	-0.03***
	(0.002)	(0.002)	(0.002)	(0.005)	(0.003)	(0.005)
years of completed education	-6.45***	-8.55***	-1.92***	-9.73***	-4.85***	-2.94***
	(0.185)	(0.273)	(0.180)	(1.303)	(0.268)	(1.124)
Religion and caste:						
SC	-3.32*	17.89***	-8.84***	-7.94	-28.51***	-10.32*
	(1.998)	(2.726)	(2.003)	(7.377)	(2.990)	(6.126)
ST	42.89***	64.09***	-22.59***	1.10	7.05**	15.57***
	(2.278)	(2.732)	(2.133)	(5.895)	(3.183)	(4.706)
Muslim	113.03***	139.94***	30.93***	79.97***	15.51***	8.50
	(3.101)	(4.093)	(2.553)	(10.185)	(3.812)	(7.868)
other minority	-40.55***	-12.93***	-35.77***	1.92	-55.90***	-48.02***
	(2.633)	(4.034)	(2.757)	(7.995)	(4.103)	(6.409)
lives in rural area	132.55***	163.91***	50.13***	-8.20	75.10***	127.91***
	(1.982)	(5.505)	(2.563)	(26.992)	(3.819)	(22.820)
Constant	71.73***	-90.89***	62.67***	-353.00***	135.67***	247.63***
	(4.895)	(19.763)	(5.974)	(66.024)	(8.830)	(58.952)
C-D F-statistic for first stage		111.899		6.750		5.534
N	279,873	216,402	116,741	88,081	119,300	90,020

Notes: Table shows full results for Panel A in Table 2.5. Cragg-Donald F-statistic for weak-instrument robust inference shown for each specification. *p <0.10, **p <0.05, ***p <0.01.

Table 2.9: Impact of reliability of electricity on labour force participation

	All individuals		Male		Female	
	Ordered Probit	IV	Ordered Probit	IV	Ordered Probit	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Low-quality supply (<18 hours/day)	0.02	0.21**	0.04***	-0.10	0.05***	0.41***
	(0.010)	(0.103)	(0.012)	(0.120)	(0.015)	(0.142)
Low-quality supply (<18 hours/day)	-0.01	0.38***	0.14***	0.38***	-0.07***	0.63***
	(0.011)	(0.096)	(0.013)	(0.106)	(0.017)	(0.137)
Demographic variables:						
size	0.02***	0.02***	-0.01***	-0.01***	-0.06***	-0.06***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
share of children	-0.21***	-0.17***	0.34***	0.43***	0.21***	0.31***
	(0.020)	(0.025)	(0.026)	(0.032)	(0.028)	(0.035)
Age	0.15***	0.15***	0.22***	0.21***	0.13***	0.13***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Agesq	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Years of completed education	0.02***	0.01***	-0.00***	-0.01***	-0.04***	-0.05***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)
Wealth:						
house is owned	0.03*	0.07***	-0.15***	-0.08***	0.14***	0.16***
	(0.016)	(0.020)	(0.018)	(0.023)	(0.024)	(0.030)
HH Owns livestock	0.21***	0.24***	-0.10***	-0.05***	0.49***	0.54***
	(0.008)	(0.014)	(0.009)	(0.016)	(0.012)	(0.020)
bpl	-0.01	-0.02	-0.13***	-0.13***	0.06***	0.07***
	(0.009)	(0.012)	(0.011)	(0.014)	(0.014)	(0.017)
is head of household	1.30***	1.33***	0.23***	0.24***	0.51***	0.49***
	(0.010)	(0.012)	(0.014)	(0.016)	(0.020)	(0.023)
Religion and caste:						
SC	0.11***	0.14***	-0.02	0.02*	0.22***	0.23***
	(0.010)	(0.012)	(0.011)	(0.014)	(0.015)	(0.018)
ST	0.19***	0.23***	0.05***	0.08***	0.26***	0.28***
	(0.012)	(0.014)	(0.013)	(0.015)	(0.018)	(0.020)
Muslim	0.32***	0.39***	-0.04**	0.03	0.66***	0.71***
	(0.016)	(0.021)	(0.018)	(0.022)	(0.023)	(0.029)
other minority	-0.06***	-0.03*	0.04***	0.09***	-0.36***	-0.32***
	(0.014)	(0.017)	(0.016)	(0.018)	(0.022)	(0.025)
Constant	2.58***	2.78***	2.58***	2.58***	2.58***	2.89***
	(0.041)	(0.083)	(0.047)	(0.095)	(0.065)	(0.116)
N	179448	139115	93057	77867	86391	72070

Notes: Table shows full results for Panel B in Table 2.5. Ordered Probit regressions. A positive coefficient implies higher likelihood of being in a higher category of LFP i.e. higher chance of being employed than unemployed and vice versa for negative sign. The first stage results are given in Table Table 2.12. *p <0.10, **p <0.05, ***p <0.01.

Table 2.10: Impact of reliability of electricity on hours spent in precarious jobs

	All individuals		Only Male		Only Female	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
low quality	125.68***	-1481.44***	148.18***	-1394.75***	134.55***	-1179.64***
	(7.688)	(212.368)	(10.882)	(259.328)	(9.062)	(295.596)
High quality	67.92***	-241.11***	96.27***	-197.55**	86.51***	-23.23
	(8.799)	(72.109)	(12.376)	(94.628)	(10.544)	(100.183)
Demographic variables:						
owns their house	-216.00***	-101.56***	-212.14***	-107.14**	-285.59***	-178.34***
	(21.159)	(33.466)	(27.272)	(41.595)	(29.833)	(49.060)
size of the household	24.18***	48.60***	13.00***	34.89***	0.91	24.76***
	(1.082)	(3.347)	(1.579)	(4.130)	(1.356)	(5.464)
share of children in the household	-60.68***	-190.45***	117.97***	-6.50	25.94	-69.76
	(15.912)	(30.670)	(23.238)	(39.634)	(18.937)	(45.827)
Wealth:						
owns livestock	-253.29***	-269.24***	-322.08***	-323.33***	-115.07***	-149.57***
	(7.408)	(11.910)	(10.181)	(15.881)	(9.167)	(16.197)
household is below poverty line	-165.18***	-390.01***	-218.15***	-425.31***	-103.93***	-288.36***
	(7.782)	(29.936)	(11.076)	(35.411)	(9.095)	(44.181)
is head of household	312.39***	307.37***	-13.90	15.64	68.49***	36.53
	(7.280)	(11.810)	(13.241)	(19.881)	(14.313)	(24.979)
age	46.91***	48.61***	70.79***	69.08***	35.49***	36.94***
	(0.856)	(1.369)	(1.333)	(2.130)	(1.073)	(1.903)
Age squared	-0.55***	-0.56***	-0.77***	-0.76***	-0.40***	-0.41***
	(0.010)	(0.016)	(0.015)	(0.023)	(0.013)	(0.023)
years of completed education	18.09***	23.89***	6.88***	14.54***	-0.53	-0.60
	(0.708)	(1.462)	(0.995)	(2.048)	(1.010)	(2.327)
Religion and caste:						
SC	-84.62***	-72.89***	-81.84***	-78.59***	-68.19***	-29.59
	(7.530)	(14.211)	(10.236)	(17.708)	(9.492)	(20.027)
ST	-225.24***	-351.24***	-269.50***	-391.90***	-150.37***	-238.10***
	(9.393)	(20.313)	(13.047)	(26.019)	(11.432)	(27.123)
Muslim	-194.69***	-267.43***	-276.22***	-364.07***	-83.27***	-110.97***
	(11.007)	(19.693)	(15.774)	(26.868)	(12.848)	(24.383)
other minority	-103.90***	20.88	-93.32***	9.59	-174.36***	-16.64
	(11.291)	(25.245)	(14.952)	(31.318)	(14.995)	(36.775)
lives in rural area	-619.50***	-510.26***	-678.21***	-566.52***	-280.58***	-195.41***
	(9.996)	(26.604)	(12.949)	(34.578)	(14.360)	(36.428)
Constant	720.52***		644.95***		574.25***	
	(29.400)		(38.974)		(40.177)	
District Fixed Effect		Yes		Yes		Yes
C-D F-statistic for first stage		42.96		29.67		14.76
N	82941	61872	51468	39034	31431	22807

Notes: Table shows full results for Panel C in Table 2.5. Cragg-Donald F-statistic for weak-instrument robust inference shown for each IV specification. See Table 2.13 for first-stage results of 2SLS estimations. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2.11: Impact of reliability of electricity on hours spent in non-precarious jobs

	All individuals		Only Male		Only Female	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
low quality	-16.75***	979.49***	-25.28***	1369.06***	6.67	690.18***
	(4.249)	(111.548)	(6.818)	(156.266)	(4.109)	(130.909)
High quality	14.39***	709.60***	62.09***	1046.80***	-11.55**	413.60***
	(4.700)	(39.834)	(7.535)	(63.856)	(4.553)	(41.194)
Demographic variables:						
owns their house	-107.06***	-97.19***	-161.64***	-146.80***	-62.27***	-65.03***
	(6.465)	(8.796)	(10.381)	(14.506)	(6.247)	(8.658)
size of the household	0.64	-10.38***	-8.48***	-23.74***	-11.59***	-20.27***
	(0.559)	(1.527)	(0.927)	(2.165)	(0.540)	(1.809)
share of children in the household	-122.04***	-34.88***	40.77***	169.37***	-23.87***	36.71***
	(8.202)	(11.574)	(13.599)	(19.402)	(7.894)	(12.005)
Wealth:						
owns livestock	-149.42***	-115.45***	-221.91***	-178.49***	-98.74***	-76.09***
	(3.515)	(5.730)	(5.608)	(9.403)	(3.428)	(5.552)
household is below poverty line	57.05***	190.44***	43.07***	227.22***	41.64***	133.88***
	(3.867)	(13.890)	(6.235)	(19.519)	(3.725)	(16.370)
is head of household	674.65***	693.90***	267.52***	273.42***	274.33***	275.38***
	(4.156)	(5.290)	(8.256)	(10.621)	(6.274)	(7.970)
age	40.40***	40.20***	79.44***	81.01***	23.17***	22.52***
	(0.291)	(0.384)	(0.575)	(0.742)	(0.265)	(0.380)
Age squared	-0.56***	-0.57***	-0.99***	-1.02***	-0.29***	-0.29***
	(0.004)	(0.005)	(0.007)	(0.009)	(0.004)	(0.005)
years of completed education	5.10***	-3.62***	-10.71***	-24.62***	-5.62***	-10.45***
	(0.371)	(0.634)	(0.627)	(1.151)	(0.377)	(0.678)
Religion and caste:						
SC	59.11***	85.09***	39.29***	86.86***	55.56***	60.32***
	(4.018)	(5.909)	(6.413)	(9.607)	(3.912)	(5.830)
ST	213.98***	268.80***	254.79***	335.03***	122.40***	152.31***
	(4.582)	(6.324)	(7.300)	(10.325)	(4.473)	(6.311)
muslim	156.53***	246.17***	105.32***	231.55***	176.50***	228.23***
	(6.238)	(9.636)	(9.999)	(15.757)	(6.043)	(9.522)
other minority	63.60***	83.84***	91.95***	117.84***	-9.83*	0.24
	(5.296)	(9.044)	(8.480)	(14.849)	(5.138)	(8.862)
lives in rural area	-28.67***	29.86***	-113.09***	-20.90	45.23***	66.14***
	(3.987)	(10.495)	(6.363)	(17.421)	(3.881)	(10.119)
Constant	-100.03***		-198.21***		-36.62***	
	(9.847)		(15.683)		(9.691)	
District Fixed Effects		Yes		Yes		Yes
C-D F-statistic for first stage		99.255		71.009		33.124
N	279,873	216,402	146,565	113,481	133,308	102,921

Notes: Table shows full results for Panel D in Table 2.5. Cragg-Donald F-statistic for weak-instrument robust inference shown for each IV specification. See Table 2.15 for first-stage results of 2SLS estimations. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table 2.12: First stage for labour force participation results, IV ordered probit

	All (1)	Male (2)	Female (3))
density	-7.39	16.71	-40.87
	(156.444)	(161.542)	(149.960)
coalkm	-99.50	-202.56	-21.55
	(991.896)	(972.244)	(1021.681)
hydrokm	-2942.46*	-2834.91*	-3028.26*
	(1242.404)	(1255.398)	(1225.213)
flash flood	-0.10*	-0.11*	-0.10*
	(0.041)	(0.042)	(0.040)
flood	-0.11**	-0.10**	-0.11**
	(0.037)	(0.038)	(0.037)
heavy rain	0.02**	0.02**	0.02**
	(0.007)	(0.007)	(0.007)
moderate flood	0.00	0.00	0.00
	(0.036)	(0.037)	(0.036)
severe flood	-0.02*	-0.02*	-0.02*
	(0.011)	(0.010)	(0.012)
owns their house	0.09	0.08	0.11
	(0.085)	(0.080)	(0.098)
size of the household	0.02*	0.02*	0.02*
	(0.008)	(0.009)	(0.009)
share of children in the hosuehold	-0.19**	-0.27***	-0.16*
	(0.073)	(0.076)	(0.075)
owns livestock	-0.18*	-0.20*	-0.14
	(0.087)	(0.086)	(0.090)
household is below poverty line	-0.32***	-0.32***	-0.32***
	(0.065)	(0.066)	(0.066)
is head of household	-0.11***	-0.06	0.00
	(0.016)	(0.032)	(0.057)
age	-0.01***	-0.01**	-0.01***
	(0.002)	(0.003)	(0.002)
Age squared	0.00***	0.00***	0.00***
	(0.000)	(0.000)	(0.000)
years of completed education	0.05***	0.04***	0.06***
	(0.006)	(0.006)	(0.007)
SC	-0.22*	-0.22*	-0.22*
	(0.108)	(0.106)	(0.111)
ST	-0.24**	-0.25**	-0.21**
	(0.076)	(0.078)	(0.078)
muslim	-0.43**	-0.42**	-0.43**
	(0.140)	(0.137)	(0.146)
other minority	-0.04	-0.06	0.00
	(0.154)	(0.154)	(0.154)
lives in rural area	-0.94***	-0.96***	-0.92***
	(0.152)	(0.153)	(0.152)
cut1			
Constant	-2.48***	-2.55***	-2.39***
	(0.343)	(0.346)	(0.342)
cut2			
Constant	-0.57*	-0.64*	-0.48
	(0.271)	(0.273)	(0.272)
sigma2_u			
Constant	0.54**	0.53**	0.54**
	(0.195)	(0.197)	(0.192)
N	77,381	40,581	36,800

Note: The table shows first-stage results for labour force participation. For second stage ordered probit results see Table 2.9. The econometric approach collapses first-stage results for low and high quality electricity into one. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

Table 2.13: First stage for precarious job results, 2SLS

	All individuals		Males		Females	
	low	high	low	high	low	high
	(1)	(2)	(3)	(4)	(5)	(6)
coalkm	-322.82***	89.97	-322.12***	138.08	-311.86**	-30.55
	(64.683)	(59.029)	(80.931)	(74.228)	(109.140)	(97.953)
hydrokm	531.72***	-1425.77***	359.39***	-1201.31***	779.60***	-1728.50***
	(48.268)	(44.050)	(60.640)	(55.617)	(80.758)	(72.481)
density	-60.14***	-8.90	-73.88***	24.07	-43.24*	-65.45***
	(12.260)	(11.189)	(15.291)	(14.024)	(20.989)	(18.838)
flash flood	0.02***	-0.04***	0.01***	-0.04***	0.02***	-0.04***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)
flood	0.04***	-0.05***	0.04***	-0.05***	0.04***	-0.05***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
heavy rain	-0.01***	0.01***	-0.01***	0.01***	-0.01***	0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
moderate flood	-0.03***	0.02**	-0.03***	0.02*	-0.04**	0.02
	(0.007)	(0.007)	(0.009)	(0.008)	(0.014)	(0.013)
severe flood	0.01***	-0.01***	0.01***	-0.01***	0.01***	-0.01***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
owns their house	-0.04	0.04*	-0.07*	0.06*	0.02	0.01
	(0.024)	(0.022)	(0.029)	(0.026)	(0.043)	(0.039)
size of the household	0.02***	-0.01***	0.02***	-0.01***	0.02***	-0.00*
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
share of children in the hosuehold	-0.17***	0.03*	-0.17***	0.05*	-0.16***	-0.02
	(0.019)	(0.017)	(0.025)	(0.023)	(0.029)	(0.026)
owns livestock	-0.03***	0.00	-0.01	-0.02	-0.07***	0.05***
	(0.008)	(0.008)	(0.011)	(0.010)	(0.014)	(0.012)
household is below poverty line	-0.08***	-0.00	-0.08***	0.01	-0.07***	-0.01
	(0.010)	(0.009)	(0.013)	(0.012)	(0.015)	(0.014)
is head of household	0.01	-0.03***	0.01	-0.03**	-0.07**	0.09***
	(0.008)	(0.008)	(0.014)	(0.013)	(0.021)	(0.019)
age	0.00***	-0.00	0.00*	-0.00	0.01**	-0.00
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Age squared	-0.00***	0.00***	-0.00**	0.00**	-0.00**	0.00**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
years of completed education	-0.00	0.01***	0.00	0.01***	-0.00	0.02***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SC	0.08***	-0.09***	0.07***	-0.08***	0.10***	-0.11***
	(0.008)	(0.007)	(0.010)	(0.009)	(0.013)	(0.012)
ST	-0.07***	0.02*	-0.09***	0.03*	-0.04**	0.02
	(0.010)	(0.009)	(0.013)	(0.012)	(0.016)	(0.015)
muslim	-0.01	-0.06***	-0.02	-0.06***	0.00	-0.06**
	(0.014)	(0.013)	(0.018)	(0.017)	(0.022)	(0.020)
other minority	-0.00	-0.01	-0.01	-0.00	-0.00	-0.02
	(0.014)	(0.013)	(0.017)	(0.015)	(0.026)	(0.023)
lives in rural area	0.19***	-0.25***	0.19***	-0.26***	0.17***	-0.23***
	(0.011)	(0.010)	(0.014)	(0.012)	(0.022)	(0.020)
N	20,079	20,079	12,412	12,412	7,656	7,656

Note: The table shows first-stage 2SLS results for hours worked in precarious jobs. For second stage results see Table 2.10. Columns 1-2 show results for all individuals for low and high quality electricity, respectively; columns 3-4 show results for males for low and high quality electricity, respectively; columns 5-6 show results for females for low and high quality electricity, respectively. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table 2.14: First stage for non precarious work results, 2SLS

	All individuals		Males		Females	
	low	high	low	high	low	high
	(1)	(2)	(3)	(4)	(5)	(6)
coalkm	200.40***	-186.92***	285.79***	-263.69***	266.61***	-252.32***
	(16.922)	(15.147)	(26.497)	(24.151)	(29.138)	(26.311)
hydrokm	-25.43	-527.72***	-87.16***	-452.89***	30.67	-535.34***
	(13.789)	(12.343)	(24.256)	(22.108)	(25.121)	(22.684)
density	-17.01***	30.81***	-18.98***	32.85***	-19.85***	33.58***
	(1.635)	(1.464)	(2.545)	(2.319)	(2.876)	(2.597)
heavy rain	-0.01***	0.02***	-0.01***	0.02***	-0.01***	0.02***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
flood	0.02***	-0.03***	0.02***	-0.03***	0.02***	-0.03***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
severe flood	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***	-0.00*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
owns their house	0.04***	-0.04***	0.03**	-0.04***	0.03***	-0.04***
	(0.005)	(0.004)	(0.008)	(0.007)	(0.008)	(0.007)
size of the household	0.01***	-0.00*	0.01***	-0.00**	0.01***	0.00
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
share of children in the hosuehold	-0.02**	-0.09***	-0.02	-0.12***	-0.03**	-0.10***
	(0.006)	(0.005)	(0.011)	(0.010)	(0.010)	(0.009)
owns livestock	0.03***	-0.08***	0.03***	-0.08***	0.03***	-0.07***
	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
household is below poverty line	-0.11***	-0.04***	-0.10***	-0.03***	-0.11***	-0.03***
	(0.003)	(0.002)	(0.005)	(0.005)	(0.005)	(0.005)
are they head of household	0.00	-0.03***	0.03***	-0.05***	-0.01	-0.00
	(0.003)	(0.003)	(0.006)	(0.006)	(0.007)	(0.007)
age	0.00***	-0.00***	-0.00**	0.01***	-0.00**	0.01***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Age squared	-0.00***	0.00***	0.00	-0.00***	0.00*	-0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
years of completed education	0.00	0.01***	0.00***	0.01***	-0.01***	0.02***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SC	0.02***	-0.06***	0.03***	-0.06***	0.02***	-0.05***
	(0.003)	(0.003)	(0.005)	(0.004)	(0.005)	(0.005)
ST	-0.01***	-0.05***	-0.02**	-0.03***	-0.03***	-0.02***
	(0.003)	(0.003)	(0.006)	(0.005)	(0.006)	(0.005)
muslim	-0.04***	-0.08***	-0.05***	-0.05***	-0.05***	-0.05***
	(0.005)	(0.004)	(0.008)	(0.007)	(0.008)	(0.008)
other minority	0.06***	-0.12***	0.08***	-0.11***	0.04***	-0.09***
	(0.004)	(0.003)	(0.007)	(0.006)	(0.007)	(0.006)
lives in rural area	0.10***	-0.22***	0.12***	-0.22***	0.09***	-0.19***
	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
N	216,402	216,402	72,238	72,238	66,877	66,877

Note: The table shows first-stage 2SLS results for hours worked in non precarious jobs. For second stage results see Table 2.11. Columns 1-2 show results for all individuals for low and high quality electricity, respectively; columns 3-4 show results for males for low and high quality electricity, respectively; columns 5-6 show results for females for low and high quality electricity, respectively. *p <0.10, **p <0.05, ***p <0.01.

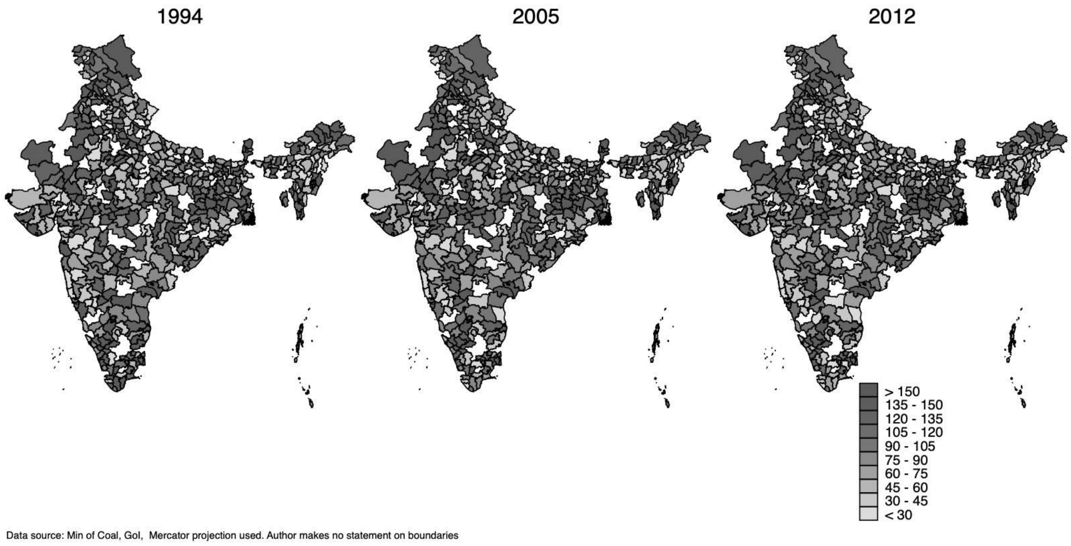
Table 2.15: First stage for firewood collection

	All individuals		Males		Females	
low quality	high quality					
	low quality	high quality	low quality	high quality		
	(1)	(2)	(3)	(4)	(5)	(6)
coalkm	33.56	14.27	180.19***	-112.20**	128.71**	-82.93*
	(34.323)	(28.377)	(55.342)	(46.290)	(60.571)	(50.287)
hydrokm	56.10***	-772.34***	-4.64	-751.16***	76.62*	-785.68***
	(20.853)	(17.240)	(38.599)	(32.286)	(39.568)	(32.850)
density	-21.35***	64.77***	-24.95***	75.47***	-24.98***	68.48***
	(4.510)	(3.728)	(7.913)	(6.619)	(8.215)	(6.820)
heavy rain	-0.01***	0.01***	-0.01***	0.01***	-0.01***	0.01***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
flood	0.01***	-0.02***	0.01***	-0.01***	0.00	-0.02***
	(0.002)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
severe flood	-0.00***	0.00**	-0.00***	0.00**	-0.00***	0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
owns their house	0.06***	-0.03***	0.07***	-0.03**	0.06***	-0.01
	(0.010)	(0.008)	(0.020)	(0.016)	(0.020)	(0.016)
size of the household	0.02***	-0.00	0.02***	-0.00	0.02***	0.00
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
share of chilren in hh	-0.07***	-0.08***	-0.07***	-0.11***	-0.08***	-0.09***
	(0.009)	(0.007)	(0.018)	(0.015)	(0.016)	(0.013)
owns livestock	-0.01***	-0.04***	-0.01*	-0.04***	-0.01**	-0.03***
	(0.004)	(0.003)	(0.006)	(0.005)	(0.007)	(0.006)
household is below poverty line	-0.13***	-0.04***	-0.12***	-0.03***	-0.13***	-0.03***
	(0.004)	(0.003)	(0.007)	(0.006)	(0.007)	(0.006)
are they head of household	-0.01	-0.02***	0.03***	-0.05***	-0.01	0.00
	(0.004)	(0.004)	(0.010)	(0.008)	(0.012)	(0.010)
Age	0.00***	-0.00***	0.00	0.01***	-0.00	0.01***
	(0.000)	(0.000)	(0.002)	(0.001)	(0.002)	(0.001)
Age squared	-0.00***	0.00***	-0.00	-0.00***	-0.00	-0.00***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
years of completed education	0.00***	0.01***	0.00***	0.01***	-0.00***	0.02***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
SC	0.01**	-0.07***	0.03***	-0.06***	0.02**	-0.07***
	(0.005)	(0.004)	(0.009)	(0.007)	(0.009)	(0.007)
ST	-0.01**	-0.06***	0.00	-0.04***	-0.01	-0.05***
	(0.005)	(0.004)	(0.009)	(0.008)	(0.010)	(0.008)
muslim	-0.03***	-0.11***	-0.03***	-0.09***	-0.02**	-0.10***
	(0.006)	(0.005)	(0.011)	(0.010)	(0.012)	(0.010)
other minority	0.01	-0.12***	0.02	-0.09***	-0.00	-0.09***
	(0.007)	(0.006)	(0.013)	(0.011)	(0.013)	(0.011)
lives in rural area	0.12***	-0.27***	0.16***	-0.29***	0.15***	-0.28***
	(0.005)	(0.004)	(0.010)	(0.009)	(0.011)	(0.009)
Constant	0.27***	0.65***	0.21***	0.48***	0.29***	0.41***
	(0.013)	(0.011)	(0.036)	(0.030)	(0.038)	(0.032)
N	94,642	94,642	28,541	28,541	27,096	27,096

Note: The table shows first-stage 2SLS results for time spent in mins per week on firewood collection. For second stage results see Table 2.8. Columns 1-2 show results for all individuals for low and high quality electricity, respectively; columns 3-4 show results for males for low and high quality electricity, respectively; columns 5-6 show results for females for low and high quality electricity, respectively. *p <0.10, **p <0.05, ***p <0.01.

2.10 Appendix II: Additional information for IVs

Distance of nearest coal plant from district centroid(km)



Distance of nearest hydro plant from district centroid

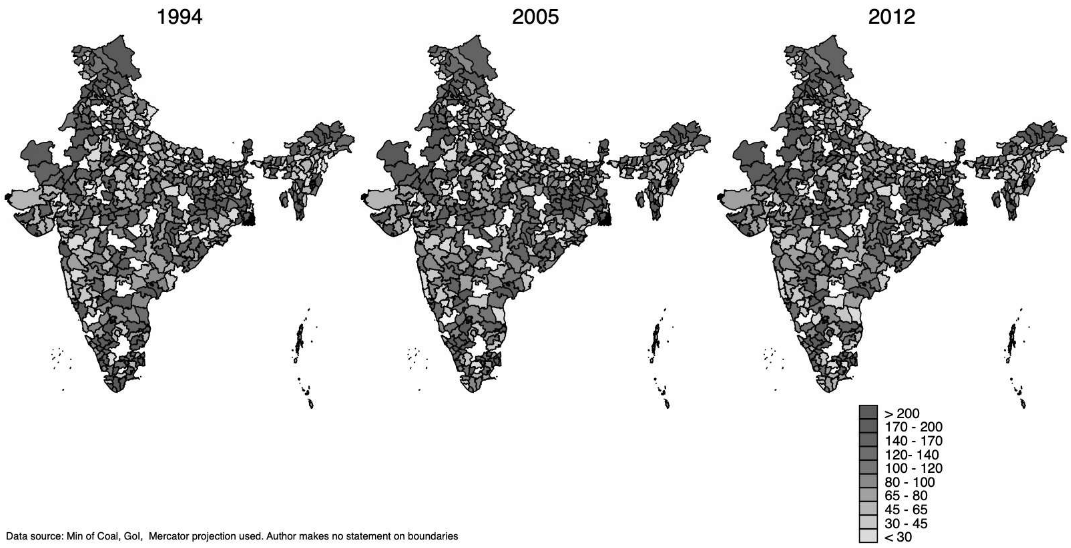


Table 2.16: IV: length of Transmission lines in km

	(1) 1994 sum	(2) 2005 sum	(3) 2012 sum
Andhra Pradesh	2,057	2,282	4,086
Assam	466	465	1,431
Bihar	1,635	1,645	5,913
Chhattisgarh	369	384	1,455
Delhi	266	80	249
Goa	49	49	0
Gujarat	1,119	2,187	3,669
Haryana	737	978	2,646
Himachal Pradesh	282	293	760
Jammu Kashmir	486	492	1,142
Jharkhand	1,320	1,327	2,550
Karnataka	2,281	2,878	3,478
Kerala	1,182	1,566	2,883
Madhya Pradesh	2,359	2,966	6,948
Maharashtra	2,338	3,100	5,697
Meghalaya	283	283	1,547
Nagaland	12	12	374
Orissa	3,569	3,621	5,443
Punjab	1,018	1,664	4,030
Rajasthan	1,108	2,145	3,895
Tamil Nadu	3,041	3,422	3,632
Uttar Pradesh	5,327	6,799	12,097
Uttaranchal	323	323	727
West Bengal	807	786	1,823
Total	32,432	39,770	76,724

Table 2.17: IV: Distance from hydro power plants (small and large)

	(1) 1994 Distance (Km)	(2) 2005 Distance (Km)	(3) 2012 Distance (Km)
Andhra Pradesh	120.54	113.58	112.34
Arunachal Pradesh	319.94	156.00	97.71
Assam	152.65	93.91	85.13
Bihar	168.97	155.78	155.78
Chandigarh	57.28	57.28	57.28
Chhattisgarh	114.55	112.77	112.59
Dadra and Nagar Haveli	66.74	31.69	31.69
Daman and Diu	188.58	148.52	148.52
Goa	42.75	41.28	41.28
Gujarat	178.42	170.57	170.57
Haryana	160.76	160.76	160.76
Himachal Pradesh	49.32	33.09	27.23
Jammu and Kashmir	34.91	32.17	30.46
Jharkhand	78.33	78.33	74.41
Karnataka	82.96	77.79	73.92
Kerala	44.11	42.78	42.78
Lakshadweep	449.62	444.37	444.37
Madhya Pradesh	120.40	94.22	87.62
Maharashtra	86.10	83.98	81.96
Manipur	47.10	47.10	47.10
Meghalaya	75.79	75.79	74.95
Mizoram	119.34	119.34	119.34
Delhi	168.33	168.33	168.33
Nagaland	176.76	51.85	51.85
Odisha	107.95	101.76	101.36
Puducherry	153.86	133.80	133.80
Punjab	113.85	113.85	113.85
Rajasthan	211.67	211.67	204.09
Sikkim	64.48	27.82	24.58
Tamil Nadu	124.54	93.13	88.73
Telangana	89.04	82.91	75.66
Tripura	58.80	58.80	58.80
Uttar Pradesh	163.06	162.68	168.12
Uttarakhand	59.77	47.79	37.66
West Bengal	145.16	133.72	130.62
Total	135.37	116.17	112.86

Table 2.18: IV: Number of days of moderate floods for the sample years

	(1)	(2)	(3)
	1994	2005	2012
	mean	mean	mean
Jammu Kashmir 01	32.44	32.44	32.44
Himachal Pradesh 02	27.38	27.38	27.38
Punjab 03	99.47	99.47	99.47
Uttarakhand 05	42.61	42.61	42.61
Haryana 06	152.11	152.11	152.11
Delhi 07	168.33	168.33	168.33
Rajasthan 08	219.87	219.87	219.87
Uttar Pradesh 09	160.04	160.04	160.04
Bihar 10	166.49	166.49	166.49
Assam 18	92.84	92.84	92.84
West Bengal 19	147.60	147.60	147.60
Jharkhand 20	51.68	51.68	51.68
Orissa 21	109.32	109.32	109.32
Chhattisgarh 22	130.69	130.69	130.69
Madhya Pradesh 23	86.84	86.84	86.84
Gujarat 24	174.55	174.55	174.55
Maharashtra 27	78.28	78.28	78.28
Andhra Pradesh 28	93.34	93.34	93.34
Karnataka 29	76.32	76.32	76.32
Goa 30	41.44	41.44	41.44
Kerala 32	39.80	39.80	39.80
Tamil Nadu 33	79.49	79.49	79.49
Total	112.68	112.68	112.68

Table 2.19: IV: Number of days of severe floods

	(1) 1994 mean	(2) 2005 mean	(3) 2012 mean
Jammu	Kashmir 01	32.44	32.44
32.44			
Himachal Pradesh 02	27.38	27.38	27.38
Punjab 03	99.47	99.47	99.47
Uttarakhand 05	42.61	42.61	42.61
Haryana 06	152.11	152.11	152.11
Delhi 07	168.33	168.33	168.33
Rajasthan 08	219.87	219.87	219.87
Uttar Pradesh 09	160.04	160.04	160.04
Bihar 10	166.49	166.49	166.49
Assam 18	92.84	92.84	92.84
West Bengal 19	147.60	147.60	147.60
Jharkhand 20	51.68	51.68	51.68
Orissa 21	109.32	109.32	109.32
Chhattisgarh 22	130.69	130.69	130.69
Madhya Pradesh 23	86.84	86.84	86.84
Gujarat 24	174.55	174.55	174.55
Maharashtra 27	78.28	78.28	78.28
Andhra Pradesh 28	93.34	93.34	93.34
Karnataka 29	76.32	76.32	76.32
Goa 30	41.44	41.44	41.44
Kerala 32	39.80	39.80	39.80
Tamil Nadu 33	79.49	79.49	79.49
Total	112.68	112.68	112.68

Table 2.20: IV: Number of days cloud burst

	(1) 1994 mean	(2) 2005 mean	(3) 2012 mean
Jammu	Kashmir 01	32.44	32.44
32.44			
Himachal Pradesh 02	27.38	27.38	27.38
Punjab 03	99.47	99.47	99.47
Uttarakhand 05	42.61	42.61	42.61
Haryana 06	152.11	152.11	152.11
Delhi 07	168.33	168.33	168.33
Rajasthan 08	219.87	219.87	219.87
Uttar Pradesh 09	160.04	160.04	160.04
Bihar 10	166.49	166.49	166.49
Assam 18	92.84	92.84	92.84
West Bengal 19	147.60	147.60	147.60
Jharkhand 20	51.68	51.68	51.68
Orissa 21	109.32	109.32	109.32
Chhattisgarh 22	130.69	130.69	130.69
Madhya Pradesh 23	86.84	86.84	86.84
Gujarat 24	174.55	174.55	174.55
Maharashtra 27	78.28	78.28	78.28
Andhra Pradesh 28	93.34	93.34	93.34
Karnataka 29	76.32	76.32	76.32
Goa 30	41.44	41.44	41.44
Kerala 32	39.80	39.80	39.80
Tamil Nadu 33	79.49	79.49	79.49
Total	112.68	112.68	112.68

Table 2.21: Impact of quality of electricity on log income, robustness checks with single instruments, Second stage

	log income (1)	(2)	(3)
low quality		2.270***	0.933***
		[0.197]	[0.0963]
High quality	1.358***	-1.647***	0.788***
	[0.157]	[0.244]	[0.0953]
lives in rural area	-0.0891*	-1.141***	-0.455***
	[0.0526]	[0.0607]	[0.0199]
size of the household	0.0362***	0.0264***	0.0421***
	[0.00335]	[0.00421]	[0.00215]
share of chilren in hh	-0.0503	-0.517***	-0.277***
	[0.0514]	[0.0500]	[0.0245]
Age	0.0218***	0.0643***	0.0403***
	[0.00371]	[0.00388]	[0.00183]
Age squared	-0.000342***	-0.000747***	-0.000513***
	[0.0000387]	[0.0000438]	[0.0000211]
years of completed education	0.0435***	0.104***	0.0714***
	[0.00448]	[0.00378]	[0.00160]
owns their house	0.0211	-0.270***	-0.102***
	[0.0235]	[0.0347]	[0.0163]
owns livestock	-0.175***	-0.483***	-0.336***
	[0.0231]	[0.0217]	[0.00996]
household is below poverty line	-0.0612**	-0.166***	-0.187***
	[0.0284]	[0.0279]	[0.0150]
are they head of household	0.670***	0.547***	0.608***
	[0.0174]	[0.0199]	[0.0101]
SC	-0.102***	-0.519***	-0.253***
	[0.0222]	[0.0307]	[0.0125]
ST	0.0327	-0.338***	-0.0822***
	[0.0231]	[0.0313]	[0.0130]
muslim	-0.112***	-0.453***	-0.251***
	[0.0360]	[0.0351]	[0.0165]
other minority	0.186***	-0.405***	-0.00431
	[0.0329]	[0.0445]	[0.0181]
no electricity		0	0
		[.]	[.]
Observations	60695	73381	76645

Note: Permutation of instruments. For (1), since there have to be as many instruments as endogenous variables,we cant use density with reliable as a categorical variable

2.11 Appendix III: Robustness test full tables

Table 2.22: Impact of quality of electricity on log income, robustness checks with single instruments, First stage

	(1)	(2)	(3)	(4)	(5)
density	50.34***				
	[4.107]				
coalkm		351.4***	-346.4***		
		[25.73]	[23.08]		
hydrokm		-343.4***	-271.7***		
		[24.63]	[22.09]		
heavy rain				-0.00923***	0.0131***
				[0.000484]	[0.000434]
flood				0.00708***	-0.0299***
				[0.00178]	[0.00160]
severe flood				-0.00292***	-0.00125***
				[0.000203]	[0.000182]
lives in rural area	-0.317***	0.111***	-0.223***	0.124***	-0.241***
	[0.00742]	[0.00521]	[0.00467]	[0.00505]	[0.00453]
size of the household	0.0153***	0.0135***	0.00131*	0.0136***	0.000854
	[0.00121]	[0.000832]	[0.000746]	[0.000805]	[0.000722]
share of chilren in hh	-0.274***	-0.0262***	-0.114***	-0.0370***	-0.108***
	[0.0146]	[0.00994]	[0.00892]	[0.00965]	[0.00866]
Age	0.0192***	-0.00166**	0.00947***	-0.000453	0.00943***
	[0.00113]	[0.000771]	[0.000691]	[0.000750]	[0.000673]
Age squared	-0.000182***	0.0000169*	-0.0000891***	0.00000355	-0.0000887***
	[0.0000138]	[0.00000935]	[0.00000838]	[0.00000910]	[0.00000817]
years of completed education	0.0272***	-0.000628	0.0141***	-0.000473	0.0140***
	[0.000619]	[0.000427]	[0.000383]	[0.000412]	[0.000370]
owns their house	-0.0629***	0.0382***	-0.0561***	0.0550***	-0.0729***
	[0.0110]	[0.00776]	[0.00696]	[0.00733]	[0.00658]
owns livestock	-0.127***	0.00772*	-0.0564***	-0.00342	-0.0506***
	[0.00604]	[0.00410]	[0.00368]	[0.00400]	[0.00359]
household is below poverty line	-0.160***	-0.0881***	-0.0455***	-0.0941***	-0.0393***
	[0.00668]	[0.00449]	[0.00403]	[0.00438]	[0.00394]
are they head of household	-0.0755***	-0.00755*	-0.0313***	-0.0115***	-0.0298***
	[0.00660]	[0.00448]	[0.00402]	[0.00436]	[0.00392]
SC	-0.101***	0.0639***	-0.0763***	0.0506***	-0.0734***
	[0.00792]	[0.00554]	[0.00497]	[0.00534]	[0.00479]
ST	-0.105***	0.0554***	-0.0765***	0.0399***	-0.0685***
	[0.00835]	[0.00585]	[0.00525]	[0.00564]	[0.00506]
muslim	-0.182***	-0.00505	-0.0805***	0.00830	-0.0780***
	[0.0109]	[0.00721]	[0.00647]	[0.00699]	[0.00628]
other minority	-0.162***	0.0659***	-0.122***	0.0795***	-0.136***
	[0.0107]	[0.00749]	[0.00672]	[0.00717]	[0.00643]
Observations	60695	73381	73381	76645	76645

Note: Income is log of monthly earnings of individuals measured in 2005 prices, standard errors are clustered at district level

Table 2.23: Impact of quality of electricity on log income: Robustness check with threshold of 20 hours, first stage

	(1) 1.r_alt2	(2) 2.r_alt2	(3) 1.r_alt2	(4) 2.r_alt2	(5) 1.r_alt2	(6) 2.r_alt2
density	-8.686***	23.34***	-3.475	18.35***	-30.19***	45.08***
	[2.978]	[2.394]	[3.276]	[2.689]	[7.154]	[5.435]
coalkm	16.20	-38.52	94.78***	-99.26***	-220.3***	135.8***
	[30.55]	[24.56]	[34.59]	[28.39]	[65.69]	[49.91]
hydrokm	-163.3***	-400.0***	-140.2***	-445.5***	-220.2***	-271.9***
	[27.34]	[21.98]	[31.76]	[26.07]	[53.91]	[40.96]
heavy rain	-0.00961***	0.0122***	-0.0110***	0.0133***	-0.00550***	0.00910***
	[0.000497]	[0.000399]	[0.000577]	[0.000474]	[0.000976]	[0.000741]
flood	0.00814***	-0.0235***	0.0106***	-0.0240***	-0.000482	-0.0206***
	[0.00220]	[0.00177]	[0.00271]	[0.00222]	[0.00380]	[0.00289]
severe flood	-0.00283***	-0.000361**	-0.00261***	-0.000483**	-0.00365***	0.000150
	[0.000215]	[0.000173]	[0.000253]	[0.000208]	[0.000409]	[0.000311]
lives in rural area	0.0660***	-0.158***	0.0643***	-0.161***	0.0626***	-0.137***
	[0.00547]	[0.00440]	[0.00630]	[0.00517]	[0.0112]	[0.00851]
size of the household	0.0141***	0.000643	0.0160***	-0.00140	0.0173***	0.00316**
	[0.000898]	[0.000722]	[0.00113]	[0.000924]	[0.00179]	[0.00136]
share of chilren in hh	-0.0558***	-0.0739***	-0.0717***	-0.0666***	-0.0866***	-0.0622***
	[0.0107]	[0.00864]	[0.0137]	[0.0112]	[0.0191]	[0.0145]
Age	0.00152*	0.00607***	-0.00170	0.00820***	0.000517	0.00598***
	[0.000834]	[0.000670]	[0.00107]	[0.000882]	[0.00156]	[0.00119]
Age squared	-0.0000221**	-0.0000515***	0.00000895	-0.0000734***	-0.0000175	-0.0000450***
	[0.0000101]	[0.00000812]	[0.0000125]	[0.0000103]	[0.0000189]	[0.0000144]
years of completed education	0.000847*	0.0105***	0.00369***	0.00859***	-0.00355***	0.0150***
	[0.000459]	[0.000369]	[0.000553]	[0.000454]	[0.000964]	[0.000732]
owns their house	0.0194**	-0.0305***	0.0174*	-0.0374***	0.0318**	-0.0124
	[0.00824]	[0.00662]	[0.00959]	[0.00787]	[0.0161]	[0.0122]
owns livestock	-0.0139***	-0.0392***	-0.0123**	-0.0405***	-0.0133	-0.0371***
	[0.00443]	[0.00356]	[0.00529]	[0.00434]	[0.00810]	[0.00616]
household is below poverty line	-0.1000***	-0.0271***	-0.0925***	-0.0308***	-0.115***	-0.0198***
	[0.00490]	[0.00394]	[0.00589]	[0.00483]	[0.00883]	[0.00671]
are they head of household	-0.0140***	-0.0211***	0.0257***	-0.0438***	-0.0156	-0.000229
	[0.00485]	[0.00390]	[0.00778]	[0.00638]	[0.0114]	[0.00869]
SC	0.0179***	-0.0307***	0.0151**	-0.0309***	0.0191	-0.0235***
	[0.00585]	[0.00471]	[0.00673]	[0.00552]	[0.0120]	[0.00910]
ST	0.0136**	-0.0425***	0.0138*	-0.0433***	0.00820	-0.0345***
	[0.00618]	[0.00497]	[0.00714]	[0.00586]	[0.0124]	[0.00945]
muslim	-0.0288***	-0.0659***	-0.0254***	-0.0702***	-0.0407***	-0.0521***
	[0.00803]	[0.00645]	[0.00976]	[0.00801]	[0.0146]	[0.0111]
other minority	0.0453***	-0.0782***	0.0459***	-0.0808***	0.0516***	-0.0683***
	[0.00795]	[0.00639]	[0.00896]	[0.00735]	[0.0175]	[0.0133]
Observations	63044	63044	45182	45182	17861	17861

Note: Income is log of monthly earnings of individuals measured in 2005 prices, standard errors are clustered at district level

Table 2.24: Impact of quality of electricity on log income: Robustness check with threshold of 20 hours, second stage

	(1) lincome	(2) lincome	(3) lincome
r_alt2=1	1.198***	1.530***	0.411**
	[0.0902]	[0.105]	[0.161]
r_alt2=2	1.104***	1.088***	1.243***
	[0.0809]	[0.0919]	[0.172]
lives in rural area	-0.412***	-0.402***	-0.390***
	[0.0154]	[0.0176]	[0.0307]
size of the household	0.0397***	-0.000873	0.00516
	[0.00226]	[0.00283]	[0.00474]
share of chilren in hh	-0.249***	0.134***	-0.0252
	[0.0254]	[0.0323]	[0.0463]
Age	0.0372***	0.0728***	0.0614***
	[0.00189]	[0.00243]	[0.00347]
Age squared	-0.000488***	-0.000802***	-0.000683***
	[0.0000224]	[0.0000278]	[0.0000408]
years of completed education	0.0657***	0.0422***	0.0595***
	[0.00138]	[0.00166]	[0.00319]
owns their house	-0.0258	-0.0451**	-0.0923***
	[0.0177]	[0.0207]	[0.0338]
owns livestock	-0.282***	-0.296***	-0.324***
	[0.0104]	[0.0125]	[0.0190]
household is below poverty line	-0.130***	-0.151***	-0.114***
	[0.0145]	[0.0170]	[0.0267]
are they head of household	0.618***	0.0586***	0.276***
	[0.0108]	[0.0170]	[0.0240]
SC	-0.217***	-0.216***	-0.161***
	[0.0127]	[0.0146]	[0.0255]
ST	-0.0649***	-0.0626***	-0.0350
	[0.0136]	[0.0158]	[0.0269]
muslim	-0.261***	-0.307***	-0.0942***
	[0.0183]	[0.0222]	[0.0333]
other minority	-0.0145	-0.0339*	-0.101***
	[0.0178]	[0.0201]	[0.0383]
Observations	63044	45182	17861

Note:Income is log of monthly earnings of individuals measured in 2005 prices, standard errors are clustered at district level

Table 2.25: Impact of quality of electricity on log income: Robustness check with threshold of 16 hours, second stage

	(1) lincome	(2) lincome	(3) lincome	(4) lincome
r_alt=1	0.167***	1.444***	1.685***	0.662***
	[0.00975]	[0.0923]	[0.106]	[0.162]
r_alt=2	0.231***	1.029***	1.097***	0.842***
	[0.0103]	[0.0801]	[0.0910]	[0.153]
lives in rural area	-0.520***	-0.452***	-0.431***	-0.453***
	[0.00936]	[0.0161]	[0.0183]	[0.0302]
size of the household	0.0521***	0.0370***	-0.00245	0.00165
	[0.00159]	[0.00229]	[0.00283]	[0.00461]
share of chilren in hh	-0.374***	-0.258***	0.121***	-0.0180
	[0.0190]	[0.0262]	[0.0327]	[0.0455]
Age	0.0460***	0.0386***	0.0749***	0.0638***
	[0.00148]	[0.00196]	[0.00249]	[0.00338]
Age squared	-0.000568***	-0.000501***	-0.000823***	-0.000697***
	[0.0000179]	[0.0000232]	[0.0000285]	[0.0000400]
years of completed education	0.0792***	0.0671***	0.0429***	0.0664***
	[0.000818]	[0.00142]	[0.00169]	[0.00297]
owns their house	-0.107***	-0.0298	-0.0463**	-0.111***
	[0.0144]	[0.0181]	[0.0210]	[0.0329]
owns livestock	-0.369***	-0.295***	-0.311***	-0.334***
	[0.00784]	[0.0110]	[0.0128]	[0.0191]
household is below poverty line	-0.280***	-0.115***	-0.143***	-0.0935***
	[0.00868]	[0.0148]	[0.0171]	[0.0260]
are they head of household	0.580***	0.615***	0.0482***	0.279***
	[0.00856]	[0.0111]	[0.0173]	[0.0234]
SC	-0.252***	-0.239***	-0.237***	-0.177***
	[0.0104]	[0.0135]	[0.0153]	[0.0264]
ST	-0.0847***	-0.0820***	-0.0733***	-0.0535**
	[0.0110]	[0.0141]	[0.0161]	[0.0270]
muslim	-0.285***	-0.274***	-0.316***	-0.101***
	[0.0137]	[0.0189]	[0.0226]	[0.0334]
other minority	-0.0215	-0.0458**	-0.0585***	-0.143***
	[0.0140]	[0.0186]	[0.0208]	[0.0378]
Constant	6.503***			
	[0.0345]			
Observations	82413	63044	45182	17861

Note: Income is log of monthly earnings of individuals measured in 2005 prices, standard errors are clustered at district level

Table 2.26: Impact of quality of electricity on log income: Robustness check with threshold of 16 hours, first stage

	(1)	(2)	(3)	(4)	(5)	(6)
	1.r_alt	2.r_alt	1.r_alt	2.r_alt	1.r_alt	2.r_alt
density	-10.22***	24.87***	-8.139**	23.02***	-17.15**	32.04***
	[2.946]	[2.759]	[3.225]	[3.044]	[7.173]	[6.595]
coalkm	282.4***	-304.7***	333.7***	-338.1***	135.8**	-220.3***
	[30.22]	[28.31]	[34.06]	[32.14]	[65.87]	[60.56]
hydrokm	-165.7***	-397.5***	-137.7***	-448.0***	-244.1***	-248.0***
	[27.04]	[25.33]	[31.26]	[29.50]	[54.05]	[49.70]
heavy rain	-0.0118***	0.0145***	-0.0128***	0.0151***	-0.00901***	0.0126***
	[0.000491]	[0.000460]	[0.000568]	[0.000536]	[0.000978]	[0.000900]
flood	0.0171***	-0.0325***	0.0183***	-0.0317***	0.0124***	-0.0335***
	[0.00218]	[0.00204]	[0.00267]	[0.00252]	[0.00381]	[0.00350]
severe flood	-0.00216***	-0.00103***	-0.00194***	-0.00116***	-0.00293***	-0.000562
	[0.000213]	[0.000199]	[0.000250]	[0.000235]	[0.000410]	[0.000377]
lives in rural area	0.101***	-0.193***	0.100***	-0.197***	0.0985***	-0.173***
	[0.00542]	[0.00507]	[0.00620]	[0.00585]	[0.0112]	[0.0103]
size of the household	0.0124***	0.00235***	0.0147***	-0.0000844	0.0139***	0.00653***
	[0.000888]	[0.000832]	[0.00111]	[0.00105]	[0.00179]	[0.00165]
share of chilren in hh	-0.0111	-0.119***	-0.0282**	-0.110***	-0.0313	-0.118***
	[0.0106]	[0.00996]	[0.0135]	[0.0127]	[0.0191]	[0.0176]
Age	-0.00133	0.00893***	-0.00505***	0.0116***	-0.000658	0.00716***
	[0.000825]	[0.000772]	[0.00106]	[0.000998]	[0.00157]	[0.00144]
Age squared	0.00000856	-0.0000822***	0.0000441***	-0.000109***	-0.00000232	-0.0000602***
	[0.00000999]	[0.00000936]	[0.0000124]	[0.0000117]	[0.0000190]	[0.0000174]
years of completed education	-0.00136***	0.0127***	0.00127**	0.0110***	-0.00558***	0.0170***
	[0.000454]	[0.000425]	[0.000545]	[0.000514]	[0.000967]	[0.000889]
owns their house	0.0117	-0.0228***	0.0150	-0.0349***	0.0101	0.00935
	[0.00815]	[0.00763]	[0.00944]	[0.00891]	[0.0162]	[0.0148]
owns livestock	0.0130***	-0.0661***	0.0150***	-0.0678***	0.0115	-0.0620***
	[0.00438]	[0.00410]	[0.00521]	[0.00491]	[0.00813]	[0.00747]
household is below poverty line	-0.0848***	-0.0422***	-0.0805***	-0.0428***	-0.0927***	-0.0416***
	[0.00485]	[0.00454]	[0.00580]	[0.00547]	[0.00885]	[0.00814]
are they head of household	-0.00227	-0.0329***	0.0386***	-0.0568***	-0.0115	-0.00429
	[0.00479]	[0.00449]	[0.00766]	[0.00722]	[0.0115]	[0.0105]
SC	0.0517***	-0.0645***	0.0469***	-0.0627***	0.0611***	-0.0655***
	[0.00579]	[0.00542]	[0.00662]	[0.00625]	[0.0120]	[0.0110]
ST	0.0302***	-0.0591***	0.0264***	-0.0559***	0.0368***	-0.0631***
	[0.00611]	[0.00572]	[0.00703]	[0.00664]	[0.0125]	[0.0115]
muslim	-0.00365	-0.0910***	-0.0101	-0.0854***	0.00632	-0.0991***
	[0.00794]	[0.00744]	[0.00961]	[0.00907]	[0.0147]	[0.0135]
other minority	0.0726***	-0.106***	0.0726***	-0.108***	0.0755***	-0.0922***
	[0.00787]	[0.00737]	[0.00882]	[0.00832]	[0.0175]	[0.0161]
Observations	63044	63044	45182	45182	17861	17861

Note: Income is log of monthly earnings of individuals measured in 2005 prices, standard errors are clustered at district level

Chapter 3

Power to learn: Reliable electricity and education in India

[1]

[1]This image has been generated using the AI DALLE by using keywords from the chapter in the style of the artist Henri Mattise

3.1 Abstract

Access to electricity is viewed as a cornerstone for economic development. We use data from two survey waves covering over 41,000 households in India to examine the links between the reliability of electricity available to households in India and children's learning outcomes, as well as the intervening mechanisms. Our results show strong positive links between the reliability of electricity and the probability of children achieving higher math, reading and writing scores. We also find that the two most plausible channels of transmission for these effects are increased time spent on homework and fewer days missed at school. Both girls and boys benefit from more reliable electricity, with no systematic gender differences. These results hold using an alternative, more fine-grained classification of electricity reliability, and we find evidence for causal relationships. The results suggest that reliable electricity is an important component of reaching basic educational policy goals in a developing country context. *Keywords*: electrification,

electricity quality, education, learning scores, India, panel data

This chapter is joint work with Dr Christa Brunnschweiler and Prof. Corrado Di Maria

3.2 Introduction

Access to electricity is viewed as a cornerstone for economic development and a large literature is dedicated to examining its impacts. Electricity is used for lighting, space conditioning and cooking; in theory, it allows exploiting new income generation opportunities and reallocating time away from activities that can be performed more efficiently with the use of electric power.[2] Results for the link between electrification and income and employment are mixed, with some studies showing positive effects (e.g., Khandker et al. 2009, Dinkelman 2011) while others find no significant effects (e.g., Lee et al. 2020, Burlig and Preonas forthcoming). Access to electricity can also have direct and indirect effects on other development outcomes, for example on health – via a reduction in household air pollution and associated lung disease and eye problems, as well as burns and poisonings from using kerosene lighting (e.g., Aklin et al. 2016 and Riva et al. 2018) or on education – usually measured in years of schooling or attendance (e.g., van de Walle et al. 2017, Burgess et al. 2020). Most of the literature so far has concentrated on the effects of gaining access to electricity; however, the quality and reliability of electrification has been gaining more attention recently. Chakravorty et al. (2014) first examined this issue to find that more daily hours of electricity increase (non-agricultural) income in India.[3]

In this paper, we study the links between the reliability or quality – terms are used interchangeably – of electricity available to households in India and the learning outcomes of the children. We make three main contributions to the literature: first, we focus on the reliability of electricity instead of just access measured as a zero-one dummy variable. Second, we look at the impact on learning outcomes and go beyond indicators of time spent at school and on homework. Third, we examine some of the possible channels through which the reliability of electricity could be affecting learning outcomes. Our empirical analysis uses a two-wave survey dataset – conducted in 2004/05 and 2011/12, respectively – covering over 41,000 households that includes standardised tests on 8–11-year-old children in India. In our main estimations, we use an ordered probit approach to estimate the links between reliability and learning outcomes, and ordinary least squares (OLS) for the mechanism analysis. We complement these with an IV approach similar to Chakravorty et al. (2014) and van de Walle et al. (2017) to gain insights into the causality of the links.

India enshrined the Right to Education Act as a constitutional amendment in 2002. The Act aims to provide free and compulsory education to all children between the age of 6-14. For a child to get free education, the family has to prove that they cannot provide the school fees of the government school, which is quite hard as these fees are low, so in practice, not many are able to get it for free. The law is not monitored well, as we can see in our dataset where in 2005 20% of the sample of school-age children had dropped out of school and another 5% dropped out in 2012. The rate of children drop-out decreases but it is far from the "free and compulsory" education promised by the state. Having access to reliable electricity is expected to affect children's education in several ways. First, having electricity gives them access to electric lighting which can help them study in the evening and hence be more engaged and achieve better

[2] Mathur and Mathur (2005) study the time reallocation effects of electrification and find that they are strongly gendered, as female members of the household spend more time on activities such as food preparation and firewood collection. See also Aguirre (2017) and Aklin et al. (2018).

[3] Jacome et al. (2019) in a recent paper look at the disruption caused by varying voltage in Tanzania, showing that lack of reliability makes it difficult for the population to reap the full benefits from electrification.

results at school. Second, since kerosene based lights also expose children to more indoor air pollution,[4] electric lighting would have health benefits, expected to result in better engagement at school and fewer missed school days. Apart from these changes, electricity also offers children access to internet, TV and mobile phones. These devices can work on both ways for learning: they could engage the child more as it involves reading and writing but also distract them and decrease time for school learning.

Our results show strong positive links between the reliability of electricity – using a three-category scale – and the probability of children achieving higher math, reading and writing scores. For example, for boys and girls, moving from no electricity access to having low-reliability electricity (i.e. under 18 hours/day) increases the probability of achieving the highest math score by just over 5pp, ceteris paribus, and reduces the probability of achieving the lowest score by roughly the same magnitude. We also find that the two most plausible channels of transmission for these effects are increased time spent on homework and fewer days missed at school, with no clear change in our third channel, namely time spent collecting firewood. Both girls and boys benefit from more reliable electricity, with no systematic gender differences. These results hold using an alternative, more fine-grained classification of electricity reliability. Finally, we find evidence for causal relationships between having more reliable electricity and our outcomes.

We contribute mainly to the existing literature on the relationship of electricity access – measured as a zero-one dummy variable – with schooling outcomes, which focuses heavily on enrolment, retention, and the number of years of schooling, often disaggregated by gender as in our study.[5] Some studies look at India as we do: e.g., van de Walle et al. (2017) use distance from coal plants as an instrument in a district-level instrumental variable (IV) approach to find a small increase in completed schooling for girls, with no significant effect on boys. Burgess et al. (2020) instead apply a regression discontinuity design at village level – exploiting a nuance in the Rajiv Gandhi Gramin Vidhutikaran Yojana (RGGVY) electrification policy where villages with fewer than 200 people were not electrified – to find no significant impact of electrification on school enrolment at the village level. In Vietnam, Khandker et al. (2009) found that household electricity connection in a sample of 42 *communes* was correlated with a 9% higher school enrolment rate for girls and 6.3% higher for boys. Khandker et al. (2012) examine the impact of the electricity access policy in Bangladesh on years of schooling and study time for boys and girls. They also use an IV approach, with distance from the electricity line as an instrument and a simple zero-one setting, where households up to 100 feet of the electricity line are given a value of 1 and those further away a value of 0, combined with village fixed effects. They find that electricity access gives a small increase in the years of completed education and study time by children, with a stronger effect for boys than girls.

Several other studies focus on Latin America: Aguirre (2017) also uses an IV approach, with distance from the transmission network as an instrument, to find that getting access to electricity allows children in Peru 94-137 minutes more study time (or homework). This is the most optimistic impact found in the literature. Lipscomb et al. (2013) instrument for electricity using a counterfactual simulated grid as their instrument and find an increase from electricity access of two years of schooling of children in their sample in Brazil. Grogan and Sadanand (2013) found that rural Nicaraguan men and women are more than twice as likely to have completed primary education if they live in households with access to electricity,

[4] Note that in the case of India, electricity is less used in food preparation.

[5] Combining health with educational outcomes, WHO and UNICEF (2021) found that access to clean and safe groundwater enabled by electric pumps can help reduce diseases (e.g., typhoid, diarrhoea, parasitic infections associated with contaminated sources of water (e.g., surface water). This can affect a child's attendance at school because of bad health.

concluding that the mechanism underlying this impact could be through time reallocation.

We add to this literature by looking beyond retention, enrolment and schooling years to educational performance, i.e. test results; by examining several channels of transmission; and by focusing on the reliability or quality of the available electricity rather than just simple access. The latter in particular has policy relevance in a developing-country context where the majority of the population has basic access to electricity, but there continue to be vast differences in how reliable the electricity availability is throughout an average day. Another difference of our study with respect to much of the literature is the unit of analysis: studies examining electrification at a larger scale such as district (e.g., Lipscomb et al. 2013 for Brazil and van de Walle et al. 2017 for India) typically find larger effects than studies with a focus on the village or household level. However, as the focus of many policies has shifted from electrifying larger units to electrifying individual households, it is important to look at the impact at a lower level for future policy guidance.

Our contribution is also more broadly related to the literature on gender differences in school effectiveness and learning. According to UNESCO (2017), girls are less likely to be in school but more likely to have good learning outcomes if they are there. However, this effect is more prominent at higher grades. Cueto et al. (2016) found that the gender gap between girls and boys starts emerging at age 15. Marshall and Moore (2022) find that in India, girls score lower in maths than boys, but this gap is less pronounced in urban areas than rural areas. These studies provide us with useful guides on appropriate control variables, and also support our focus on educational outcomes by gender.

The rest of the article is organised as follows. Section 3.3 offers a brief background on electrification in India; the data are described in Section 4.4 and the methodology in Section 3.5; the main results are discussed in Section 3.6 and the sensitivity analysis in Section 3.7; and Section 3.8 concludes.

3.3 Background

Electrification policy in India can be divided into three main periods: 1900-1947 (pre-independence), 1947-1990, and post-1991 (Palit and Bandyopadhyay 2017). These periods are distinguished by the different ownership of the resources and infrastructure and (lack of) encouragement of market mechanism. The first period started by introducing basic regulations for safety and security of the grid network and establishing the basic laws for electrification; actual electrification remained very limited. The second period was driven by state ownership of generation, transmission and distribution of the power, set out in the Electricity (Supply) Act of 1948. Following independence of India, the initial focus was to electrify cities and towns with no target for rural villages. With food shortages in the 1960s the focus of electricity provision in rural areas was shifted to powered irrigation to increase productivity of agriculture, with electrification of rural villages and households being a possible co-benefit that was still not explicitly targeted.[6] Mounting financial pressure on the State Electricity Boards moreover led to deteriorating reliability of electricity supply, with either complete blackouts at select times or 'brownouts', where electricity was available but

[6]The focus on pump set irrigation led to a period of increased agricultural productivity popularly known as the "green revolution", which saw a steady increase in economic growth and electrification. Since household electrification was not the focus in this second period, the definition of an 'electrified village' was comprised of two factors: first, if the grid has been extended to the village, and second if one connection has been energised in the revenue area of the village (usually a farm).

of too low voltage to be used Dubash (2018).

The current post-1991 period has seen a steady liberalisation and development of energy markets in India. The consumer end, i.e. the distribution sector, is still largely state controlled.[7] In 1997 the Ministry of Power declared that a village was deemed electrified if electricity was used in the inhabited area of the village. The recognition of the right to electricity as a fundamental right under Article 21 of the Indian constitution meant that both the state and central governments became legally responsible for providing electricity (Palit and Bandyopadhyay 2017). Before 2005, electrification of a village was largely the responsibility of the individual states, and hence the progress of electrification in India has been heterogeneous. By 2005, 55% of households in villages were electrified, electrification was uneven across states and not all households had access to electricity even in electrified villages (Office of the Registrar General & Census Commissioner 2016).[8]

The central government launched a new electrification policy in 2005 called the Rajeev Gandhi Grameen Vidyutikaran Yojana (RGGVY), making electrification the joint responsibility of the central and the state governments, but primarily managed by the central government. The RGGVY policy aimed at complete village electrification of India by 2009 through the accelerated electrification of 100,000 villages and 10 million households. This led to more rapid progress as the RGGVY was the first policy in India that had an explicit target on village *and* household electrification. The scheme was not successful in terms of complete electrification by 2009, but it did manage to electrify a large part of the country (Ministry of Power 2010). The scheme also led to a comprehensive definition of electrification: 'A village will be deemed to be electrified if: basic infrastructure such as distribution transformers and distribution lines are provided within the inhabited locality; electricity is provided to public places like schools, *panchayat* offices, health centres, dispensaries, community centres etc., and the number of households electrified should be at least 10% of the total number of households in the village.'[9]

Our focus is on the reliability of electrification of households and how this relates to learning outcomes. Considered a co-benefit of agrarian-sector electrification policy before 2005, household-level electrification – or at least of 10% of village households – became an explicit target under the RGGVY policy. Technically therefore, there is an intention-to-treat with electricity access at household level throughout our two periods of analysis, but no clear goal for the quality, or reliability of electricity.

3.4 Data description

This paper uses the Indian Human Development Survey (IHDS) conducted in two waves by the University of Maryland and the National Council of Applied Economic Research (NCAER) India (see Desai and

[7]Post 2015, the state has been encouraging entry of private players through distributed generation (such as mini grid or solar rooftop based generation). This lies outside the scope of our analysis.

[8]Before 2005, most of the effort on electrification was based on providing electricity for agriculture and ensuring that farming was cost effective, as described above. Therefore, with the exception of the states of Uttar Pradesh (UP) and Bihar, most of the agrarian states progressed faster on providing electricity outside of cities and towns than non-agrarian ones.

[9]In recent years, the policy focus has shifted more squarely towards electrifying all households, but this lies beyond our period of analysis.

Vanneman 2005 and Desai and Vanneman 2012).[10] This is a panel dataset collected in 2004-05 and 2011-12, respectively, covering 41,554 households and 1,503 villages in 31 out of 33 states of India.[11] The same households are targeted in the two surveys, making it a longitudinal study at the household level. The dataset collects details on consumption expenditure, gender relations and other development related variables. The survey was carried out in face-to-face interviews containing the following modules: An interview with a knowledgeable informant — typically the head of the household — regarding socio-economic condition of the household including income, employment, educational status and consumption expenditure; and an interview with a married woman aged 15-49 regarding health, education, fertility, family planning, marriage, and gender relations in the household and community. A final module looked at village-level characteristics, assessing employment opportunities and infrastructure facilities in the village.

As part of the wider survey questionnaire, enumerators also conducted short reading, writing, and math knowledge tests with all available children aged 8-11 in the household. These test scores are available for 8,983 children in 2004-05 and 10,068 children in 2011-12. The codebook does not clarify how exactly the children to be tested were selected, stating merely that "available" children in the household were tested. There is, however, an equal split by gender. Note that children in the age group of 8-11 years were tested in both surveys in the same households, meaning that individual children would only take the tests in one of the two survey waves. Therefore, at the individual child level, this is not a longitudinal panel, implying that we need to use a pooled cross-section approach for individual-level analysis.

In our sample, 72% of the children live in rural areas in 2005 and 74% in 2012. The average household size is between 6-7 people; about 80% of the sample reports a household size of 8 people or smaller and 85% of the sample reports a household size of 9 or smaller in 2012.[12] The most dramatic change is in the ownership of mobile phones: in 2004-05 it was 6% and in 2011-12 it was 81%, in line with the penetration of mobile technology in India (which surpasses that of toilets). The data used in the analysis are summarised in Table 4.1. We now turn to describing the variables in more detail, beginning with our outcome variables.

[10] An earlier wave of IHDS was carried out in 1994, called the Human Development Profile of India at the time (National Council on Applied Economic Research 1994), but without the children's test score questions; hence, we cannot use the 1994 data for our purposes. The IHDS survey was supposed to release its new survey in 2021 but it has been postponed to 2023 due to the COVID-19 pandemic.

[11] The exceptions are the two island territories of Andaman & Nicobar and Lakshadweep.

[12] A household size of 28 is the maximum. We did not remove apparent outliers because about 10% of the sample report large households and they consider themselves to be a household making decisions together.

	IHDS I					IHDS II				
	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N
Outcome variables:										
Math score	1.55	1.02	0.00	3.00	8983	1.50	0.97	0.00	3.00	10068
Reading score	2.59	1.33	0.00	4.00	8983	2.54	1.38	0.00	4.00	10068
Writing score	0.68	0.47	0.00	1.00	8983	0.75	0.44	0.00	1.00	10068
Homework Hrs/week	7.51	5.63	0.00	60.00	8697	7.71	5.66	0.00	90.00	9657
Days school missed/ month	2.97	5.24	0.00	30.00	8694	3.60	4.95	0.00	30.00	9567
Time collecting firewood (mins/week)	185.63	252.11	0.00	2160.00	4803	162.60	340.11	0.00	3360.00	3784
Electricity										
Reliability of electricity (0-2)	1.039	.762	0.00	2	8,377	1.141	.691	0.00	2	9,469
Control variables:										
Lives in rural area	0.72	0.45	0.00	1.00	8983	0.74	0.44	0.00	1.00	10068
size of the household	7	3	2	28	8983	6	3	2	27	10068
Share of boys in the household	0	0	0	1	8983	0	0	0	1	10068
Share of girls in the house	0	0	0	1	8983	0	0	0	1	10068
Owns their house	0.94	0.24	0.00	1.00	8983	0.94	0.24	0.00	1.00	10068
Log household income	10.99	0.97	3.37	14.74	8858	11.16	0.97	5.30	15.30	9947
Hours watching TV	1.26	1.30	0.00	10.00	8707	1.75	1.39	0.00	20.00	9906
Hours watching TV squared	3.27	5.53	0.00	100.00	8707	5.02	13.48	0.00	400.00	9906
Household has a mobile	0.06	0.24	0.00	1.00	8973	0.81	0.39	0.00	1.00	10063
Age	9.43	1.06	8.00	11.00	8983	9.53	1.08	8.00	11.00	10068
Age squared	90.11	20.00	64.00	121.00	8983	91.92	20.56	64.00	121.00	10068
Highest female education in the HH (in years)	3.80	4.52	0.00	15.00	8914	4.72	4.82	0.00	15.00	10033
Caste/religion (6 categories)	3.68	1.38	2.00	7.00	8983	3.75	1.34	2.00	7.00	10068
Gender (1=boy, 2=girl)	1.46	0.50	1.00	2.00	8983	1.47	0.50	1.00	2.00	10068
Household is below poverty line	0.29	0.45	0.00	1.00	8978	0.26	0.44	0.00	1.00	10064

Table 3.1: Summary statistics for IHDS I (2005) and IHDS II (2012)

Learning outcomes. We have three main learning outcome variables captured by our test scores. The first is math scores, which are collected on a 4-point scale where 0 means that the child cannot recognise numbers; 1 that it can recognise numbers; 2 that it can perform addition and subtraction, and 3 that it can perform multiplication and division. The second is reading scores, which are registered along a 5-point scale where 0 indicates that the child cannot read; 1 that it can recognise letters; 2 that it can read words; 3 that it can read paragraphs; and 4 that it can read a story assigned to them. Finally, writing scores were collected on a 3-point scale where 0 indicates that a child cannot write; 1 that it can write with one or two mistakes; and 2 that it can write with no mistakes. None of the children scored 2, so in practice this is a binary scale for writing indicating whether a child can write at all or not.[13] In the 5 years elapsed between the surveys, students got better at maths and have a higher score, largely this increase is at the lower level, going not recognising numbers (score 0) to recognising numbers (score 1) and performing addition and subtraction. Fewer students got score 3 which is if they can perform multiplication and division. So, most of the improvement is in the middle of the distribution (score 1 and 2). For writing score, 75% of children can write compared to 68% in 2005-06, which is a large change. **??** illustrates these scores across different levels of electricity access in households.

In the first wave, children spend about 7.5 hours on their homework but there is a disparity on how this is spread, boys who live in households without electricity spend about 6.13 hours in both years, but girls go from 6.01 hours to 5.91 hours, a slight decline, even for the no electricity households. For households with low quality electricity, boys spent 7.4 hours in both waves, girls slightly reduce their hours from 7.51 to 7.38. In households with high quality electricity boys increase their hours spent studying at home from 8.7-9.2 and girls reduce their hours from 8.93-8.9. In all cases, girls reduce their hours spent on HW slightly, but boys increase time studying except in homes with no electricity.

On average children miss about 2 days a month of school. Girls miss more school days than boys except for households with high quality electricity where boys miss one extra day on average than girls. Both were missing more days than the previous wave if they live in a household with no electricity. The starkest gender difference is seen in time spent collecting firewood where boys spend 22 mins per week and girls spend 40 mins per week, which increased to 38 and 65 mins per week respectively. This increase is driven by the households that don't have electricity, where time spent by children increases 2.6 times for boys and 1.9 times for girls with boys spending 65 mins and girls spending 94 mins per week. This also increases for households with low quality electricity from 18-28 hours for boys and 33 to 63 hours for girls. It remains stable for households with high quality electricity.

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Mechanisms. We exploit the rich dataset to explore three possible channels of transmission or mechanisms through which more reliable electricity may affect learning outcomes. First, we look at how much time children spend on their homework in hours per week, as more reliable electricity and lighting –

[13]It is important to note that these are not conventional test scoring scales: we can say that 2 is better than 1, but we cannot say by how much.

	IHDS 1		IHDS 2	
	Boys	**Girls**	**Boys**	**Girls**
Math score				
Cannot recognise numbers 0	729	833	758	859
can recognise numbers 1	1,579	1,343	1,912	1,715
can add and subtract 2	1,361	1,093	1,606	1,398
Can multiply and divide 3	1,197	848	1,060	760
Reading score				
Cannot read 0	391	445	571	552
Can read letters 1	633	580	710	711
Can read words 2	1,053	821	1,076	965
Can read paragraph 3	1,059	876	1,028	858
Can read a story 4	1,730	1,395	1,951	1,646
Writing score				
Cannot write 0	1,478	1,368	1,307	1,259
Can write 1	3,388	2,749	4,029	3,473
Total	4,866	4,117	5,336	4,732

particularly in the evening – could influence time reallocation, and in turn impact the learning outcomes. Children spent roughly similar average amounts of time per week doing their homework in the two waves, 7.51 hours in 2005 and 7.71 hours in 2012. Second, we look at another indicator of time reallocation and use the time spent collecting firewood (in minutes per week). This is non-school work that is often performed by children and it could be affected by more reliable electricity, for example through increased household income that would enable buying (part of) of the firewood needed by the household.[14] Third, we look at the number of school days missed as a proxy of school attendance, which could be affected for example through improved health thanks to more reliable electricity. Children missed on average 3 school days per month in 2005 and 3.6 days in 2012.

In the first wave, children spend about 7.5 hours on their homework but there is a disparity on how this is spread, boys who live in households without electricity spend about 6.13 hours in both years, but girls go from 6.01 hours to 5.91 hours, a slight decline, even for the no electricity households. For households with low quality electricity, boys spent 7.4 hours in both waves, girls slightly reduce their hours from 7.51 to 7.38. In households with high quality electricity boys increase their hours spent studying at home from 8.7-9.2 and girls reduce their hours from 8.93-8.9. In all cases, girls reduce their hours spent on HW slightly, but boys increase time studying except in homes with no electricity.

On average children miss about 2 days a month of school. Girls miss more school days than boys except for households with high quality electricity where boys miss one extra day on average than girls. Both were missing more days than the previous wave if they live in a household with no electricity. The starkest

[14]Note that cooking with firewood remains widespread in India even after the introduction of electricity in households due to firewood being available for free and lack of adequate supply chains for liquified petroleum gas (LPG) (Banerjee et al. 2016).

Time spent doing HW				
	Boys IHDS1	Boys IHDS2	Girls IHDS1	Girls IHDS2
no electricity	6.14	6.13	6.01	5.91
low quality	7.42	7.43	7.51	7.38
High quality	8.67	9.12	8.93	8.90
Total	7.46	7.75	7.55	7.61
Days missed at school				
	Boys IHDS1	Boys IHDS2	Girls IHDS1	Girls IHDS2
no electricity	4.05	5.19	4.20	5.10
low quality	2.91	3.82	3.01	3.86
High quality	2.45	2.35	2.02	2.59
Total	3.08	3.60	3.03	3.68
Time spent collecting firewood				
	Boys IHDS1	Boys IHDS2	Girls IHDS1	Girls IHDS2
no electricity	25.13	65.57	49.05	94.04
low quality	18.11	28.78	33.61	63.05
High quality	27.12	22.14	36.79	36.57
Total	22.58	37.61	39.99	65.66

gender difference is seen in time spent collecting firewood where boys spend 22 mins per week and girls spend 40 mins per week, which increased to 38 and 65 mins per week respectively. This increase is driven by the households that don't have electricity, where time spent by children increases 2.6 times for boys and 1.9 times for girls with boys spending 65 mins and girls spending 94 mins per week. This also increases for households with low quality electricity from 18-28 hours for boys and 33 to 63 hours for girls. It remains stable for households with high quality electricity. This is tabulated in **??**

Reliability of electricity. The survey asks households whether they have electricity access and for how many hours per day on average. Reliability is defined in terms of the hours of electricity the households receive every day: more average hours of electricity indicate more reliable electricity access. Reliability is defined as 0 if the household does not use any electricity (i.e. is not connected); 1 if the household receives less than 18 hours of electricity per day on average; and 2 if the household receives more than 18 hours of electricity per day on average. Therefore, letting h represent the hours of electricity available per day, we have:

$$E = \begin{cases} 0, & \text{if } h = 0 \\ 1, & \text{if } 0 < h < 18 \\ 2, & \text{if } h \geq 18 \end{cases} \tag{3.1}$$

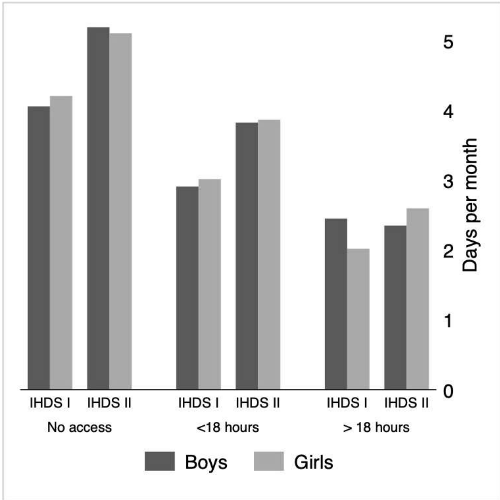


Figure 3.1: Electricity reliability across the two survey waves, in number of children reported living in a household in given reliability category.

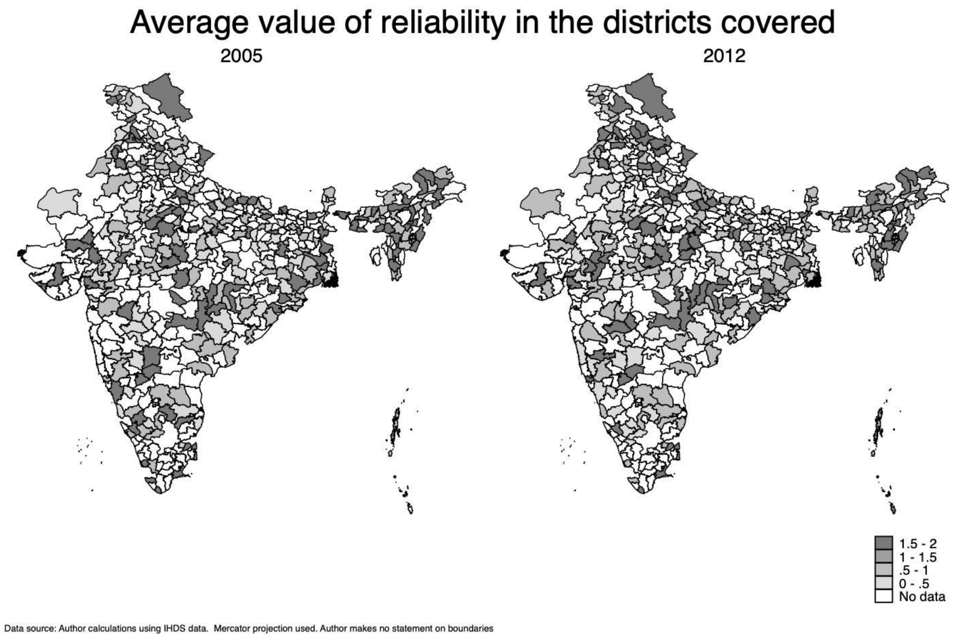


Figure 3.2: Electricity reliability across the two survey waves by districts in India. Reported household electricity reliability (0=no electricity; 1=low reliability; 2=high reliability) is averaged at district level.

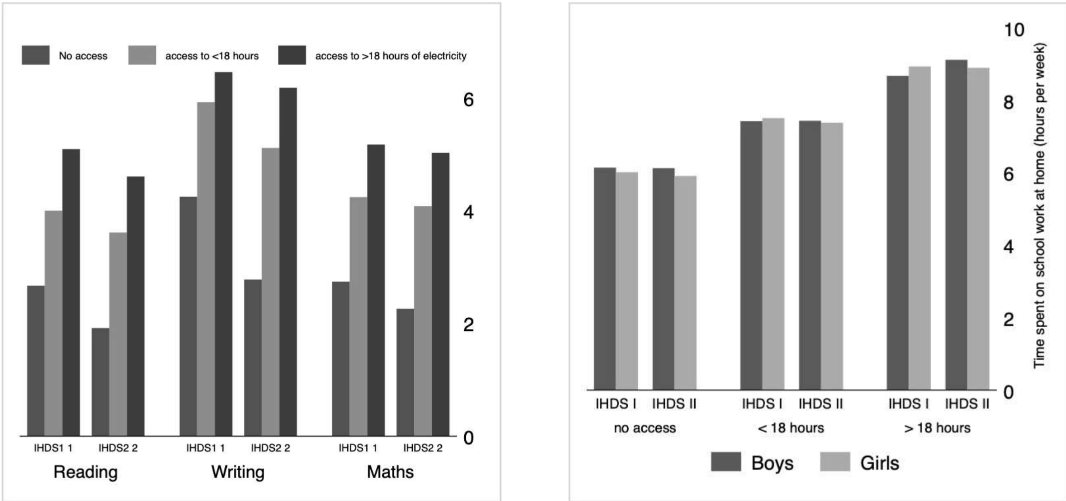


Figure 3.3: Test scores (left) and time spent on homework in hours per week (right) by electricity reliability, own calculations based on Indian Human Development Surveys (IHDS) of 2004-2005 (IHDS1) and 2011-2012 (IHDS2).

Our three categories are inspired by the multi-tier framework of the Energy Sector Management Assistance Program (ESMAP).[15] The ESMAP framework is very detailed and looks at hours of access (duration) between day and night, voltage issues, affordability, having access to formal connection and health & safety aspects. However, in the absence of that detail we are making some approximations. Our category of 1, which is electricity for less than 18 hours a day, captures the tier 3 of electricity access according to ESMAP; our category 2, which is more than 18 hours, captures tiers 4 and 5 in ESMAP. 18 hours is the critical point where the household will get access to electricity in the evening or dusk hours; Chakravorty et al. (2014) for example also follow this approach. We perform a robustness check in Section 5 and further break down our reliability categories to align even more closely with the definition under ESMAP.

Figure 3.1 shows the distribution of average electricity reliability across the two waves, measured by the number of children living in households with a given category. We see that on average, electricity has become more reliable, with a decrease in the number of children reported to live in households with no electricity; a marked increase in those with up to 18 hours of electricity per day; and a more modest increase in the number of children living in households with 18 or more hours of electricity per day. Figure 3.2 maps the district average household electricity reliability for the two survey waves, showing overall improvement in access to better-quality electricity over time, but also some mixed progress in the south of India.

Figures 3.3-3.4 show our test score and mechanism variables by electricity reliability and gender in the two survey waves. In Figure 3.3, we note that while all three test scores increase with electricity reliability in each wave, scores overall slightly decreased across the two waves. Time spent on homework similarly increases with more reliable electricity for both genders, indicating some time reallocation, but there is no clear change from one wave to the next. This can be explained by the increase in school attendance by

[15]ESMAP is a partnership between the World Bank and 24 partners to help low and middle-income countries reduce poverty and boost growth through sustainable energy solutions.

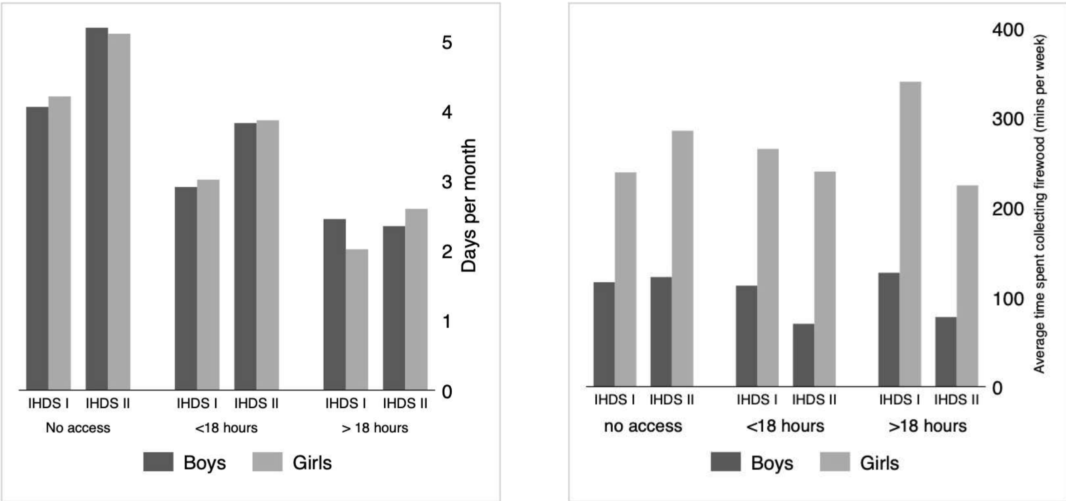


Figure 3.4: Days per month children are absent from school (left) and time spent on collecting firewood in minutes per week (right), by electricity reliability and reported separately for boys and girls. Own calculations based on Indian Human Development Surveys (IHDS) of 2004-2005 (IHDS1) and 2011-2012 (IHDS2).

children. As children who have never attended school start school their performance is not as good as the other children who have been enrolled for longer. Figure 3.4 shows that average school days missed per month decrease for both genders with more reliable electricity, while there is no clear relationship between electricity reliability and average time spent gathering firewood. We do note that boys reportedly spend a lot less time on this non-school activity than girls in both waves. This is a reflection of deep rooted patriarchal norms in Indian society where the male heir is seen as a 'pension' for old age and females are largely seen as a burden or 'someone else's property' (to borrow a popular Bollywood phrase) because they will get married and contribute to another household.[16] These norms include, among others, that women should work at home, women should obey their husbands and only boys have the right to perform the last rites of the parents (Evans et al. 2022).

Control variables. For control variables, we follow the literature on learning (e.g., Marshall and Moore 2022) and electricity access (e.g., Chakravorty et al. 2014). We use three types of controls: demographic variables such as size of the household (total number of adults and children), share of boys and girls in the household (total number of boys respectively girls divided by the size of the household),[17] age of the child in years and age squared.[18] We add wealth proxies including a dummy for whether the household owns the house they live in, the income of the household (monthly household income earned by the household in

[16]This is evident by the extremely skewed sex ratio at birth (Chao et al. 2019), indicating that families are more likely to decide to abort if the child is determined to be a female.The government's response to this has been to outlaw ultrasounds based sex determination but since people have to do an ultrasound during pregnancy, it comes down to the corruptibility of technicians or doctors, which is hard to monitor.

[17]We include this instead of the share of children because we believe a priori that in the Indian context the gender of the children might impact their treatment at home or in school.

[18]Age is the age of the child in years, all the children in our sample are between the age of 8-11 years. We also add a squared term for age to check for non-linearities, though given the short age period and relative ease of the tests we don't anticipate major improvements over the years.

log scale), a household livestock ownership dummy, and a dummy for whether the household is below the poverty line. Finally, we add a series of other variables including a rural-area dummy variable, a measure of time spent at home on other non-school activities, i.e. watching television,[19] and religion and caste of the child. Regarding religion and caste, SC is a dummy for being from the community of castes that are outlined as in a 'schedule' in the Indian constitution because of historical discrimination ('Scheduled Caste'); ST is a dummy for being from the communities referred in the Indian constitution's schedule as protected tribes ('Scheduled Tribe'), referred to as *Adivasi* in Hindi. Muslim is a dummy for people following the Muslim faith. Other minorities are categorised together in a dummy signifying people who follow the Christian, Jain and Sikh faith. The reference category is "forward" or "upper" caste Hindus. Amongst the minorities, the Sikh and Jain minorities are generally wealthier than the rest; they are also the smallest minority in the sample. We do not see anybody from other faiths such as Buddhism, Parsis or Jewish communities possibly because of the survey's overall emphasis on rural areas.

3.5 Methodology

We investigate the relation between electricity reliability and children's educational scores and the intervening mechanisms. Empirically, we use an ordered probit model because the scores in the survey are defined as categories of assessment rather than conventional continuous variable grades. We pool the data because – though the same households are visited in the two surveys – each individual child is only tested in one of the two surveys due to the age restriction.

Let y_{it} be the score assigned to the child i, with t denoting the survey wave. Ordered probit assumes there is an underlying continuous variable, so we assume y_i* be the child's score in mathematics in an exam scored on 0-1000. [20]

y_{it} e (0 , 1000)

Also, let X_{it} be the vector of characteristics that determine the scores of the child at t.

$$y_{it} = \beta_1 X_{it} + u_{it} \tag{3.2}$$

β is a vector of parameters not containing an intercept. y_i* is unobservable but y_i is observed and the relationship between y_i* and y_i is :

$$y_{it} = \begin{cases} 0, \text{ if } 0 < y_{it}* < \kappa 0 \\ 1, \text{ if } \kappa 0 < y_{it}* < \kappa 1 \\ 2, \text{ if } \kappa 1 < y_{it}* < \kappa 2 \\ 3, \text{ if } \kappa 2 < y_{it}* < 1000 \end{cases} \tag{3.3}$$

where, κj j = 0,1,2 are cut point or threshold parameters. Let, $P_{it}(y)$ be the probability that the ith

[19]Children spent around 1.26 hours per day watching TV in 2004-05, which increased to 1.75 per day hours in 2012.

[20]It can be easier if we think of y_{it} as a letter grade and indexing the hypothetical marks from 0-1000 for y_i*

respondent's response is y. This probability is as follows:

$$P_{it}(y) = P(\kappa y - 1 < y * i < \kappa y) = \phi(\kappa yit - X'it\beta - \phi(\kappa yit - 1, y = 0, 1, 2 \quad (3.4)$$

where, ϕ is the standard normal cumulative distribution function. Based on a sample (n =16000) the log likelihood function is:

$$LogL = \Sigma \log[Pi(yit)] = \Sigma \log[\Phi(\kappa yit - x'it\beta) - \Phi(\kappa yit - 1 - x'it\beta)] \quad (3.5)$$

This is then maximised with respect to β and with the cut points κj. This case is similar for reading and writing score. However, for the writing score, there are only two point scores so the ordered probit collapses to a simple binomial probit. In this the cutpoint can be interpreted as the constant but with opposite sign, so we make this change while reporting the answers.

The mechanism analysis is performed with ordinary least squares (OLS) analysis, as the outcomes are on a continuous scale. For both oprobit and OLS estimations, standard errors are clustered at the district level.

In the sensitivity analysis in Section 3.7, we also address the possible endogeneity of electricity reliability and use an instrumental variables (IV) approach to check the robustness of our results and gain more insight into the causal nature of the relationship between electricity reliability and learning outcomes. We have two different cases: first, when both the outcome and the treatment are discrete and ordered variables (i.e. with scores and reliability of electricity). In this case, we use two stage ordered probit and report the Wald statistic for post estimation.

In the second case, the outcome is continuous and the treatment is still discrete, so we run the following: let the 0 outcome be the base case, which is no access to electricity. Then define dummy variables d1, d2, d3 for the different implementation levels. Let w be the implementation level itself. For us, $w = 0, 1, 2$. In the first stage, we use ordered probit of w on all exogenous variables as described above but also including instruments. We then use this as the new first stage. Wooldridge (2010) [21]

$$w_{it} = X_{it} + Z_{it} + u_{it}, \quad (3.6)$$

with $w = 0, 1, 2$. We use this to calculate predicted probability for w, $pr(\hat{w})$. These fitted probabilities will act as IV for d_i and elements of x act as their own IVs:

$$r_{it} = \gamma 0 + \gamma 1 X_{it} + \gamma 2 pr\hat{w} + e_{it} y_{it} = \alpha 0 + \alpha 1 X_{it} + \alpha 2 r_{it} + v_{it}. \quad (3.7)$$

We can't use an OLS for the first three outcomes (the math, reading and writing scores) this is because the scores given are not traditional scores but a category, they describe an increased order of learning, but we don't know how much one differs from the other. For example, the math score is 0 if the child can't recognise numbers, 1 if the child can recognise numbers but can't perform any operations, 2 if the child can add and subtract numbers, and 3 if the child can multiply and divide. Evidently, there is an order meaning a higher score is better, but we can't say how much better is it to know multiplication

[21] Extension of procedure 21.1 as explained at "Wooldridge ("2014")

Table 3.2: Math scores and electricity reliability, ordered probit

	(1) All	(2) Boys	(3) Girls
low quality	0.24***	0.24***	0.26***
	(0.036)	(0.042)	(0.049)
High quality	0.23***	0.21***	0.26***
	(0.044)	(0.049)	(0.056)
Demographic variables:			
lives in rural area	-0.16***	-0.10**	-0.23***
	(0.033)	(0.042)	(0.040)
size of the household	-0.02***	-0.02***	-0.02***
	(0.004)	(0.005)	(0.006)
Share of boys in the household	-0.55***	-0.61***	-0.48***
	(0.101)	(0.124)	(0.140)
Share of girls in the house	-0.49***	-0.49***	-0.53***
	(0.091)	(0.115)	(0.126)
Wealth:			
owns their house	-0.01	-0.01	-0.01
	(0.041)	(0.048)	(0.056)
log household income	0.08***	0.09***	0.07***
	(0.012)	(0.016)	(0.018)
hours watching TV	0.03***	0.03*	0.03**
	(0.011)	(0.015)	(0.015)
hours watching TV sq	-0.00**	-0.00	-0.00
	(0.001)	(0.002)	(0.002)
have a mobile	-0.11***	-0.13***	-0.10***
	(0.026)	(0.032)	(0.033)
Age	0.88***	0.81***	0.92***
	(0.165)	(0.213)	(0.255)
Age squared	-0.03***	-0.03**	-0.04***
	(0.009)	(0.011)	(0.014)
highest female education in the HH (yrs)	0.05***	0.05***	0.06***
	(0.003)	(0.004)	(0.004)
household is below poverty line	-0.21***	-0.24***	-0.18***
	(0.024)	(0.030)	(0.033)
Religion and caste:			
OBC 3	-0.09***	-0.11***	-0.07*
	(0.032)	(0.041)	(0.040)
Dalit 4	-0.28***	-0.30***	-0.26***
	(0.033)	(0.042)	(0.045)
Adivasi 5	-0.35***	-0.33***	-0.36***
	(0.050)	(0.063)	(0.063)
Muslim 6	-0.38***	-0.44***	-0.32***
	(0.040)	(0.052)	(0.051)
Christian, Sikh, Jain 7	-0.14**	-0.18***	-0.07
	(0.057)	(0.066)	(0.082)
cut1	4.35***	4.15***	4.66***
	(0.794)	(1.034)	(1.207)
cut2	5.53***	5.34***	5.83***
	(0.793)	(1.033)	(1.207)
cut3	6.49***	6.29***	6.81***
	(0.796)	(1.035)	(1.208)
N	17,127	9,152	7,975

Note: Math scores are on a 4-point scale where 0 - can't recognise numbers; 1 - can recognise numbers; 2- can perform addition subtraction and 3 - can perform multiplication and division. Children are in the age group 8-11. Oprobit estimations with log likelihood reported. *cuti* reports the likelihood of moving from category i to i-1. Marginal effects are reported in Figure 3.5. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

rather than just knowing addition compared to not knowing numbers to recognising numbers. In other words, going from score 0 to 1 and then 1 to 2 can't be compared, except in a sense of ordinality. This is important because the OLS coefficients must be interpreted units change in dependent variable as a response to a change in its explanatory variable **?**. For the binary indicator, the ordered probit collapses into a probit so its mathematically equivalent.

3.5.1 identification

The concern around endogeneity and scores are easy to dismiss because households are not able to make the decision of getting higher quality electricity, these decisions are primarily controlled by the distribution company that provides electricity in the area. However, there is still possible endogeneity due to missing variable such as income impacting both scores and quality of electricity. It is possible that higher income households have better quality of electricity and better grades because high income households have more time to dedicate to helping their children or they simply care more about their children's educational achievements.

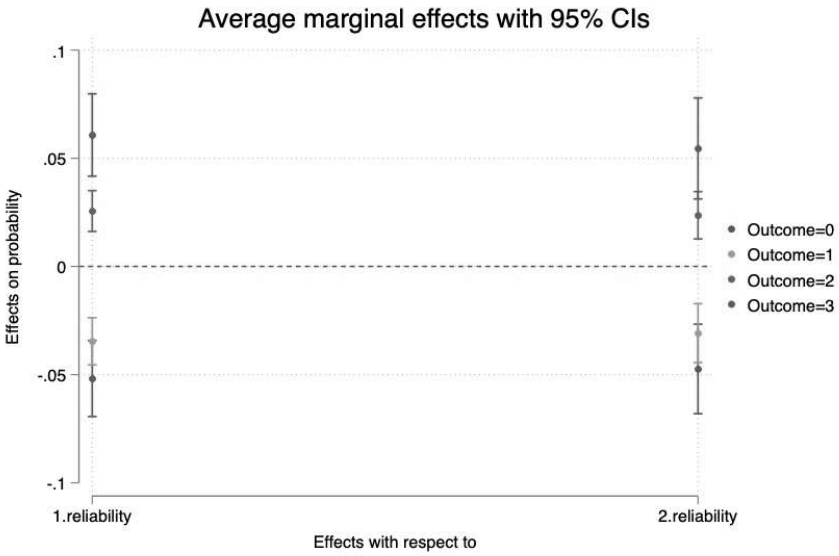
To address endogeneity, we use an instrument variable approach we use three set of instruments – density of transmission lines, distance of the district centroid from the coal plant, and distance of the village centroid from the hydro plants. The treatment – households being electrified and accessing electricity for different hours is always at the household level and the outcome variables are at individual level. For the density of transmission lines, these lines were built for more strategic industries and not to provide household or school electrification and hence instrumenting quality of electricity provides us with variation that impacts educational scores through the density of transmission lines. For the exclusion restriction to not work, we would need that the density of transmission lines vary systematically with the educational score, which is not the case. A second set of instruments are distance from coal and hydro plants. The distance from the powerplants determine the infrastructure required to service electricity and hence its cost of provisions. Therefore, it is relevant to the quality of electricity. It cannot plausibly be argued that the distance from the powerplants can impact educational scores of school children and hence the instrument gives us the variation for quality of electricity on scores.

3.6 Results

3.6.1 Reliability of electrification and learning outcomes

We first look at the results for the oprobit estimations of the relation between electricity reliability and our main learning outcomes. Table 3.2 shows that having access to electricity, even at low reliability, significantly increases the likelihood of obtaining a higher score for all children (column 1) and boys (column 2) and girls (column 3) separately. The magnitudes of the coefficients are similar between low and high reliability; both significantly increase children's likelihood of getting higher math scores compared to not having any electricity access (the base category).

Looking at the control variables, we see that living in rural areas has a significant negative impact on the likelihood of obtaining a higher math score for both genders; larger households and larger shares of boys and girls decrease the likelihood of getting high math scores, perhaps indicating that nuclear families



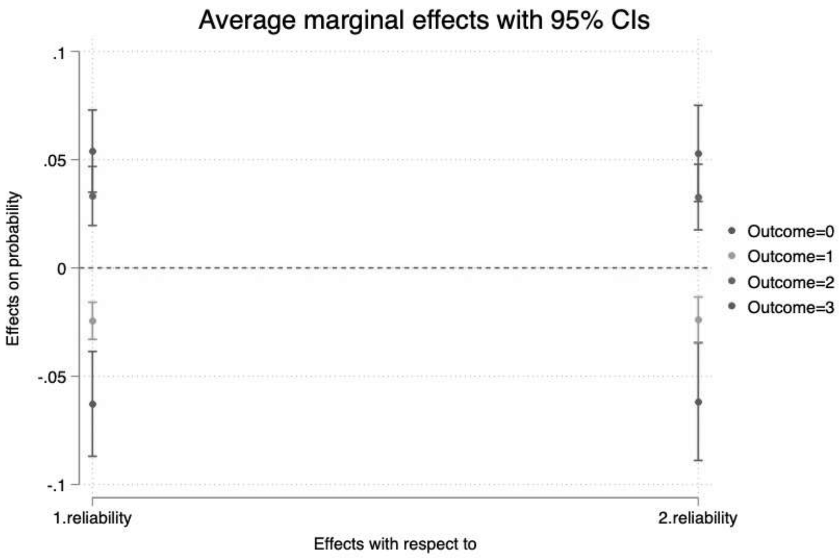


Figure 3.5: Average marginal effects of electricity reliability on math scores for boys (top) and girls (bottom). Outcomes are the 4 scores awarded from 0 (lowest) to 3 (highest); reliability is low (1, on left) or high (2 ,on right), with no access being the base outcome.

spend more time on their children instead of other (care) responsibilities. The literature finds that the gender gap shows up later (post puberty), while the children in our sample are 8-11 years old, so it is difficult to prove this claim. Income and having a better-educated female in the household have a positive relation with math scores; the latter reinforces the importance of female education in inter-generational benefits. Having access to a mobile phone and being below the poverty line have a significant negative link with scores. Both hours spent watching TV and age of the child have an inverted-U shaped relationship with math scores. Finally, the caste and religion dummies have a significant and negative link with math scores, indicating that differences compared with upper-caste Hindus still exist in the Indian society.

Figure 3.5 gives marginal effects of electricity reliability on math scores disaggregated for boys (top) and girls (bottom). We see that the positive relationship seen in Table 3.2 is driven both by an increase in the probability of achieving the high scores 2 and 3 and a decrease in the probability of achieving low scores 0 and 1. This is a very encouraging result: the likelihood of a child not identifying numbers (score 0) drops after the child's household gets electricity access, and similarly the probability that the child can do some basic numerical operations increases. For example, Figure 3.5 suggests that for boys and girls, moving from no electricity access to having electricity under 18 hours/day (i.e. the left-hand side of the graphs) increases the probability of achieving a high math score of 3 by just over 5pp, *ceteris paribus*, and reduces the probability of achieving the lowest score of 0 by roughly the same magnitude. The right-hand side of the graphs shows comparable effects of moving to high-reliability electricity. The effects are quite similar in size for boys and girls, though the link with high scores is slightly larger for boys and that with low scores larger for girls, but the differences are small.

Table 3.3 gives the results for reading scores, and Table 3.4 for writing scores, which show qualitatively very similar results to those discussed for math scores in Table 3.2 above. Figure 3.6 and Figure 3.7 give the corresponding marginal effects graphs for reading and writing, respectively. Recall that writing scores collapse into a 0-1 dummy because no child was able to write with no mistake. The marginal effects graphs for reading and writing show a similar pattern to those for math in Figure 3.5, namely a decrease in the probability of achieving low and an increase in the probability of achieving high scores for children living in electrified households, with no noticeable differences in marginal effects between high- and low-reliability electricity. It is worth pointing out that the increase in the probability of achieving the highest test scores with electrification is highest for the reading scores of all our three test score outcomes, at around 7-8pp for both boys and girls. The increase in probability in achieving the second-highest score, as well as the decrease in probability of achieving the two lowest scores is instead more modest for reading than for math and writing, again with the caveat that writing scores are on a 0-1 scale.

Finally, Figure 3.8 shows the average marginal effects of all explanatory variables on the three test scores. This allows us to compare the average magnitude of the cumulative marginal effects for all children across our three main outcome variables. Looking at the top two results for our variables of interest, we see that living in a household with access to electricity – either of low or high reliability – increases the probability of getting higher math and reading scores to a similar extent, and slightly less for writing scores.

Table 3.3: Reading scores and electricity reliability, ordered probit

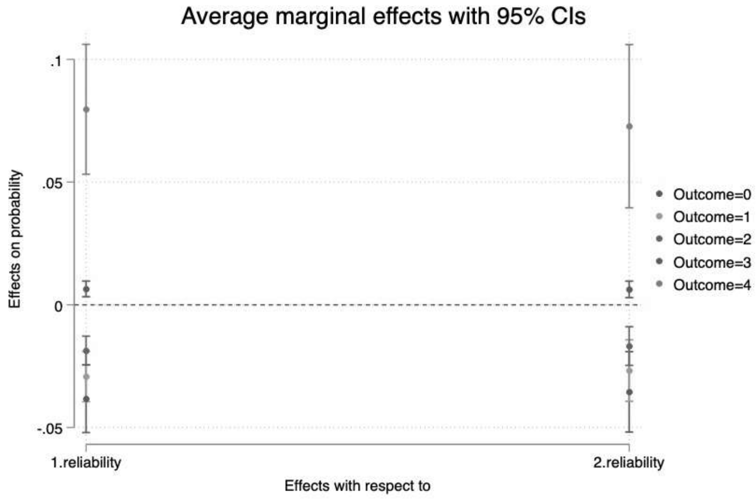
	(1) All	(2) Boys	(3) Girls
low quality	0.24***	0.24***	0.24***
	(0.035)	(0.043)	(0.045)
High quality	0.24***	0.21***	0.28***
	(0.043)	(0.052)	(0.054)
Demographic variables:			
lives in rural area	-0.14***	-0.09**	-0.18***
	(0.034)	(0.041)	(0.041)
size of the household	-0.02***	-0.02***	-0.02***
	(0.004)	(0.005)	(0.006)
Share of boys in the household	-0.57***	-0.67***	-0.42***
	(0.099)	(0.115)	(0.149)
Share of girls in the house	-0.58***	-0.55***	-0.63***
	(0.088)	(0.112)	(0.130)
Wealth:			
owns their house	-0.04	-0.09*	-0.00
	(0.039)	(0.051)	(0.052)
log household income	0.04***	0.03**	0.05***
	(0.012)	(0.016)	(0.018)
hours watching TV	0.05***	0.05***	0.06***
	(0.011)	(0.014)	(0.015)
hours watching TV sq	-0.00***	-0.00**	-0.01***
	(0.001)	(0.001)	(0.001)
have a mobile	-0.09***	-0.11***	-0.08**
	(0.026)	(0.032)	(0.033)
Age	0.71***	0.73***	0.65***
	(0.163)	(0.208)	(0.239)
Age squared	-0.02***	-0.02**	-0.02*
	(0.009)	(0.011)	(0.013)
highest female education in the HH (yrs)	0.05***	0.04***	0.05***
	(0.003)	(0.003)	(0.004)
household is below poverty line	-0.22***	-0.24***	-0.19***
	(0.025)	(0.032)	(0.032)
Religion and caste:			
OBC 3	-0.07*	-0.07*	-0.05
	(0.033)	(0.041)	(0.042)
Dalit 4	-0.27***	-0.29***	-0.23***
	(0.033)	(0.043)	(0.046)
Adivasi 5	-0.30***	-0.27***	-0.33***
	(0.059)	(0.070)	(0.074)
Muslim 6	-0.33***	-0.40***	-0.25***
	(0.041)	(0.051)	(0.056)
Christian, Sikh, Jain 7	-0.03	-0.11	0.10
	(0.076)	(0.082)	(0.116)
cut1	3.16***	3.12***	3.12***
	(0.792)	(0.992)	(1.148)
cut2	3.80***	3.75***	3.77***
	(0.793)	(0.993)	(1.149)
cut3	4.46***	4.43***	4.42***
	(0.794)	(0.996)	(1.147)
cut4	5.04***	5.01***	5.01***
	(0.796)	(0.997)	(1.149)
N	17,127	9,152	7,975

Note: Reading scores are ordinally assigned where 0 - cant read; 1 - can recognise letters; 2 - can read words; 3- can read paragraphs; 4 - can read a story assigned to them. Children are in the age group 8-11. Oprobit estimations with log likelihood reported. *cuti* reports the likelihood of moving from category i to i-1. Marginal effects are reported in Figure 3.6. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.4: Writing scores and electricity reliability, ordered probit

	(1) All	(2) Boys	(3) Girls
low quality	0.19***	0.18***	0.20***
	(0.042)	(0.049)	(0.055)
High quality	0.17***	0.15**	0.19***
	(0.054)	(0.062)	(0.070)
Demographic variables:			
lives in rural area	-0.10**	-0.05	-0.15***
	(0.041)	(0.049)	(0.055)
size of the household	-0.03***	-0.02***	-0.03***
	(0.005)	(0.006)	(0.008)
Share of boys in the household	-0.63***	-0.61***	-0.64***
	(0.118)	(0.138)	(0.186)
Share of girls in the house	-0.47***	-0.35**	-0.65***
	(0.116)	(0.143)	(0.169)
Wealth:			
owns their house	-0.10*	-0.07	-0.15*
	(0.056)	(0.068)	(0.077)
log household income	0.02	0.03*	0.01
	(0.017)	(0.020)	(0.023)
hours watching TV	0.03**	0.03	0.04**
	(0.013)	(0.018)	(0.019)
hours watching TV sq	-0.00**	-0.00	-0.00
	(0.001)	(0.002)	(0.002)
have a mobile	0.15***	0.13***	0.18***
	(0.037)	(0.046)	(0.044)
Age	0.95***	0.94***	0.91***
	(0.216)	(0.275)	(0.331)
Age squared	-0.04***	-0.04***	-0.04**
	(0.012)	(0.015)	(0.018)
highest female education in the HH (yrs)	0.06***	0.06***	0.06***
	(0.003)	(0.005)	(0.005)
household is below poverty line	-0.18***	-0.22***	-0.12***
	(0.029)	(0.042)	(0.042)
Religion and caste:			
OBC 3	-0.08*	-0.07	-0.08
	(0.045)	(0.056)	(0.057)
Dalit 4	-0.24***	-0.23***	-0.25***
	(0.042)	(0.057)	(0.059)
Adivasi 5	-0.32***	-0.26***	-0.38***
	(0.066)	(0.082)	(0.082)
Muslim 6	-0.36***	-0.41***	-0.31***
	(0.054)	(0.067)	(0.068)
Christian, Sikh, Jain 7	-0.05	-0.09	0.03
	(0.096)	(0.116)	(0.159)
cut1	4.57***	4.68***	4.27***
	(1.032)	(1.313)	(1.567)
N	17,127	9,152	7,975

Note: Writing scores were ordinally assigned on a 3 point scale where 0 - cannot write; 1 - can write with one or two mistakes; 2 - can write with no mistakes. None of the children scored 2, so in practise this is a binary scale. Children are in the age group 8-11. Oprobit estimations with log likelihood reported. *cuti* reports the likelihood of moving from category i to i-1. Marginal effects are reported in Figure 3.7. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.



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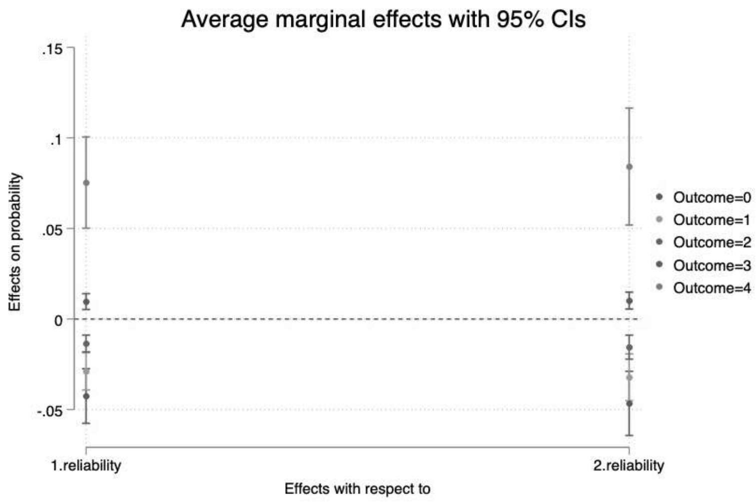

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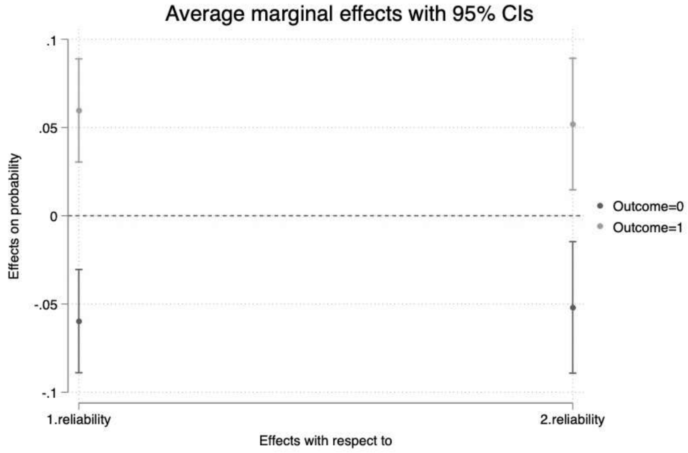
Figure 3.6: Average marginal effects of electricity reliability on reading scores for boys (top) and girls (bottom). Outcomes are the 4 scores awarded from 0 (lowest) to 3 (highest); reliability is low (1, on left) or high (2, on right), with no access being the base outcome.



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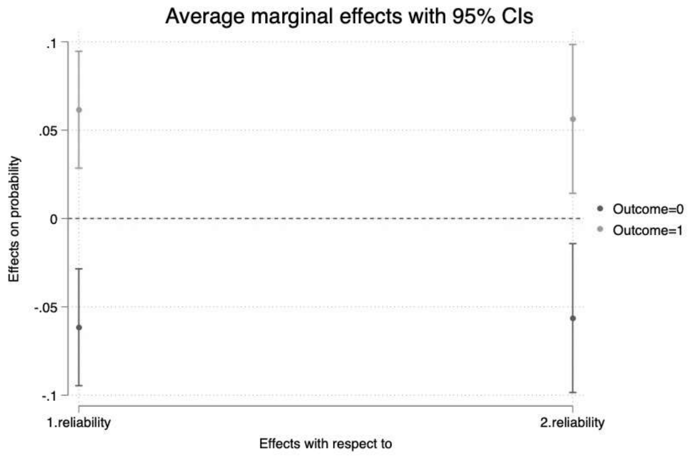

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Figure 3.7: Average marginal effects of electricity reliability on writing scores for boys (top) and girls (bottom). Outcomes are the 2 scores awarded from 0 (lowest) to 1 (highest); reliability is low (1, on left) or high (2 ,on right), with no access being the base outcome.

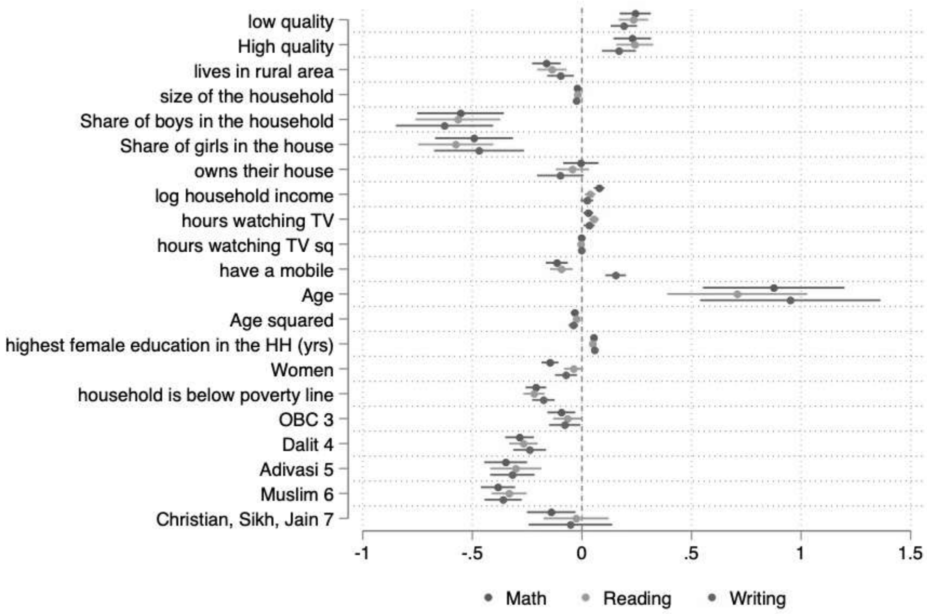

Figure 3.8: Coefficient plots for all three test scores of all explanatory variables. Dots denote marginal effect size and lines the 95% confidence intervals. Values to the right (left) of 0 indicate positive (negative) marginal effects.

3.6.2 Mechanism analysis

After examining our main outcomes of interest and finding that living in a household with electricity access is strongly linked to better learning achievements by the household's children, we next turn to the analysis of the underlying mechanisms. We first examine two measures of engagement with school work: time spent on homework and school days missed. The former can also be seen as a manifestation of time reallocation, while the latter has been found to be linked with positive health effects from electrification. Our third mechanism looks at another time reallocation proxy, namely the time spent collecting firewood. Recall that we now look at OLS estimation results.

Time spent on homework

Table 3.5 shows the estimation results for the relation between electricity reliability and time spent on homework in hours per week. Having access to electricity significantly increases children's time spent on homework each week, suggesting that this is indeed a possible channel of transmission for the positive results we saw above for electricity reliability and learning outcomes. Moreover, column 1 shows that the average magnitude of the coefficient for high quality electricity is nearly three times as large as that for low quality electricity.[22] Ceteris paribus, having access to electricity for 18 hours or more per day is related to

[22] Tests show that coefficients for low and high quality are significantly different in the specification for all children (column 1) but not for boys (column 2) and girls (column 3) separately.

Table 3.5: Homework and electricity reliability, OLS

	All (1)	Boys (2)	Girls (3)
low quality	0.34***	0.68***	0.57***
	(0.120)	(0.170)	(0.180)
High quality	1.13***	0.79***	0.38*
	(0.139)	(0.210)	(0.225)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.41***	-0.51***	-0.69***
	(0.111)	(0.154)	(0.165)
size of the household	-0.05***	0.03	-0.05*
	(0.017)	(0.024)	(0.025)
Share of boys in the household	-2.79***	-0.43	-1.97***
	(0.427)	(0.584)	(0.634)
Share of girls in the house	-1.52***	0.55	-1.25**
	(0.394)	(0.536)	(0.581)
Wealth:	ref.	ref.	ref.
owns their house	-0.09	-0.15	-0.19
	(0.189)	(0.256)	(0.273)
log household income	0.12**	0.07	0.23***
	(0.054)	(0.073)	(0.080)
Age	0.97	0.89	0.17
	(0.809)	(1.077)	(1.159)
Age squared	-0.03	-0.03	0.01
	(0.043)	(0.057)	(0.061)
hours watching TV	-0.02	0.02	0.02
	(0.050)	(0.069)	(0.072)
hours watching TV sq	0.01**	-0.01	0.02***
	(0.006)	(0.008)	(0.008)
have a mobile	-0.15	0.15	-0.13
	(0.092)	(0.125)	(0.133)
highest female education in the HH (yrs)	0.18***	0.17***	0.14***
	(0.011)	(0.016)	(0.017)
Religion and caste:	ref.	ref.	ref.
OBC 3	-0.60***	-0.25	-0.58***
	(0.127)	(0.172)	(0.189)
Dalit 4	-0.60***	-0.52***	-0.86***
	(0.139)	(0.187)	(0.204)
Adivasi 5	-0.50***	-0.50*	-0.94***
	(0.189)	(0.268)	(0.289)
Muslim 6	-0.36**	-0.53**	-0.77***
	(0.156)	(0.219)	(0.233)
Christian, Sikh, Jain 7	0.07	-0.44	0.14
	(0.305)	(0.427)	(0.488)
household is below poverty line	-0.79***	-0.86***	-0.89***
	(0.105)	(0.145)	(0.151)
Constant	1.23	2.15	5.79
	(3.846)	(5.157)	(5.540)
N	16,482	8,836	7,646
R squared	82%	81%	80%

Note: Dependent variable is time spent on homework measured in hours per week. The specifications are OLS. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

around 1.1 more hours spent on homework per week on average for all children, while the lower-reliability electricity is linked to an average increase of only 0.34 hours compared to having no electricity. Looking at the differences between boys and girls in columns 2-3, we see that the link is particularly strong for boys and larger for high-reliability electricity, while high-reliability electricity has a smaller and weaker relation with time spent on homework for girls.

Looking at the control variables, we see that these are largely consistent with those found above for our learning outcomes. The size of the household and share of boys and girls in the household are negatively (though not always significantly) linked to homework time, possibly because of less attention by parents or because of siblings/cousins spending more time playing together. The share of boys in the household has a larger negative coefficient than the share of girls, perhaps because at this age parents are stricter with girls than with boys. Income only seems to be linked to girls' time spent on homework, perhaps showing early signs of bias in the attention adults can afford to give to girls' versus boys' education; households below the poverty line however see their children of either gender spending less time on homework. We also see that having a more educated adult female in the household has a strong positive relationship with children's time spent on homework, regardless of their gender. The caste variables are again significant, showing differences in outcomes by population group.

Missed school days

Table 3.6 shows the link between electricity reliability and missed days of school per month. At both low and high levels of electricity reliability, the relation is negative and highly significant meaning that an increase in electricity access from no access to low quality access is linked to a reduction in days absent. We also note the difference in magnitude of the coefficients between low and high reliability.[23] At low reliability children are gaining on average close to one day per month of school compared to children in households with no electricity, and at high reliability children are gaining over one-and-a-half days of school per month. Results are similar for boys and girls. These clear findings make this another possible channel of transmission for our main results on the links between electricity reliability and learning outcomes.

Looking at the control variables, we see that home ownership, household income, being above the poverty line and having a more educated adult female in the household are all significantly linked to fewer days missed at school of children. Having access to a mobile phone tends to see more missed days at school for both genders, and most caste and religion variables are again significant, which is an unfortunate but consistent result.

Time spent gathering firewood

Table 3.7 gives the results for time spent collecting firewood. Theoretically, having access to more reliable electricity could be affecting the time spent on this non-school activity especially through an income channel, with households being able to more readily afford to buy firewood instead of sending children out to gather it. Surprisingly, we find a significant and positive link between having access to high-reliability electricity and children's time in minutes spent per week in collecting firewood (column 1). It is unclear where this is stemming from, as boys seem to reduce the time they collect firewood (column 2) but there

[23]Tests show that the coefficients for low and high quality are significantly different in all three specifications.

Table 3.6: Number of days missed at school per month and electricity reliability, OLS

	(1) All b/se	(2) Boys b/se	(3) Girls b/se
low quality	-0.78***	-0.84***	-0.69***
	(0.208)	(0.236)	(0.254)
High quality	-1.62***	-1.64***	-1.59***
	(0.240)	(0.269)	(0.286)
Demographic variables:	ref.	ref.	ref.
lives in rural area	0.23	0.10	0.37*
	(0.179)	(0.207)	(0.193)
size of the household	-0.00	0.02	-0.03
	(0.022)	(0.030)	(0.027)
Share of boys in the household	0.47	0.96	0.06
	(0.491)	(0.593)	(0.659)
Share of girls in the house	0.47	0.61	0.24
	(0.426)	(0.560)	(0.556)
Wealth:	ref.	ref.	ref.
owns their house	-0.44*	-0.40	-0.46*
	(0.246)	(0.322)	(0.273)
log household income	-0.18***	-0.15**	-0.21**
	(0.066)	(0.075)	(0.086)
Age	-1.93***	-2.13**	-1.68
	(0.710)	(1.003)	(1.041)
Age squared	0.10***	0.11**	0.09
	(0.038)	(0.053)	(0.055)
hours watching TV	-0.11	-0.08	-0.14
	(0.075)	(0.086)	(0.087)
hours watching TV sq	0.01	0.02	0.01
	(0.012)	(0.014)	(0.011)
have a mobile	0.58***	0.54***	0.63***
	(0.158)	(0.179)	(0.171)
highest female education in the HH (yrs)	-0.05***	-0.05***	-0.06***
	(0.013)	(0.017)	(0.016)
Religion and caste:	ref.	ref.	ref.
OBC 3	0.36**	0.34	0.38**
	(0.166)	(0.204)	(0.192)
Dalit 4	0.42**	0.27	0.59***
	(0.171)	(0.210)	(0.215)
Adivasi 5	0.13	0.16	0.09
	(0.248)	(0.334)	(0.264)
Muslim 6	0.52**	0.43*	0.60**
	(0.221)	(0.258)	(0.266)
Christian, Sikh, Jain 7	-0.40	-0.45	-0.35
	(0.286)	(0.345)	(0.326)
household is below poverty line	0.25*	0.34**	0.15
	(0.130)	(0.164)	(0.185)
Constant	14.84***	15.20***	14.32***
	(3.496)	(4.842)	(5.032)
N	16409	8774	7635
R squared	35%	31%	41%

Note: Dependent variable is missed school days per month. The specifications are OLS. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.7: Time spent collecting firewood and electricity reliability, OLS

	All (1)	Boys (2)	Girls (3)
low quality	-6.40	-22.44**	4.70
	(8.095)	(8.925)	(15.283)
High quality	26.55***	-22.80*	-29.42
	(10.039)	(11.805)	(20.494)
Demographic variables:	ref.	ref.	ref.
lives in rural area	69.63***	39.32***	62.95***
	(12.841)	(13.288)	(22.644)
size of the household	3.05**	4.14***	2.05
	(1.360)	(1.437)	(2.396)
Share of boys in the household	-7.53	-10.11	-33.80
	(33.807)	(34.420)	(60.710)
Share of girls in the house	-19.12	-10.03	-38.87
	(31.344)	(31.695)	(56.434)
Wealth:	ref.	ref.	ref.
owns their house	26.76	7.61	12.74
	(23.724)	(24.041)	(41.863)
log household income	6.30	7.08	6.18
	(4.301)	(4.430)	(7.722)
Age	24.34	79.38	-18.39
	(62.575)	(61.987)	(110.048)
Age squared	-1.31	-4.18	0.84
	(3.309)	(3.276)	(5.824)
hours watching TV	4.87	4.94	0.12
	(3.876)	(3.985)	(6.803)
hours watching TV sq	0.35	-0.00	1.01
	(0.448)	(0.457)	(0.767)
have a mobile	-35.46***	-26.61***	-41.02***
	(7.398)	(7.499)	(13.051)
highest female education in the HH (yrs)	-4.62***	-2.28**	-5.87***
	(0.991)	(1.038)	(1.816)
Religion and caste:	ref.	ref.	ref.
OBC 3	-40.15***	-34.83***	-11.08
	(10.794)	(10.971)	(20.182)
Dalit 4	-44.34***	-43.52***	-3.18
	(11.267)	(11.306)	(20.642)
Adivasi 5	0.99	-32.93**	29.47
	(13.563)	(14.145)	(25.485)
Muslim 6	-80.20***	-52.47***	-38.59
	(13.930)	(14.756)	(25.587)
Christian, Sikh, Jain 7	-135.81***	-47.69	-86.84
	(39.401)	(41.784)	(75.078)
household is below poverty line	19.38***	18.53**	-1.66
	(7.501)	(7.781)	(13.339)
Constant	-138.15	-380.92	308.20
	(298.058)	(298.209)	(527.513)
N	7,662	4,051	3,611
R squared	91%	85%	82%

Note: Dependent variable is time spent gathering firewood measured in minutes per week. The specifications are OLS. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

is no significant link for girls (column 3). It is therefore uncertain whether any time reallocation in this activity is contributing to our positive results for learning outcomes.

Regarding the control variables, children – especially boys – living in larger households and households below the poverty line tend to spend more time gathering firewood. Having a more educated adult female in the household is linked to less time spent gathering firewood for both genders, as is having a mobile.

Figure 3.9 summarises the results for our three mechanisms, or channels of transmission, giving the marginal effects for all children.

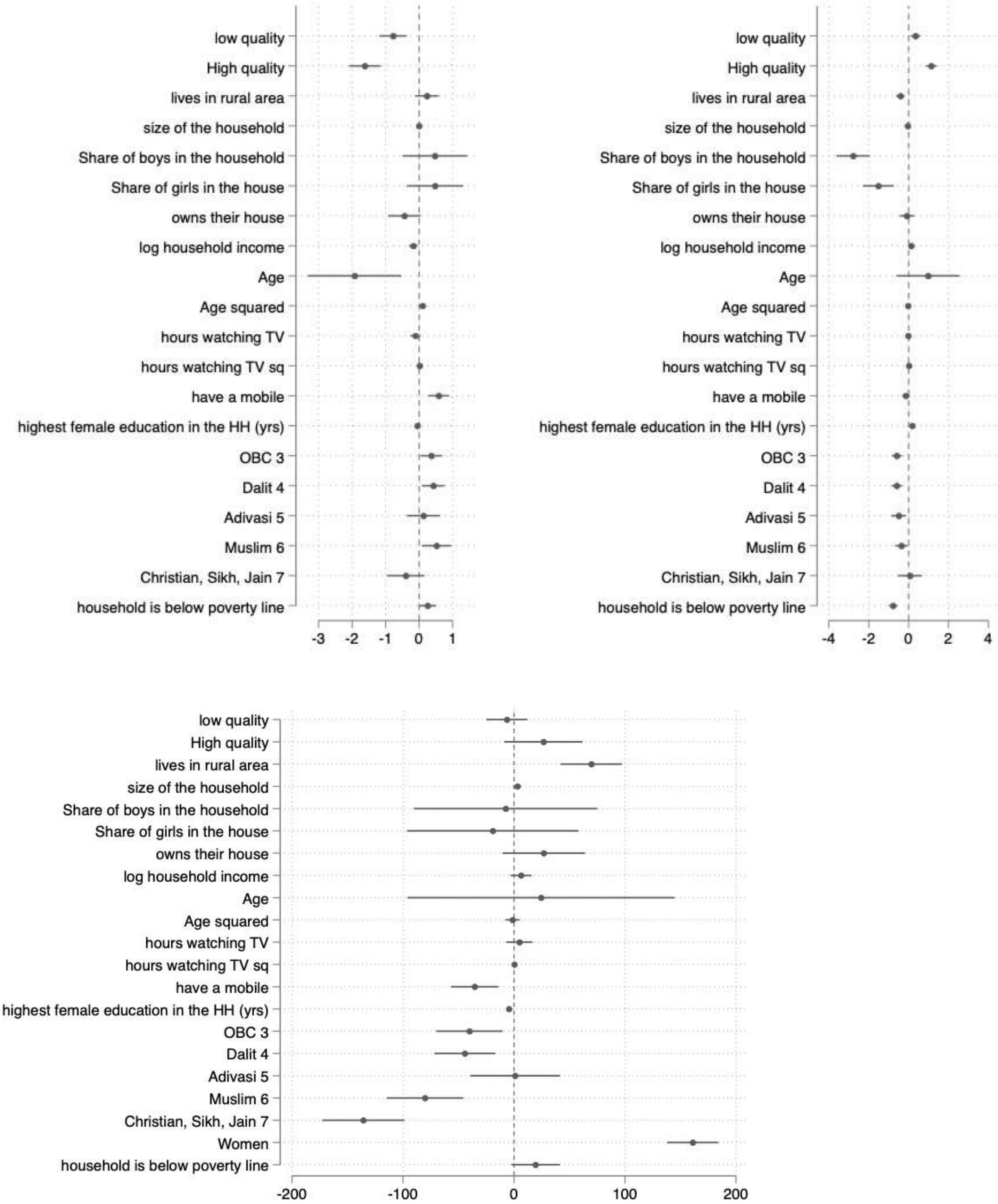

Figure 3.9: Coefficient plots of the relationship between electricity access and the various channels of transmission from the OLS estimations. The plots present the beta coefficients visually along with their confidence interval. The top panel gives the results for missed school days (left) and time spent on homework (right), and the bottom panel for time spent gathering firewood.

3.7 Robustness analysis

3.7.1 Instrumental variables estimations

So far, our main results strongly indicate that there is a positive link between a household having more reliable electricity and its children achieving better learning outcomes, with increased time spent on homework and fewer days missed at school having been identified as two possible mechanisms. However, there is a possibility of electrification – and electricity reliability – suffering from endogeneity because of measurement error or omitted variables, e.g. political factors or shocks common to some areas of the country that we have not controlled for that affect both the (quality of) electrification of a household and the educational prospects of children. This would bias our oprobit and OLS estimation results, though it is unclear in which direction the overall bias would likely go.

To address this issue, we construct instruments using approaches common in the literature: a first instrument is based on the density of transmission lines (see e.g., Chakravorty et al. 2014), and a set of second instruments is based on the distance from coal power plants and distance from hydroelectric power plants (see e.g., van de Walle et al. 2017). We describe these instruments and their construction in detail in the section 3.9. The instruments are constructed at district level, with the basic idea that denser transmission lines and higher proximity to power plants would be correlated with more reliable electricity access for households in that district. Therefore, we expect the transmission density IV to enter the first-stage estimations with a positive sign, and the distance measures with negative signs. We believe that none of the IVs is likely to have a direct impact on our main outcomes of interest – math, reading and writing scores – or our channels of transmission – time spent on homework or gathering firewood and school days missed.

We re-run all estimations for our learning outcomes as two-stage ordered probit, while our mechanism estimations are performed using 2SLS. We run Hausman tests for all estimations to test which approach is preferable, and find support for using the IV approach only in the case of two of our channels — missed days at school and time spent doing homework – and none of our main learning outcomes. Nevertheless, we show all IV results in the Appendix for the sake of completeness and briefly discuss them below.

Tables 3.8 - 3.10 show two-stage oprobit results for math, reading and writing scores, respectively. The positive impacts from the obprobit results are confirmed, especially for math and reading; the IV results suggest that these are strong for girls but not boys. The results for writing scores are weaker. Overall, this suggests that our main oprobit results identified a positive causal relationship between electricity reliability and math and reading scores.

We now turn to the mechanism analysis. 3.tables 3.11 - 3.13 show the 2SLS estimations for time spent doing homework, days missed at school, and time spent gathering firewood, respectively. Recall that the Hausman test confirmed that 2SLS is preferable to OLS in the case of the former two mechanisms. Table 3.11 shows that there are overall positive effects of electricity on the time spent doing homework, but also that for both genders these effects are strong only when going from no to low-reliability electricity. High-quality electricity instead has no significant impact for either gender on its own (columns 2-3). Of note is the magnitude of the impact: these are more than twice as large as those found with OLS, suggesting that OLS had a downward bias. Having low reliability electricity has boys spend on average 2.5 hours more on homework per week than having no electricity access, and girls just over three hours more.

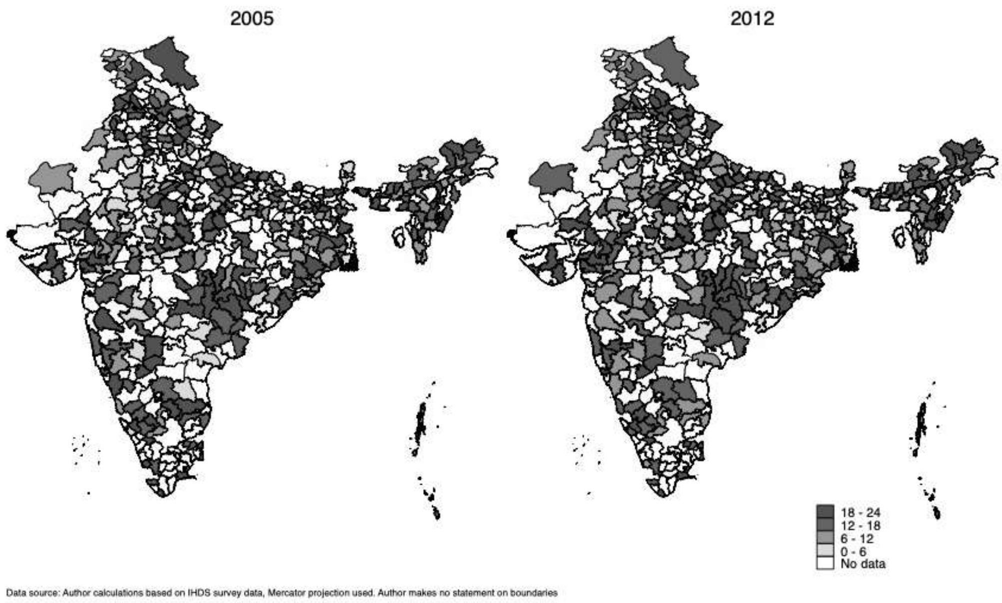

Figure 3.10: Average district electricity reliability (alternative measure, in hours per day) in India, in two survey waves

Table 3.12 similarly suggests that our OLS results identified a causal impact, though again with a downward bias. Only the coefficients for high-quality electricity are significant, but they are strong for both genders. Impact magnitudes have roughly quadrupled compared with the corresponding OLS specifications: boys living in households with high-quality electricity miss on average over 6 school days per month less than boys in households with no electricity, while the corresponding figure for girls is just under seven school days per month. These results strongly suggest that increased engagement with school work through homework and school attendance is a strong mechanism through which the quality of electricity affects learning outcomes.

Table 3.13 shows 2SLS results for time spent gathering firewood, which show a strong positive impact for both genders on this non-school activity. This is similar to what we found in the OLS estimations for all children, though not for the separate genders; however, the Hausman test suggested that the OLS approach is preferable. We therefore think that these results should be interpreted with much caution.

3.7.2 Alternative measure of electricity reliability

To further check the robustness of our main results, we look at an alternative measure of electricity quality. Instead of collapsing the tiers 0-3 from the multi-tier framework of ESMAP, we expand the tiers to a total of five to avoid possible arbitrary cutoffs.[24] The categories are now zero hours of electricity per day (our

[24] A note of caution still on interpreting this is in order: as explained above, ESMAP uses a detailed framework with multiple parameters such as voltage, wattage, appliance use and if the connection has been legally used. We

base outcome); more than zero but less than eight hours; between eight and 12 hours; between 12 and 18 hours; and 18 hours or more per day. Figure 3.10 shows a map with the average district reliability of electricity across India in the two survey waves according to these more detailed categories. We see that fewer districts are in the lowest category in the second wave, but we also note some mixed progress especially in the south.

We again use an oprobit approach for our estimations; all tables are in the Appendix. We see in Table 3.14 that at each tier children of both genders benefit from access to electricity: increasing hours of electricity increases the likelihood of a higher math score compared to having no electricity at all. All other variables give the expected results. Similarly, Table 3.15 and Table 3.16 give highly significant positive results for reading and writing scores, respectively, for all levels of electricity quality. These results are also presented visually in the coefficient plots given in Figure 3.11. We see that on average, the likelihood of achieving better math and reading scores is higher the more hours of electricity the child's household has, and that the relationships – though not the differences in magnitudes – are significant (given by the 95% confidence interval lines). The pattern is less clear for writing scores, though the likelihood of achieving higher scores with access to electricity is clearly positive, and there is an increase from the lowest-quality (over 0 but less than 8 hours per day) to the highest-quality (18 hours and more) electricity.

3.8 Conclusions

Access to electricity is viewed as a cornerstone for economic development, though empirical evidence on the links between electrification and income and other development outcomes is mixed. We use data from two survey waves covering over 41,000 households in India to examine the links between the reliability of electricity available to households in India and children's learning outcomes, as well as the intervening mechanisms.

Overall, we find that reliable electricity access has a positive relationship with learning outcomes. In some cases, even a low level of reliability, as defined by at least 18 hours of electricity, is enough to get a significant increase in learning. We find that the two most plausible channels of transmission for these effects are increased time spent on homework and fewer days missed at school: low levels of reliability are enough to encourage children to do more homework and attend school more (i.e. miss fewer school days), but high levels of reliability make an even bigger difference, especially to attendance. There are no large gender differences in these results. These findings hold using an alternative, more fine-grained classification of electricity reliability, and we find evidence for causal relationships.

The results suggest that reliable electricity is an important component of reaching basic educational policy goals in a developing country context. There is much scope for future research both on India and other developing countries to better define the causal relationships, as well as examine the persistence of effects by using longer and more recent time periods.

are unable to include these in this analysis because of lack of data in the survey on these parameters. So, care should be taken to interpret them directly as tiers of access. Tier for tier, we have a higher level than the ESMAP estimates.

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3.9 Appendix I: Construction of the instruments

Density of transmission lines. To calculate the density of electricity transmission lines in each district, we required the length of transmission cables within each district and the area of the district. The map for cables in 2005 was kindly shared with us by Chakravorty et al. 2014. For the cable length for 2012, we digitised official geographical state maps available in pdf format available from the Grid Controller of India [25] upon written request and used QGIS to overlaid the cables onto the map. After this, the district map of India was overlaid onto the cables. We then calculated the length of the cables within the district polygon. For consistency with data received from Chakravorty et al. (2014), we used only the 440 kV lines. The 440 kV lines constitute the bulk of the transmission network in India. This data is not reported at the district level, so to check this, we added the length of lines to state level and used the data from Central Electricity Authority 2013 .[26] For the area of the districts, we use the district boundaries as of 2005 and calculate the area inside the polygon.

A note on changing district boundaries over time: Indian states and districts have been broken up, to balance administrative costs, language spoken in the district, and cultural identities. For the districts in 2011/12, we use Asher et al. 2021 which provides a mapping of districts using a common identifier to match the district to the 2005 level. All households in a district have the same transmission line density IV value for a survey wave.

Distance from power plants. These variables are constructed by using the coordinates of the power plants available from the Ministry of Power, GoI but compiled and made available publicly by KAPSARC (2023) along with the coordinates, other information about capacity (MW), utilisation, and technology of the plant. This information is compiled for coal-based plants and hydroelectric plants (small and large). The IHDS dataset does not give access to village or household geographical identification information to avoid the possibility of identifying villages and households, therefore the distance of the power plants is calculated from the centroid of the district polygon to the power plants, meaning that all households in a district have the same distance from a power plant.

[25] formerly known as Power System Operation Cooperation Limited or POSOCO

[26] We find some discrepancy in the state of Rajasthan, where the lines under construction seem to have been added to the total lines. For the relevance of our instrument we only use the existing lines.

3.10 Appendix II: Instrumental variable estimation results

Table 3.8: Impact on math score, two-stage ordered probit

	All (1)	Boys (2)	Girls (3)
low quality	0.31**	0.13	0.49***
	(0.122)	(0.172)	(0.184)
High quality	0.40*	0.01	0.78**
	(0.243)	(0.338)	(0.371)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.18***	-0.12***	-0.25***
	(0.026)	(0.036)	(0.039)
size of the household	-0.02***	-0.02***	-0.02***
	(0.004)	(0.006)	(0.006)
Share of boys in the household	-0.51***	-0.71***	-0.54***
	(0.102)	(0.143)	(0.153)
Share of girls in the house	-0.70***	-0.54***	-0.60***
	(0.093)	(0.131)	(0.138)
Wealth:	ref.	ref.	ref.
owns their house	-0.01	0.01	-0.04
	(0.042)	(0.058)	(0.060)
log household income	0.07***	0.08***	0.06***
	(0.013)	(0.018)	(0.019)
hours watching TV	0.02**	0.02	0.03
	(0.011)	(0.015)	(0.017)
hours watching TV sq	-0.00**	-0.00***	-0.00
	(0.001)	(0.001)	(0.002)
have a mobile	-0.10***	-0.12***	-0.08**
	(0.022)	(0.030)	(0.032)
Age	0.92***	0.78***	1.08***
	(0.191)	(0.262)	(0.278)
Age squared	-0.04***	-0.03**	-0.05***
	(0.010)	(0.014)	(0.015)
highest female education in the HH (yrs)	0.05***	0.05***	0.06***
	(0.003)	(0.004)	(0.004)
household is below poverty line	-0.22***	-0.25***	-0.18***
	(0.025)	(0.036)	(0.036)
Religion and caste:	ref.	ref.	ref.
OBC 3	-0.11***	-0.12***	-0.09**
	(0.032)	(0.043)	(0.046)
Dalit 4	-0.28***	-0.28***	-0.25***
	(0.034)	(0.047)	(0.050)
Adivasi 5	-0.35***	-0.31***	-0.37***
	(0.047)	(0.065)	(0.067)
Muslim 6	-0.39***	-0.47***	-0.30***
	(0.039)	(0.054)	(0.056)
Christian, Sikh, Jain 7	-0.14*	-0.15	-0.08
	(0.072)	(0.089)	(0.118)
cut1	4.52***	3.67***	5.46***
	(0.918)	(1.265)	(1.320)
cut2	5.68***	4.85***	6.58***
	(0.918)	(1.267)	(1.319)
cut3	6.60***	5.76***	7.52***
	(0.917)	(1.269)	(1.318)
First stage			
coalkm	-337.45**	-168.58	-443.71*
	(155.310)	(220.925)	(235.688)
hydrokm	-2114.30***	-2203.69***	-2017.89***
	(139.663)	(191.313)	(203.766)
density	22.26*	26.66*	20.28
	(12.503)	(15.866)	(21.143)
Wald stat	2812.47	1359.88	1628.30
N	11,848	6,319	5,529

Note: Two-stage ordered probit results. Second stage coefficients are reported, with first-stage coefficients for the IVs. Hausman tests indicate that oprobit is more appropriate. First-stage cut points not shown. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.9: Impact on reading score, two stage ordered probit

	All (1)	Boys (2)	Girls (3)
low quality	0.40***	0.28	0.51***
	(0.118)	(0.169)	(0.175)
High quality	0.59**	0.29	0.86**
	(0.236)	(0.335)	(0.356)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.17***	-0.12***	-0.22***
	(0.026)	(0.036)	(0.039)
size of the household	-0.02***	-0.02***	-0.02***
	(0.004)	(0.006)	(0.006)
Share of boys in the household	-0.70***	-0.84***	-0.64***
	(0.103)	(0.143)	(0.156)
Share of girls in the house	-0.71***	-0.65***	-0.68***
	(0.093)	(0.131)	(0.140)
Wealth:	ref.	ref.	ref.
owns their house	-0.01	-0.03	-0.01
	(0.044)	(0.061)	(0.064)
log household income	0.04***	0.02	0.06***
	(0.013)	(0.018)	(0.019)
hours watching TV	0.05***	0.05***	0.04***
	(0.011)	(0.015)	(0.016)
hours watching TV sq	-0.00***	-0.00***	-0.01***
	(0.001)	(0.001)	(0.001)
have a mobile	-0.07***	-0.09***	-0.05
	(0.022)	(0.031)	(0.032)
Age	0.79***	0.58**	0.99***
	(0.192)	(0.264)	(0.279)
Age squared	-0.03***	-0.02	-0.04***
	(0.010)	(0.014)	(0.015)
highest female education in the HH (yrs)	0.05***	0.04***	0.05***
	(0.003)	(0.004)	(0.004)
household is below poverty line	-0.22***	-0.24***	-0.19***
	(0.025)	(0.035)	(0.035)
Religion and caste:	ref.	ref.	ref.
OBC 3	-0.10***	-0.09**	-0.11**
	(0.032)	(0.044)	(0.046)
Dalit 4	-0.27***	-0.29***	-0.24***
	(0.034)	(0.047)	(0.050)
Adivasi 5	-0.30***	-0.24***	-0.35***
	(0.047)	(0.067)	(0.067)
Muslim 6	-0.34***	-0.43***	-0.24***
	(0.038)	(0.053)	(0.056)
Christian, Sikh, Jain 7	-0.03	-0.11	0.13
	(0.083)	(0.106)	(0.133)
cut1	3.61***	2.31*	4.89***
	(0.918)	(1.269)	(1.329)
cut2	4.25***	2.95**	5.53***
	(0.918)	(1.269)	(1.328)
cut3	4.89***	3.61***	6.15***
	(0.917)	(1.269)	(1.327)
cut4	5.44***	4.17***	6.70***
	(0.917)	(1.269)	(1.327)
First stage			
coalkm	-361.86**	-198.41	-487.06**
	(157.052)	(228.862)	(225.719)
hydrokm	-2113.94***	-2203.34***	-2017.66***
	(139.594)	(191.368)	(203.353)
density	21.81*	26.53*	12.91
	(12.135)	(15.812)	(19.469)
Wald Stat	2368.05	1137.75	1350.56
N	11,848	6,319	5,529

Note: Two-stage ordered probit results. Second stage coefficients are reported, with first-stage coefficients for the IVs. Hausman tests indicate that oprobit is more appropriate. First-stage cut points not shown. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.10: Impact on writing score, two-stage ordered probit

	All (1)	Boys (2)	Girls (3)
low quality	0.33**	0.34	0.29
	(0.167)	(0.233)	(0.244)
High quality	0.50	0.45	0.49
	(0.338)	(0.471)	(0.491)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.12***	-0.05	-0.20***
	(0.035)	(0.049)	(0.052)
size of the household	-0.03***	-0.03***	-0.03***
	(0.005)	(0.007)	(0.008)
Share of boys in the household	-0.61***	-0.69***	-0.69***
	(0.135)	(0.189)	(0.201)
Share of girls in the house	-0.60***	-0.39**	-0.71***
	(0.122)	(0.172)	(0.184)
Wealth:	ref.	ref.	ref.
owns their house	-0.10	-0.10	-0.12
	(0.065)	(0.087)	(0.098)
log household income	0.02	0.02	0.02
	(0.017)	(0.023)	(0.024)
hours watching TV	0.03	0.03	0.03
	(0.016)	(0.021)	(0.023)
hours watching TV sq	-0.00	-0.00*	-0.00
	(0.002)	(0.002)	(0.003)
have a mobile	0.14***	0.13***	0.15***
	(0.028)	(0.039)	(0.042)
Age	0.78***	0.53	1.04***
	(0.249)	(0.343)	(0.367)
Age squared	-0.03**	-0.02	-0.04**
	(0.013)	(0.018)	(0.020)
highest female education in the HH (yrs)	0.06***	0.06***	0.06***
	(0.004)	(0.005)	(0.005)
household is below poverty line	-0.18***	-0.20***	-0.16***
	(0.031)	(0.043)	(0.044)
Religion and caste:	ref.	ref.	ref.
OBC 3	-0.06	-0.04	-0.08
	(0.044)	(0.060)	(0.065)
Dalit 4	-0.24***	-0.23***	-0.25***
	(0.046)	(0.063)	(0.069)
Adivasi 5	-0.30***	-0.27***	-0.32***
	(0.061)	(0.084)	(0.091)
Muslim 6	-0.36***	-0.38***	-0.33***
	(0.051)	(0.070)	(0.077)
Christian, Sikh, Jain 7	-0.05	0.02	-0.12
	(0.118)	(0.157)	(0.180)
First stage			
coalkm	-341.78**	-205.31	-489.66**
	(155.555)	(218.609)	(229.242)
hydrokm	-2112.71***	-2201.54***	-2014.24***
	(139.889)	(191.727)	(204.190)
density	22.77*	27.72*	14.70
	(12.616)	(16.311)	(20.054)
Wald Stat	1426.70	1389.33	757.31
N	11,848	6,319	5,529

Note: Two-stage ordered probit results. Second stage coefficients are reported, with first-stage coefficients for the IVs. Hausman tests indicate that oprobit is more appropriate. First-stage cut points not shown. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.11: Impact on time spent on homework, 2SLS

	(1) All	(2) Boys	(3) Girls
low quality	2.64***	2.51***	3.07***
	(0.660)	(0.855)	(1.028)
High quality	2.45*	2.33	3.18
	(1.382)	(1.805)	(2.158)
Demographic variables:			
lives in rural area	-0.36	-0.36	-0.23
	(0.285)	(0.376)	(0.441)
size of the household	-0.02	0.01	-0.06**
	(0.020)	(0.028)	(0.028)
Share of boys in the household	-0.99*	0.16	-2.14***
	(0.513)	(0.711)	(0.753)
Share of girls in the house	-0.15	0.83	-1.33*
	(0.476)	(0.649)	(0.720)
Wealth:			
owns their house	-0.02	0.01	-0.07
	(0.278)	(0.400)	(0.382)
log household income	0.06	0.07	0.05
	(0.073)	(0.103)	(0.104)
hours watching TV	-0.23*	-0.24*	-0.19
	(0.132)	(0.126)	(0.203)
hours watching TV sq	0.03	0.01	0.04
	(0.026)	(0.015)	(0.041)
have a mobile	-0.17	0.08	-0.49***
	(0.118)	(0.162)	(0.175)
Age	1.48	1.03	2.25
	(0.948)	(1.274)	(1.416)
Age squared	-0.06	-0.04	-0.11
	(0.050)	(0.068)	(0.075)
highest female education in the HH (yrs)	0.16***	0.17***	0.15***
	(0.017)	(0.023)	(0.024)
household is below poverty line	-0.54***	-0.43**	-0.60***
	(0.130)	(0.182)	(0.191)
Religion and caste:			
OBC 3	-0.20	-0.19	-0.20
	(0.170)	(0.218)	(0.268)
Dalit 4	-0.61***	-0.64***	-0.55**
	(0.183)	(0.243)	(0.279)
Adivasi 5	-0.65**	-0.40	-0.92**
	(0.256)	(0.352)	(0.373)
Muslim 6	-0.54**	-0.61**	-0.47
	(0.211)	(0.264)	(0.336)
Christian, Sikh, Jain 7	0.90**	0.74	1.15
	(0.445)	(0.574)	(0.700)
Constant	-1.58	-0.60	-4.22
	(4.594)	(6.128)	(6.900)
N	11427	6112	5315
1st stage C-D F-statistic	84.756	47.728	35.355
Low rel.: Distance from coal plant (proj.)	0.9555 ***	0.9800 ***	0.9343 ***
Low rel.: Distance from hydro plant (proj.)	-0.1801 **	-0.1419	-0.2060
High rel.: Distance from coal plant (proj.)	0.1276 **	0.1286 *	0.1169
High rel.: Distance from hydro plant (proj.)	1.1191 ***	1.1520 ***	1.0589

Note: Two-stage least squares (2SLS) results. Second stage coefficients are reported, with first-stage Cragg-Donald F-statistics for weak-instrument-robust inference and coefficients for the IVs. Hausman tests indicate that 2SLS is more appropriate. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.12: Impact on number of days missed at school per month, 2SLS

	(1) All	(2) Boys	(3) Girls
low quality	-1.69	-0.20	-3.23
	(2.784)	(3.016)	(2.828)
High quality	-6.60***	-6.11**	-6.89***
	(2.354)	(2.580)	(2.437)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.68*	-0.80**	-0.51
	(0.362)	(0.399)	(0.398)
size of the household	-0.07**	-0.04	-0.08**
	(0.028)	(0.035)	(0.034)
Share of boys in the household	-1.30	-0.65	-1.60*
	(0.818)	(1.006)	(0.905)
Share of girls in the house	-0.61	-0.37	-0.93
	(0.607)	(0.813)	(0.659)
Wealth:	ref.	ref.	ref.
owns their house	-0.89***	-1.09***	-0.67**
	(0.280)	(0.370)	(0.298)
log household income	0.01	0.01	0.01
	(0.106)	(0.123)	(0.118)
Age	-1.85**	-2.06*	-1.54
	(0.817)	(1.162)	(1.184)
Age squared	0.10**	0.11*	0.08
	(0.043)	(0.062)	(0.063)
hours watching TV	0.17	0.11	0.20
	(0.237)	(0.273)	(0.232)
hours watching TV sq	-0.00	0.00	-0.01
	(0.019)	(0.022)	(0.017)
have a mobile	0.48**	0.37	0.66**
	(0.240)	(0.251)	(0.273)
highest female education in the HH (yrs)	0.01	0.02	-0.00
	(0.025)	(0.031)	(0.028)
Religion and caste:	ref.	ref.	ref.
OBC 3	0.11	0.08	0.14
	(0.208)	(0.260)	(0.225)
Dalit 4	0.35*	0.23	0.49*
	(0.210)	(0.256)	(0.252)
Adivasi 5	0.21	0.15	0.31
	(0.300)	(0.392)	(0.317)
Muslim 6	0.33	0.25	0.43
	(0.275)	(0.325)	(0.309)
Christian, Sikh, Jain 7	-0.19	-0.34	-0.09
	(0.369)	(0.477)	(0.368)
household is below poverty line	0.21	0.39	-0.01
	(0.280)	(0.313)	(0.320)
Constant	16.24***	16.29***	15.49***
	(4.395)	(5.932)	(5.969)
N	15662	8402	7260
1st stage C-D F statistic	28.542	13.834	15.549
Low rel.: Distance from coal plant (proj.)	0.9619***	0.9832***	0.9444 ***
Low rel.: Distance from hydro plant (proj.)	-0.1696***	-0.1382***	-0.1875***
High rel.: Distance from coal plant (proj)	0.1255***	0.1321***	0.1090***
High rel.: Distance from hydro plant (proj)	1.1274***	1.1735***	1.0542***

Note: Two-stage least squares (2SLS) results. Second stage coefficients are reported, with first-stage Cragg-Donald F-statistics for weak-instrument-robust inference and coefficients for the IVs. Hausman tests indicate that 2SLS is more appropriate. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.13: Impact on time spent on collecting firewood, 2SLS

	All (1)	Boys (2)	Girls (3)
low quality	407.74***	182.27*	611.02***
	(124.383)	(100.846)	(232.605)
High quality	932.31**	615.97*	1237.87**
	(369.590)	(374.438)	(629.485)
Demographic variables:	ref.	ref.	ref.
lives in rural area	186.83***	138.18**	227.08**
	(55.786)	(59.887)	(88.771)
size of the household	0.17	2.43	-1.60
	(2.591)	(2.605)	(4.557)
Share of boys in the household	103.08	25.85	171.66
	(69.398)	(62.018)	(132.166)
Share of girls in the house	30.63	6.98	91.87
	(54.129)	(49.668)	(104.976)
Wealth:	ref.	ref.	ref.
owns their house	38.25	18.51	70.42
	(40.557)	(38.974)	(78.969)
log household income	-11.00	-5.02	-17.35
	(9.320)	(8.575)	(17.093)
hours watching TV	-38.28**	-23.91	-49.00*
	(16.685)	(16.283)	(27.752)
hours watching TV sq	3.10***	2.04	3.73**
	(1.189)	(1.260)	(1.773)
have a mobile	-82.45***	-48.91***	-112.38***
	(21.124)	(17.805)	(39.394)
Age	-114.36	-28.56	-258.49
	(102.461)	(102.102)	(205.907)
Age squared	5.76	1.46	12.95
	(5.396)	(5.364)	(10.808)
highest female education in the HH (yrs)	-10.83***	-6.57***	-14.10***
	(2.649)	(2.363)	(5.041)
	(12.875)		(.)
household is below poverty line	35.50**	32.70**	32.58
	(16.193)	(14.852)	(29.785)
Religion and caste:	ref.	ref.	ref.
OBC 3	-14.81	-29.87	7.57
	(20.727)	(20.210)	(40.912)
Dalit 4	-2.20	-22.84	19.60
	(21.761)	(20.328)	(41.636)
Adivasi 5	54.74*	29.42	66.46
	(32.346)	(33.680)	(53.748)
Muslim 6	-50.55*	-51.08*	-46.16
	(26.667)	(26.461)	(49.085)
Christian, Sikh, Jain 7	-44.13	2.11	-84.83
	(69.685)	(61.650)	(178.351)
Constant	200.45	-35.29	894.29
	(495.361)	(530.670)	(939.599)
N	5,124	2,676	2,448
1st stage C-D F-statistic	84.76	47.73	35.36
Low rel.: Distance from coal plant (proj.)	0.9555***	0.9800***	0.9343 ***
Low rel.: Distance from hydro plant (proj.)	-0.1801**	-0.1419	-0.2060**
High rel.: Distance from coal plant (proj.)	0.1276***	0.1286**	0.1169**
High rel.: Distance from hydro plant (proj.)	1.1191***	1.1520***	1.0589***

Note: Two-stage least squares (2SLS) results. Second stage coefficients are reported, with first-stage Cragg-Donald F-statistics for weak-instrument-robust inference and coefficients for the IVs. Hausman tests indicate that oprobit is more appropriate. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

3.11 Appendix III: Hausman test

(1) Hausman test for absence Null: resid = 0

F(1, 30) = 112.74 Prob ¿ F = 0.0000

Fail to reject the null =¿ OLS is not consistent, so we need to use the instruments

(2) Homework Null: hwresid = 0

F(1, 30) = 5.54 Prob ¿ F = 0.0253 Fail to reject the null =¿ OLS is not consistent, so we need to use the instruments

(3) Fuel wood collection

Null: fuelresid = 0

F(1, 26) = 2.31 Prob ¿ F = 0.1405 Can reject the null, so OLS is consistent we dont need instruments

(4) res_math1 = 0

chi2(1) = 2.43 Prob ¿ chi2 = 0.1190 Can reject the null, so OLS is consistent we dont need instruments

5 [read]res_read = 0

chi2(1) = 0.56 Prob ¿ chi2 = 0.4550 Can reject the null, so OLS is consistent we dont need instruments

6 res_write = 0

chi2(1) = 0.00 Prob ¿ chi2 = 0.9771 Can reject the null, so OLS is consistent we dont need instruments .

3.12 Appendix IV: Results using alternative measure of electricity reliability

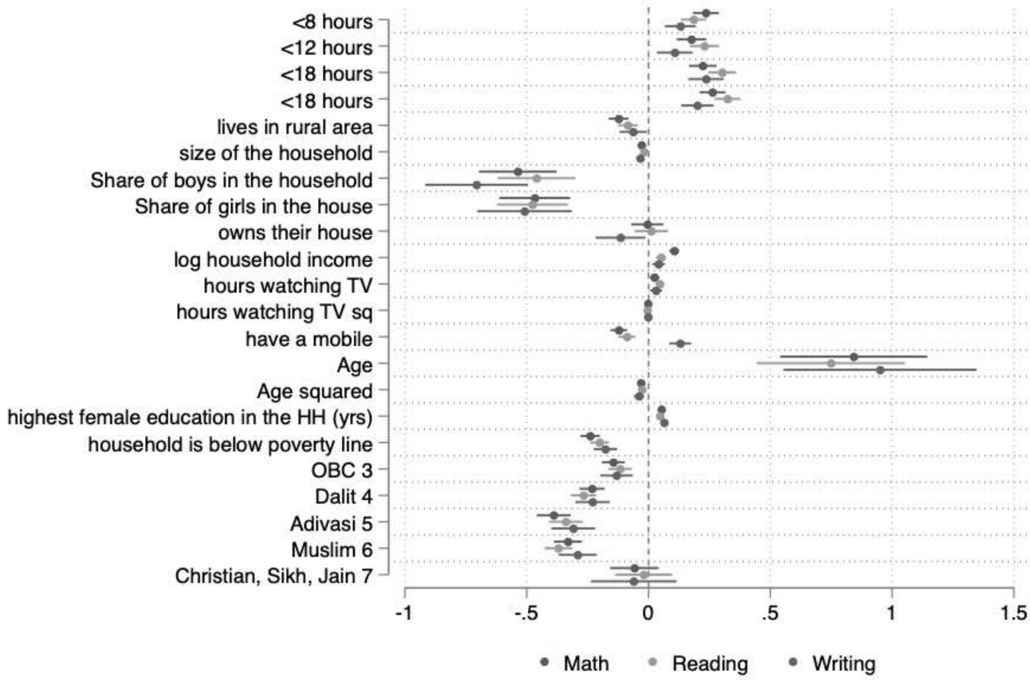

Figure 3.11: Coefficient plots on learning scores using the alternative measure of electricity reliability. The reference category is no electricity access.

Table 3.14: Electricity reliability and math scores using alternate measure of reliability, oprobit

	(1) All	(2) Boys	(3) Girls
less than 8 hours	0.25***	0.26***	0.25***
	(0.029)	(0.040)	(0.042)
less than 12 hours	0.22***	0.19***	0.28***
	(0.032)	(0.044)	(0.048)
less than 18 hours	0.25***	0.24***	0.26***
	(0.031)	(0.042)	(0.046)
Greater than 18 hours	0.23***	0.20***	0.26***
	(0.031)	(0.043)	(0.045)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.16***	-0.10***	-0.23***
	(0.022)	(0.030)	(0.032)
size of the household	-0.02***	-0.02***	-0.02***
	(0.003)	(0.005)	(0.005)
Share of boys in the household	-0.53***	-0.58***	-0.45***
	(0.084)	(0.115)	(0.125)
Share of girls in the house	-0.48***	-0.48***	-0.51***
	(0.077)	(0.106)	(0.112)
Wealth:	ref.	ref.	ref.
owns their house	-0.00	-0.02	0.00
	(0.034)	(0.047)	(0.050)
log household income	0.08***	0.09***	0.08***
	(0.011)	(0.014)	(0.016)
hours watching TV	0.03***	0.02*	0.04***
	(0.010)	(0.014)	(0.014)
hours watching TV sq	-0.00**	-0.00	-0.00*
	(0.001)	(0.002)	(0.001)
have a mobile	-0.11***	-0.13***	-0.09***
	(0.018)	(0.025)	(0.026)
Age	0.81***	0.75***	0.86***
	(0.155)	(0.211)	(0.228)
Age squared	-0.03***	-0.03**	-0.03***
	(0.008)	(0.011)	(0.012)
highest female education in the HH (yrs)	0.05***	0.05***	0.06***
	(0.002)	(0.003)	(0.003)
household is below poverty line	-0.21***	-0.23***	-0.19***
	(0.021)	(0.029)	(0.030)
Religion and caste:	ref.	ref.	ref.
OBC 3	-0.09***	-0.10***	-0.08**
	(0.025)	(0.034)	(0.037)
Dalit 4	-0.28***	-0.29***	-0.27***
	(0.027)	(0.037)	(0.040)
Adivasi 5	-0.36***	-0.34***	-0.38***
	(0.038)	(0.051)	(0.056)
Muslim 6	-0.37***	-0.41***	-0.32***
	(0.031)	(0.043)	(0.045)
Christian, Sikh, Jain 7	-0.15***	-0.17**	-0.10
	(0.055)	(0.070)	(0.087)
cut1	4.07***	3.90***	4.40***
	(0.738)	(1.009)	(1.085)
cut2	5.25***	5.10***	5.57***
	(0.738)	(1.009)	(1.085)
cut3	6.21***	6.05***	6.55***
	(0.738)	(1.010)	(1.085)
N	18,248	9,774	8,474
cdf			

Note: Results show coefficients from oprobit estimations using electricity reliability categories that are aligned more closely with ESMAP's tiers of access. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.15: Electricity reliability and reading scores using alternate measure of reliability, oprobit

	(1) All	(2) Boys	(3) Girls
less than 8 hours	0.21***	0.21***	0.23***
	(0.028)	(0.039)	(0.040)
less than 12 hours	0.25***	0.24***	0.26***
	(0.032)	(0.043)	(0.047)
less than 18 hours	0.34***	0.33***	0.34***
	(0.031)	(0.042)	(0.046)
Greater than 18 hours	0.25***	0.22***	0.29***
	(0.030)	(0.041)	(0.045)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.13***	-0.08***	-0.17***
	(0.022)	(0.030)	(0.032)
size of the household	-0.02***	-0.02***	-0.03***
	(0.003)	(0.005)	(0.005)
Share of boys in the household	-0.55***	-0.64***	-0.41***
	(0.084)	(0.115)	(0.126)
Share of girls in the house	-0.54***	-0.52***	-0.60***
	(0.077)	(0.106)	(0.113)
Wealth:	ref.	ref.	ref.
owns their house	-0.04	-0.10**	0.02
	(0.035)	(0.050)	(0.051)
log household income	0.04***	0.03**	0.05***
	(0.010)	(0.014)	(0.015)
hours watching TV	0.05***	0.05***	0.06***
	(0.009)	(0.013)	(0.013)
hours watching TV sq	-0.00***	-0.00**	-0.01***
	(0.001)	(0.001)	(0.001)
have a mobile	-0.10***	-0.11***	-0.08***
	(0.018)	(0.025)	(0.026)
Age	0.71***	0.73***	0.65***
	(0.156)	(0.213)	(0.230)
Age squared	-0.02***	-0.03**	-0.02*
	(0.008)	(0.011)	(0.012)
highest female education in the HH (yrs)	0.05***	0.05***	0.05***
	(0.002)	(0.003)	(0.003)
household is below poverty line	-0.22***	-0.24***	-0.20***
	(0.021)	(0.029)	(0.030)
Religion and caste:	ref.	ref.	ref.
OBC 3	-0.06**	-0.05	-0.06
	(0.025)	(0.035)	(0.037)
Dalit 4	-0.26***	-0.27***	-0.23***
	(0.027)	(0.037)	(0.040)
Adivasi 5	-0.30***	-0.27***	-0.34***
	(0.038)	(0.053)	(0.056)
Muslim 6	-0.32***	-0.38***	-0.25***
	(0.031)	(0.043)	(0.045)
Christian, Sikh, Jain 7	-0.03	-0.11	0.09
	(0.064)	(0.085)	(0.099)
cut1	3.20***	3.15***	3.22***
	(0.741)	(1.011)	(1.093)
cut2	3.85***	3.78***	3.87***
	(0.741)	(1.011)	(1.094)
cut3	4.51***	4.45***	4.52***
	(0.741)	(1.012)	(1.094)
cut4	5.09***	5.04***	5.11***
	(0.741)	(1.012)	(1.094)
N	18,248	9,774	8,474
cdf			

Note: Results show coefficients from oprobit estimations using electricity reliability categories that are aligned more closely with ESMAP's tiers of access. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Table 3.16: Electricity reliability and writing scores using alternate measure of reliability, oprobit

	(1) All	(2) Boys	(3) Girls
less than 8 hours	0.19***	0.18***	0.20***
	(0.034)	(0.047)	(0.049)
less than 12 hours	0.17***	0.14**	0.21***
	(0.039)	(0.053)	(0.057)
less than 18 hours	0.22***	0.22***	0.20***
	(0.040)	(0.055)	(0.059)
Greater than 18 hours	0.17***	0.15***	0.18***
	(0.040)	(0.054)	(0.058)
Demographic variables:	ref.	ref.	ref.
lives in rural area	-0.10***	-0.05	-0.15***
	(0.030)	(0.041)	(0.044)
size of the household	-0.03***	-0.02***	-0.03***
	(0.004)	(0.006)	(0.006)
Share of boys in the household	-0.58***	-0.56***	-0.58***
	(0.112)	(0.152)	(0.167)
Share of girls in the house	-0.41***	-0.30**	-0.59***
	(0.102)	(0.139)	(0.152)
Wealth:	ref.	ref.	ref.
owns their house	-0.08	-0.07	-0.12
	(0.053)	(0.071)	(0.079)
log household income	0.02*	0.03	0.02
	(0.014)	(0.019)	(0.020)
hours watching TV	0.03***	0.03	0.05**
	(0.013)	(0.017)	(0.019)
hours watching TV sq	-0.00	-0.00	-0.00
	(0.002)	(0.002)	(0.002)
have a mobile	0.16***	0.14***	0.18***
	(0.023)	(0.032)	(0.034)
Age	0.90***	0.87***	0.91***
	(0.204)	(0.279)	(0.301)
Age squared	-0.04***	-0.03**	-0.04**
	(0.011)	(0.015)	(0.016)
highest female education in the HH (yrs)	0.06***	0.06***	0.06***
	(0.003)	(0.004)	(0.004)
household is below poverty line	-0.17***	-0.22***	-0.12***
	(0.025)	(0.035)	(0.037)
Religion and caste:	ref.	ref.	ref.
OBC 3	-0.08**	-0.06	-0.11**
	(0.035)	(0.048)	(0.052)
Dalit 4	-0.24***	-0.22***	-0.25***
	(0.037)	(0.050)	(0.055)
Adivasi 5	-0.32***	-0.26***	-0.39***
	(0.049)	(0.067)	(0.073)
Muslim 6	-0.36***	-0.40***	-0.32***
	(0.042)	(0.057)	(0.062)
Christian, Sikh, Jain 7	-0.04	-0.07	0.02
	(0.096)	(0.124)	(0.150)
cut1	4.36***	4.24***	4.39***
	(0.970)	(1.327)	(1.430)
N	18,248	9,774	8,474
cdf			

Note: Results show coefficients from oprobit estimations using electricity reliability categories that are aligned more closely with ESMAP's tiers of access. Standard errors are clustered at the district level. ***, **, * denotes significance at 1%, 5% and 10% level, resp.

Chapter 4

Electricity access and appliances in India: Some observations


[1]

[1]This image has been generated using the AI DALLE by using keywords from the chapter in the style of the artist Henri Mattise and Andy Warhol's colours

4.1 Abstract

This paper sheds light on the relationship between electricity access and well-being in India through a detailed examination of the use of appliances in households with different levels of income and over different vintages of electricity connection. The paper finds that most households tend to use very basic appliances even after 5-6 years of having an electricity connection. Most households use electric lighting, a charging point and a fan or TV. There is no significant 'appliance ladder' where households who are using electricity for a while use more sophisticated appliances: the data show that households do not in fact keep moving to more and more sophisticated appliances. There is also continued use of kerosene, which previous literature shows has negative health effects. We also find that appliances that can reduce unpaid household labour are taken up by very few households and hence, this lack of an appliance ladder is particularly serious for women.

Keywords: electricity, appliance ladder, survey data, households, India *This chapter was done at the International Energy Agency for the Clean energy environment and empowerment (C3E) Fellowship, which is a competitive international scholarship for women working in the energy sector. Each year one woman is selected and invited to work at the IEA for 6 months, and Aayushi was selected for 2019-2020.*

4.2 Introduction

In a world that is increasingly interconnected and digital a universal and functioning electricity sector is the lifeblood of modern functioning economies. The relationship between electricity and human well-being is complex, has many layers, and goes both ways (van de Walle et al., 2017). Access to energy services enabled by electricity lets people enjoy their life and make it easier. It is also true that areas with higher population densities (cities) and more economic development, a measure of human well-being, get priority access to better quality and quantity of electricity (Kemmler, 2007). Moreover, the benefits of access to electricity are conditional on some basic level of development. For example, a household that can afford to purchase appliances is better placed to use electricity and save time instead of doing household work. Similarly, a village where more people are able to start a business and increase their productivity is able to benefit much more from electricity compared to a similar village with lower income.

Electricity usage also has gender implications -– access to electricity has the potential to better allocate women's time making days longer through light in the evening or saving time cooking in bulk and storing in refrigerators (Rosenberg et al., 2020). Electrification also mitigates negative health impacts of using kerosene lamps, which typically impacts women more because they tend to stay at home longer. In the longer term, electrification can enable more participation in the paid labour force and increase enrolment of children, particularly girls, potentially creating a virtuous cycle.[2] However, there is evidence that this positive gender effect has not been strong and women are often not direct beneficiaries of electricity, because usually the first appliances bought in a household are not the ones of greatest productive benefit to women (Rosenberg et al., 2020).

These observations raise some pertinent questions from an energy policy perspective: first, for households that are getting connected later and are possibly at lower incomes, how can they transition to using more electricity and energy services, and increase their well-being? This is a question of converting to a virtuous cycle and breaking the so-called poverty trap for energy. Second, once the households get access to electricity, how does that translate into individuals actually using appliances? This is a question of intensity of use of electricity and the so-called appliance ladder, i.e. an increasing set of appliances used by households over time. This paper sheds light on the relationship between electricity access and well-being in India through a detailed qualitative examination of data on the use of energy services over time. It analyses the use of appliances in households with different levels of income and over different vintages of electricity connection, and comments on households' transition to more intensive electricity use. The paper uses a data set with information from 2015 and 2018 from India's six lowest-income states – which were all electrified after 2005 – to track their energy service usage and make recommendations on how policy action can improve people's usage of electricity.

We find that most households tend to use very basic appliances even after 5-6 years of having an electricity connection. Most households use electric lighting, a charging point and a fan or TV. The household's choice also matches with the preferences of the un-electrified households. The basket of electric services that the un-electrified households want and the electrified households have are very similar. There is no significant 'appliance ladder' where households who are using electricity for a while use more sophisticated appliances: the data show that households do not in fact keep moving to more and more sophisticated appliances. There is also continued use of kerosene, though the use has declined somewhat. Since electric

[2] We saw the last two effects in chapters 2 and 3 respectively.

light bulbs are very cheap lighting solutions, this indicates that the reason for this fuel stacking is more than just an affordability question. We also find that appliances that can reduce unpaid household labour are taken up by very few households and hence, this lack of an appliance ladder is particularly serious for women, who do the bulk of this work. Moreover, the continued use of kerosene impacts the health of women who are at home and have longer exposure to the harmful fumes. Therefore, even though in theory women can benefit the most from electricity access, in practice, this benefit has not reached them yet.

These questions are highly relevant for emerging economies like India, where most of the households have been connected recently. In 2005, 45% of Indian households did not have an electricity connection and in March 2019, India declared 100% household electrification. This also means that 45% of the connections in India are less than 15 years of age and 10% of the households have a connection that is less than 5 years old. These disparities in the connectivity gets even higher considering that many states in India were able to electrify completely by the late 1980s, meaning that the new connections are highly concentrated in a few lower-income states.

The paper is organised as follows: section 2 summarises the literature; section 3 describes the data; section 4 discusses the results; and section 5 concludes with a discussion and policy recommendations.

4.3 Literature review

There have been many studies examining the transformative effect electricity can have on the well-being of households and individuals using indicators such as: income generations activities, education, health and labour supply to measure well-being. Most studies find a positive impact of electricity, however this impact is highly variable. This variability depends on the mechanisms that link electricity use and households' decisions.

There has been a particular interest in studying two impacts – increased labour force participation and increased education outcomes. Khandker (2013) found that household electricity connection in a sample of 42 communes in Vietnam was correlated with a 9% higher school enrolments rate for girls and 6.3% higher for boys. Similarly, Grogan and Sadanand (2013) found that rural Nicaraguan men and women are more than twice as likely to have completed primary education if they live in households with access to electricity. The mechanism underlying this impact could be through time reallocation. Mathur and Mathur (2005) note that the households with and without electricity in India have a marked difference in allocation of time towards productivity activities. The women in the households reported spending two-thirds of their waking time in collecting firewood. They also found that while all women benefited from electricity, women from lower income houses with electricity lead more balanced lives than women in higher income households without electricity. These pressures then force households to withdraw children from school, especially girls. In South Africa, access to electricity lead to a nearly 10 percentage point increase in female labour force participation (Dinkelman, 2011), in Nicaragua it lead to a 23 percentage point increase in female propensity to work outside of their home (Grogan and Sadanand, 2013). In India, the increased access lead to 0.5 percentage point increase in labour supply for non-agricultural based labour (Burlig and Preonas, forthcoming). In terms of educational outcome, the range of impact has been between 2 years increase in years of schooling in Brazil (Lipscomb et al., 2013) and between 0.5 to no statistically significant increase in schooling in India (respectively, van de Walle et al. 2017 and Burlig and Preonas forthcoming). The mechanism driving this change could be the reallocation of time freed up from firewood collection which enables participation in paid employment as opposed to unpaid work. Dinkelman (2011) attributes this result to use of electric cook stoves and other time saving appliances.

In some of the recent experimental economics literature the relationship between electricity and development seems to be modest. To establish causal relationship between off-grid solar power on broad human development indicators, Aklin et al. (2017) studied the impact in a total sample of 1281 households in the city of Bihar in India. Within a year of solar panel provision, the electrification rate in the treatment group increased by 36 percentage points. They found that there was no consistent effect on savings, expenditure, business creation or gender relations in the treatment group. They also didn't find significant reduction in kerosene expenditure, indicating that there is no significant displacement in fuels. Similarly, in Kenya, Lee et al. (2020) find that on average there is no evidence of significant economic and non-economic gains across a range of outcomes such as savings in kerosene spending, health status, number of appliances owned and value of total assets. These studies are examples of when the mechanism for translating electricity access to impact break down. In the first case, even though the number of houses with access to electricity increased the hours of electricity available did not increase substantially and the uses available to the households were lighting and mobile charging. Both these studies examine samples for a short period.

Electricity access also has non income related benefits, health being the most notable one. Aklin and Urpelainen (2020) and Riva et al. (2018) found that electric lighting can reduce household air pollution and associated lung disease and eye problems, as well as burns and poisonings caused by the use of kerosene.

It is one thing to look at the mechanism and but there can also be inertia in adjusting to the mechanism. It can be argued that households take time to adjust to electricity, in effect a new technology for them. To study long term impacts of electricity access, van de Walle et al. (2017) examined two distinct mechanisms -– internal, when the household gets electrified, and, external when the household can benefit from village electrification even if the household itself does not have access to electricity. The external benefits can be street lighting leading to safer streets, changing social norms and overall increase in welfare due to the village benefiting from electricity. They find that there are significant consumption gains from electrification, especially through extra labour earnings; however, the gains in earning are through extra work by men and there are no gains for women, even in the long term. They also find that the gains by workforce are from moving from casual to regular work attributing this to men being able to reallocate daytime leisure time to permanent and salaried work.

To summarise, the literature seems to suggest that electricity has sizeable impacts when it reaches the beneficiary successfully and benefits are multi-fold such as reduced risk of health hazards, increased enrolment and educational attainment, increased employment and paid labour, business activity etc. However, the impact has been varied and sometimes quite modest. This is because of electricity not reaching the beneficiary in the intended way. This is particularly true for women, the connection to electricity is not able to impact women's life as much as men. This is because of the mechanisms that govern this transformation break down: households are not able to access the appliances that enable women to reallocate their time; enough time is not freed up to participate in the labour force; they are not able to use electricity in their enterprise. The underlying cause of this could be either the connections

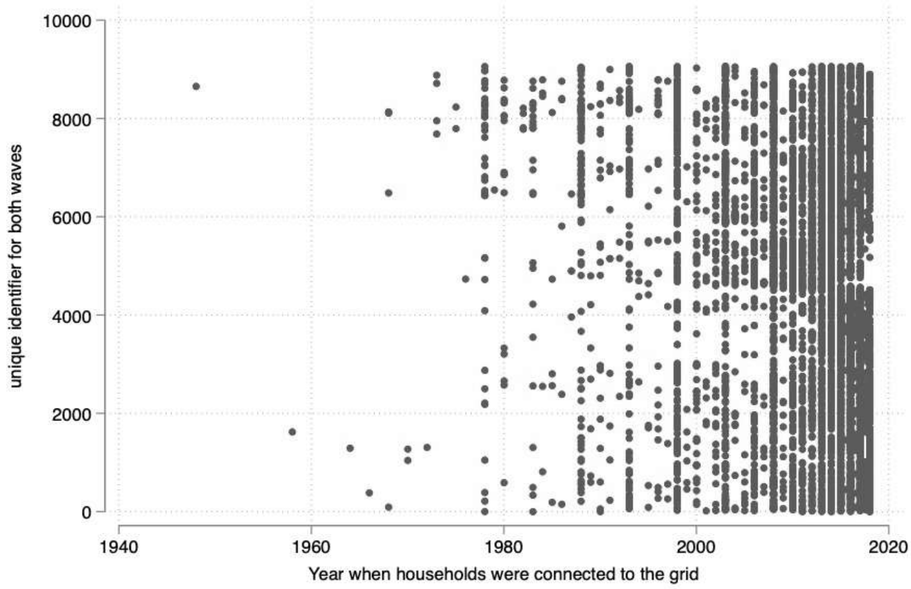

Figure 4.1: Scatter plot of the household and the year in which they were electrified in this sample. Sample collected in 2015 and 2018

are not reliable, there are blackouts, the households are not able to afford the electricity charges or households are not able to afford the appliances that can benefit them. In this chapter we focus on adoption of appliances by households and examine the households that are disconnected from the grid after initially receiving a connection.

4.4 Data

Electricity in India is in the concurrent list in the constitution, which means that it is a joint responsibility for states and the central government; until 2005 there was no federal level electrification policy. Therefore, there is quite a strong variation in un-electrified households by states. Some of the wealthier states, mostly concentrated in western and southern India, were able to achieve 100% electrification even by the 1990s. Starting in 2005, the Central government introduced three policies sequentially targeted at rural electrification. As a result of the central government effort, in May 2019, India declared 100% household electrification, which is an impressive task. As outlined above, the access to electricity is only the beginning, it is uncertain how this electrification effort is translating into use of energy services.

This paper uses data from India from the ACCESS survey to examine household electrification and appliance use. This dataset is publicly available and was collected in two waves and published in 2015 and 2018. It covers of 8563 households across the six poorest states in India. The households are all in the rural areas of these states. The survey is an electricity and cooking access focussed survey with detailed questions on appliance ownership, income, savings, and satisfaction with electricity, usage patterns, blackout days etc.

	2015					2018				
	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N
Number of years household is connected to the grid	8.11	8.42	1.00	58.00	5115	7.10	7.95	0.00	70.00	6807
Hours of available electricity (hours/day)	12.28	6.27	0.00	24.00	5953	14.87	5.43	0.00	24.00	7834
Evening hours of being electrified (hours/day)	3.00	2.00	0.00	8.00	5953	4.00	1.00	0.00	6.00	7834
Days without power throughout the day (days/month)	4.00	5.00	0.00	25.00	5670	2.00	4.00	0.00	30.00	7834
Days with broken equipment due to voltage fluctuation (days/month)	1.61	3.21	0.00	25.00	5620	0.96	2.35	0.00	30.00	7834
=1 if household owns a business	0.17	0.38	0.00	1.00	7558	0.16	0.36	0.00	1.00	9072
=1 if the business has electricity	0.40	0.49	0.00	1.00	1298	0.32	0.47	0.00	1.00	1431
Yearly saving (rupee/year)	4852.07	21098.13	0.00	600000.00	8059	6134.66	25681.13	0.00	600000.00	8946
Monthly expenditure (rupee/month)	5301.57	3901.33	500.00	60000.00	8563	6246.84	4362.00	0.00	80000.00	9008
Yearly borrowing (rupee/year)	12427.41	39778.10	0.00	800000.00	8059	13978.86	50222.17	0.00	3000000.00	6799

Table 4.1: Summary statistics of the ACCESS survey for 2015 and 2018

The states in the sample are Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengaland; these states had the least level of electrification rate in 2001, when the first federal level electrification policy started and hence were some of the last ones to get electrified. Figure 4.1 helps visualise this in a different way, each household is represented by a point and plotted against the year they were electrified. The points start clustering and keep darkening over the years, especially in the 2000s, demonstrating an acceleration in electricity access for these households.

Table 4.1 gives summary statistics for the data. In 2015, nearly 66% of the households were electrified and by 2018, 80% of the households were electrified. This is in line with expectation given that the Government of India declared 100% households level electrification in May 2019. On average households have been connected for 8 years. They get about 12 hours of electricity in 2015 and this increases to nearly 15 hours per day in 2018. However, of these only 3 hours in 2015 and 4 hours in 2018 were during evening hours. This shows how total hours of electricity per day can be a misleading measure.

Figure 4.2 shows ost of the increase in access has been through extension of the grid; last mile connectivity is still a challenge. A small percentage of households use off-grid solutions like solar home systems and micro grids to supplement the grid electricity. There has been rapid increase in electricity access for all households, at all income levels and all states. The data shows an intensification of this access in the years post 2015, demonstrating the success of the new electrification policies in India. In the sample, households are classified according to the type of electricity connection (see those that are connected to the grid, those with solar home systems, those connected to mini-grids and the un-electrified. There is also intersection in these categories, some households use mini-grids and solar home systems to complement the grid connection.

The average expenditure of the households at a national level is about Rs. 5300 and this ranges from Rs. 3000 in Odisha to Rs. 5000 in UP and these increase to the range of Rs 4000 (Odisha) to 6000 (UP) in 2018. On average, most of these households have 4-5 people. Most households don't have an opportunity to save, in fact 30% of the households are indebted.

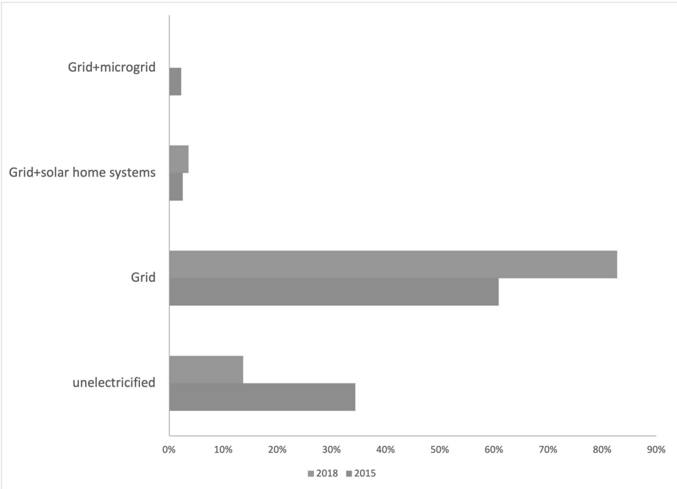

Figure 4.2: Percentage of households in the sample by the type of electricity connection

4.5 Appliance adoption: Examining ownership, use and aspirations of households

4.5.1 Overview of energy use and appliance adoption

Figure 4.3 shows the appliance currently owned by households, these have been classified as lighting, space conditioning, convenience appliances and miscellaneous. There is a clear increase in lighting and space conditioning appliances. An interesting change is the move towards LEDs in the two years. The households seem to be substituting incandescent bulbs and CFL bulbs with LED bulbs, which is a positive change for efficient appliances. This also is a nod to the success of the LED programme by the Government of India. The LED programme was introduced by the Bureau of Energy Efficiency (BEE) by mass buying LED light bulbs and reducing the price and making them available to consumers. This shows that households respond positively and rapidly to reduced prices and it is possible to change their appliance use. Most households own a mobile phone, there are very few households that own kitchen/convenience appliances such as fridge (12%) , washing machine (WM) (3%).

4.5.2 Aspirations: What appliances do households want to own?

In the survey, the unelectrified households were asked to rank their preferences of the appliances that they wanted to buy once they get electrified. The electrified households were asked what appliances would they want to buy if they were assured a reliable supply of electricity. Their preferences are shown in Figure 4.4, top panel for electrified households and bottom panel for unelectrified households. The overwhelmingly majority of unelectrified households indicate electric lighting as the first priority for them, followed by fan, and TV. Appliances like fridge, cooler and washing machine were ranked as not a priority at all, this is understandable since the unelectrified households are lower income than electrified households and are unfamiliar with electricity usage, so aspire for the basic appliances as outlined in tier 2 of the multi-tier

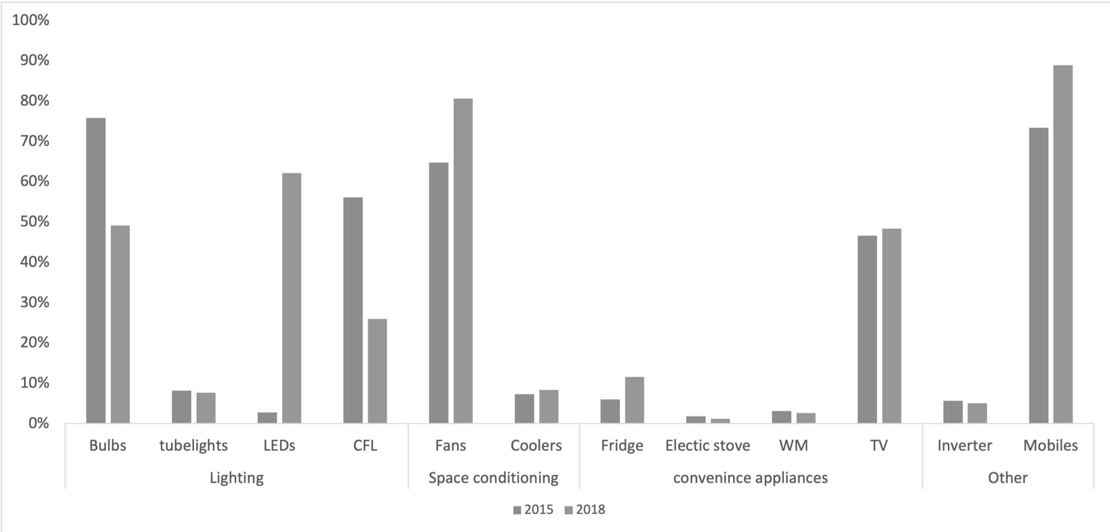

Figure 4.3: Percentage of households in the sample that own given appliance

framework (MTF). The ranking is similar for electrified households, as the households already own fan and TV (Figure 4.3). There seems to be an increase in aspiration, as electrified households show interest in buying coolers and fridge. Interestingly, the households also say no to electric stove, even after getting electrified. Comparing, panel A and B, these preferences seem consistent over time as the households give the same response in both the waves 2015 and 2018. The households in the sample want to switch to electric lighting as soon as they get a connection, after lighting, the next appliance they want is a fan followed by a TV. We checked the appliance preferences by male and female headed households are remarkably similar, so we dont show that figure here. However, this means merely having a female head of household will not create change for women living in the household.

4.5.3 Appliance ladder

The Energy System Management Assistant Programme (ESMAP) Bhatia and Angelou (2015) [3], electric lighting brings households into tier 1 of access; to move towards tier 2, the households should have access to air circulation, TV and phone charging. The ESMAP framework does not increase the appliance requirements for households beyond that. Any further progression on the tiers is through better quality of supply. However, as Rosenberg et al. (2020) find, appliances that are used most by women are kitchen fan, kitchen light, sewing machine, grinder etc. are not in the bundle of appliances they own.

The analysis so far gives us an idea about the overall ownership of appliances in the households. However, we need to understand how many appliances do the households use in all, which helps to increase their well-being. To understand how many electricity services people are able to use, the following four bundles are defined and measured, based on the multi-tier framework (MTF) proposed by ESMAP. In the MTF, there is also a 5th tier (or bundle), which is very high power appliances which is not present here because of the limited appliance basket in the rural households in the survey. The tiers or bundles are characterised

[3] page 6

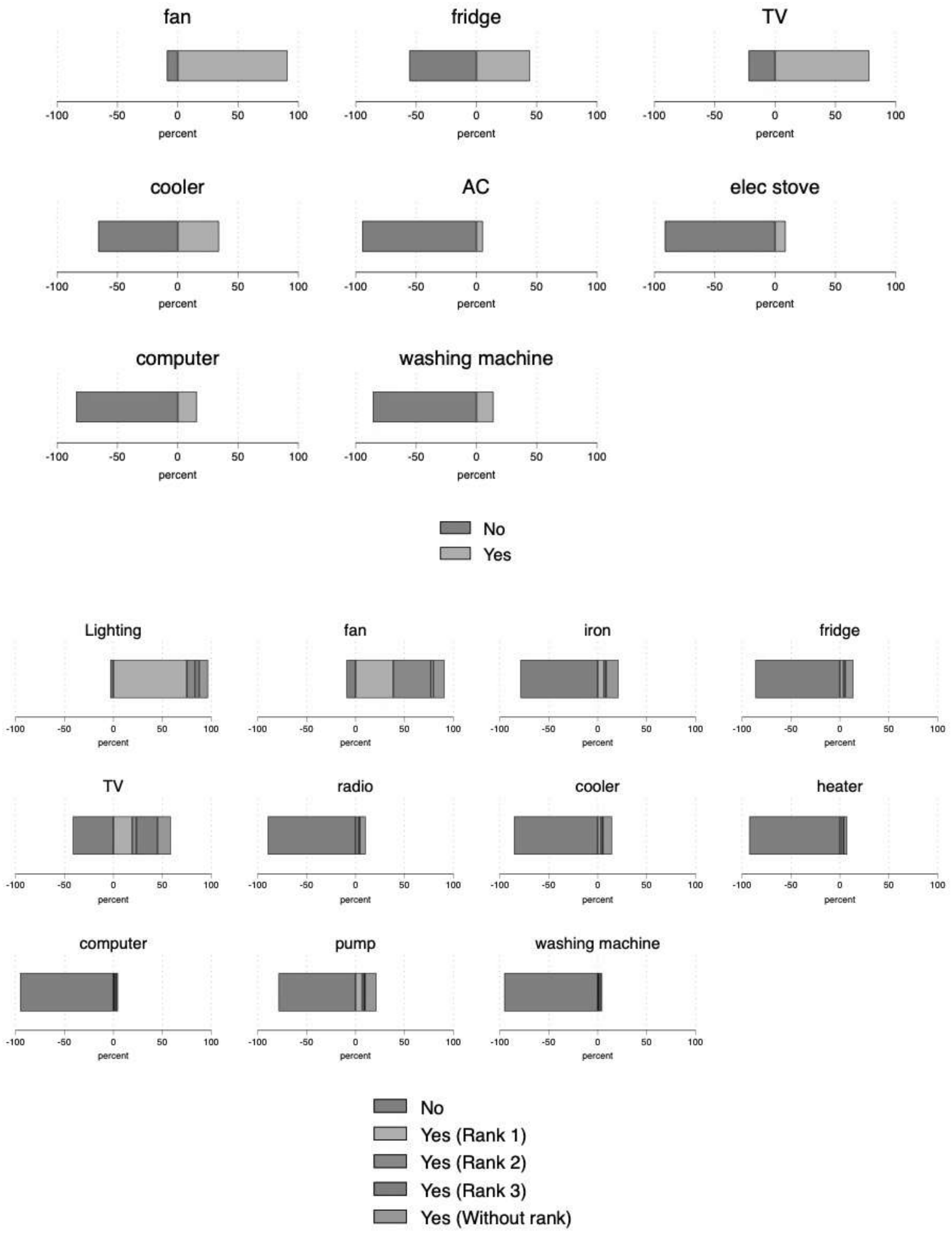

Figure 4.4: Aspirations: (Top panel) Percentage of households that report using an appliance, response is to the question "Do you use this appliance if power supply is good?", no is recorded as negative.(Bottom) Percentage of households that report aspiring to buy an appliance. In the graph, a positive measurement means that the households expressed their desire to buy the appliance, each colour indicates the rank

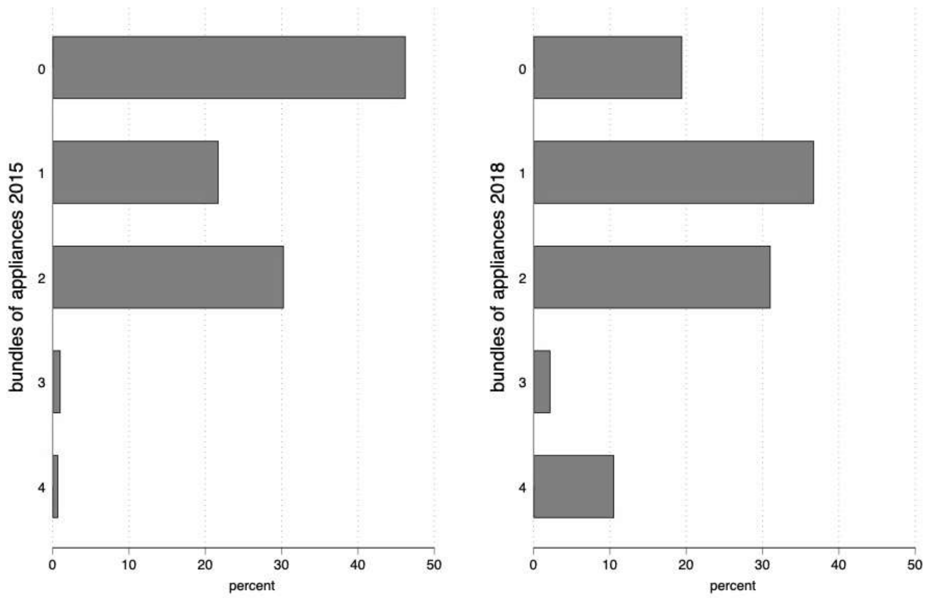

Figure 4.5: Distribution of the households by appliance ownership bundles (0=lowest to 4=highest in sample, see text for details), 2015 (left) and 2018 (right).

as follow:

- 0: Either only lighting or un-electrified
- 1: Lighting and phone charging
- 2: bundle 1+ TV and fan
- 3: bundle 2+ medium power appliances (fridge)
- 4: bundle 3+ high powered appliance (Washing machine)

Figure 4.5 shows that even though there is a marginal increase in the 3rd and 4th bundle households, the majority of the sample in 2015 and 2018 are in the 0, 1 or 2 bundles. This is quite concerning because the main changes and reallocation of time away from household chores is done after bundle 3. Bundles 1, 2, 3 can be seen as giving increased well-being in terms of ease of life but are not able to change significantly the productive opportunities for the households.

Figure 4.6 gives the median income arranged by the households in the four bundles. On average the minimum income of the households that can afford to use bundle 2 is more than Rs. 4000 per month. In both years, the difference between bundle 2 and 3 is large. The reduction in income level in 2018 might be explained by the fact that households report their expenditure per month and that is used as a proxy for income, these households may have significant savings.

Figure 4.7 gives the vintage of the connection by each bundle. The households that have bundles 3 and 4 have the oldest connections, approximately 10 years old. The households in the bundles 0, 1, 2 are the

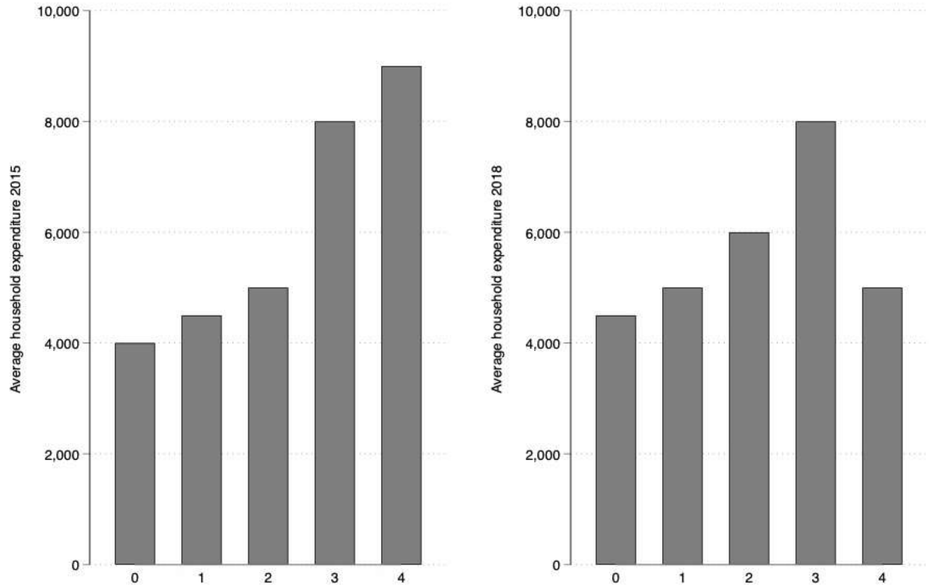

Figure 4.6: Median income of the households in the appliance ownership bundles (0=lowest to 4=highest in sample, see text for details), 2015 (left) and 2018 (right).

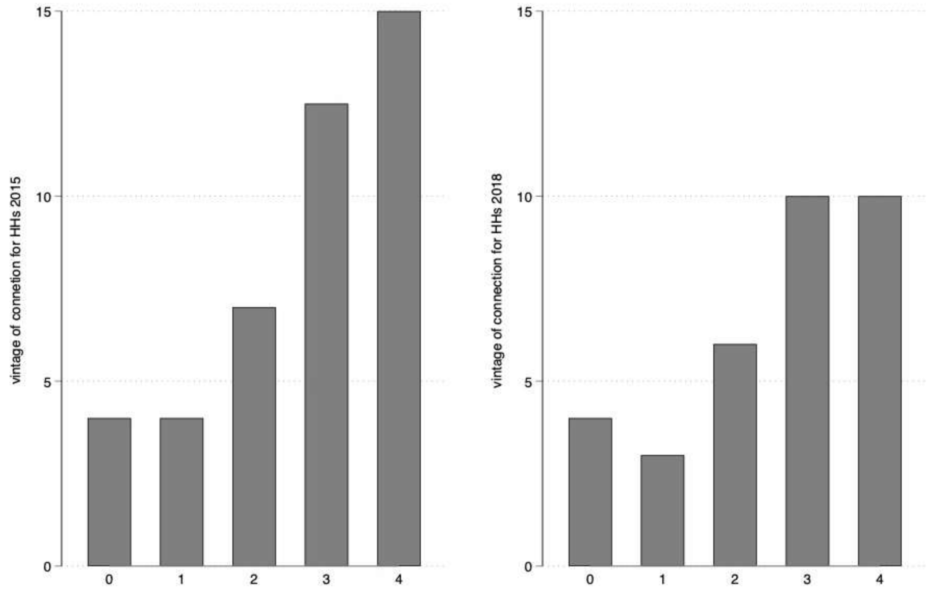

Figure 4.7: Vintage of the electricity connection by the appliance ownership bundles (0=lowest to 4=highest in sample, see text for details), 2015 (left) and 2018 (right).

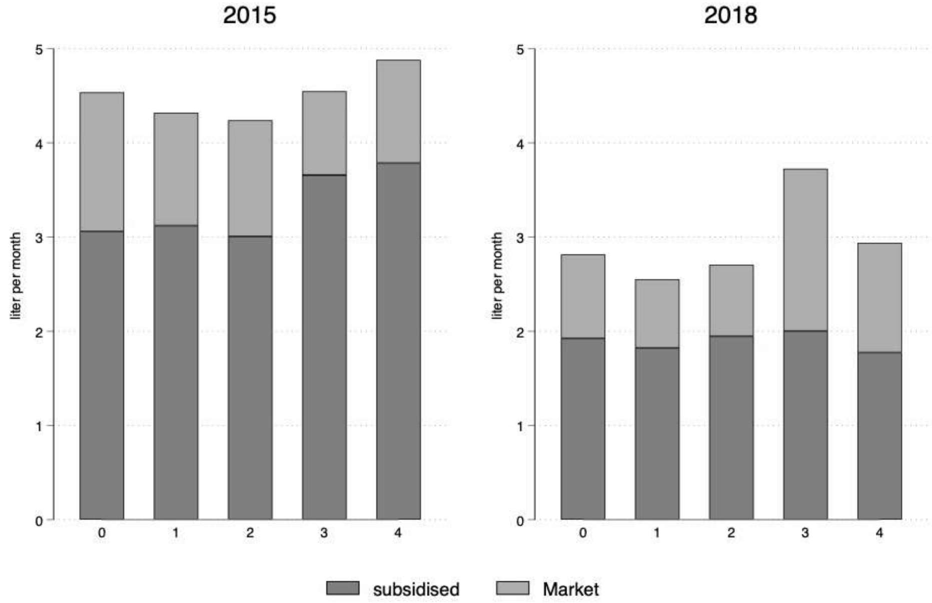

Figure 4.8: Kerosene use (liter per month) by the households by the the appliance ownership bundles (0=lowest to 4=highest in sample, see text for details), 2015 (left) and 2018 (right).

households that are newly connected (less than 6 years of connection). This can mean that the earlier electrification efforts were aimed at households that were wealthier or high income and these households have been able to benefit from the electricity they have. Either way, it seems that it takes about people 4-5 years of connection to be able to jump from the lower tiers to higher tiers.

A discussion on the interesting tier 0 households is important here. The Government of India classifies a household as electrified if they use electric lighting. Therefore, some households in the 0 bundle have been connected to the grid but are not using any appliance other than a light bulb. In Figure 4.5, there is a significant increase in this bundle, even though the total households unelectrified decreased in the second wave (2018). This is concerning because it means that many households are not able to benefit from electricity beyond light bulbs.

Figure 4.8 shows usage of kerosene and makes it clear that households are stacking kerosene and electricity. The most striking take away from this is that households across all bundles stacking kerosene, and some upper-bundle households are using more than the 0 bundle. This is a puzzling finding because one would expect the households to move away from kerosene as they use more and more electricity. The most astonishing finding is that bundles 3 and 4, that have been connected for an average of 15 years, are still using kerosene. Further, the households are not only using kerosene that is subsidised but also buying from the market. However, overall there is a decline in kerosene use, which is good from a health perspective.

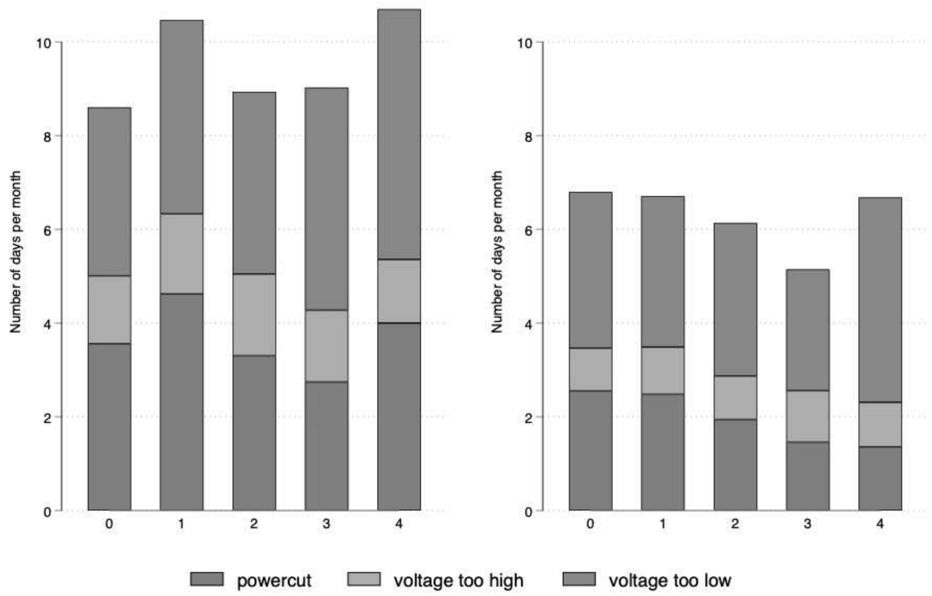

Figure 4.9: Reliability of electricity over appliance ownership bundles (0=lowest to 4=highest in sample, see text for details), 2015 (left) and 2018 (right).

4.5.4 Quality and reliability of electricity

4.9 Electricity is not reliably available, 2-5 days of power cut each month seems to be the norm. The households that are connected to the electric system have increased but there is still an issue with the quality and reliability of connections. Secondly, Powercuts are not the only defining point for electricity reliability/usability, voltage fluctuations are beginning to be a bigger problem than powercuts, as seen in 2018. 4.10 shows this varies greatly across states, this makes sense since intra state transmission lines and other infrastructure is owned by state governments. Looking at more detailed data, there is a clear reliability issue with electricity in each of the states, on average in 2015 households in Bihar would expect 4-5 days of power cuts per month, on top of this the experienced 4-5 days of low voltage electricity where many appliances (including lights) don't run. This means they experienced about 10 days of unreliable electricity per month. In 2018, the situation has improved for Bihar but deteriorated for Odisha, Jharkhand and West Bengal. [4]

4.5.5 Affordability

Finally we examine the aspect of affordability for these households, ESMAP describes a total energy expenditure of less than 5% for households. 4.11 shows the bundles wise expenditure on electricity as a percentage of monthly household expenditure. Households in all of the bundles, spend more than 5%. This is especially alarming because this does not include the expenditure on other energy sources, such

[4] author calculations from ACCESS data

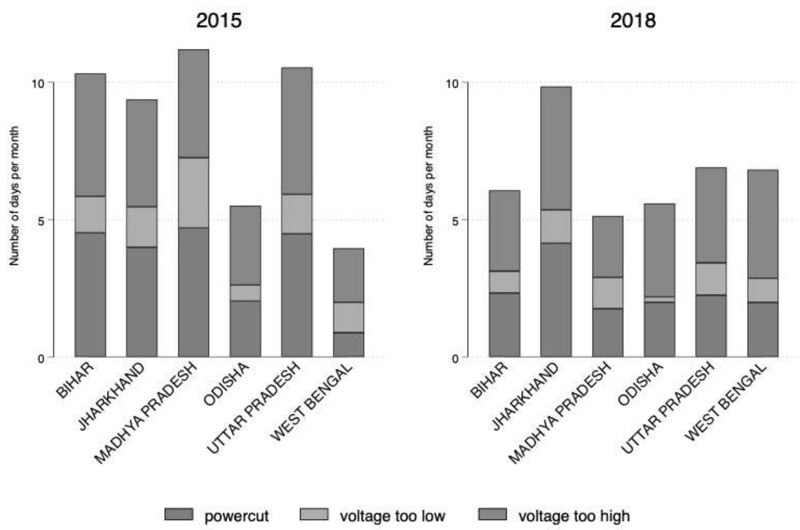

Figure 4.10: state wise reliability(power cuts) and quality of electricity (number of days with low voltage.

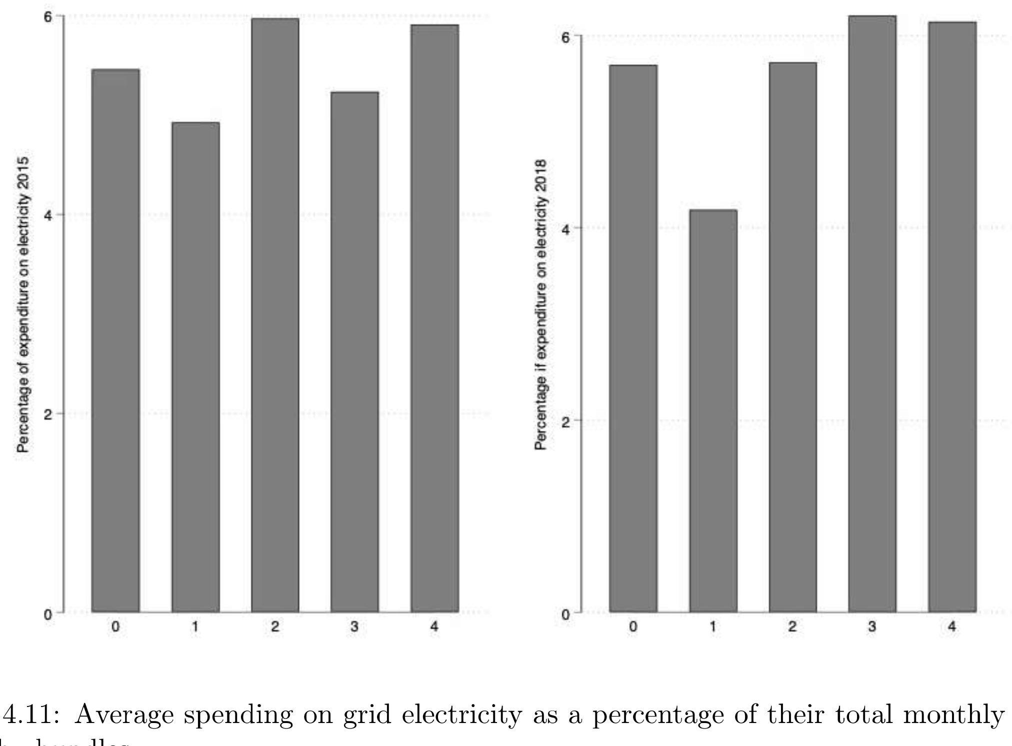

Figure 4.11: Average spending on grid electricity as a percentage of their total monthly expenditure by bundles

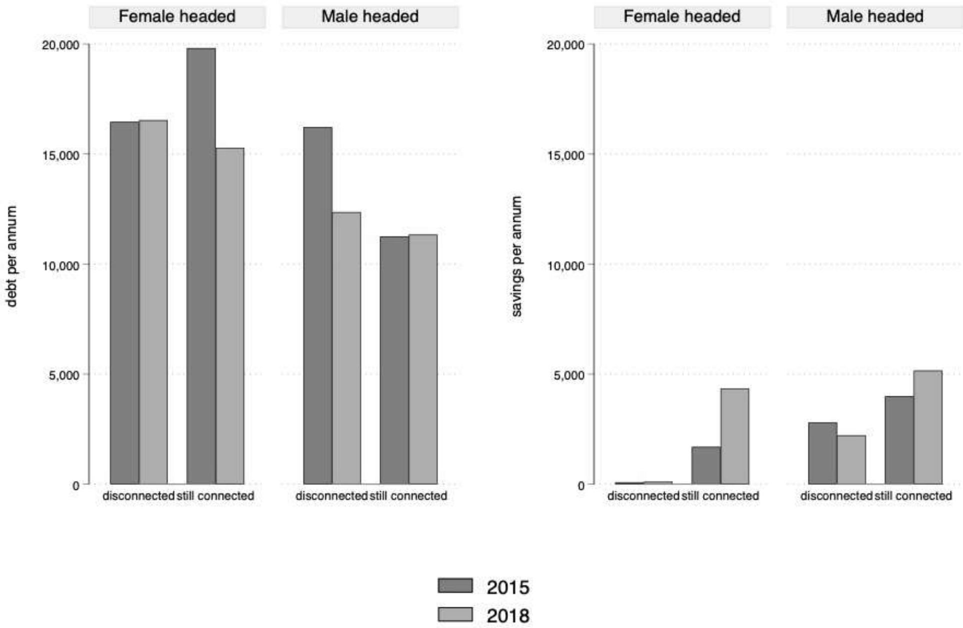

Figure 4.12: Debt and savings in the households that were newly connected, categorised by whether they stayed connected in the second wave.

as for cooking, and is only on electricity.

4.6 Examining disconnected households

A total of 1091 households were electrified in the years 2014-2015, when they were measured in the first wave of the survey; out of these, 391 households did not stay connected by the second wave. This is a 35% failure rate. Out of the households that got disconnected, 27% were female headed households. This section compares the characteristics of the households that got disconnected with the households that retained connection to understand what the important enabling conditions for a household required to stay connected.

4.13 shows that the households that are connected last have lower average incomes than the overall sample, the households that get disconnected have lower savings than the rest of the sample, and these households that don't have savings have a higher debt than the rest of the sample.

Overall the reliability and quality of the electricity has increased quite rapidly between the two rounds as we see from Figure 4.9. Over time, the grid has become more reliable so the number of days without power (outage) has reduced, but the days with unreliable voltage are still similar. Currently the voltage problems are seen as a smaller problem than a powercut, however, the better way to think of these is to treat them equally. Figure 4.13 uses this approach and stacks the three together. This gives a picture of why households are still getting disconnected after being connected to the grid. Figure 4.13 shows that

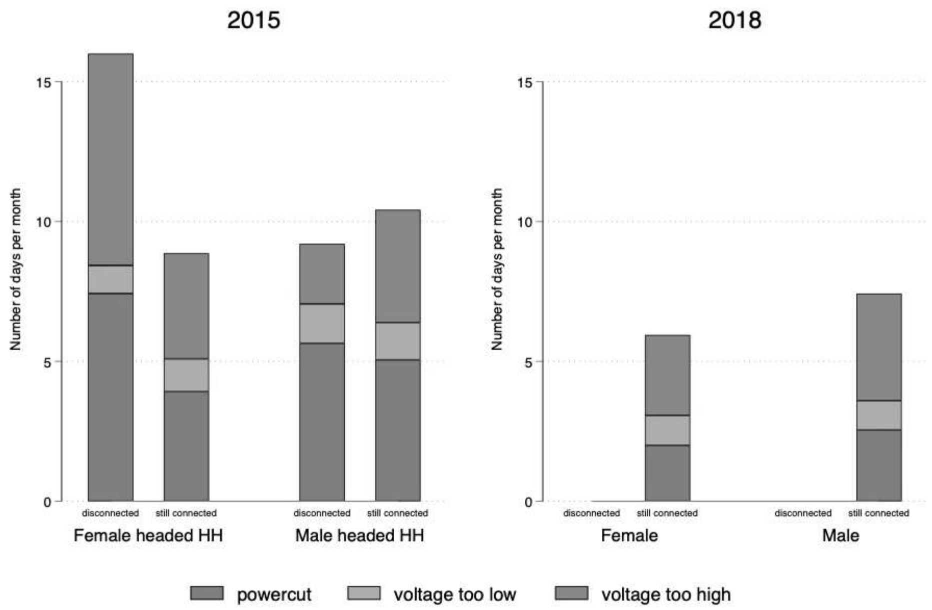

Figure 4.13: Reliability of power in the household, disconnected stands for households that were disconnected in 2018

the households that got disconnected had more days of unreliable power. Interestingly, female headed households are at a massive disadvantage, they got considerably more power cuts average of 7 days. This also varies across the states: while most states have seen an improvement — i.e. a decrease in the number of power cuts – West Bengal has seen a drastic increase in the number of days of power cut and voltage change. This implies 5-7 days per month the households don't get electricity the way they would like. However, comparing between the households that were disconnected and the houses that retained electricity, the difference is coming from the number of days of power cuts. It seems that the households getting disconnected are not getting disconnected because of the reliability of the power; the consumers seem to have internalised the low reliability of the power.

Figure 4.14 breaks down the households that disconnected into different bundles again as described above. If we consider appliances as an investment towards electricity, buying more and relatively expensive appliances implies that households have confidence that they will continue to stay connected.

97% of the disconnected households are in the 0-2 categories, while a very small number is also in category 3 and 4. One would expect that the houses getting disconnected would be from the lowest tiers of connections and hence its not surprising that households in tier 0 and 1 can end up being disconnected again because here people use just electric light and phone charging. However, substantial bundle 2 households are getting disconnected.

To sketch the characteristics of the households that were disconnected, these households were the ones that had lower income, lower savings, higher debts and were mostly using a light bulb and phone charging. A few of these households had access to fan and a TV. These households also experienced unreliable

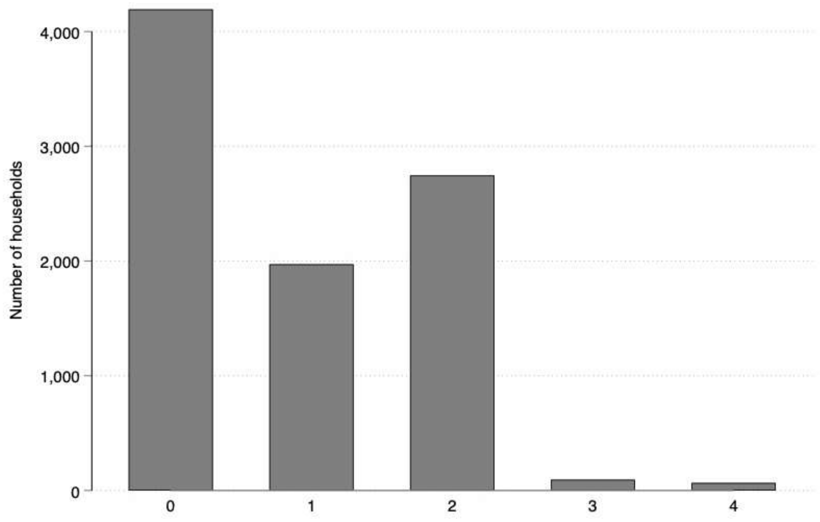

Figure 4.14: Percentage of households disconnected over appliance ownership bundles (0=lowest to 4=highest in sample, see text for details).

electricity and this unreliability was significantly more than their peers that were connected together, especially so for female headed households.

4.7 Discussion and Conclusion

This chapter started with the investigation of why the impact of electricity on development is heterogeneous. The obvious answer is that there is variability in the quality of electricity that reaches the people. However, as we connect more and more people, the last ones connected are invariably more vulnerable in terms of income and wealth. Rural households have a lower income that the national average, these rural households also fall in the poorest 6 states in India. Therefore, these households are more and more vulnerable to getting disconnected, after initial getting connected.
The households also use limited electricity services and appliances. The largest number of households use electricity for lighting and phone charging. 60% of households (in tier 1 and tier2) in 2015 used either lighting alone or lighting with phone charging as the only use of electricity, this number reduced to 55% in 2018. Only a small number of households can use more sophisticated appliances like refrigerator, TV etc. The survey shows that households continue using basic appliances even after 6-7 years of being connected to the grid. Changes in electricity consumption patterns that indicate full benefits of electrification appear on average after 10 years of grid connection.
The household's appliance ownership reflects the realisations of the preference of these households when they were not connected. The households have a very simple consumption basket of appliances and there does not seem to be an appliance ladder that households are climbing while buying more appliances. This has implications for everyone but especially for women that are involved in more unpaid household labour. Households continue the practice of fuel stacking by using kerosene with electricity. The most concerning

part is that households continue to use kerosene for lighting. Given that light bulbs are affordable to all households, this implies that affordability is not the only reason that the households don't shift completely to electricity for lighting, low reliability is a possible answer for this puzzling observation.
The other part of this puzzle is the reliability and quality of electricity. While electricity has become increasingly more reliable and there are fewer power cuts, there are still on average between 2-5 days of power cut, it is unclear if these are all scheduled or unscheduled. However, households are unable to use electricity when the quality is not good, i.e., the voltage is either too high or too low for the households to use any appliances. Taking these days of low quality voltage into account, households experience 6-8 days without useful electricity per month?. Losing a week every month to unreliable and low-quality electricity helps explaining why households don't invest in appliances, especial high-power appliances that need a stable voltage to run.
Comparing by the gender of the head of the household, the aspirations and preferences of the female and male headed households are similar. In this sample, the average expenditure of the female and male headed households is also similar. However, female headed households experience worse quality of electricity than male headed households.
There seems to be a catch-22, the households don't use appliances because the electricity is unreliable and low quality and are unable to change their well-being in a meaningful way. They can't invest into appliances and equipment to benefit from electricity by increasing productivity, either their own or of their business. At the same time, these households pay on average 6% of their monthly budget on electricity, which according to the ESMAP framework is indicative to be higher range for households to be comfortable.
Therefore there is an **energy trilemma**, the policy maker's problem is to increase the quality of electricity access rapidly has to increase the intensity of electricity use but there cannot be an increase in tariff because it will push these households to a point of not being able to afford electricity.

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