

Subedi, Mukti Nath; Bharadwaj, Bishal; Rafiq, Shuddhasattwa

**Preprint**

## Who benefits from the decentralized energy system (DES)? Evidence from Nepal's micro-hydropower (MHP)

*Suggested Citation:* Subedi, Mukti Nath; Bharadwaj, Bishal; Rafiq, Shuddhasattwa (2021) : Who benefits from the decentralized energy system (DES)? Evidence from Nepal's micro-hydropower (MHP), ZBW - Leibniz Information Centre for Economics, Kiel, Hamburg

This Version is available at:

<https://hdl.handle.net/10419/246816>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

**Who benefits from the decentralized energy system (DES)? Evidence from Nepal's micro-hydropower (MHP)**

Mukti Nath Subedi

[msubedi@deakin.edu.au](mailto:msubedi@deakin.edu.au)

Department of Economics, Deakin University, Australia

Ministry of Federal Affairs and General Administration, Kathmandu, Nepal

Bishal Bharadwaj

University of Queensland, Australia

[b.bharadwaj@uq.edu.au](mailto:b.bharadwaj@uq.edu.au)

Shuddhawasta Rafiq

Department of Economics, Deakin University, Australia

[srafiq@deakin.edu.au](mailto:srafiq@deakin.edu.au)

# Who benefits from the decentralized energy system (DES)? Evidence from Nepal's micro-hydropower (MHP)

Mukti Nath Subedi<sup>a,b</sup>

Bishal Bharadwaj<sup>c</sup>

Shuddhawasta Rafiq<sup>a</sup>

<sup>a</sup>Deakin University, Australia

<sup>b</sup>Ministry of Federal Affairs and General Administration, Kathmandu, Nepal

<sup>c</sup>University of Queensland, Australia

***Abstract:*** In low-income countries, uneven access to clean energy has posed a challenge to reduce socioeconomic inequalities across gender and disadvantaged groups. To address this issue, development planners see potentials from the decentralized energy system (DES) that provides electricity access in those areas where the national electricity grid is not available. To assess whether the DES helps reduce inequality and improve gender empowerment, this study focuses on the micro-hydropower (MHP) scheme, a widely adopted DES in Nepal, to study its impact on educational attainment and employment outcomes by caste and gender. The results show MHP improves the educational outcomes and facilitates a labour shift from traditional agriculture to waged and salaried jobs. However, a disaggregated analysis shows the educational outcome of access to MHP electricity is higher for women and lower caste individuals; however, the positive employment related effects are inclined toward socially dominant groups like males and upper caste individuals. These results reveal that while in general the DES improves educational and labour market outcomes, it may need complementary conditions to signify its labour effects on women and lower caste individuals.

Keywords: Decentralized energy system; education, labour market, caste, gender

JEL Classifications: I25, J15, Q42

## 1. Introduction

Between 1998 and 2018, the proportion of the global population with access to electricity increased from 72 to 89 percent (World Bank, 2021). However, more than 800 million people still lack access to electricity worldwide (UN, 2020). The majority of this population live in remote rural areas of the poorest countries, and many of them are ethnic/racial minorities or socially and economically marginalized groups. However, the expansion and maintenance costs of centrally planned grid electricity is very high and unlikely to recover due to very low electricity demand (Lee et al., 2020). Therefore, development planners need to look for more innovative and contextual solutions to those areas aiming to provide energy at households and uplift the socioeconomic status of marginalized groups. In this regard, the Decentralized Energy System (DES) such as Micro-hydro Power (MHP) and off-grid solar has gained much attention in recent years as cleaner and more cost-efficient alternative solutions for mass electrification (Narula et al., 2012, Alstone et al., 2015, Grimm et al., 2020). Unlike the national grid that requires heavy infrastructures on transmission lines and substations, DES uses low-cost technology, distributed through micro/mini-grid and managed by community user groups making a suitable alternative solution for remote rural areas.

Access to electricity brings a bundle of direct and indirect benefits at the household. Electrified households can transition to modern living with clean, reliable, and efficient lighting, cooking, and heating facilities. In an indirect way, the productive use of electricity contributes to improve a wide range of welfare outcomes such as employment, labour shift, education, gender equality and health. These direct and indirect impacts of electricity are documented by several studies<sup>1</sup>. However, existing studies on the impacts of electrification mainly focus on the extension of grid electricity and on aggregate population. The impact of

---

<sup>1</sup>See Jeuland et al. (2021) for a recent literature review on the impact of electrification on different welfare outcomes.

country and context-specific DES such as off-grid solar, wind and MHP on development outcome is largely understudied (Jeuland et al., 2021). Only a few studies focusing on off-grid solar are available (Grimm et al., 2017, Aklin et al., 2017, Wagner et al., 2021, Bharadwaj et al., 2021). The United Nations Sustainable Energy for All (SE4ALL) initiative has predicted that by 2030, 70% of new connections in rural areas will be provided through DES (International Energy Agency and World Bank, 2014). The majority of the new beneficiaries who access electricity through DES are disadvantaged groups either socially or economically or both. Given the fact that energy is essential for socioeconomic transformation, access to electricity can play a key role in reducing inequality ensuring social inclusion and gender empowerment. Therefore, accessing the disaggregated impact of DES on the welfare outcomes of disadvantaged groups is an important research agenda from both academic and policy perspectives.

One can argue that the welfare impacts of DES and grid electricity are comparable as both provide lighting solutions for households. However, there are at least three main reasons why the welfare effects from these two types of energy solutions are not identical. First, the context of grid-connected areas and DES targeted areas are substantially different. Grid expansion needs transportation of transmission poles and transformer that requires a road network. Additionally, grid electricity usually targets densely populated places and market centres. This systematic bias of grid expansion toward populated and accessible areas means areas targeted by DES are in lack of basic infrastructures, which eventually adds additional cost for other public services such as schooling. Second, DES is a more localized and community-based solution. This localization means the type capacity of DES are constrained by the availability of local resources and the socioeconomic strength of the community. Therefore, the selection and use of DES in a particular location are endogenous to the observable and unobservable community characteristics. For example, observable

characteristics such as the availability of all-year-round water with an appropriate elevation profile may choose MHP. Similarly, the area with suitable solar radiation or wind potential may go for a solar home system or wind energy. Areas with a higher demand for electricity with a lower chance of getting grid connection are likely to invest more in DES. At the same time, some characteristics that are difficult to observe but inherently associated with social or gender norms play roles in adopting DES. Third, grid electricity is an ultimate energy solution, whereas DES is promoted as a transitional lighting solution. DES usually operates in peak electricity demand hour, not metered; charges (if any) are based on the number of lighting bulbs used at households. Given the fact that DES is primarily designed for a basic lighting solution, the operation of high-wattage appliances is restricted. Usually, experiences from developing countries show that when DES areas get access to the grid, households shift to grid connection for reasons like reliability and sufficiency of electricity.

Considering above mentioned distinct features of DES that differentiate it from the national grid, this study aims to fill the gap in the literature by studying the effects of household access to DES on educational attainment and employment outcomes of individuals by gender and caste. For this, we take the case of MHP system in Nepal—a hydro project with installed capacity of less than 100kW and use a mini/micro-grid to distribute generated power to nearby households. Nepal provides an ideal context to study the impact of MHP on household welfare for at least a couple of reasons. Firstly, many MHPs supply electricity to a significant number of people from different social groups from different periods and locations, which provides extensive variations that can be exploited to analyze the impact of MHP on household welfare. Secondly, Nepal being a developing country, has made significant strides in educational outcomes and labour shifts in the last two decades. We explore the possible causal link between MHP expansion and educational and employment-related outcomes in rural, remote areas of Nepal.

We use microdata from the national population and housing census 2001 and 2011 combining with data from other multiple administrative sources. We employ an instrumental variable approach to address the possible concern of endogeneity. Overall, the results indicate that access to MHP electricity at households improves educational outcomes as proxied by adult literacy, years of schooling and years of schooling z-score that measures the cumulative progress among school-aged children. We also find shreds of evidence of labour shifts from traditional subsistence agriculture to non-agriculture sectors such as salaried jobs and business activities affected by the expanding access to MHP. We extend the analysis to explore how gender and traditional social hierarchy/class (caste/ethnicity) affect the distribution of such benefits from MHP electricity access. Results indicate that educational outcomes are more evident among female and lower caste individuals, whereas employment outcomes are evident among upper castes, middle castes and males.

This study contributes to the existing literature in four ways. At first, it contributes to build existing literature on the economic impacts of infrastructure expansions particularly focusing on rural electrification through DES. In developing countries, the improvement in educational attainment is usually associated with lowering the schooling cost (Duflo, 2001). However, in this study, we argue that behavioural changes brought by MHP electricity at the household level can also improve the educational attainment at the current educational cost shifts labour from non-productive household chores and subsistence agriculture sector to productive activities.. Second, this study contributes to building the emerging literature on the intersection of race/ethnicity, gender and energy access by examining the heterogeneous impacts among different castes and gender. Governments around the globe are implementing several programmes, including affirmative action in education and employment for disadvantaged groups, to reduce socioeconomic inequalities caused by historical discrimination based on gender and caste. However, this study provides evidence that access

to basic services like clean energy helps disadvantaged groups to catch up with the dominant group.

Third, this study is particularly relevant and timely regarding the achievement of sustainable development goals (SDGs) by 2030. Specifically, how achieving Goal 7 (access to clean energy) impacts achieving other goals: quality education (Goal 4), decent work and economic growth (Goal 8) and reduced inequalities (Goal 10). The results from this study can be beneficial for planners from other parts of the world where lack of access to energy, low education with wide inequality among social groups and dependency on subsistence farming are key challenges they face. In this regard, this study can help planners to seek alternative cost-effective options for electrifying remote and high elevation areas independent of grid reliability, simultaneously reducing inequality. Last but not least, this study contributes to the emerging literature on carbon pricing. MHP is clean hydropower that can contribute to meet the global carbon emission reduction target by reducing the pressure on burning biomass fuel for lighting and earning revenue in return. It is worth mentioning here that Nepal's MHP sector already started to gain carbon revenue by displacing diesel fuels (WB, 2015).

The rest of the paper is organized as follows. In section 2, we discuss the context of the study, followed by a literature review and analytical framework in section 3. In section 4, we present data and method. In section 5 and 6, we present results, and discussions and conclusion, respectively.

## **2. Context**

### **2.1 MHP development and its impact in Nepal**

The MHP is akin to the conventional hydro project in principle but is usually of less than 100KW installed capacity. It utilizes land gradient and current water and combines with widely adopted technology of turbine and generator to produce electricity. In Nepal, slopy land and snowy mountainous areas in the Northern part sets the ideal situation for MHP in both technical



and practical aspects. Technically, when snow-fed rivers and streams run down from the steep slope, it provides an appropriate elevation profile and abundance of current water that MHP requires as preconditions. With regards to the practical aspect, rugged terrain with scattered settlements sets a barrier to national grid extension and makes MHP a desirable alternative to those areas. MHP does not require extensive infrastructures such as access roads, huge dams and machinery, and tunnels. Additionally, extreme weather with thick fog for several weeks in high elevation area makes other alternatives such as solar home system less feasible. Therefore, MHP is the best alternative that can be installed and operated near to demand centre reducing the initial infrastructure financing required for grid extension.

MHP technology adoption in Nepal started as early as 1960. Until the 1990s, MHPs were primarily used to replace diesel-powered agro-mills in the mid-hills (Cromwell, 1992). By the 1990s, nearby households started to electrify using surplus electricity from those mills (Kumar et al., 2015). At the same time, Nepal Electricity Authority (NEA) – a state-owned enterprise that manages grid electricity development, transmission and distribution in Nepal, initiated some isolated hydro projects in economic centers of the remote hill and mountain districts. The MHP installation accelerated after the establishment of the Alternative Energy Promotion Centre (AEPCC) in 1996. AEPCC is a government agency responsible for developing and promoting alternative and renewable energy in 1996, with supports from development partners.

The installation and operation of MHP projects receive a fixed amount of subsidy for each kilowatt (kW) from the government. A top-up subsidy is also provided based on the distance of MHP location from accessible areas; thus, villages far from access roads get larger subsidies comparing to the nearest ones. Roughly half of the installation cost is covered by subsidy and, users contribute the rest. A typical MHP cost US\$2100 per kW (Müller et al.,

2018). As of 2020, more than 2000 MHP projects in the country electrified more than 200,000 households in remote rural and off-grid areas (See Figure 1).

In some instances, MHP can be a better solution in rural and remote sites from environmental and cost-effective perspectives. As the MHP does not require a big dam, the diverted water can be sent back immediately to its original flows that mitigate ecological damages usually occurred with conventional big hydro projects. Additionally, the local community can own MHP to access much-required electricity at their places without bearing the costly infrastructure and maintenance of grid electricity. This initial cost-saving makes the MHP a cheaper and more efficient way of providing clean electricity in remote rural areas of countries like Nepal (Islar et al., 2017, Kumar et al., 2015).

## 2.2 Social hierarchy, gender, and electricity access in Nepal

Nepal is a diverse country and the land of 125 castes and ethnic groups as of National Population and Housing Census 2011. Each caste is believed to be linked with certain occupations in the past (Bista, 1991). Traditional caste-based social hierarchy roots deep into Nepalese society that divides society into three layers – upper/high caste (*tagadhari* or twice born), non-caste Janajatis/indigenous people (*matwali* or Liquor-drinking) and lower-caste (impure or water-untouchable)(Bennett et al., 2006). For a particular caste being up in social hierarchy means privileged and superior to others. However, being lower in the social hierarchy for a particular caste means poor socioeconomic outcomes and perhaps difficulties in accessing public services such as access to energy, education and employment. Different social groups may respond differently to the access to energy as they are inherited with their values, cultural practices and norms, which subsequently determines impacts on outcomes such as education. In addition, due to the traditional gender norms deep-rooted in patriarchal society men outrank women in household decisions. These variations mean women and disadvantaged individuals from lower caste or ethnic groups may respond differently with access to electricity, leading to

disproportionate effects by gender and ethnic groups (UNESCAP, 2013). Being in the lower ladder of social hierarchy means already an individual from that group is underprivileged and lacks access to clean energy folding the degree of disadvantages.

The welfare outcomes of electricity connections depend on how household members utilize the electricity for productive purposes. The productive use of electricity depends upon several observable characteristics such as income, education and geographical locations. However, on the other hand, as highlighted and discussed in Kumar Sedai et al. (2021) and Thorat et al. (2017) in the Indian context unobserved social characteristics constraints marginalized groups in accessing and using technologies such as DES. Similarly, previous studies show the effects of access to energy vary by social strata, such as gender (Dinkelman, 2011, DAS et al., 2020), income group (Lee et al., 2020), and castes (Pelz et al., 2021). In the Nepalese context, a previous study by Bridge et al. (2016) documented the lower probability of access to electricity for lower caste people. The electricity access of three different social groups indicates that people who belong to the lowest social hierarchy had the lowest access to electricity (a detailed discussion is offered in Section 5.1).

### **3. Economic Effects of Access to Electricity: Literature and Analytical Framework**

The construction of large-scale infrastructure projects such as big dams, rail-network, electricity, and roads aims to provide basic services to people and improve their well-being. Their impacts on development outcomes such as education, health and employment are being explored in economic literature<sup>2</sup>. Several studies have also attempted to assess the effects of electricity infrastructure expansion on development outcomes. The results are mixed. A set of literature such as (Dinkelman, 2011, Lipscomb et al., 2013, Grogan, 2018, Litzow et al., 2019,

---

<sup>2</sup> For instance irrigation dams (Duflo and Pande, 2007), railroad (Donaldson, 2018). For literature survey on impact evaluation of infrastructure and electrification, see (Estache, 2010, Jeuland et al., 2021).

Fujii and Shonchoy, 2020, Thomas et al., 2020) has documented large and positive welfare effects. For instance, a seminal work by Dinkelman (2011) documents the positive effect of the expansion of rural electrification on employment. Similarly, Lipscomb et al. (2013) study the impacts of electricity infrastructure expansion in Brazil and reveal a large effect on human development. Fujii and Shonchoy (2020) link rural electrification with fertility in Bangladesh and find that access to electricity reduces total fertility. Another set of studies have documented very small or no economic effects of rural electrification on welfare outcomes (Burlig and Preonas, 2016, Lee et al., 2020). However, all of these studies use grid expansion as the treatment.

Only a few studies are available on identifying the causal effect of DES on development outcomes. The majority of them focus on off-grid solar (Grimm et al., 2017, Aklin et al., 2017, Wagner et al., 2021, Bharadwaj et al., 2021). Wagner et al. (2021) find that solar home system leads to the net increase in lighting time and improves household environmental quality reducing the kerosene consumption. Grimm et al. (2017) study the impact of Pico-Photovoltaic solar kit and find a significant and positive effect on household energy expenditure; however, they report only a modest effect on health and productivity. Similarly, Aklin et al. (2017) study the effect of off-grid solar on economic outcomes in India, however do not find a systematic change despite positive effects on access to electricity and expenditure. In spatial regression discontinuity setting, Bharadwaj et al. (2021) documented a large impacts of household solar lighting on educational and employment outcomes in Nepal. A non-causal study by Kirubi et al. (2009) documented that access to any form of electricity brings positive changes in socioeconomic outcomes. Regarding the effects of MHP, a few non-casual studies such as Arnaiz et al. (2018) in Bolivia and the Philippines and Murni et al. (2013) in Malaysia have documented some positive socioeconomic benefits of the micro-hydro system. More importantly, Arnaiz et al. (2018) further point to differential effects on men and women.

A limited number of studies have attempted to investigate the heterogeneous impacts of energy related activities among ethnic groups. Poyer et al. (1997) document the significant variations in fuel consumption patterns of Latinos and non-Latinos in the United States and further recommend policymakers to consider that variation of energy use and expenditure across ethnic groups in energy policymaking. Similarly, the impact of the boom in the energy industry was different among different ethnic groups and gender in Texas, yielding higher employment gains for minorities, i.e. Black and Hispanic males and hence increased ethnic/racial diversity in oil and gas industry employment (Cai et al., 2019). In the context of an ethnically diverse country, Churchill and Smyth (2020) find that energy poverty increases with higher ethnic diversity in Australia. A recent study in India by Pelz et al. (2021) find that caste-based energy inequities exist in India, worsening the Schedule Caste (SC), which pointed to the requirements of multidimensional energy supply assessment.

Access to clean energy contributes to the advancement of socioeconomic outcomes such as education, health and labour productivity (Kanagawa and Nakata, 2008). The country and context-specific DES have contributed to getting people out of the darkness providing basic lighting solutions in recent years, and is being expected to grow in future. At the same time, more equitable access to modern energy services is becoming one of the key agendas to be considered so that marginalized segments of the population can smoothly transition to modern energy solutions. Governments and donors in recent years are making the investment in DES, such as solar home systems and MHP, to provide basic clean lighting solutions to the people using biomass fuel such as kerosene lighting. In this regard, understanding the development impacts of such energy systems on different strata of society is an important agenda for both the academic and policy realm. Therefore, in this paper, we study both the aggregate effects of MHP on educational and employment related outcomes and disaggregated effects on different strata of the population.

The MHP in Nepal mainly provides lighting solutions to households in remote rural areas. The MHP can improve educational and employment outcomes by changing the behaviour of time use patterns. Electrified homes get extended lighted hours so that household members can allocate these added hours on productive purposes. Children can study in the evening or early morning. It is important to note that students have to spend several hours to get to school. According to the Nepal Living Standard Survey 2011, it takes approximately an hour to get to secondary school in the hill and mountainous areas. Additionally, several social practices of engaging children in household chores hinder children from additional study at home in the daytime. In this situation, not having good light means students cannot do their homework and studies, pushing them to inferior or fail grades and eventually drop out. Electricity at household gives an opportunity to school-aged children to study at home during the evening, night or early morning. Similarly, the adult can shift household chores to nighttime and utilize daylight for some income generation opportunities. They can start their own business or can work as an employee.

Clean light means getting rid of kerosene lamp soot (unburned carbon particles). Kerosene lamp in Nepal uses cloth string that soaks kerosene and burns to produce light and soot. Members of the household that does not have access to clean energy, especially women and children, move very close to kerosene lamp to study and work. This exposure to kerosene lamp that produces toxics can cause illness (Lam et al., 2012). Less soot means less illness and less absenteeism in school and work. Additionally, households can use electric-powered modern appliances such as radio and television depending on the wattage of energy supplied by MHP. Household members can get access to useful information for their studies and work, which may eventually improve their educational and employment outcomes.

## 4. Data and Method

### 4.1 Data

In this study, we use the data from the Population and Housing Census of Nepal administered in 2001 and 2011. The Central Bureau of Statistics, a government agency, conducts a nationwide population and housing census in every ten years. The data set represents approximately 12.5% of total households during the time of the census. The data set provides us with information on variables of interest at the household level (e.g. household access to electricity, household amenities and other household-level facilities), and at the individual level (e.g. literacy, years of schooling, age, sex and caste/ethnicity). As we are extending our analysis at different stratum of social hierarchy, we match caste/ethnic information from census data with Dahal (2003) – which allows us to create three broader caste-based social groups– upper-caste, Aadiwasi/Janajati (middle caste hereafter) and Dalit (lower caste hereafter).

The key challenge using census data in our analysis is that it does not provide information about which household uses electricity from MHP and from grid connection. We access several administrative records of the NEA. We successfully identify which Village Development Committee (VDC), a self-governing administrative and political boundary in Nepal before 2015, has got connected to the national grid. Additionally, we got MHP project installation data with their location (Village and District), installation completion date and installed capacity from AEPC. Using this database, we identify the VDC that had MHP in the census year 2001 and 2011. There are some MHP installed or initiated by the NEA before the establishment of AEPC (before 1996). We get the information about those old MHP data from NEA records. We focus this study in hill and mountainous areas where MHP is technically feasible. That exclude VDCs from southern plain area of Nepal. We also exclude the VDCs those had grid connection by 2011 given that our aim is assessing the impact of MHP electricity

on individuals from households with MHP electricity comparing to individuals from households without MHP electricity.

We use three outcome variables for education and three for employment outcomes. Education outcome variables include; adult literacy, grade completed by school-aged children (years of schooling) and education z-score. The education z-score— which measures the deviation from median years of schooling for a particular age and sex<sup>3</sup> is preferred over standard grade by age as it captures the cumulative falling behind of certain sex (age) (Orazem and King, 2007). We construct this variable as:

$$zscore = \frac{s - \bar{s}}{sd}$$

where,  $s$  is the years of schooling,  $\bar{s}$  is the median years of schooling for specific age and sex.  $sd$  is the standard deviation of schooling.

As the first employment outcomes, we use usual activity of an individual—agriculture, own business, salaried jobs and household chores. The usual activity refers to the main usual activity of an individual had in last twelve months. The second employment outcome is current employment status of an individual – employee, employer and family worker. Our third outcome variable is the working industry of an individual – agriculture and forestry, manufacturing, hotel and restaurant, and trade. These employment outcomes are binary measurements. Tables 1 and 2 present the summary statistics of key variables.

---

<sup>3</sup> The grade-for-age does not account for ‘cumulative nature of failing behind’ for the children of particular age (and sex) Orazem and King (2007). Therefore, the z-score captures the growing dispersion in years of schooling.



## 4.2 Method

We begin our estimation with pooled OLS at the individual level. We compare the outcomes of individuals from households having access to electricity to those without electricity. The regression takes the following form:

$$Y_{ihvt} = c_1 + \beta(E_{hvt}) + \delta_t + \gamma_v + X'_{ihvt}\theta + \epsilon_{ihvt} \quad (1)$$

where,  $Y_{ihvt}$  is the outcome of interest for individual  $i$  in household  $h$ , in village  $v$ , in census year  $t$ .  $E_{hvt}$  is the indicator variable for households using electricity,  $\delta_t$  and  $\gamma_v$  are census-year and village fixed effects. Village level fixed effects account for all time-invariant differences across VDCs that affect our outcomes variables, and year fixed effects capture effects of any government policy changes or aggregate factors those are common for both type of households.  $X'_{ihvt}$  is the vector of other controls at household and individual levels. We add age fixed effects to account for age-specific characteristics of individuals from treated and untreated households. Many of our outcome variables are binary (except years of schooling and education z-score). However, as Greene (2004) highlights, given the large individual-level data and a large number of fixed effects, a linear probability model (LPM) is preferred over non-linear models such as logit or probit. Previous work, such as Cai et al. (2019), also used the LPM with similar justification.

The key challenge using equation (1) in our identification strategy is the endogeneity issue that comes with the non-random placement of MHP at the community/settlement level and the household's connection to MHP electricity. The community with relatively higher population density and easily accessible may get MHP installation first as it is cost-effective. Additionally, the MHP project itself requires certain technical conditions like reliability and around the year water availability and suitable elevation profile. The final decision of MHP installation in a particular community is made by the AEPC - an external agency. The

installation is mainly driven by the subsidy that government provides based on VDCs – those are established in 1991 before the establishment of AEPC and enactment of renewable energy policy. For instance, in Nepal, subsidy covers approximately 50% of total installation cost – the rest is covered by community contribution (Müller et al., 2018). Once the community gets MHP installed, households decide whether to connect to electricity or not—household-level characteristics may determine it.

Many of the previous works rely on instrumental variables (IV) approach to deal with endogeneity issues (for example; land gradient (Dinkelman, 2011), distance to electricity pole (Thomas et al., 2020), census segment code (Grogan, 2018) and electrification at the higher administrative boundary (Fujii and Shonchoy, 2020, Van de Walle et al., 2017)). Other studies, such as Meeks et al. (2021), use result of a carpet study<sup>4</sup>, and Müller et al. (2018) use watershed catchment areas. MHP is a community/settlement-based solution; the spatial variables such as water availability, watershed catchment area and elevation profile may be correlated with economic activities at that community. Being particularly designed for a certain locality, the distance to the grid or other distance measurement may not be relevant. Keeping this in mind, we use the VDC level MHP incidence as an instrument variable in this study. In our specification if a VDC has at least a installed MHP or connected to MHP electricity from neighbouring VDC it takes value one, zero otherwise<sup>5</sup>. The old MHPs that are relatively larger in installed capacity provide electricity to more than one VDC. Similarly, the MHP install at

---

<sup>4</sup> Carpet Study, does the feasibility study and MHP suitability at particular location based on all year water availability and elevation profile.

<sup>5</sup> We construct MHP incidence as follows: the microhydropower plant level data from AEPC gives the location(VDC) and year of installation of MHP project. A few MHP projects (seven) has missing location information and 174 MHP have missing installation date, so it is unclear whether they were installed before 2011. Some MHP projects supply electricity to the households from more than one VDC. This is usually a case if the MHP capacity is larger or it is located in the border of multiple VDCs. Therefore, to construct electrification incidence precisely we calculate mean electrification ( $\bar{E}_{vt}$ ) at village  $v$  in year  $t$ . Therefore if  $1 \geq \bar{E}_{vt} \geq 0$  than our instrument  $Z_{vt}$  takes value 1 otherwise it takes value 0. Given that we have segregated our study area from grid connected area, electricity at household comes from MHP.

the boundary of multiple VDC's can supply electricity in more than one VDC. The first stage equation takes the following form:

$$E_{ihvt} = c_1 + \beta(Z_{vt}) + \delta_t + \gamma_v + X'_{ihvt}\theta + \epsilon_{hivt} \quad (2)$$

where  $E_{ihvt}$  indicates whether the household has MHP electricity connection for individual  $i$  in household  $h$  living in VDC  $v$  in census year  $t$ . We indexed household level electrification status with individual  $i$  as we are analysing at the individual level. The instrument must be relevant and exogenous. At first, it is relevant to households access to electricity. A community within a VDC can get connected to MHP electricity if a VDC has MHP installed or connected from neighbouring villages. Further, households can get connected to the electricity only in the case if the community where the household is located has a connection to MHP electricity. The village-level MHP electrification indicator affects individual-level outcomes only through the household level electrification. The MHP is mainly designed for lighting purposes in households. Therefore, there is very little chance that VDC indicator affects individual outcomes the other way around.

Second, as discuss and used in Fujii and Shonchoy (2020), a community-level indicator can be used as a relevant IV for individual-level outcome variables that are private in nature. Education and employment are mostly private decisions of a household and individual. It is worth mentioning that Nepal did not have the provision of universal and compulsory education; households and individuals decide whether to enrol in school or not. MHP is designed to provide lighting solutions at the household level. Therefore, whatever education and employment gain we expect would be due to the changes in household members behaviour after access to MHP electricity and household and family-based business or enterprises activities. However, as the issue highlighted in Fujii and Shonchoy (2020), using a community-level indicator as an IV is debatable due to the non-random placement of MHP, a potential

concern of satisfying exclusion restriction. However, in our case, a VDC is a larger administrative boundary that can have several communities with MHP projects installed. Therefore, the severity of endogeneity substantially decreases in larger geographic areas (Dustmann and Preston, 2001). In our data set, a single VDC has up to 16 MHP projects installed. Therefore, a VDC level MHP indicator serves as a plausibly exogenous instrument for individual-level outcomes.

## **5. Results**

### **5.1 Access to electricity**

Nepal has made significant progress between 2001 and 2010 regarding the proportion of people with access to electricity, from 41% to 68% (details in Table 3). The access to electricity connection was uneven among the three social classes in 2001. For instance, one in two upper caste households had electricity connection compared to only one in five in the lower caste population. The gap becomes a bit narrower in 2011 (though still big), with an average of 69% upper-caste and 52% lower caste. The access to electricity for middle caste people was similar to national average in 2001(41%) and slightly higher than national average in 2011(70%).

The access to electricity is far below in off-grid locations served by MHP. In this area, only 8% of people had access to electricity in 2001, increasing to 27% in 2011. Middle caste people had the biggest share with 12% of MHP electrified households in 2001, which increased by 24% increment to reach 36% in 2011. In 2001, 7% of upper caste households were connected to MHP electricity which increased to 23% in 2011. Only 5% lower caste had access to electricity in 2001, which levelled up with upper caste in 2011.

### **5.2 Effects on education**

This section reports the estimated effect on educational outcomes, including heterogeneous impact by gender and caste. Results are presented in Table 4-6. In each table, OLS results are

reported in columns 1, 3 and 5 for all samples, male subsample and female subsample, respectively. Their corresponding instrumental variable (IV) results are presented in columns 2, 4 and 6. In all instrumental variable specifications, the first stage F-statistics is sufficiently larger than 16.38 (critical value at 10% maximal IV size), which provides evidence of no weak correlation with the control variable at the 10% maximal IV size (Stock and Yogo, 2005)<sup>6</sup>. In all specifications, we control for individual and household level covariates. We also add census year fixed effect to account for unobservables those were common for both electrified and non-electrified households in both census years, and VDC fixed effects to account unobservables at VDC.

Table 4 reports the results for years of education. Both OLS and IV results consistently point towards positive and significant effects of MHP on years of education for school-aged children. The IV result indicates that, on average school-aged children from electrified households are likely to have 0.39 additional years of schooling. The impact is almost similar among the male and female sub-samples. In panels B, C and D, we investigate the heterogeneous impacts in different sub-samples based on their caste classification. The impact is more evident in lower caste males and females, both likely to have an additional year of education. Similarly, middle castes are likely to have additional 0.55 years of schooling and are mainly driven by the female sub-sample (0.76). However, we do not find a significant effect in the upper-caste sub-sample.

In Table 5, we report the estimated coefficients of zscore of school-aged children. Likewise, with respect to the impacts on years of schooling, we also find a positive effect on the z-score. It is mainly driven by the positive effect of lower caste males and females. The result suggests that MHP electricity positively impacts the school-aged children to complete

---

<sup>6</sup> The first stage results are reported in Table A2.

their school on time, reducing the dropout rate and reduces education stunting. Therefore, MHP potentially helping students belonging to lower caste move away from cumulative lagging behind in education.

Table 6 presents the impacts on adult literacy. Household's electrification access positively affects the adult literacy rate irrespective of their gender and caste. The effect is higher for females (15 percentage points) compared to males (11 percentage points). Regarding the effects in caste subsamples, the impact is higher in lower caste as compared to higher and middle caste. Similarly, the effect is more pronounced among lower caste males (29 percentage points) comparing to middle caste (11 percentage points). It is also true for the female subsample.

### 5.3 Effects on employment outcomes

The results for employment market outcomes are presented in Table 7 to Table 10 for all sample, upper-caste, middle-caste and lower-caste sub-samples, respectively. Results from Table 7 indicate the labour shift from traditional sectors such as agriculture to modern salaried jobs and manufacturing. The results from the top panel show that the likelihood of males working in agriculture decreases, whereas the likelihood of working in salaried jobs increases for both males and females. This indicates potential labour shifts from traditional subsistence agriculture that is in practice in rural Nepal for a long time to modern salaried jobs. However, we do not find any significant effects on own business and household chores related works. In the middle panel, we present the result on employment status. People from households with access to MHP are more likely to be an employee. The results also indicate that males are less likely to be an employer and more likely to be an employee. In the bottom panel, we estimated the result for the working industry. Results indicate that males from MHP electrified

households are less likely to work in the agro-forestry and hotel-restaurant industry and more likely to work in manufacturing.

In table 8, we report the result in the upper-caste sub-sample. The results are in line with our main results in table 7.. For instance, upper-caste males are more likely to work (15.4 percentage points) in salaried jobs comparing to their counterparts. The results also indicate that the impact on owning a business increases for both upper-caste males and females. Similarly, both males and females are more likely to be an employee and less likely to be an employer (middle panel). In the bottom panel, males are more likely to work in the manufacturing industry and trade and are less likely to work in the hotel and restaurant industry. In Table 9, we present the results for the middle caste sub-sample. Both middle-caste males and females from MHP electrified households are less likely to work in the agriculture sector and are more likely to work in salaried jobs. However, the impact on owning a business declines for both middle-caste males and females. Results from the bottom panel indicate that middle caste males are less likely to work in the agro-forestry industry, trade, and hotel restaurants and more likely to work in the manufacturing industry. Similarly, middle caste females are less likely to work in the hotel-restaurant industry and more likely to work in manufacturing. The remaining IV coefficients are not statistically different to zero. In Table 10, we offer the results for the lower caste sub-sample. The results indicate that lower caste males from MHP electrified households are more likely to work in salaried jobs, while the effects on other labour outcomes are imprecisely estimated.

#### 5.4 Behavioral changes

Throughout the paper, we assume that the gain in educational attainment and labour shifts are resulted from the time use behaviour changes at households after having access to MHP. We attempt to estimate the impact of MHP on the time use pattern of household members. We rely

on two proxies regarding the behavioural changes related to the educational attainment of school-aged children. First, both the 2001 and 2011 census data contain information on whether the study was the usual activity in the past 12 months for an individual aged more than ten years. Second, the census of 2011 provides information on the total months spent on the study in the past 12 months for individuals older than ten years. We estimate the effect of households having access to electricity on both variables for those aged 10 or above and less than 18. The IV results for both variables are reported in Table 11 (columns 1-3 for study as usual activity and 4-6 for study months). The results indicate that 10–18-year aged males from MHP electrified households are more likely to claim ‘study’ as their usual activity. The results indicate a significant effect on study months for females, consistent with the main estimates for educational outcomes. These estimates are evidence of time-shift behaviour among females in electrified households. This is typically important in a Nepalese society where girls and women should bear more responsibility for tedious household chores activities that require a significant amount of time.

Further, we investigate the time use pattern for all adults aged 15 years and older. The results are reported in Table 12. Overall, results indicate the changes in time use behaviour from agriculture and household chores to salaried works, which further supports our results for employment related outcomes. However, results from this section should be interpreted cautiously due to two reasons. First, we have excluded the school-aged sample (aged 6-9) in Table 11 as the census questions were asked only to those at least 10 years older during the census. Second, both outcomes are retrospective and can have recall bias, and time use data are measured in the month, which may not precisely capture the daily activities.



## 5.5 Robustness

We perform three robustness tests. At first, the public investment during 2001 and 2010 that target to improve educational quality may confound our educational outcomes. To check this possible confounder, we collect the data on the secondary level student-teacher ratio (STR) at the district level from the Department of Education, Nepal. Given that the government agency that looks after the school education in Nepal is the District Education Office, the district-level STR ratio captures the possible changes in the quality of education at that district. We observe a large variation in STR during 2001 and 2011 across districts (mean STR in 2001 was 24, whereas it was 18 in 2011). We estimate the effects on years of education and education z-score those are likely to be affected by changes in the education quality. The results are reported in Table A3. The results are not different to our original estimates from Tables 4, 5 and 6.

Second, we exclude the district headquarters from our sample to check the sensitivity of our results. The district headquarters are the places with relatively larger scale economic activities. District headquarters have the MHP with relatively higher capacity and for a longer time which were mainly installed by Nepal Electricity Authority. The results are reported in Table A4 for both educational and employment outcomes for each sample. Overall, the results are not different to our original estimates indicating that our results are not sensitive to economic opportunities at district headquarters.

Finally, we perform a placebo test to ensure that our results are not driven by coincidence. We drop all electrified households from our sample, and then we randomly assigned approximately 8% and 28% of households (corresponding individuals) from 2001 and 2011 as placebo. The assigned placebos are from the VDC's that had MHP. By doing this, we can also test the validity of our IV. If MHP affects individual-level welfare outcomes other than through household electrification, perhaps we could see these effects in other individuals

without access to electricity from the same VDC. We repeat this procedure 500 times for each outcome variable and report the percentage that we fail to reject the null hypothesis of placebo coefficient -- that is the coefficient is different to zero at the conventional 5% level. Results are reported in Table A5. In most cases, we could not reject the null hypothesis that the coefficients of placebo are different from zero. Only for two employment related outcomes (out of 14), we reject the null hypothesis relatively higher proportion of time. We further investigated the magnitude of the estimated coefficients of these two variables and found that each time coefficients were close to zero. Hence, we get confidence that our results are driven by household access to MHP electricity.

## **6. Discussions and Conclusion**

We study the impact of a decentralized energy system (DES) on educational attainment and labour market outcomes of both dominant and marginalized groups in Nepal. The result shows that household's access to MHP electricity positively affects the educational attainments as indicated by adult literacy, years of schooling and education z-score of school-aged children. The result also indicates that the positive impacts on education are more evident among girls and lower caste individuals, contributing to gender empowerment and social equity. We further find the positive effects of the labour shift from the traditional agriculture sector to salaried jobs. However, these labour shift effects are more evident for upper caste individuals and males. The result highlights MHP as a potential off-grid electricity solution that improves educational attainment among marginalized groups in rural Nepal and is perhaps applicable to countries facing similar challenges.

This study finds evidence that DES positively affects the educational attainment of school-aged children from the lower caste, helping to reduce inequality among ethnic groups; development planners should think of DES as a sustainable solution to those areas. Therefore, a properly coordinated and planned approach will help in minimizing such resource wastes.

Similarly, we find some shreds of evidence of labour shift from traditional to modern sectors, though the effects are mainly concentrated in the dominant groups. Given that the capacity of MHP is not enough to power a sizeable industry, impacts on employment related outcomes are not that strong and evenly distributed across social classes. This is another area that planners should think about MHP beyond household access to energy making it a ultimate energy solution in remote and rural areas.

Additionally, in remote areas with scattered populations, hard infrastructure projects such as additional school are not only costly but also less feasible. Therefore, interventions that reduce drop-out rates and increase educational outcomes with other measures are desirable. Our study highlight DES can be one of such interventions that helps to change the behaviour through providing longer lighted hours. However, only dominant groups (dominant caste and male) are successfully utilizing those extra lighted hours in productive works. This triggers policy makers for other complementary conditions so that disadvantaged groups and female can shift labour to productive sector and narrow-down the employment outcomes gap.

## References

- AKLIN, M., BAYER, P., HARISH, S. & URPELAINEN, J. 2017. Does basic energy access generate socioeconomic benefits? A field experiment with off-grid solar power in India. *Science advances*, 3, e1602153.
- ALSTONE, P., GERSHENSON, D. & KAMMEN, D. M. 2015. Decentralized energy systems for clean electricity access. *Nature Climate Change*, 5, 305-314.
- ARNAIZ, M., COCHRANE, T., HASTIE, R. & BELLEN, C. 2018. Micro-hydropower impact on communities' livelihood analysed with the capability approach. *Energy for Sustainable Development*, 45, 206-210.
- BENNETT, L., TAMANG, S., ONTA, P. & THAPA, M. 2006. Unequal citizens: Gender, caste and ethnic exclusion in Nepal. *Department for International Development and The World Bank, Kathmandu*.
- BHARADWAJ, B., DENDUP, N., PATTANAYAK, S. K. & ASHWORTH, P. 2021. Impacts of Solar Subsidy: Evidence from Geographic Regression Discontinuity Design in Nepal.
- BISTA, D. B. 1991. *Fatalism and development: Nepal's struggle for modernization*, Orient Blackswan.
- BRIDGE, B. A., ADHIKARI, D. & FONTENLA, M. 2016. Household-level effects of electricity on income. *Energy Economics*, 58, 222-228.
- BURLIG, F. & PREONAS, L. 2016. Out of the darkness and into the light? development effects of rural electrification. *Energy Institute at Haas WP*, 268, 26.
- CAI, Z., MAGUIRE, K. & WINTERS, J. V. 2019. Who benefits from local oil and gas employment? Labor market composition in the oil and gas industry in Texas and the rest of the United States. *Energy Economics*, 84, 104515.
- CHURCHILL, S. A. & SMYTH, R. 2020. Ethnic diversity, energy poverty and the mediating role of trust: Evidence from household panel data for Australia. *Energy Economics*, 86, 104663.
- CROMWELL, G. 1992. What makes technology transfer? Small-scale hydropower in Nepal's public and private sectors. *World Development*, 20, 979-989.
- DAHAL, D. R. 2003. Social composition of the population: caste/ethnicity and religion in Nepal. *Population monograph of Nepal*, 1, 87-135.
- DAS, I., KLUG, T., KRISHNAPRIYA, P., PLUTSHACK, V., SAPARAPA, R., SCOTT, S., SILLS, E. & JEULAND, M. 2020. A VIRTUOUS CYCLE? Reviewing the evidence on women's empowerment and energy access, frameworks, metrics and methods. <https://energyaccess.duke.edu/publication/a-virtuous-cycle-reviewing-the-evidence-on-womens-empowerment-and-energy-access-frameworks-metrics-and-methods/>.
- DINKELMAN, T. 2011. The effects of rural electrification on employment: New evidence from South Africa. *American Economic Review*, 101, 3078-3108.
- DONALDSON, D. 2018. Railroads of the Raj: Estimating the impact of transportation infrastructure. *American Economic Review*, 108, 899-934.
- DUFLO, E. 2001. Schooling and labor market consequences of school construction in Indonesia: Evidence from an unusual policy experiment. *American economic review*, 91, 795-813.
- DUFLO, E. & PANDE, R. 2007. Dams. *The Quarterly Journal of Economics*, 122, 601-646.
- DUSTMANN, C. & PRESTON, I. 2001. Attitudes to ethnic minorities, ethnic context and location decisions. *The Economic Journal*, 111, 353-373.
- ESTACHE, A. 2010. A survey of impact evaluations of infrastructure projects, programs and policies. *European Centre for Advanced Research in Economics (ECARES) Working Paper*, 5, 2010.
- FUJII, T. & SHONCHOY, A. S. 2020. Fertility and rural electrification in Bangladesh. *Journal of Development Economics*, 143, 102430.
- GREENE, W. 2004. The behaviour of the maximum likelihood estimator of limited dependent variable models in the presence of fixed effects. *The Econometrics Journal*, 7, 98-119.
- GRIMM, M., LENZ, L., PETERS, J. & SIEVERT, M. 2020. Demand for off-grid solar electricity: Experimental evidence from Rwanda. *Journal of the Association of Environmental and Resource Economists*, 7, 417-454.

- GRIMM, M., MUNYEHIRWE, A., PETERS, J. & SIEVERT, M. 2017. A first step up the energy ladder? Low cost solar kits and household's welfare in rural Rwanda. *The World Bank Economic Review*, 31, 631-649.
- GROGAN, L. 2018. Time use impacts of rural electrification: Longitudinal evidence from Guatemala. *Journal of Development Economics*, 135, 304-317.
- INTERNATIONAL ENERGY AGENCY, I. E. A. & WORLD BANK, W. B. 2014. *Sustainable Energy for All 2013-2014: Global Tracking Framework Report*, The World Bank.
- ISLAR, M., BROGAARD, S. & LEMBERG-PEDERSEN, M. 2017. Feasibility of energy justice: Exploring national and local efforts for energy development in Nepal. *Energy Policy*, 105, 668-676.
- JEULAND, M., FETTER, T. R., LI, Y., PATTANAYAK, S. K., USMANI, F., BLUFFSTONE, R. A., CHÁVEZ, C., GIRARDEAU, H., HASSEN, S. & JAGGER, P. 2021. Is energy the golden thread? A systematic review of the impacts of modern and traditional energy use in low-and middle-income countries. *Renewable and Sustainable Energy Reviews*, 135, 110406.
- KANAGAWA, M. & NAKATA, T. 2008. Assessment of access to electricity and the socio-economic impacts in rural areas of developing countries. *Energy policy*, 36, 2016-2029.
- KIRUBI, C., JACOBSON, A., KAMMEN, D. M. & MILLS, A. 2009. Community-based electric micro-grids can contribute to rural development: evidence from Kenya. *World development*, 37, 1208-1221.
- KUMAR, P., YAMASHITA, T., KARKI, A., RAJSHEKAR, S., SHRESTHA, A. & YADAV, A. 2015. Nepal-Scaling up electricity access through mini and micro hydropower applications: a strategic stock-taking and developing a future roadmap. The World Bank.
- KUMAR SEDAI, A., JAMASB, T., NEPAL, R. & MILLER, R. 2021. Electrification and Welfare for the Marginalized: Evidence from India. *Energy Economics*, 102.
- LAM, N. L., SMITH, K. R., GAUTHIER, A. & BATES, M. N. 2012. Kerosene: a review of household uses and their hazards in low-and middle-income countries. *Journal of Toxicology and Environmental Health, Part B*, 15, 396-432.
- LEE, K., MIGUEL, E. & WOLFRAM, C. 2020. Experimental evidence on the economics of rural electrification. *Journal of Political Economy*, 128, 1523-1565.
- LIPSCOMB, M., MOBARAK, A. M. & BARHAM, T. 2013. Development effects of electrification: Evidence from the topographic placement of hydropower plants in Brazil. *American Economic Journal: Applied Economics*, 5, 200-231.
- LITZOW, E. L., PATTANAYAK, S. K. & THINLEY, T. 2019. Returns to rural electrification: Evidence from Bhutan. *World Development*, 121, 75-96.
- MEEKS, R., THOMPSON, H. F. & WANG, Z. 2021. Electrification to Grow Manufacturing? Evidence from Nepal.
- MÜLLER, M. F., THOMPSON, S. E. & GADGIL, A. J. 2018. Estimating the price (in) elasticity of off-grid electricity demand. *Development Engineering*, 3, 12-22.
- MURNI, S., WHALE, J., URMEE, T., DAVIS, J. & HARRIES, D. 2013. Learning from experience: A survey of existing micro-hydropower projects in Ba'Kelalan, Malaysia. *Renewable energy*, 60, 88-97.
- NARULA, K., NAGAI, Y. & PACHAURI, S. 2012. The role of Decentralized Distributed Generation in achieving universal rural electrification in South Asia by 2030. *Energy Policy*, 47, 345-357.
- ORAZEM, P. F. & KING, E. M. 2007. Schooling in developing countries: The roles of supply, demand and government policy. *Handbook of development economics*, 4, 3475-3559.
- PELZ, S., CHINDARKAR, N. & URPELAINEN, J. 2021. Energy access for marginalized communities: Evidence from rural north India, 2015–2018. *World Development*, 137, 105204.
- POYER, D. A., HENDERSON, L. & TEOTIA, A. P. 1997. Residential energy consumption across different population groups: comparative analysis for Latino and non-Latino households in USA. *Energy Economics*, 19, 445-463.
- STOCK, J. H. & YOGO, M. 2005. Testing for weak instruments in linear IV regression. *Identification and inference for econometric models: Essays in honor of Thomas Rothenberg*, 80, 1.

- THOMAS, D. R., HARISH, S., KENNEDY, R. & URPELAINEN, J. 2020. The effects of rural electrification in India: An instrumental variable approach at the household level. *Journal of Development Economics*, 146, 102520.
- THORAT, A., VANNEMAN, R., DESAI, S. & DUBEY, A. 2017. Escaping and falling into poverty in India today. *World development*, 93, 413-426.
- UN. 2020. *The 17 Goals* [Online]. Available: <https://sdgs.un.org/goals> [Accessed].
- UNESCAP 2013. Partnership for Universal Access to Modern Energy Services.
- VAN DE WALLE, D., RAVALLION, M., MENDIRATTA, V. & KOOLWAL, G. 2017. Long-term gains from electrification in rural India. *The World Bank Economic Review*, 31, 385-411.
- WAGNER, N., RIEGER, M., BEDI, A. S., VERMEULEN, J. & DEMENA, B. A. 2021. The impact of off-grid solar home systems in Kenya on energy consumption and expenditures. *Energy Economics*, 99, 105314.
- WB. 2015. The World Bank. Available: <https://www.worldbank.org/en/news/feature/2015/09/15/micro-hydros-earn-first-carbon-revenue-in-nepal> [Accessed].
- WORLD BANK, W. B. 2021. The World Bank. Available: <https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS> [Accessed July 2 2021].

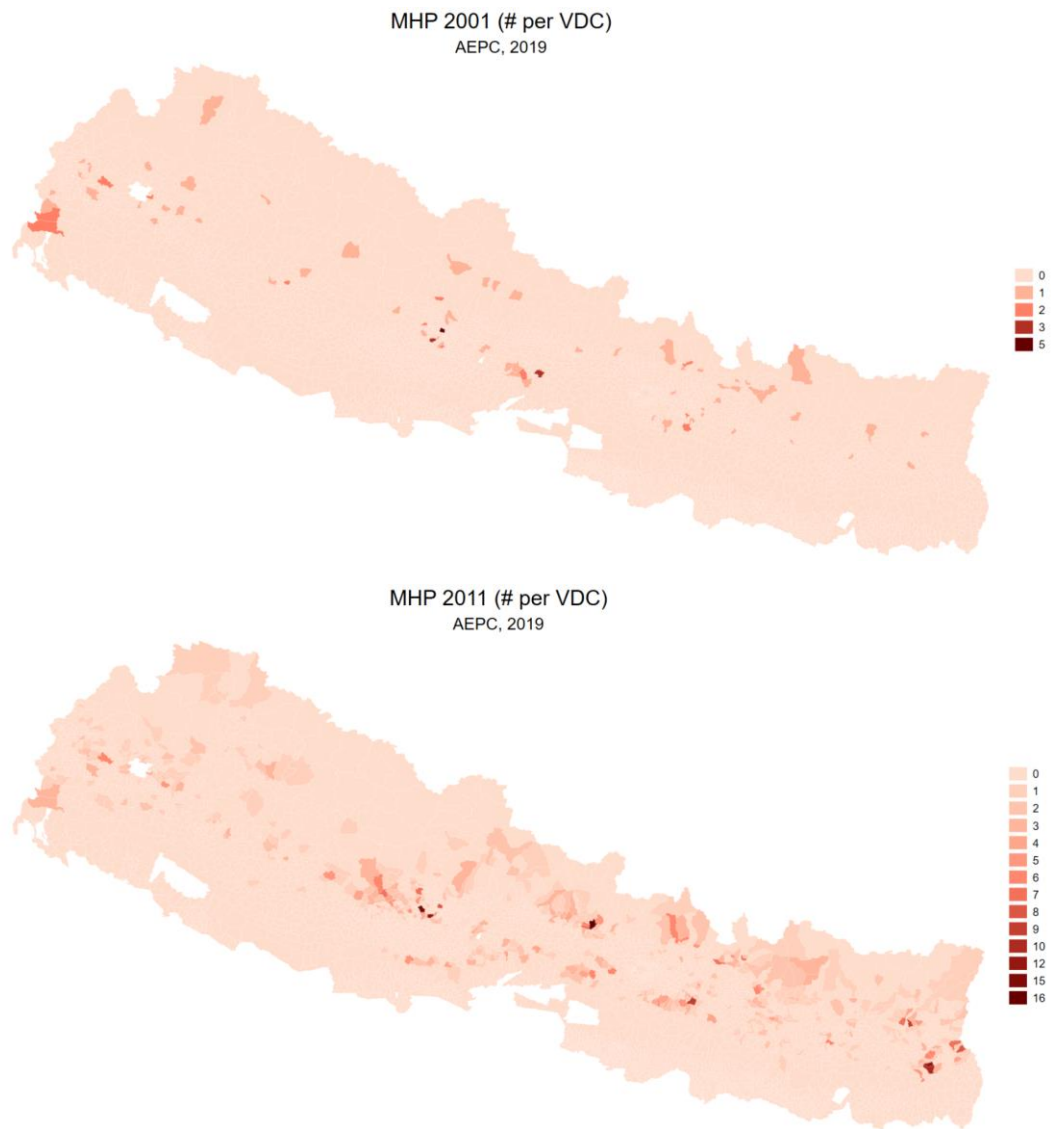


Figure 1: Number of MHP at Village Development Committee (VDC) in 2001 and 2011. MHP installation data is taken from Alternative Energy Promotion Centre (AEPC), Nepal.

## Tables

Table 1: Descriptive Statistics (Education)

Variables	HHS with electricity				HHS without electricity			
	2001		2011		2001		2011	
	N	Mean	N	Mean	N	Mean	N	Mean
<b>All</b>								
Years of schooling	8913	3.24	55469	4.13	106235	2.20	156893	3.57
Z-score	8913	.089	55469	-0.20	106235	-0.32	156893	-0.37
Adult literacy	17355	0.53	97136	0.63	168725	0.35	236565	0.51
<b>Male</b>								
Years of schooling	4488	3.48	27324	4.17	53841	2.64	77293	3.74
Z-score	4488	0.014	27324	-0.18	53841	-0.30	77293	-0.32
Adult literacy	8828	0.69	44246	0.77	80496	0.52	108949	0.69
<b>Female</b>								
Years of schooling	4425	2.99	28145	4.10	52394	1.74	79600	3.41
Z-score	4425	0.17	28145	-0.21	52394	-0.33	79600	-0.43
Adult literacy	8527	0.37	52890	0.51	88229	0.19	127616	0.36

Note: Author's calculation using National Population and Housing Census 2001 and 2011 data.



Table 2: Descriptive Statistics (Employment)

Variables	HHS with electricity				HHS without electricity			
	2001		2011		2001		2011	
	N	Mean	N	Mean	N	Mean	N	Mean
<b>Panel A: Usual activity</b>								
Agriculture	17355	0.51	97136	0.64	168725	0.72	236565	0.73
Salaried	17355	0.17	97136	0.23	168725	0.06	236565	0.19
Own business	17355	0.09	97136	0.19	168725	0.03	236565	0.18
Household chores	17355	0.06	97136	0.43	168725	0.06	236565	0.49
<b>Employment</b>								
Employee	17355	0.19	97136	0.15	168725	0.07	236565	0.10
Employer	17355	0.02	97136	0.01	168725	0.02	236565	0.01
Family worker	17355	0.09	97136	0.02	168725	0.05	236565	0.01
<b>Working industry</b>								
Agro-forestry	17355	0.57	97136	0.58	168725	0.78	236565	0.68
Manufacturing	17355	0.05	97136	0.02	168725	0.04	236565	0.02
Trade	17355	0.05	97136	0.03	168725	0.02	236565	0.02
Hotel, restaurant	17355	0.03	97136	0.02	168725	0.002	236565	0.004

Note: Author's calculation using National Population and Housing Census 2001 and 2011 data.

Table 3: Access to electricity by census year and caste

	2001			2011		
	All	Male	Female	All	Male	Female
<b>Nepal</b>						
All	0.41	0.41	0.40	0.68	0.68	0.68
Upper caste	0.49	0.50	0.48	0.69	0.69	0.69
Middle caste	0.41	0.41	0.40	0.70	0.70	0.70
Lower caste	0.19	0.19	0.19	0.52	0.51	0.52
<b>MHP Area</b>						
All	0.08	0.09	0.08	0.27	0.27	0.28
Upper caste	0.07	0.07	0.07	0.23	0.23	0.23
Middle caste	0.12	0.12	0.12	0.36	0.36	0.36
Lower caste	0.05	0.05	0.05	0.23	0.23	0.23

**Note:** Author's calculation using National Population and Housing Census 2001 and 2011 data.

Table 4: Impact of MHP electricity on education

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Years of education					
	OLS	IV	OLS	IV	OLS	IV
<b>Panel A: All</b>	All		Male		Female	
Electricity	0.186*** (0.019)	0.387** (0.170)	0.179*** (0.022)	0.397** (0.199)	0.195*** (0.023)	0.396** (0.201)
Observations	327,510	327,510	162,946	162,946	164,564	164,564
K-P F stat		330.4		300.2		328.5
<b>Panel B: Upper caste</b>						
Electricity	0.124*** (0.027)	0.044 (0.222)	0.118*** (0.031)	0.058 (0.266)	0.131*** (0.034)	0.018 (0.268)
Observations	159,403	159,403	79,585	79,585	79,780	79,780
K-P F stat		176.4		153.3		180.8
<b>Panel C: Middle caste</b>						
Electricity	0.185*** (0.026)	0.549* (0.301)	0.155*** (0.032)	0.325 (0.351)	0.222*** (0.032)	0.755** (0.359)
Observations	112,682	112,682	55,451	55,451	57,181	57,181
K-P F Stat		134.2		121.3		127.7
<b>Panel D: Lower caste</b>						
Electricity	0.228*** (0.043)	0.738* (0.409)	0.258*** (0.052)	1.002* (0.547)	0.185*** (0.055)	1.011** (0.512)
Observations	49,687	49,687	24,903	24,903	24,715	24,715
K-P F Stat		82.88		68.37		74.46
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: In all specifications, the dependent variable is years of education completed by school-aged children. Household control includes household ownership, household facilities: toilet, drinking water and television, family size and household members involvement in salaried jobs and anyone abroad from a household. Individual controls include age FE, marital status and relationship to households head. Robust standard errors in parentheses. Standard errors are clustered at the community (ward) level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 5: Impact of MHP electricity on z-score

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	z-score (school education)					
	OLS	IV	OLS	IV	OLS	IV
<b>Panel A: All</b>	<u>All</u>		<u>Male</u>		<u>Female</u>	
Electricity	0.093*** (0.010)	0.215** (0.090)	0.095*** (0.012)	0.302*** (0.107)	0.092*** (0.011)	0.121 (0.099)
Observations	327,510	327,510	162,946	162,946	164,564	164,564
K-P F stat		330.4		300.2		328.5
<b>Panel B: Upper caste</b>						
Electricity	0.063*** (0.014)	0.063 (0.118)	0.064*** (0.017)	0.207 (0.143)	0.063*** (0.016)	-0.073 (0.132)
Observations	159,403	159,403	79,585	79,585	79,780	79,780
K-P F stat		176.4		153.3		180.8
<b>Panel C: Middle caste</b>						
Electricity	0.093*** (0.013)	0.188 (0.156)	0.083*** (0.017)	0.171 (0.181)	0.105*** (0.015)	0.208 (0.172)
Observations	112,682	112,682	55,451	55,451	57,181	57,181
K-P F Stat		134.2		121.3		127.7
<b>Panel D: Lower caste</b>						
Electricity	0.114*** (0.022)	0.489** (0.215)	0.129*** (0.028)	0.542* (0.283)	0.091*** (0.027)	0.512** (0.248)
Observations	49,687	49,687	24,903	24,903	24,715	24,715
K-P F Stat		82.88		68.37		74.46
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: In all specifications, the dependent variable is the education Z-score of school-aged children. Household control includes household ownership, household facilities: toilet, drinking water and television, family size and household members involvement in salaried jobs and anyone abroad from a household. Individual controls include age FE, marital status and relationship to households head. Robust standard errors in parentheses. Standard errors are clustered at the community (ward) level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 6: Impact of MHP electricity on adult literacy

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Adult literacy					
	OLS	IV	OLS	IV	OLS	IV
<b>Panel A: All</b>	<u>All</u>		<u>Male</u>		<u>Female</u>	
Electricity	0.036*** (0.004)	0.117*** (0.026)	0.031*** (0.005)	0.105*** (0.036)	0.041*** (0.004)	0.156*** (0.029)
Observations	519,781	519,781	242,519	242,519	277,262	277,262
K-P F stat		350.4		325.2		357.8
<b>Panel B: Upper caste</b>						
Electricity	0.024*** (0.005)	0.048 (0.034)	0.014** (0.007)	0.005 (0.047)	0.033*** (0.005)	0.112*** (0.041)
Observations	252,335	252,335	119,545	119,545	132,744	132,744
K-P F stat		172.2		153.4		181.8
<b>Panel C: Middle caste</b>						
Electricity	0.033*** (0.005)	0.112*** (0.040)	0.040*** (0.006)	0.147*** (0.055)	0.030*** (0.005)	0.112** (0.044)
Observations	188,219	188,219	86,465	86,465	101,689	101,689
K-P F Stat		171.7		168.3		164.5
<b>Panel D: Lower caste</b>						
Electricity	0.049*** (0.008)	0.232*** (0.071)	0.026** (0.012)	0.246** (0.107)	0.068*** (0.009)	0.286*** (0.073)
Observations	69,827	69,827	31,966	31,966	37,820	37,820
K-P F Stat		90.93		80.78		92.16
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: In all specifications, the dependent variable is adult literacy. Household control includes household ownership, household facilities: toilet, drinking water and television, family size and household members involvement in salaried jobs and anyone abroad from a household. Individual controls include age FE, marital status and relationship to households head. Robust standard errors in parentheses. Standard errors are clustered at the community (ward) level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 7: Impact on employment outcomes (All sample)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
	<u>All</u>		<u>Male</u>		<u>Female</u>	
<b><u>Usual activity</u></b>						
Agriculture	-0.015*** (0.003)	-0.028 (0.035)	-0.013*** (0.004)	-0.062* (0.034)	-0.017*** (0.004)	-0.003 (0.049)
Salaried job	0.003 (0.004)	0.142*** (0.027)	0.011** (0.006)	0.308*** (0.041)	0.002 (0.003)	0.038* (0.022)
Own Business	-0.009** (0.004)	0.046 (0.040)	-0.008 (0.005)	0.037 (0.044)	-0.008* (0.005)	0.067 (0.042)
Households Chores	0.005 (0.004)	0.025 (0.046)	-0.012** (0.005)	-0.005 (0.050)	0.009* (0.005)	-0.042 (0.056)
<b><u>Employment status</u></b>						
Employee	0.000 (0.002)	0.030* (0.018)	0.006 (0.004)	0.064** (0.027)	-0.001 (0.002)	0.019 (0.014)
Employer	-0.002** (0.001)	-0.017 (0.010)	-0.002 (0.001)	-0.019* (0.011)	-0.002** (0.001)	-0.014 (0.012)
Family worker	0.005*** (0.002)	-0.001 (0.022)	0.002 (0.001)	0.005 (0.015)	0.008*** (0.002)	-0.008 (0.033)
<b><u>Working Industry</u></b>						
Agro-forestry	-0.013*** (0.003)	-0.020 (0.032)	-0.014*** (0.004)	-0.054 (0.033)	-0.015*** (0.004)	-0.010 (0.044)
Manufacturing	0.002* (0.001)	0.022* (0.012)	0.003** (0.002)	0.031** (0.012)	0.003* (0.001)	0.020 (0.017)
Trade	0.004*** (0.001)	-0.013 (0.011)	0.002 (0.002)	-0.001 (0.011)	0.005*** (0.001)	-0.022 (0.017)
Hotel, restaurant	-0.001 (0.001)	-0.014*** (0.004)	-0.002 (0.001)	-0.015*** (0.005)	0.000 (0.001)	-0.013*** (0.005)
Observations	519,781	519,781	242,519	242,519	277,262	277,262
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes
K-P F Statistics		350.5		324.0		357.3

Each coefficients represent the coefficients for electrification status. Variables list represent the outcome variable. Robust standard errors in parentheses. Standard errors are clustered at ward level.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 8: Impact on employment outcomes (Upper caste)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
	<u>All</u>		<u>Male</u>		<u>Female</u>	
<b><u>Usual activity</u></b>						
Agriculture	-0.015*** (0.005)	0.053 (0.047)	-0.015*** (0.006)	0.035 (0.046)	-0.016*** (0.005)	0.071 (0.067)
Salaried job	-0.004 (0.005)	0.154*** (0.035)	0.000 (0.008)	0.327*** (0.057)	-0.003 (0.004)	0.036 (0.028)
Own Business	-0.009 (0.007)	0.180*** (0.057)	-0.002 (0.007)	0.202*** (0.062)	-0.014* (0.007)	0.173*** (0.061)
Households Chores	0.005 (0.006)	0.036 (0.061)	-0.010 (0.007)	0.065 (0.068)	0.010 (0.007)	-0.068 (0.076)
<b><u>Employment status</u></b>						
Employee	-0.003 (0.003)	0.038** (0.019)	0.002 (0.005)	0.063* (0.034)	-0.006*** (0.002)	0.030** (0.013)
Employer	-0.004*** (0.001)	-0.049*** (0.016)	-0.003** (0.002)	-0.045*** (0.016)	-0.004** (0.002)	-0.053*** (0.018)
Family worker	-0.000 (0.002)	0.025 (0.028)	-0.001 (0.002)	0.019 (0.021)	0.000 (0.003)	0.031 (0.041)
<b><u>Working Industry</u></b>						
Agro-forestry	-0.011** (0.004)	-0.024 (0.042)	-0.013** (0.006)	-0.048 (0.043)	-0.011** (0.005)	-0.013 (0.058)
Manufacturing	0.002 (0.001)	0.012 (0.014)	0.005*** (0.002)	0.026** (0.012)	-0.000 (0.002)	0.003 (0.022)
Trade	0.003 (0.002)	0.020 (0.014)	0.003 (0.003)	0.038** (0.016)	0.003* (0.002)	0.006 (0.018)
Hotel, restaurant	0.002* (0.001)	-0.006 (0.004)	0.001 (0.001)	-0.010* (0.005)	0.002** (0.001)	-0.002 (0.004)
Observations	252,335	252,335	119,545	119,545	132,744	132,744
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes
K-P F Statistics		172.2		153.3		181.3

Each coefficients represent the coefficients for electrification status. Variables list represent the outcome variable. Robust standard errors in parentheses. Standard errors are clustered at ward level.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 9: Impact on employment outcomes (Middle caste)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
	<u>All</u>		<u>Male</u>		<u>Female</u>	
<b><u>Usual activity</u></b>						
Agriculture	-0.019*** (0.005)	-0.150*** (0.049)	-0.016*** (0.006)	-0.230*** (0.052)	-0.022*** (0.006)	-0.093 (0.070)
Salaried job	0.018*** (0.004)	0.169*** (0.036)	0.030*** (0.007)	0.342*** (0.059)	0.014*** (0.004)	0.070** (0.027)
Own Business	-0.005 (0.005)	-0.162*** (0.062)	-0.012* (0.007)	-0.220*** (0.074)	0.002 (0.006)	-0.104* (0.060)
Households Chores	0.015*** (0.006)	0.006 (0.063)	-0.003 (0.006)	-0.088 (0.073)	0.019*** (0.007)	-0.024 (0.079)
<b><u>Employment status</u></b>						
Employee	0.005* (0.003)	0.044* (0.025)	0.010** (0.005)	0.090** (0.040)	0.004* (0.002)	0.019 (0.019)
Employer	-0.002 (0.001)	0.004 (0.014)	-0.001 (0.002)	-0.009 (0.016)	-0.002 (0.001)	0.017 (0.016)
Family worker	0.012*** (0.003)	-0.035 (0.030)	0.006** (0.003)	-0.014 (0.021)	0.018*** (0.004)	-0.056 (0.047)
<b><u>Working Industry</u></b>						
Agro-forestry	-0.014*** (0.005)	-0.034 (0.048)	-0.011* (0.006)	-0.092* (0.052)	-0.018*** (0.006)	-0.006 (0.066)
Manufacturing	0.002 (0.002)	0.043*** (0.015)	0.001 (0.002)	0.037** (0.016)	0.003 (0.002)	0.050** (0.022)
Trade	0.004** (0.002)	-0.054** (0.022)	-0.002 (0.002)	-0.045** (0.019)	0.009*** (0.002)	-0.059* (0.036)
Hotel, restaurant	-0.005*** (0.002)	-0.034*** (0.009)	-0.007*** (0.002)	-0.032*** (0.009)	-0.003* (0.002)	-0.033*** (0.010)
Observations	188,219	188,219	86,465	86,465	101,689	101,689
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes
K-P F Statistics		172.3		168.3		165.0

Each coefficients represent the coefficients for electrification status. Variables list represent the outcome variable. Robust standard errors in parentheses. Standard errors are clustered at ward level.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1



Table 10: Impact on employment (Lower caste)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
	<u>All</u>		<u>Male</u>		<u>Female</u>	
<b><u>Usual activity</u></b>						
Agriculture	-0.007 (0.009)	-0.076 (0.104)	-0.003 (0.012)	-0.063 (0.119)	-0.011 (0.009)	-0.117 (0.123)
Salaried job	-0.014 (0.008)	0.066 (0.100)	-0.012 (0.012)	0.252* (0.132)	-0.009 (0.009)	-0.024 (0.097)
Own Business	-0.017** (0.009)	0.079 (0.095)	-0.018 (0.012)	0.068 (0.124)	-0.014 (0.009)	0.109 (0.091)
Households Chores	-0.001 (0.010)	0.023 (0.099)	0.000 (0.013)	-0.052 (0.108)	-0.010 (0.011)	-0.022 (0.125)
<b><u>Employment status</u></b>						
Employee	-0.001 (0.007)	-0.073 (0.093)	-0.000 (0.011)	-0.054 (0.120)	0.003 (0.006)	-0.045 (0.089)
Employer	-0.001 (0.002)	0.039 (0.030)	0.000 (0.003)	0.045 (0.037)	-0.003 (0.003)	0.034 (0.032)
Family worker	0.001 (0.003)	0.010 (0.040)	-0.001 (0.003)	0.016 (0.034)	0.004 (0.003)	0.002 (0.057)
<b><u>Working Industry</u></b>						
Agro-forestry	-0.009 (0.008)	-0.005 (0.090)	-0.014 (0.012)	-0.036 (0.113)	-0.010 (0.009)	-0.035 (0.110)
Manufacturing	0.008* (0.005)	0.010 (0.052)	0.009 (0.008)	0.081 (0.079)	0.010** (0.004)	-0.019 (0.054)
Trade	0.003* (0.002)	0.007 (0.018)	0.003 (0.003)	0.010 (0.025)	0.004* (0.002)	0.011 (0.024)
Hotel, restaurant	0.001 (0.001)	0.004 (0.004)	0.001 (0.001)	0.003 (0.008)	0.001 (0.001)	0.005 (0.004)
Observations	69,827	69,827	31,966	31,966	37,820	37,820
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes
K-P F Statistics		90.79		80.67		91.90

Each coefficients represent the coefficients for electrification status. Variables list represent the outcome variable. Robust standard errors in parentheses. Standard errors are clustered at ward level.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 11: Impact of MHP on Study

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Study as usual activity			Study months		
	<u>All</u>	<u>Male</u>	<u>Female</u>	<u>All</u>	<u>Male</u>	<u>Female</u>
<b>All:</b>						
OLS	0.006* (0.004)	0.009** (0.004)	0.003 (0.005)	0.093** (0.042)	-0.034 (0.046)	0.221*** (0.053)
IV	0.141*** (0.046)	0.221*** (0.051)	0.065 (0.056)	-0.062 (0.153)	-0.595*** (0.158)	0.468** (0.199)
Observations	212,724	105,529	107,195	138,517	67,932	70,585
<b>Upper caste:</b>						
OLS	-0.015*** (0.005)	-0.010* (0.005)	-0.021*** (0.007)	0.026 (0.058)	-0.078 (0.061)	0.138* (0.074)
IV	0.011 (0.057)	0.104 (0.064)	-0.080 (0.070)	-0.330* (0.189)	-0.766*** (0.192)	0.136 (0.255)
Observations	102,812	51,158	51,616	68,308	33,657	34,651
<b>Middle caste:</b>						
OLS	0.029*** (0.006)	0.022*** (0.007)	0.035*** (0.007)	0.223*** (0.065)	0.066 (0.073)	1.029*** (0.350)
IV	0.404*** (0.085)	0.430*** (0.095)	0.362*** (0.103)	0.687** (0.276)	0.290 (0.279)	1.029*** (0.350)
Observations	74,533	36,561	37,931	45,781	22,096	23,685
<b>Lower caste:</b>						
OLS	-0.007 (0.009)	0.008 (0.012)	-0.020 (0.013)	0.259*** (0.091)	0.218** (0.104)	0.307** (0.123)
IV	0.066 (0.114)	0.162 (0.151)	0.078 (0.150)	0.572* (0.296)	-0.114 (0.339)	1.305*** (0.430)
Observations	31,804	15,903	15,788	23,465	11,693	11,772
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes			
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table reports results for two outcome variables. In columns (1)-(3), variable is study as usual activity. In columns (4)-(6) dependent variable is study months. The sample includes children aged 10 years and above and less than 18 years. For study months, only data of 2011 are included. Household control includes household ownership, household facilities: toilet, drinking water and television, family size and household members involvement in salaried jobs and anyone abroad from a household. Individual controls include age FE, marital status and relationship to the household head. Robust standard errors in parentheses. Standard errors are clustered at the community (ward) level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 12: Yearly Time Use

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Months Spent in a Year											
	All	Upper caste			Middle caste			Lower caste				
	All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female
<b><u>Agriculture</u></b>												
OLS	-0.051 (0.065)	-0.149* (0.077)	0.013 (0.069)	-0.086 (0.085)	-0.186* (0.100)	-0.037 (0.092)	-0.063 (0.092)	-0.238** (0.109)	0.079 (0.102)	-0.293** (0.142)	-0.425** (0.191)	-0.208 (0.154)
IV	0.315 (0.207)	0.109 (0.229)	0.442* (0.236)	0.107 (0.305)	-0.151 (0.328)	0.260 (0.352)	0.541** (0.255)	0.487* (0.295)	0.564* (0.293)	-0.477 (0.472)	-1.474*** (0.563)	0.285 (0.541)
<b><u>Salaried jobs</u></b>												
OLS	0.205*** (0.022)	0.350*** (0.038)	0.114*** (0.016)	0.163*** (0.030)	0.340*** (0.055)	0.075*** (0.023)	0.234*** (0.025)	0.390*** (0.044)	0.104*** (0.021)	0.384*** (0.061)	0.566*** (0.110)	0.265*** (0.044)
IV	0.397*** (0.058)	0.734*** (0.104)	0.195*** (0.040)	0.394*** (0.080)	0.752*** (0.149)	0.176*** (0.053)	0.293*** (0.066)	0.636*** (0.117)	0.059 (0.055)	0.869*** (0.191)	1.518*** (0.318)	0.467*** (0.148)
<b><u>Own business</u></b>												
OLS	0.078*** (0.025)	0.094*** (0.033)	0.074*** (0.023)	0.034 (0.033)	0.055 (0.043)	0.030 (0.032)	0.119*** (0.033)	0.108** (0.044)	0.128*** (0.032)	0.045 (0.044)	0.101 (0.072)	0.023 (0.036)
IV	0.136** (0.063)	0.146* (0.085)	0.160*** (0.058)	0.312*** (0.083)	0.344*** (0.111)	0.315*** (0.080)	-0.178* (0.108)	-0.270* (0.147)	-0.087 (0.093)	0.123 (0.125)	0.293 (0.196)	0.069 (0.110)
<b><u>Household chores</u></b>												
OLS	-0.126*** (0.027)	-0.120*** (0.020)	-0.167*** (0.041)	-0.111*** (0.037)	-0.112*** (0.028)	-0.180*** (0.057)	-0.115*** (0.034)	-0.091*** (0.026)	-0.129** (0.052)	-0.139** (0.058)	-0.123** (0.049)	-0.196** (0.087)
IV	-0.237** (0.098)	-0.128 (0.084)	-0.462*** (0.149)	-0.077 (0.135)	0.027 (0.117)	-0.317 (0.203)	-0.464*** (0.124)	-0.367*** (0.107)	-0.612*** (0.188)	-0.009 (0.198)	0.172 (0.179)	-0.390 (0.304)
Observations	333,701	153,195	180,506	165,508	77,253	88,255	115,614	51,939	63,675	50,141	22,783	27,358
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VDC Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: For all specifications, the dependent variable is time spent in the past 12 months on work specified in the variable column. Samples are from population and housing census 2011. Household control includes household ownership, household facilities: toilet, drinking water and television, family size. Individual controls include age FE, education, marital status and relationship to the household head. Robust standard errors in parentheses. Standard errors are clustered at the community (ward) level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## Appendix

Table A1: Descriptive Statistics (Education) by Caste

Variables	HHS with electricity				HHS without electricity			
	2001		2011		2001		2011	
	N	Mean	N	Mean	N	Mean	N	Mean
<b>Panel A: Upper caste</b>								
Years of schooling	3535	3.35	23463	4.35	50150	2.41	82275	3.76
Z-score	3535	0.21	23463	-0.09	50150	-0.21	82275	-0.27
Adult literacy	6390	0.58	41061	0.65	80467	0.34	124447	0.53
<b>Male</b>								
Years of schooling	1810	3.69	11625	4.43	25478	2.96	40696	3.98
Z-score	1810	0.18	11625	-0.06	25478	-0.14	40696	-0.20
Adult literacy	3382	0.78	18972	0.82	38941	0.58	58281	0.73
<b>Female</b>								
Years of schooling	1725	2.98	11838	4.28	24672	1.84	41579	3.55
Z-score	1725	0.25	11838	-0.12	24672	-0.27	41579	-0.35
Adult literacy	3008	0.36	22089	0.50	41526	0.18	66166	0.35
<b>Panel B: Middle caste</b>								
Years of schooling	4615	3.31	23159	4.16	39729	2.22	45214	3.64
Z-score	4615	0.06	23159	-0.20	39729	-0.33	45214	-0.40
Adult literacy	9625	0.52	43052	0.64	63042	0.36	77562	0.55
<b>Male</b>								
Years of schooling	2304	3.49	11282	4.11	1979	2.53	21972	3.69
Z-score	2304	0.06	11282	-0.22	19979	-0.38	21972	-0.39
Adult literacy	4782	0.65	19420	0.76	29798	0.51	32519	0.68
<b>Female</b>								
Years of schooling	2311	3.14	11877	4.22	19750	1.91	23287	3.60
Z-score	2311	0.17	11877	-0.19	19750	-0.28	23287	-0.41
Adult literacy	4843	0.38	23632	0.55	33244	0.23	40043	0.44
<b>Panel D: Lower caste</b>								
Years of schooling	617	2.11	8476	3.46	12335	1.48	28275	2.92
Z-score	617	-0.35	8476	-0.46	12335	-0.61	28275	-0.63
Adult literacy	1027	0.34	12287	0.51	18670	0.21	37854	0.38
<b>Male</b>								
Years of schooling	310	2.26	4222	3.60	6329	1.90	14091	3.15
Z-score	301	-0.44	4222	-0.43	6329	-0.62	14091	-0.55
Adult literacy	491	0.45	5445	0.64	8715	0.34	17338	0.53
<b>Female</b>								
Years of schooling	316	1.97	4254	3.31	6006	1.04	14184	2.70
Z-score	316	-0.28	4254	-0.52	6006	-0.60	14184	-0.71
Adult literacy	536	0.24	6842	0.40	9955	0.09	20516	0.25

Table A2: First Stage Regression

VARIABLES	(1)	(2)	(3)
	Household access to electricity		
	All	Male	Female
MHP Indicator	0.135*** (0.007)	0.136*** (0.007)	0.134*** (0.007)
Observations	803,532	384,431	419,101
R-squared	0.498	0.502	0.496
Individual controls	Yes	Yes	Yes
Household controls	Yes	Yes	Yes
Age FE	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes

Note: For all specifications, the dependent variable is household access to electricity. Controls are similar to the main results. Robust standard errors in parentheses. Standard errors are clustered at the community (ward) level.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A3: Impact on education and education z-score (Robustness)

VARIABLES	(2)	(4)	(6)	Education z-score		
	All	Male	Female	All	Male	Female
<b>All:</b>						
OLS	0.201*** (0.019)	0.191*** (0.022)	0.215*** (0.023)	0.097*** (0.010)	0.097*** (0.012)	0.098*** (0.011)
IV	0.420** (0.172)	0.425** (0.203)	0.437** (0.204)	0.225** (0.092)	0.311*** (0.109)	0.134 (0.101)
Observations	327,510	162,946	164,564	327,510	162,946	164,564
<b>Upper caste:</b>						
OLS	0.152*** (0.028)	0.140*** (0.031)	0.167*** (0.034)	0.075*** (0.014)	0.073*** (0.017)	0.078*** (0.016)
IV	0.062 (0.216)	0.072 (0.264)	0.041 (0.260)	0.071 (0.115)	0.214 (0.142)	-0.064 (0.129)
	159,403	79,585	79,780	159,403	79,585	79,780
<b>Middle caste:</b>						
OLS	0.180*** (0.027)	0.154*** (0.032)	0.215*** (0.032)	0.088*** (0.013)	0.079*** (0.017)	0.098*** (0.015)
IV	0.549* (0.307)	0.326 (0.358)	0.753** (0.365)	0.181 (0.159)	0.166 (0.185)	0.201 (0.175)
	112,682	55,451	57,181	112,682	55,451	57,181
<b>Lower caste:</b>						
OLS	0.225*** (0.043)	0.264*** (0.052)	0.172*** (0.055)	0.110*** (0.022)	0.127*** (0.028)	0.085*** (0.027)
IV	0.736* (0.406)	0.979* (0.537)	1.011** (0.511)	0.489** (0.213)	0.537* (0.279)	0.512** (0.248)
	49,687	24,903	24,715	49,687	24,903	24,715
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: In this table, columns (1)-(3) dependent variable is years of education, and in column (4)-(6) Z-score of school-aged children. Household control includes household ownership, household facilities: toilet, drinking water and television, family size and household members involvement in salaried jobs and anyone abroad from the household. Individual controls include age FE, marital status and relationship to the household head. Robust standard errors in parentheses. Standard errors are clustered at the community (ward) level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Appendix Table A4: Effects on Educational and EOutcomes (excluding district headquarters)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
		All			Upper caste			Middle caste			Lower caste		
		All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female
<b>A. Education</b>													
a. Years of education													
OLS	0.172***	0.166***	0.180***	0.108***	0.102***	0.115***	0.164***	0.138***	0.198***	0.243***	0.282***	0.187***	
	(0.020)	(0.022)	(0.024)	(0.029)	(0.032)	(0.036)	(0.027)	(0.033)	(0.033)	(0.045)	(0.055)	(0.058)	
IV	0.316*	0.312	0.344*	0.000	0.001	-0.006	0.413	0.183	0.616*	0.781*	1.028*	1.055**	
	(0.170)	(0.200)	(0.202)	(0.222)	(0.267)	(0.268)	(0.311)	(0.364)	(0.370)	(0.400)	(0.530)	(0.505)	
Observations	314,717	156,517	158,200	152,353	75,981	76,334	109,351	53,822	55,480	47,572	23,856	23,647	
b. z-score													
OLS	0.087***	0.089***	0.085***	0.055***	0.056***	0.055***	0.085***	0.075***	0.095***	0.116***	0.138***	0.085***	
	(0.010)	(0.012)	(0.011)	(0.015)	(0.018)	(0.017)	(0.014)	(0.017)	(0.015)	(0.024)	(0.029)	(0.029)	
IV	0.181**	0.259**	0.098	0.041	0.182	-0.090	0.123	0.097	0.149	0.517**	0.554**	0.556**	
	(0.091)	(0.107)	(0.099)	(0.118)	(0.144)	(0.133)	(0.161)	(0.187)	(0.178)	(0.210)	(0.275)	(0.245)	
Observations	314,717	156,517	158,200	152,353	75,981	76,334	109,351	53,822	55,480	47,572	23,856	23,647	
c. Adult literacy													
OLS	0.030***	0.024***	0.035***	0.021***	0.008	0.032***	0.025***	0.033***	0.021***	0.041***	0.016	0.060***	
	(0.003)	(0.005)	(0.003)	(0.005)	(0.006)	(0.005)	(0.004)	(0.006)	(0.005)	(0.008)	(0.012)	(0.008)	
IV	0.094***	0.087**	0.148***	0.044	-0.009	0.136***	0.057	0.097*	0.084*	0.201***	0.279***	0.193***	
	(0.025)	(0.034)	(0.027)	(0.032)	(0.044)	(0.039)	(0.040)	(0.055)	(0.043)	(0.064)	(0.100)	(0.064)	
Observation	495,251	230,044	265,207	238,876	112,543	126,287	181,228	83,051	98,112	66,389	30,281	36,067	
<b>B. Labour market</b>													
a. Usual Activity													
Agriculture													
OLS	-0.011***	-0.010**	-0.014***	-0.009**	-0.008	-0.012**	-0.017***	-0.013**	-0.022***	-0.007	-0.009	-0.007	
	(0.003)	(0.004)	(0.004)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)	(0.009)	(0.011)	(0.010)	
IV	-0.041	-0.065*	-0.024	0.045	0.044	0.051	-0.170***	-0.246***	-0.117	-0.099	-0.092	-0.134	
	(0.036)	(0.034)	(0.050)	(0.048)	(0.046)	(0.067)	(0.052)	(0.055)	(0.073)	(0.101)	(0.116)	(0.120)	
Salaried job													
OLS	0.001	0.008	0.002	-0.007	-0.004	-0.005	0.016***	0.026***	0.014***	-0.012	-0.011	-0.007	
	(0.003)	(0.005)	(0.003)	(0.005)	(0.007)	(0.004)	(0.004)	(0.007)	(0.004)	(0.009)	(0.013)	(0.009)	
IV	0.126***	0.280***	0.036	0.134***	0.291***	0.032	0.159***	0.326***	0.071**	0.062	0.229*	-0.020	
	(0.027)	(0.041)	(0.022)	(0.035)	(0.056)	(0.029)	(0.037)	(0.061)	(0.029)	(0.098)	(0.128)	(0.095)	

Own Business												
OLS	-0.013*** (0.005)	-0.013** (0.005)	-0.012** (0.005)	-0.014** (0.007)	-0.009 (0.008)	-0.018** (0.008)	-0.008 (0.006)	-0.016** (0.007)	-0.001 (0.006)	-0.020** (0.009)	-0.018 (0.013)	-0.020** (0.009)
IV	0.034 (0.041)	0.017 (0.045)	0.061 (0.043)	0.168*** (0.057)	0.180*** (0.062)	0.171*** (0.061)	-0.184*** (0.066)	-0.251*** (0.078)	-0.119* (0.063)	0.060 (0.092)	0.046 (0.119)	0.089 (0.089)
Household chores												
OLS	0.001 (0.004)	-0.015*** (0.005)	0.005 (0.005)	-0.001 (0.006)	-0.014* (0.008)	0.004 (0.007)	0.013** (0.006)	-0.004 (0.007)	0.016** (0.007)	-0.004 (0.010)	-0.009 (0.013)	-0.009 (0.011)
IV	-0.004 (0.046)	-0.029 (0.051)	-0.069 (0.057)	0.006 (0.060)	0.041 (0.068)	-0.093 (0.076)	-0.029 (0.065)	-0.119 (0.076)	-0.063 (0.083)	0.001 (0.096)	-0.068 (0.105)	-0.037 (0.122)
b. Employment status												
Employee												
OLS	-0.001 (0.002)	0.003 (0.003)	-0.002 (0.002)	-0.007*** (0.003)	-0.002 (0.005)	-0.008*** (0.002)	0.004 (0.003)	0.008* (0.005)	0.004* (0.002)	0.000 (0.007)	-0.001 (0.011)	0.006 (0.006)
IV	0.026 (0.018)	0.055** (0.028)	0.022 (0.014)	0.032* (0.019)	0.051 (0.033)	0.033** (0.013)	0.038 (0.027)	0.083** (0.042)	0.020 (0.020)	-0.057 (0.091)	-0.034 (0.116)	-0.034 (0.088)
Employer												
OLS	-0.002** (0.001)	-0.002 (0.001)	-0.002* (0.001)	-0.004** (0.001)	-0.003* (0.002)	-0.003** (0.002)	-0.002 (0.001)	-0.001 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.000 (0.003)	-0.002 (0.003)
IV	-0.016 (0.010)	-0.015 (0.011)	-0.015 (0.012)	-0.049*** (0.016)	-0.042*** (0.016)	-0.056*** (0.018)	0.006 (0.015)	-0.006 (0.017)	0.018 (0.017)	0.041 (0.029)	0.046 (0.036)	0.037 (0.031)
Family worker												
OLS	0.006*** (0.002)	0.003* (0.002)	0.009*** (0.002)	0.001 (0.002)	-0.001 (0.002)	0.002 (0.002)	0.013*** (0.003)	0.006** (0.003)	0.018*** (0.004)	0.002 (0.003)	-0.000 (0.003)	0.004 (0.004)
IV	-0.005 (0.023)	0.003 (0.015)	-0.014 (0.033)	0.021 (0.029)	0.017 (0.022)	0.024 (0.041)	-0.041 (0.032)	-0.016 (0.023)	-0.066 (0.049)	0.006 (0.039)	0.008 (0.033)	0.001 (0.056)
c. Working industry												
Agro-forestry												
OLS	-0.009*** (0.004)	-0.009** (0.004)	-0.012*** (0.004)	-0.005 (0.005)	-0.006 (0.006)	-0.007 (0.005)	-0.012** (0.005)	-0.008 (0.006)	-0.018*** (0.006)	-0.007 (0.009)	-0.014 (0.012)	-0.006 (0.010)
IV	-0.025 (0.033)	-0.051 (0.034)	-0.022 (0.045)	-0.021 (0.042)	-0.032 (0.043)	-0.020 (0.058)	-0.045 (0.050)	-0.097* (0.055)	-0.022 (0.069)	-0.025 (0.087)	-0.067 (0.109)	-0.043 (0.107)
Manufacturing												
OLS	0.002* (0.002)	0.003* (0.002)	0.002* (0.002)	0.002 (0.002)	0.005*** (0.002)	0.000 (0.002)	0.001 (0.002)	0.000 (0.002)	0.003* (0.002)	0.006 (0.002)	0.010 (0.002)	0.006 (0.002)



IV	(0.001) 0.022* (0.012)	(0.002) 0.033*** (0.012)	(0.001) 0.017 (0.017)	(0.001) 0.007 (0.014)	(0.002) 0.022* (0.012)	(0.002) -0.005 (0.021)	(0.002) 0.048*** (0.016)	(0.002) 0.042** (0.016)	(0.002) 0.054** (0.023)	(0.005) 0.011 (0.050)	(0.008) 0.085 (0.076)	(0.004) -0.023 (0.053)
Trade OLS	0.004*** (0.001)	0.001 (0.002)	0.006*** (0.001)	0.004** (0.002)	0.003 (0.003)	0.005*** (0.002)	0.003* (0.002)	-0.002 (0.002)	0.008*** (0.002)	0.002 (0.002)	0.001 (0.003)	0.003 (0.002)
IV	-0.014 (0.011)	-0.003 (0.011)	-0.020 (0.017)	0.023* (0.014)	0.037** (0.016)	0.013 (0.018)	-0.060*** (0.023)	-0.050** (0.020)	-0.067* (0.037)	0.011 (0.017)	0.012 (0.024)	0.017 (0.024)
Hotel restaurant OLS	-0.002** (0.001)	-0.003** (0.001)	-0.001 (0.001)	0.000 (0.001)	0.000 (0.001)	0.001 (0.001)	-0.005*** (0.002)	-0.007*** (0.002)	-0.004** (0.002)	0.001 (0.001)	0.001 (0.001)	0.000 (0.001)
IV	-0.013*** (0.004)	-0.014*** (0.005)	-0.011** (0.004)	-0.004 (0.004)	-0.009* (0.005)	0.001 (0.004)	-0.034*** (0.010)	-0.033*** (0.010)	-0.033*** (0.011)	0.005 (0.004)	0.005 (0.008)	0.005 (0.004)
No. of Observations	495,251	230,044	265,207	238,876	112,543	126,287	181,228	83,051	98,112	66,389	30,281	36,067
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VDC FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Regressions in this table are similar to the main results. Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A5: Placebo Test

Variables	Percent (Placebo is significant)
Education	
Years of education	8.2
Education z-score	4.2
Adult literacy	7.6
Usual activity	
Agriculture	3.2
Salaried	34.2
Own business	2.6
Household chores	11.4
Employment status	
Employee	3
Employer	4
Family worker	1.6
Working Industry	
Agro-forestry	3.6
Manufacturing	3.2
Trade	29.6
Hotel restaurant	5.8