Electrification to Grow Manufacturing? Evidence from Mini-grids in Nepal*

Robyn C. Meeks,†
Hope Thompson,‡
Zhenxuan Wang§

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Abstract

Firms in developing countries often identify electricity as a major constraint to operations. Decentralized renewable energy sources could help alleviate these constraints. We investigate whether electrification in Nepal – via microhydro plants and their mini-grids – helped grow the manufacturing sector. Mini-grids significantly increased manufacturing establishments; yet their overall presence remained limited due to low baseline numbers. Following electrification, females and males were more likely to be employees and less likely to be self-employed. Likewise, usual employment activities shifted from labor in agriculture to salary and wage work. In more remote locations, the impacts of mini-grids on manufacturing establishments and labor were significantly muted.

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†Duke University, Sanford School of Public Policy. Email: robyn.meeks@duke.edu.

‡Federal Emergency Management Agency. Email: hope.f.thompson@gmail.com.

§University Program in Environmental Policy, Nicholas School of the Environment and Sanford School of Public Policy, Duke University. Email: zhenxuan.wang@duke.edu.

1 Introduction

Growing the manufacturing sector can modernize a country's economy, shifting labor from the agricultural sector to skilled, better-paying jobs (Tybout, 2000). Yet, in developing countries, insufficient electrification may limit the sector's growth. Although electrification benefits industry in some settings (Lipscomb et al., 2013; Rud, 2012; Kassem, 2021) – albeit not all (Peters et al., 2011), the significant cost of constructing long distance, high-voltage transmission lines prevents grid extensions to many poor, rural communities (Bhattacharyya and Palit, eds, 2014).

Mini-grids may overcome this obstacle to electrification, yet some question whether these technologies are sufficient to support development (United Nations Development Programme, 2011). With their generation sources situated near load centers (i.e., the population to which it provides electricity), mini-grids can electrify rural locations at a lower cost than grid extensions (Harvey, 1993; Mainali and Silveira, 2011; ESMAP, 2019; Burgess et al., 2020). Further, when their generation source is renewable and mitigates CO_2 emissions, mini-grids were open for finance through the Clean Development Mechanism (CDM) of the Kyoto Protocol. With an estimated 47 million individuals connected to 19,000 mini-grids across 134 countries (ESMAP, 2019), mini-grids play a substantial role in increasing electricity access (International Energy Agency, 2010). The extent to which decentralized renewables and their mini-grids can benefit firms, powering electric equipment and increasing workers' productivity, is important for sustainable development; yet causal evidence remains limited.

There are multiple reasons as to why mini-grids powered by decentralized renewable energy sources may have less impacts than grid electrification. First, these mini-grids may be powered by generation sources with capacities insufficient to power substantial changes in the economy.[1] Second, mini-grids are often constructed to serve remote and

[1] For example, Aklin et al. (2017) study solar micro-grids in India through a randomized experiment. The particular technology in their study, however, provided households with only 5 hours of electricity per day to power two light sources and charge a phone.

rural communities, which may face constraints to manufacturing growth other than electricity access. Third, populations may perceive mini-grids to be inferior to grid electrification (Burgess et al., 2020), resulting in less investment in enterprises following their construction.

We study the impacts of electrification, via microhydro plants with generation capacities of up to 100 kW, on manufacturing establishments and allocation of labor in rural Nepal.[2] Since the CDM's inception, 303.8 billion USD has been invested in climate and sustainable development projects (United Nations Framework Convention on Climate Change, 2018), including some funding Nepal's microhydro plants. Yet whether CDM projects, and climate finance, more generally, could induce development while aiding the environment is debated (see, e.g., Subbarao and Lloyd, 2011; Du and Takeuchi, 2019; Mori-Clement, 2019). To inform the debate, we provide evidence on two research questions. First, can decentralized renewable energy – as a source of electrification, more broadly – increase manufacturing and shift labor from the agricultural sector? Second, do these impacts of electrification differ depending on proximity to other development?

Nepal, a lower-income country in South Asia with a population just under 30 million people (World Bank, 2020), provides an ideal location for this study. Only 14.7% of the country's rural population had access to electricity as of 2001 and 68.8% of firms identified electricity as a major constraint to their business operations (World Bank, 2020). Since then, Nepal experienced one of the world's greatest increases in electrification.[3] With an estimated 1,519 mini-grids installed in the country – the fourth highest in the world, after Afghanistan, Myanmar, and India (ESMAP, 2019) – this technology plays an important role in the country's recent rural electrification gains. In communities with microhydro, the average capacity is 38 kW, sufficient to power activities such as sawing,

[2]Nepal's Central Bureau of Statistics defines manufacturing as the "physical or chemical transformation of materials or components into new products, whether the work is performed by power-driven machines or by hand."

[3]Other countries rapidly electrified during this period include Bangladesh, India, Kenya, Myanmar, and Rwanda (ESMAP, 2019).

milling, sewing, processing foods, and running mechanical workshops.

Our analyses hinge on data locating microhydro sites, which are collected at Nepal's Alternative Energy Promotion Center (AEPC), the government entity created in the 1990s to coordinate international donors' funding for renewable energy projects. Analyses employ AEPC data, on both locations geophysically appropriate for microhydro and those in which plants were actually constructed, in addition to secondary data collected from Nepal's Central Bureau of Statistics. We digitize and employ data collected via the country's Census of Manufacturing Establishments (2006/2007 and 2011/2012) and the National Economic Census (2017/2018) to create a panel dataset of manufacturing establishments for the country. Two rounds of microdata (2001 and 2011) on individuals' employment status and work activities from the National Population Census provide labor outcomes to assess indicators of structural transformation.

To estimate the impact of micro-hydro construction in Nepal over time, we employ an empirical strategy related to Duflo and Pande (2007). Our analyses employ two sources of variation. First, we exploit the variation over time in the funding that AEPC received from bilateral and multilateral international donor organizations for microhydro plants and their mini-grids. The year-to-year variation in microhydro plant construction is determined by – and therefore positively correlated with – these national budgets for microhydro in Nepal, but coordinated and dispersed through AEPC in a way that is plausibly exogenous to individual municipalities within the country.[4] To proxy for the annual donor budgets for microhydro, we employ data on the total number of microhydro plants constructed per year in Nepal. Second, we exploit cross-sectional variation in whether a location within Nepal is geo-physically appropriate for microhydro plants and their mini-grids. Microhydro requires year-round river flow and substantial river slope to generate electricity, so these characteristics are key in determining whether a site is geo-physically

[4]We refer to municipalities throughout this description, as that is the lowest spatial unit in our main regressions. For additional outcomes using the census microdata, the spatial unit is the village development council (VDC), which represents a cluster of villages. We explain spatial units in greater detail later.

appropriate for the technology. When AEPC, together with donor organizations, sought to rapidly increase funding for microhydro plant construction in 2006, they launched a GIS study to identify locations geophysically appropriate for the technology. The classification of sites as appropriate or inappropriate for microhydro serves as the second source of variation. Using these two variation sources, we construct the interaction and use this to instrument for the number of microhydro plants constructed in a municipality by a given year. Our main estimates, which use panel data for 747 municipalities within Nepal, include municipality fixed effects that control for time-invariant differences between municipalities and province-year fixed effects that control for changes over time that affect municipalities within a province similarly.

Our identification strategy relies on the excludability of the instrument, conditional on the fixed effects. We address three specific threats to the exclusion restriction. First, the exclusion restriction is violated if the instrument predicts changes in other infrastructure, such as road construction, in municipalities over time. In practice, the geophysical characteristics that make a location appropriate for a microhydro plant – rivers and steep gradient – are associated with higher construction costs for road infrastructure (Shrestha, 2020); this decreases the likelihood that roads will change in these rural municipalities during our study period. Nevertheless, to support our claim that these geophysical characteristics did not affect development through other channels that change over time, we show results are robust to controlling for the interaction of average municipality slope and year fixed effects. Second, it would be problematic if the instrument predicted increases in facilities such as schools or health centers, which could occur if, for example, bilateral and multilateral funders targeted school construction to the same locations that received microhydro investments. To support the assertion that such additional community facilities were not directed to microhydro sites, we show that the instrument does not not predict changes in the number of schools, the number of students, or the distance to the nearest health facility. Third, increased migration to microhydro locations could provide an alternative channel through which manufacturing establishments and salary and wage work increase. Tests show that the instrument does not predict changes in population overall, or for males and females separately.

We address two known weaknesses of this type of instrument (Gallea, 2023).[5] First, to support the claim that the causal relationships we identify are unaffected by selection bias and spurious time trends, we conduct Monte Carlo simulations proposed by Christian and Barrett (2017). Second, given that residuals may be correlated across locations with similar exposure to shocks (Adao et al., 2019), such as the national-level funding for microhydro, we employ the arbitrary clustering method proposed by Colella et al. (2019).

Our study produces three main results. First, we find that rural electrification via microhydro plants led to a small and statistically significant increase in formal manufacturing establishments employing 10 or more individuals. Given a very low baseline number of manufacturing establishments, the overall presence of manufacturing remained limited post-electrification in these locations. Robustness checks using alternative instrumental variables and different identification methods produce similar results. Supplemental evidence using the Nepal Living Standards Survey panel dataset suggests that non-agricultural and informal household enterprises, as well as their net revenue, also grew from microhydro.

Second, and consistent with the first findings, individuals' labor shifts away from self-employment and own agricultural/farming work to work as an employee and earning salary or wages. These labor impacts imply the start of a structural transformation within the economy and, together with the manufacturing establishment results, indicate that such mini-grids can support manufacturing gains.

Our third main finding is that manufacturing establishments increased significantly less from microhydro plants when constructed in locations far from the national grid – our proxy for access to other inputs to the manufacturing process – relative to those con-

[5] Although not a standard shift-share instrument, our instrument is susceptible to the same weaknesses.

structed close to the grid. Additionally, labor is differentially affected across these two location types. Individuals are less likely to become employees, working for salary and wages, and more likely to remain self-employed, working on their family farms, in these farther locations post-electrification. These results add nuance to the story: although decentralized renewables can support increased manufacturing and labor transformation, electrification alone is insufficient in the presence of other constraints.

Our study helps fill a knowledge gap, as to whether CDM projects, and climate finance more broadly, can result in win-wins: inducing development while delivering environmental gains. In doing so, the paper contributes to the broader, but still relatively small, body of causal evidence on the extensive margin impacts of electrification on industrial development (Lipscomb et al., 2013; Rud, 2012; Peters et al., 2011; Kassem, 2021).[6] Further, our findings that mini-grid impacts are substantially muted in locations farther from the grid, provides a plausible, yet under-explored, explanation as to why studies on household electrification find substantial effects in some settings (see, e.g., Dinkelman, 2011; Grogan and Sadanand, 2013; Khandker et al., 2013; Barron and Torero, 2017), but not others (see, e.g., Burlig and Preonas, 2016; Lee et al., 2020b).

The paper proceeds as follows. Section 2 provides a conceptual framework as to how electrification might impact manufacturing and lead to structural transformation, shifting labor from the traditional sector to the modern sector. Section 3 provides background information on manufacturing establishments, labor, and electricity in Nepal. Section 4 describes the electrification data, as well as the microdata from the manufacturing and household censuses. Sections 5 and 6 cover our instrumental variable and empirical strategy, respectively. Section 7 presents the main results, robustness checks, and supplemental evidence. Section 8 investigates heterogeneous impacts and Section 9 concludes.

[6] There is also a larger literature on the intensive margin, estimating the impacts on and response of firms to electricity shortages and outages (Allcott et al., 2016; Alam, 2013; Fisher-Vanden et al., 2015; Cole et al., 2018; Abeberese, 2019; Abeberese et al., 2021; Mahadevan, 2021; Fried and Lagakos, 2021).

2 Conceptual Framework

In presenting a conceptual framework, we have two overarching goals. First, we aim to provide a synopsis as to how electrification of a community could induce a structural transformation, growing manufacturing enterprises and shifting labor from low productivity activities to higher productivity activities. Second, we seek to illustrate how electrification via mini-grids does not necessarily bring the same benefits as grid electrification due two at least two additional potential constraints: a limit on the magnitude of power available for each consumer and the higher probability of being constructed in remote locations with limited access to markets.

Following Midrigan and Xu (2014) and Fried and Lagakos (2020), we consider a scenario, in which there are two types of firms: those that operate in the traditional sector and those that operate in the modern sector. Both types of firms use capital and labor in the production process; however, firms in the traditional sector do not require electricity, whereas modern firms do.[7] Modern sector firms are more productive than the traditional sector firms.

In a community without access to electricity, a firm may either operate in the traditional sector without electricity or within the modern sector by fully self-generating electricity. Self-generation is expensive, so most firms will choose to operate in the traditional sector in locations where there is no grid.[8] As a result, labor in these locations will be primarily allocated to the traditional sector. Firms will remain small and relatively unproductive in their use of capital and labor. In this scenario, individuals are primarily either self-employed on their own farms or employed elsewhere in the traditional sector.

When a community is electrified via the national grid, firms – both formal manu-

[7] We assume, however, that electricity reliability (i.e., frequency of outages) and service quality (i.e., voltage fluctuations) are the same across different electricity sources.

[8] Self generation requires not only on-going fuel costs but also the large upfront cost to purchase a generator. In much of rural Nepal, generators were prohibitively expensive for most enterprises, so prior to community electrification many would rely on manual labor and basic fuels (e.g., kerosene lamps for lighting).

facturing establishments and informal household enterprises – can use electricity as an input at a substantially lower cost per unit of electricity than was previously feasible. Firms may choose to shift to the modern sector, as it is more productive due to the modern technologies now feasible. And electrification may either increase the productivity of existing businesses (e.g., clothing producers can make more items in a given amount of time with electric sewing machines than person-powered machines) or enable new businesses that were not previously feasible (e.g., an enterprise dependent on refrigeration is only be possible post-electrification). New firms would enter the modern sector (either existing traditional sector firms shifting to the modern sector or those newly developed in modern sector) and existing modern firms would increase in size. If there is an increase in the number and size of modern sector firms, individuals may shift from self-employment in agriculture to working as employees for salary and wages in businesses.

There are two characteristics common to decentralized renewables and their mini-grids that differ from grid electricity and might act as constraints on the structural transformation illustrated above. First, given the limited generation capacity of small-scale decentralized renewables, it is not uncommon for mini-grid operators to restrict the quantity of power provided per customer, including firms, via the mini-grid. Second, the propensity to construct mini-grids in remote locations, which by definition are far from market centers, limits access to both inputs in the production process and markets for end product sales. As a result, it is not obvious ex ante that mini-grid electrification would result in structural transformation.

3 Background on Nepal: Manufacturing and Electrification

3.1 Manufacturing Establishments and Employment

Nepal, a country with three distinct ecological regions (the flat terai region, hills, and mountains), has an economy historically driven by the agricultural sector. As of 2001, agriculture, forestry, and fishing contributed 35.3% of GDP value added, whereas manufacturing contributed only 8.7% (World Bank, 2020).

The relative strength of these sectors has implications for employment. According to 2001 International Labor Organization estimates, unemployment was low (e.g., 2.0% of the male labor force was unemployed) and labor force participation rates were high (e.g., 90.2% among the male population age 15 years or older). Yet a substantial proportion of the population was in "vulnerable employment" due to a high rate of self-employment and a low rate of salary and wage workers (83.9% and 16.1% of total employment, respectively) (World Bank, 2020).

Using 2001 census microdata for communities that were not yet electrified but eventually have a microhydro plant constructed, we can better understand baseline employment in unelectrified locations (Appendix Table A1). Few individuals – female or male – were employers. Employees accounted for 9.8% of males and 2.8% of females. Most individuals worked for themselves ("own account workers"), 54.3% and 60.9% of males and females respectively. The "other" group, which includes unpaid family workers and individuals not reporting any employment status, represented approximately one-third of both males and females. Individuals' usual work activity within the past 12 months show that over half of both females (54.8%) and males (50.8%) reported own agriculture / farming as their main activity. Owning one's own business constituted the next largest group for males (33.7%) but not for females (1.7%). Similarly, 8.7% of males are in salary and wage positions, compared with less than 1% of females. Conversely, 10.3% of females report housework to be their usual activity, in comparison to only 1.2% of males. High percentages of both females and males report studying as their usual activity (20.6% and 28.5%, respectively).[9] The remainder worked in extended economic activities, collecting fuel and water and preparing goods for home consumption.

Overall, these statistics are consistent with an agriculture-dominated subsistence econ-

[9]The census collects data for individuals 10 years and older.

omy with limited manufacturing. Indeed, only 21.6% of these municipalities had a manufacturing establishment that was formally registered with the government and employs 10 or more people.[10] Since then, the number of manufacturing establishments has steadily increased over time across Nepal. Between 2001/2002 and 2006/2007, the number of registered manufacturing establishments within the country increased slightly, from 3,213 to 3,446. The types of establishments that grew during that period included those milling grains, producing carpets and rugs, woodworking, and building furniture, among others (Central Bureau of Statistics, 2014). The following period (2006/2007 to 2011/2012) experienced larger gains in the number of establishments, increasing to 4,076 by 2011/2012.[11]

As we will cover in the next section, electrification also increased substantially during this latter period; however, the extent to which changes in electrification drove any increases in manufacturing, particularly in rural locations, is not obvious.

3.2 Electrification

The state-owned Nepal Electricity Authority (NEA) is responsible for transmission and distribution of electricity through the country's national grid. Almost all of Nepal's electricity (99%) is generated via hydroelectric sources (Mainali and Silveira, 2011). Generation for the national grid is typically large-scale and consolidated at points such that transmission connecting to load centers is necessary. Electricity is transmitted through high-voltage lines across the terai and into the Kathmandu Valley and some of the largest population centers in the hill and mountain regions.[12]

Connecting the remaining rural communities to the grid has been slow for multiple reasons. First, extending the national grid to remote communities is often prohibitively expensive given the high costs of purchasing the associated infrastructure (e.g., sub-

[10] Calculations based on the 2006/2007 Census of Manufacturing Establishments data.

[11] Calculations based on data from the Census of Manufacturing Establishments.

[12] In an effort to electrify district headquarters in remote regions during the 1980s, the government also constructed several mini-hydro (100 – 1000 kW) plants that electrify some regional government headquarters and their surrounding areas.

stations) and constructing high-voltage transmission lines over long distances, particularly in mountainous terrain like much of Nepal (Bhattacharyya and Palit, eds, 2014). Second, communities comprised of traditional sector firms typically consist of households with limited income and asset ownership, including limited electric appliances. This, in conjunction with few manufacturing establishments, can result in low demand for electricity upon a community's initial connection to the grid. Third, rural communities are often located farther from market centers, which may both provide inputs to the manufacturing process as well as opportunities for sales.

These factors contributed to substantial rural-urban differences in electrification rates. In 2001, 85.7% of the urban population had access to electricity, in contrast to 14.7% of the rural population. With 86.1% of the population inhabiting rural areas, most of its people were impacted by the low electrification rates (World Bank, 2020).

Starting in the early 2000s, the country began to prioritize rural electrification. This induced a substantial increase in the percent of the rural population with access to electricity, as depicted in Figure 1. By 2018, 93.5% of the rural population had access to electricity (World Bank, 2020).[13] Noticeably, there were not comparable improvements in all rural services over this time period. For example, we do not witness a similar increase in the rural population using basic or safe drinking water sources or hand-washing facilities during this period (also shown in Figure 1).

The following sub-sections document the main pathways for community electrification in Nepal during our study period.[14]

[13]These changes in electrification over time are also illustrated by the maps in Appendix Figure A1.

[14]During this time, individual households could purchase rooftop solar home systems. The capacity of these systems is not sufficient for electrifying a community nor is it sufficient to support manufacturing, particularly establishments large enough to employ 10 or more people, and therefore we do not consider them here. However, the solar home systems could power small household enterprises.

3.2.1 Electrification through Microhydro Plants with Mini-Grids

Microhydro plants generate between 10 kW and 100 kW of electricity. A mini-grid then distributes the electricity to residential consumers and enterprises (World Bank, 2016). In Nepal, these microhydro mini-grids are typically decentralized and not interconnected with the national electricity grid.

As a technology, microhydro is not new to Nepal; however, the technology's prevalence increased greatly since the 2000s. Figure 2 documents the increases in both the number of microhydro plants and their installed capacity (kW) between 1998 and 2018. The uptick in microhydro plant construction contributed substantially to the country's rural electrification gains during this period. Maps in Figure 3 illustrate how the microhydro plant construction varied across Nepal over time. This variation was driven by two key factors – geographic characteristics and external donor funding – as explained below.

Certain geophysical characteristics determine whether a location is appropriate for plant construction. Microhydro systems are typically run-of-river (i.e., there is no dam or reservoir of water), so they require continuous, year-round river flow. Unlike solar-powered mini-grids, they do not require battery storage.[15] Part of a river's flow is diverted to a channel that runs alongside the contours of a hill, in order to maintain a high elevation. From the channel, the water passes through a closed pipe with a large drop in elevation, connecting to a turbine located at a substantially lower elevation below. The water falling to the lower elevation moves the turbine, generating electricity (Harvey, 1993). Due to these design requirements, a location's river slope is a main geophysical determinant of microhydro plant construction and they are typically targeted to the hill and mountain regions where year-round rivers flow through terrain with sufficient slope (Harvey, 1993).[16]

[15]The absence of a dam limits the system's negative impacts on the environment, such as requiring large quantities of concrete, flooding valleys for reservoirs, etc.

[16]Solar home systems were targeted to electrify individual houses in the highest mountain regions, as transporting microhydro equipment to these places is too difficult.

The increased construction of microhydro plants over time was induced by large investments made by bilateral and multilateral donor organizations. When AEPC and international donors sought to rapidly expand microhydro funding and construction in the mid-2000s, AEPC and partners undertook a study to identify locations with the geographic conditions necessary for microhydro plants. This study lasted between 2005 and 2008 and had two components: a GIS-based desk study (the "carpet study") and a field-based feasibility study (Alternative Energy Promotion Centre, 2012). The carpet study used GIS and spatial data to remotely identify locations physically appropriate for microhydro plants (Müller et al., 2016). Beyond the necessary geophysical conditions described above, the carpet study ensured construction locations were proximate to load centers to prevent plant construction far from communities to use the electricity. Through the carpet study, 882 Village Development Committees (VDCs) – which from 1990 to 2017 were the primary local administrative units in the country, with one VDC representing a small cluster of villages – were identified as geophysically appropriate for a microhydro plant.

AEPC and partners intended to avoid building microhydro plants in locations where the national electricity grid was likely to soon reach (Alternative Energy Promotion Center, 2009); however, in practice, the Nepal Electricity Authority (NEA) and AEPC communicated little and, as a result, microhydro plant site selection was relatively uninformed by future electricity grid placement. Although some plants were constructed more than 100 km from the grid, others were constructed within 10 km (Appendix Figure A2).

Not all locations identified as appropriate through the carpet study had microhydro plants constructed by the end of our study period (Appendix Figure A3). After the carpet study, in-person feasibility studies were conducted in the GIS-identified VDCs to assess community demand for microhydro. Communities identified through the carpet study were eligible for a subsidy, coordinated by AEPC and funded by bilateral and multilateral international donor organizations. The subsidy covered approximately 50% of the system cost and the community mobilized funding for the balance (Kumas et al., 2015).[17]

3.2.2 Electrification through Community Grid Connections

Microhydro plants were not the only pathway for rural electrification at this time. Communities could also be newly-electrified as a result of grid extensions. In 2004, the Community Rural Electrification Programme (CREP) launched as a collaboration between the Government of Nepal and NEA to expand access to electricity services in unelectrified VDCs. Through CREP, communities could submit an application for a connection to the national grid, which was evaluated primarily based on a cost estimate. If the cost was deemed acceptable, the Government of Nepal would subsidize 90% (Nepal Electricity Authority, 2018). Due to transmission line construction expenses, community distance from the existing national grid was the main determinant of extension cost, so typically only communities located within 25 km of the existing grid were eligible for CREP.

4 Data and Variable Construction

The analyses utilize datasets collected by Nepal's Central Bureau of Statistics, the NEA and the AEPC. We decribe these datasets and the variables created from them.

4.1 Electrification Data

We combine data on the main sources of community electrification in Nepal: microhydro plants and their associated grids, the national grid, and extensions to that grid. Datasets are described below and additional supporting information is in Data Appendix A1.

[17] The subsidy increased over time. In 2006, it was 10,000 Nepali rupees (NPR) per household (HH), not to exceed 85,000 NPR/kW (1 NPR = 0.0104 USD) for the system. In 2009, it was 15,000 NPR/HH (125,000 NPR/kW maximum). In 2013, the subsidy changed for some sites, with remote and very remote locations receiving 15,000 NPR/HH (100,000 NPR/kW) and 25,000 NPR/HH (130,000 NPR/kW), respectively (Kumas et al., 2015). Communities were also responsible for managing and maintaining the microhydro mini-grid, so these arrangements and rules vary across sites.

4.1.1 Microhydro plants

AEPC provided datasets on microhydro plant siting and construction. The first dataset is comprised of the carpet study output: a list of locations, at the VDC-level, that were identified through the carpet study as being geophysically appropriate for microhydro plant construction.[18] These data are based only on the GIS desk study, not the field visits that determined community demand for the microhydro plants.

The second AEPC dataset provides details on the actual microhydro plant construction through 2018. Data include the location (VDC and district) of microhydro plants, plants' construction completion date, and the plants' expected capacities. We use these data to create variables counting the total number of microhydro plants per year per location – VDC, municipality, district, and the entire country.

4.1.2 National grid and community grid extensions

We map the coverage of the national electricity grid, including the 132 kV, 66 kV, and 33 kV lines. These data, available at the NEA website[19], allow us to calculate locations' distances to the national electric grid. We use data on the location of grid extensions funded via the CREP, provided by the entity coordinating the program, the National Association for Community Electricity Users Nepal (NACEUN). With these data, we can perform robustness checks dropping the CREP-electrified locations.

4.2 Geo-spatial Data

Given the input files used to perform the national GIS "carpet study" are not publicly-available, we use alternative geo-spatial datasets from OpenStreetMap and NASA's Shuttle Radar Topography Mission to compute one key component that determines whether

[18] We do not have the GIS layers of data that were used to conduct the study, as some of the government and NEA datasets are not available to the public. For this reason, we use the outputs of the GIS study.

[19] NEA website: www.nea.org.np.

a location is geophysically appropriate for a microhydro plant: river slope. Details on the sources and processing of these data are documented in Data Appendix A2.

Using these data, we calculate the length of rivers within a VDC, the average elevation and slope of a VDC, and – by restricting attention to cells through which a river flows – the average river gradient. We create four binary variables indicating whether a VDC's average river slope (in degrees) falls within one of the following gradient bins: 0-3, 3-20, 20-30, or greater than 30. These variables both allow us to check the extent to which river slope predicts a location's designation as geophysically appropriate via the carpet study and provide an alternative set of instrumental variables for robustness checks.

4.3 Data on Manufacturing Establishments

With data from the Government of Nepal's Central Bureau of Statistics, we compile a panel dataset of the number of manufacturing establishments that employ 10 or more people per municipality in a given year. Data are from the 2006/2007 and 2011/2012 iterations of the Nepal Census of Manufacturing Establishments (Nepal Central Bureau of Statistics, 2014) and the 2017/2018 National Economic Census (Nepal Central Bureau of Statistics, 2019). Together, these provide one baseline iteration, collected before the carpet study was completed, and two post-carpet study iterations for this outcome variable. To use all three rounds of data together, we address the changes in administrative boundaries, from VDCs to municipalities, which occurred in 2015. Further details on the steps to build the manufacturing establishment panel dataset are in Data Appendix A3.

The Census of Manufacturing Establishments and the National Economic Census data have important commonalities. They both use the same definitions for "establishments" and "manufacturing," permitting us to use the three census rounds as a consistent count of manufacturing establishments over time.[20] Notably, their definition of manufac-

[20]The definition of "establishment" is an economic unit, under single ownership, engaged in one economic activity type at single physical location.

turing includes "physical or chemical transformation of materials or components into new products, whether the work is performed by power-driven machines or by hand." By definition, these data incorporate manufacturing establishments in both electrified and non-electrified locations. By nature of the data collection process, these establishments are all registered with the government; these data do not capture informal enterprises.

The panel data are complemented by cross-sectional data from the Census of Manufacturing Establishments survey in 2010/2011. These provide more detailed data on Nepal's manufacturing establishments, including the number of employees (persons who work in or for the establishment and receive pay, in cash or in kind, at regular intervals) and the total establishment benefits (the establishments' sum of direct wages, salaries, and non-monetary compensation, including both cash remuneration for work performed and time not worked due to holidays or for other reasons).

4.4 Individuals' Employment Status and Activities

Nepal's National Population Census is implemented every 10 years by the Central Bureau of Statistics. Micro data, identifiable at the VDC level, are available for a random sample of households from the 2001 and 2011 census iterations. This results in a microdata sample of 841,567 (15.5% of households) and 520,624 (12.2% of households) households, in 2001 and 2011 respectively.[21] Across the two census rounds, there are microdata on 2,442,232 males and 2,610,184 females.

The census microdata contain household and individual characteristics and the economic and non-economic activities of each family member age 10 years and older. Outcome variables used in this analysis include individuals' employment status and individuals' usual work activities in past 12 months. Employment status can be as an employer, employee, own account work (i.e., self-employed), or other, which includes unpaid family work as well as those that do not report an employment status. Work activities consist

[21] Due to political unrest, 83 VDCs were not included in the 2001 census enumeration.

of own agriculture/farming, wage or salaried work, and small business activities, extended economic work (collecting fuel and water, preparing goods for consumption at home), household chores (cooking, cleaning, child care, etc.), and studies. Agricultural work outside the family that is performed for a salary or wage is covered by the second category. Complete descriptions of the census variables are in Data Appendix A4.

4.5 Household Enterprises

We use data on small, non-agricultural household enterprises from the Nepal Living Standards Survey (NLSS). The NLSS is a household survey implemented by the country's Central Bureau of Statistics. We use data from two surveys rounds, which were conducted in 2003/2004 (NLSS-II) and 2010/2011 (NLSS-III), as a stacked panel. The datasets have samples of 3,912 and 5,988 households, respectively.[22] Both rounds collect detailed information on non-agricultural household enterprises, including the number of enterprises operated by the household, whether the enterprise is formally registered with the government, the number of people in the household working in the enterprise, the number of employees hired by the enterprise, and the gross and net household enterprise income.

5 Instrumental Variable: Microhydro Plant Construction

OLS regressions estimating the effect of a microhydro plant built on business enterprises or labor allocations are likely biased. For example, locations anticipating growth in enterprises may be more likely to invest in microhydro plants, even if the location is not geo-physically appropriate for the technology. To avoid such sources of bias, we employ an instrumental variable approach.

[22] Conflict in Nepal continued through 2006. The NLSS-II did not cover areas with active conflict in 2003 to 2004. As a result, the NLSS-II had a smaller sample size than the NLSS-III.

5.1 Construction of Instrumental Variable

To estimate the impact of community electrification via microhydro plants constructed across Nepal over time, we exploit the exogenous variation in their annual construction budget through an instrumental variable estimation. Our instrument, Z, is the predicted number of microhydro plants constructed in a particular location by a given year. We create the instrument by interacting measures of the two factors driving variation in microhydro plant construction over time across Nepal: cross-sectional differences across locations in the geophysical suitability for plant construction and variation over time in the national annual budget for microhydro plant construction.

In the following sub-sections, we outline the two sources of variation employed in constructing the instrumental variable and describe a set of alternative IVs used for robustness checks.

5.1.1 Step 1: A Measure of Geophysical Suitability for Microhydro

Our first objective is to identify a measure of a location's geophysical suitability for microhydro plant construction. The AEPC data contains a straightforward measure, which is an output of the carpet study: a binary indicator equalling 1 if the VDC was identified as geophysically appropriate for microhydro ("carpet study identified") and 0 otherwise.

To shed light on this variable and the information it captures, we estimate a linear probability model, regressing this binary variable on baseline (i.e., pre-carpet study) VDC and household characteristics. Results are in Table 1. As expected, locations in the hill and mountain regions were significantly more likely to be identified as being appropriate for microhydro plants, relative to the flatter, terai region. Similarly, locations with an average river slope (in degrees) between 20 and 30 or 30 and 50 degrees are significantly more likely to be identified as appropriate for microhydro than those with a smaller average river slope. River length and population density are not significant predictors of carpet study identification. The carpet-identified locations are more likely to be farther from the nearest city, road, and electric grid relative to the those not identified.[23]

5.1.2 Step 2: District Microhydro Plant Construction Budgets over Time

Our second objective is to develop a measure capturing the year-to-year variation in annual national budgets for microhydro plants, which were determined by bilateral and multilateral donors' investments and then coordinated through AEPC. These were determined at the country-level and are exogenous to individual locations (i.e., VDCs or municipalities). To proxy for the annual national budget for microhydro plants, we use data on the total number of microhydro plants constructed per year in Nepal, which were illustrated in Figure 2.

5.1.3 Step 3: Interaction to Create the Instrumental Variable

We bring together the two measures from Steps 1 and 2 and interact them to create the instrumental variable, Z_{it}. The IV proxies for the predicted number of microhydro plants constructed in location, i, by a given year, t. The location, i, can be either at the municipality or VDC level, depending on the dataset used in the analysis.

The instrument is constructed as follows:

$$Z_{it} = \text{carpet}_i \times N_t \tag{1}$$

in which the first term – carpet_i – is a binary indicator for whether location i was identified by the GIS carpet study as being appropriate for microhydro plant construction based on its geophysical characteristics. The second term, N_t, is the total number of microhydro plants constructed in Nepal as of year t, which provides a proxy measure of the nationwide budget for microhydro construction. The instrument varies by munici-

[23]The one baseline household characteristic for which the difference between groups is statistically significant and could change over time is the presence of toilets. Therefore, we control for access to toilets when possible.

pality and time, capturing the variation in funding over time for microhydro plants that is directed to locations that are geophysically appropriate for the technology.

5.2 Alternative Set of Instrumental Variables

As was shown in Table 1, the average river slope within a VDC significantly predicts whether a location was identified as geophysically appropriate for microhydro. Using these data, we construct an alternative set of instrumental variables that do not rely on the carpet study output and can be used in robustness checks.

The set of alternative instrumental variables are three interaction terms, $\text{SlopeBin}_i^b \times N_t$, where $\{\text{SlopeBin}_i^b\}$ is a series of indicators defined by which of the three slope bins $b \in B = \{3-20, 20-30, > 30\}$ the average river slope in location i falls in. The 0-3 category is omitted and used as the reference group. These slope bins are then interacted with N_t, which is the proxy for nationwide budget for microhydro plant construction in year t, as it was calculated previously for use in Equation 1.

For transparency and to build confidence in our primary instrument, we redo our main 2SLS regressions using these instrumental variables as robustness checks.

6 Empirical Strategy

To estimate the impacts of microhydro on enterprises and employment activities, we use the instrumental variable in 2SLS regressions. Given data and analyses are at different location levels, either municipality or VDC, we illustrate the empirical approach separately for the manufacturing establishments and employment activities.

6.1 Number of Manufacturing Establishments

We estimate the first-stage equation, using the municipality-level construction of the instrumental variable depicted in Equation 1. This first-stage is as follows:

$$\text{MHP}_{mt} = \beta Z_{mt} + \lambda_m + \theta_{j(m)t} + \epsilon_{mt}, \tag{2}$$

in which MHP_{mt} is the cumulative number of microhydro plants in municipality m by year t. The instrumental variable in these analyses is $Z_{mt} = \text{Carpet}_m \times N_t$, where Carpet_m equals 1 if the municipality contained *any* VDCs identified in the GIS study as appropriate for microhydro construction and 0 otherwise. The remainder of the instrumental variable is as constructed in Equation 1. We include municipality fixed effects, λ_m, to control for time-invariant characteristics, such as proximity to urban centers, elevation, and land gradient. Lastly, we control for province-year fixed effects, $\theta_{j(m)t}$, to allow the time effects to differ by province within Nepal thereby capturing the changes over time that affect all municipalities within a province similarly.

In robustness checks, we add a vector of municipality-year controls that are the interactions of the logarithm of municipality average elevation and slope with year fixed effects. These control for characteristics that could potentially have also affected development in ways – other than microhydro feasibility – that could change over time.

In the second-stage regression, we estimate the following:

$$\text{Establishments}_{mt} = \beta \widehat{\text{MHP}}_{mt} + \lambda_m + \theta_{j(m)t} + \xi_{mt}, \tag{3}$$

in which the first-stage regression's predicted microhydro construction, $\widehat{\text{MHPnum}}_{mt}$, is used to estimate the impact on the number of manufacturing establishments (with 10 or more employees) within municipality m in province j during time period t. The province-time and municipality fixed effects (as well as the municipality-year controls in robustness checks) remain the same as in the first-stage regression. Standard errors are clustered at the district level, which is one level above municipalities.

The outcome variable is the inverse hyperbolic sine transformation of the number of manufacturing establishments, which permits us to interpret the coefficient as a log-linear regression specification (Bellemare and Wichman, 2020). This transformation is preferred over the log transformation, as it allows us to retain the observations with zero manufacturing establishments, which is not uncommon among rural municipalities.

As with other instrumental variable estimates, the 2SLS estimates here represent local average treatment effect; that is the effect for observations that comply with the instrument. Compliers in our setting are those municipalities that have more microhydro plants constructed due to the increase in microhydro funding nationally. Our instrumental variable estimates do not capture the effects of microhydro constructed in locations that are not geophysically appropriate for the technology.

6.2 Individual Employment Activities

We implement an analogous approach using the census microdata to estimate the impacts of microhydro on individual (male and female) employment activities. Given that males and females often engage in different activities and may be differentially affected by electrification, we run these regressions separately by sex.

The regressions in both the first and second stages differ from those in the previous sub-section for two reasons. First, the census microdata are at the individual level and analysis at this level allows us to control for individual and household characteristics. Second, because the microdata are available for only 2001 and 2011 and the shift from VDCs to municipalities as the primary administrative unit of governance had not yet occurred, our "treatment" variable remains at the VDC level.

In the first stage, we estimate:

$$\text{MHP}_{vt} = \beta Z_{vt} + \eta_v + \theta_{j(v)t} + \epsilon_{vt}. \tag{4}$$

in which MHP_{vt} is the cumulative number of microhydro plants in VDC v by time t. The instrumental variable in these analyses is $z_{vt} = \text{Carpet}_v \times N_t$, where Carpet_v equals 1 if the VDC was identified as appropriate for a microhydro plant and 0 otherwise. We include VDC fixed effects, η_v, to control for time-invariant VDC characteristics. Lastly, we include province-year fixed effects, $\theta_{j(v)t}$, to control for changes over time that impact all VDCs within a province similarly.

The second-stage regression that we estimate is as follows:

$$\text{Labor}_{ivt} = \beta \widehat{\text{MHP}}_{vt} + \gamma' X_{ivt} + \eta_v + \theta_{j(v)t} + \xi_{ivt}, \tag{5}$$

in which the first-stage regression's predicted microhydro construction, $\widehat{\text{MHP}}_{vt}$, in VDC v by time period t is used to estimate microhydro impact on the labor-related outcomes (employment status and usual work activity) of individual i in VDC v during time period t. X_{ivt} is a vector of individual-level controls including the individual's age, level of education, the size of their household, and whether the household has a toilet. Standard errors in these regressions are clustered at the district level.

7 Results

In this section, we present results from our first stage regressions and evidence in support of the instrument's validity. Second-stage results estimating the impacts of microhydro mini-grids are then followed by a series of robustness checks.

7.1 First-Stage Results

First-stage regression results are presented in Table 2. We show the first-stage results for each of the samples used in our main analyses: the CME panel (column 1), the census microdata sample of males (column 2), and the census microdata sample of females (column 3). Given the observations in these datasets are at different levels (municipalities versus individuals), the fixed effects and clustering of standard errors differ between column 1 and columns 2 and 3. Results in all columns indicate that the instrument performs well in predicting the cumulative number of microhydro plants in a municipality (CME sample) or VDC (census samples) in a given year. The point estimates are all statistically significant at the 1 percent level and show a strong correlation between funding directed towards microhydro and microhydro plant construction. F-statistics on the first-stage regressions fall between 48.39 and 57.65.

7.2 Validity of the Instrument

Causal inference using the instrumental variable above relies on the assumption that, conditional on controls, the interaction between the proxy measure for Nepal's nationwide budget for microhydro construction and whether a location is geophysically appropriate for a microhydro plant only affects manufacturing establishments and labor through the construction of a microhydro plant. The main concern with this assumption is that this interaction may affect manufacturing and labor through alternative channels such as increases in infrastructure (i.e., roads), facilities (i.e., schools or health centers), or migration into the location. We present both qualitative and quantitative evidence on all three of these potential channels, as well as report on a broader test, to build confidence in the instrument's validity.

First, Nepal is a country experiencing tremendous migration, particularly from rural areas. It would would be problematic if the interaction instrument predicted increases in migration to these locations, as an increase in manufacturing establishments could occur through an increase in population rather than through microhydro. We do not believe this is occurring, as most of the country's migration is rural to urban, with migrants moving either to Kathmandu, the capital city, or abroad for work. Nevertheless, we can check whether the instrument, Carpet $\times$ N_t, predicts changes in population using VDC-level census data. Our results show that the instrument does not predict changes in population size overall, or male and female population sizes separately (Appendix Table A3, col 1-3).

Second, it would be problematic if the interaction instrument predicted increases in facilities such as schools or health facility construction, which could occur, for example, if bilateral and multilateral funding organizations were targeting school construction to these locations receiving microhydro investments. Again, we do not believe this to be the case; unlike the construction of larger dams in Nepal, which independent power producers are investing in, these smaller-scale microhydro systems do not come with social safe-guards or investments in local facilities. To check this assertion, we test the correlation between the instrument and indicators of facilities using the NLSS data. We find the instrument does not predict changes in the number of schools, the number of students, or the distance to the nearest health facility; if anything, the instruments predicts a small magnitude and marginally significant decrease in the number of health facilities in these locations (Appendix Table A3, col 4-7).

Third, it would violate the exclusion restriction if the instrument predicted construction of roads in these municipalities. This is the concern raised by Lee et al. (2020a) and other regarding the validity of geographic cost-based instruments, which use characteristics that reduce the cost of electrification, but also potentially reduce the cost of other investments, particularly roads. Notably, our instrument is not cost-based. In fact, the geophysical characteristics that make a location appropriate for a microhydro plant – rivers and steep gradient – are associated with higher construction costs for road infrastructure in Nepal (Shrestha, 2020) and decrease the likelihood that roads will change in these municipalities during our study period. Despite countless efforts, we have not been able to acquire data on changes in roads over time during our study period, so we cannot conduct tests analogous to those reported above for schools, health facilities, and population. Nevertheless, to support our claim that these characteristics did not affect development in other ways that could change over time, we show results are robust to including the interaction of average elevation and slope within a municipality with year fixed effects.

As further support for the validity of the instrument, we conduct Monte Carlo simulations proposed by Christian and Barrett (2017), employ the arbitrary clustering method proposed by Colella et al. (2019), replicate the analyses using an alternative set of instrumental variables, as well as perform additional robustness checks. Results aof these tests are presented in Section 7.4.

7.3 Second-Stage Results

We employ the predicted cumulative number of microhydro plants from the first-stage regressions in the second stage to estimate the impacts on enterprises and labor outcomes.

7.3.1 Impacts on Manufacturing Establishments

Table 3 presents the impacts of microhydro plant construction on the number of manufacturing establishments (employing 10 or more people) within the municipality. The dependent variable is the inverse hyperbolic sine of the number of manufacturing establishments. The independent variables is the cumulative number of microhydro plants (MHPs) in the municipality in that year. Therefore, the coefficients are the percent increase in manufacturing establishments from one additional microhydro plant constructed within a municipality.

We find that microhydro construction within a municipality leads to a small and statistically significant increase in manufacturing establishments. Results in column 1 show a 42.7 percent increase in manufacturing establishments on average resulting from one additional microhydro plant constructed within the municipality. Column 2, our preferred specification, replaces year fixed effects with province-year fixed effects to allow changes over to time to differ by provinces. The coefficient indicates a 32.8 percent increase in manufacturing establishments on average resulting from one additional microhydro plant constructed within the municipality. Column 3 provides an additional check, adding municipality-year controls, which account for the fact that location characteristics could not only affect microhydro plant placement, but also other development in ways that could change over time. Results show that the coefficient is quite stable and the results are robust to their inclusion.

Given the low baseline mean of 0.216 manufacturing establishments per municipality, an increase of 32.8% means that there are 0.287 enterprises per municipality on average following the construction of one additional microhydro plant. In other words, less than one-third of municipalities, on average, had such a manufacturing establishment after the microhydro construction. Given the census of manufacturing establishment only includes enterprises with 10 or more employees; there could be increases in smaller manufacturing establishments that are not captured here.

Given the spatial boundaries change over the time period covered by this dataset, as detailed in Data Appendix A3.2, we present results employing alternative approaches to addressing the boundary changes and show that results are robust to these alternative methods (Appendix Table A2, columns 1 and 2).

7.3.2 Impacts on Labor Outcomes

Using the census microdata, we estimate the impacts of a microhydro plant constructed within a VDC on two labor outcomes: employment status and work activities. Results are presented separately for the male (Panel A) and female (Panel B) census samples.

Table 4 presents results of second stage regressions in which the dependent variable is the reported employment status in the past 12 months. The outcome variables are binary indicators equaling 1 if the employment status falls into that category (employer, employee, own account/self-employed, or other) and zero otherwise. Among the males, there is no significant impact on the probability of being an employer (column 1). There is a 9.5 percentage point increase the probability that a male works as an employee (column 2), up from a baseline of 9.8 percent. This increase in working as an employee comes with a decrease in self-employment ("own account" work) of 8 percentage points (column 3). Both of these are statistically significant at the 99% level. There is also no statistically significant decrease effect in the probability of males being employed in "other" work (column 4), which includes household family work.

The estimated impacts of microhydro construction on female employment status are similar to those of males. Females have a small (1.0 percentage point) and marginally significant decrease in the probability of being an employer. The estimated impacts on probability of being an employee (increase of 2.8 percentage points) or self-employed (decrease of 6 percentage points) are statistically significant and qualitatively similar to the effects among males, albeit of smaller magnitudes. There are no statistically significant effects on "other" employment, which includes unpaid family work (column 4).

Table 5 reports the second stage results with usual work activities as the dependent variable. Both males and females have reductions in the probability of working in own agriculture (column 1) and increases in the probability of work activities that are for salary and wages (column 2) that are both statistically significant and economically meaningful. Only among males is there a marginally statistically significant and small in magnitude, increase in work activity for one's own non-agricultural enterprise (column 3). There are some shifts in activities related to home production among males and females: males reduce their probability of extended economic work (collecting fuel and water, preparing goods for consumption at home) (column 4) and females increase the probability of household chore work (cooking, cleaning, child care, etc.) (column 5). Notably, both males and females experience statistically significant increases in probability of studying that are of comparable magnitudes (column 6). Given we saw no evidence of impacts on the number of schools or total students, we interpret this last result to mean that children are shifting their time from agriculture to additional studies.

7.4 Robustness Checks

We show results are robust to multiple additional tests, such as employing arbitrary clustering methods, dropping certain locations and using alternative identification methods.

7.4.1 Arbitrary Clustering

Our instrumental variables are constructed based on geographic characteristics, which might be highly correlated between nearby regions. In addition, as Adao et al. (2019) suggest, the regression residuals from a shift-share design could be correlated across regions with similar shares, making the typical robust or clustered standard errors too small.

To address this, we employ the arbitrary clustering method proposed by Colella et al. (2019) for the inference in two different ways.[24] First, we account for spatial correlations among nearby regions using the distance between districts. Specifically, we construct a distance matrix based on the pair-wise distance among districts and use this matrix to define the correlation structure. We test two distance cutoffs, 50km and 100km, within which the error terms of two observations are assumed to be correlated. Second, we account for correlations among regions with similar geographic characteristics. In the spirit of Gallea (2023), we leverage the Bray-Curtis index to measure the pairwise dissimilarity between two districts, which is mainly used for abundance data with continuous values. Results are robust to this alternative inference method, for manufacturing establishments (Table A4), employment status (Table A5), and usual activities (Table A6). A complete discussion of both arbitrary clustering approaches employed is in Appendix A5.

[24]When attempting the command package developed by Adao et al. (2019), we encounter the same issue described by Gallea (2023); if we include all of our standard controls and fixed effects, then the variation of the instrument is close to idiosyncratic and therefore the standard errors estimated are near zero.

7.4.2 Monte Carlo Simulations

To support the claim that the causal relationships we identify are unaffected by selection bias and spurious time trends, we conduct Monte Carlo simulations proposed by Christian and Barrett (2017). This test is based on a randomization inference method. Within a given year, the key variable of interest, the cumulative number of microhydro plants, is randomly assigned to regions (i.e., municipalities for the CME data or VDCs for the census data) that have microhydro plants. We generate 500 randomized allocations of microhydro plants and then estimate the baseline 2SLS model using these randomized microhydro variables. Reassuringly, the distribution of the estimated coefficients shift towards zero (Table A7), as expected when the identification is unaffected by spurious time trends. Full details as to how we operationalize this placebo test are in Appendix A6.

7.4.3 Dropping the CREP Areas

As discussed in Section 3.2.2, rural communities could be electrified by one alternative means: extension of the electrical grid through the Community Rural Electrification Program. To ensure that we are not capturing any effects of the CREP, we perform a series of robustness checks, running our main regressions again but dropping locations that were at some point during the study period electrified via the CREP. All of our results are robust to dropping these locations. The estimated impacts of microhydro mini-grids are similar qualitatively and close in magnitude for the results on manufacturing establishments (Appendix Table A2, Column 3), employment status (Appendix Table A8), and usual work activities (Appendix Table A9) analyses.

7.4.4 Alternative Instruments

As an additional robustness check, we can use the average river slope variables described in Section 5.2 as a set of alternative instrumental variables. The first-stage regression results for the manufacturing and census datasets, all have strong first stages (Appendix

Table A10). We re-do these main analyses, using these alternative instruments in the first-stage, and have similar findings: an additional microhydro plant constructed within a municipality led to a 23.9 percent increase in manufacturing establishments (Appendix Table A11, Column 1) and individuals shift to work as an employee (Appendix Table A12, Panels A and B) for salary and wages and away from agricultural work activities (Appendix Table A13, Panels A and B).

7.4.5 OLS specifications

Lastly, we also use difference-in-differences regressions. With insufficient periods of pre-intervention data, we cannot provide standard evidence in support of the parallel trends assumption and therefore put less weight on these results. We do find that these difference-in-differences estimates tell the same story qualitatively: microhydro is associated with increases in manufacturing establishments (Appendix Table A11, column 3), shifts from self-employment to being an employee (Appendix Table A14, Panels A and B), and movement from agricultural activities to work for salary and wages (Appendix Table A15, Panels A and B).

Not surprisingly, the OLS coefficients overall are smaller in magnitude than the IV estimates. Microhydro mini-grids can be – and were – constructed in some locations that were not geophysically appropriate for the technology (Appendix Figure A3). For example, they were sometimes constructed at sites that do not actually have year-round river flow. Such sites would benefit less from microhydro construction than those with year-round river flow, because the plants could only generate electricity during particular seasons. These locations would be captured in our difference-in-differences estimate, but not in the instrumental variables estimate.

7.5 An Economic Value of the Impacts of Microhydro Plants

We provide additional evidence that the microhydro plants had an economic impact on these communities. First, we provide suggestive evidence that the additional microhydro plants brought increased employment and employee financial benefits along with the increase in the overall number of manufacturing establishments. Second, we present evidence that microhydro also increased household non-agricultural enterprises, indicating that smaller, informal businesses also benefited from electrification.

7.5.1 Manufacturing Establishments

We use cross-sectional survey data from the 2011 Census of Manufacturing Establishments in IV regressions, similar to those in Equations 2 and 3. In the cross-section, we omit province-year fixed effects and location-specific fixed effects. In their absence, we include controls for VDC characteristics and we define the "MHP number" as the cumulative number of microhydro plants in a VDC by the end of 2011.

Results from these regressions are in Table 6. The first-stage results in column 1 indicate a strong first-stage, with an F-stat of 33.03. Second-stage results, in the remaining columns, indicate that an additional microhydro plant constructed within a VDC by 2011 is associated with an additional 45 employees (column 2) and 3,550 thousand Nepali rupees in total annual benefits per VDC (column 3).[25] Based on the average 2011 exchange rate, these benefits equal 2,664 USD per month per VDC.[26]

We interpret these cross-sectional results with caution, but note their consistency with our main findings. The greater number of employees working for these enterprises per VDC is consistent with both the growth in the number of enterprises (Table 3) and the increase in the probability of working as an employee (Table 4) and for salary and wages (Table 5). The greater total benefits (in column 3 of Table 6) provides us with some indica-

[25] Analysis is at the Village Development Committee (VDC) level, as the government change in boundaries had not yet occurred at the time of the 2011 survey.

[26] The average exchange rate in 2011 was 1 Nepali Rupee to 0.0135 USD.

tion that these shifts in labor, translate into additional monetary benefits for individuals in these communities.

7.5.2 Household Non-Agricultural Enterprises

The magnitude of the labor shifts presented in Tables 4 and 5 may seem large, given the relatively modest increases found in manufacturing establishments. The manufacturing establishments in the census data, however, capture only formal manufacturing establishments of 10 or more employees. Yet some of the labor changes captured in the census microdata are likely due to changes in the smaller and informal enterprises.

To better understand the relationship between microhydro and small, non-agricultural household enterprises, we employ household data from the Nepal Living Standards Survey (NLSS). Using the NLSS in an unbalanced, stacked panel, we estimate 2SLS regressions with our instrumental variable with measures of non-agricultural household enterprises as our second-stage outcome variable.

Table 7 presents these results. The first-stage results (Column 1) show a strong first-stage. Columns 2 - 6 present results for non-agricultural household enterprise outcomes (inverse hyperbolic sine). We find that with a plant constructed, the number of household non-agricultural enterprises increases by 15.7 percent (column 2); however, there is no significant increase in formal enterprises (column 3). This indicates that the growth in household non-agricultural enterprises occurs among the informal enterprises. There is a 21.8 percent increase in the number of employees (column 4). Reported revenues of the household non-agricultural enterprises, both in the gross revenues (column 5) and net revenues (column 6), also increase. This growth in revenues could be coming as the result of increased productivity among existing household enterprises, not just in new enterprises. There is no significant impact on the farm net revenue (column 7).

8 Heterogeneous Impacts on Microhydro

As described earlier, AEPC originally intended to target microhydro mini-grids to locations in which the national electricity grid was unlikely to reach in the near future. Yet, in actuality, the Nepal Electricity Authority did not share or coordinate plans of grid extensions with the AEPC and microhydro plants were constructed in varying proximity to the national grid (Appendix Figure A2). This quirk and resulting heterogeneity in plants' proximity to the grid provides a unique opportunity to test for heterogeneous impacts in the impacts of microhydro – and electrification more broadly. Impacts likely vary depending on other market frictions, for example the development (or lack of development) in the surrounding areas. If the site of microhydro plant construction is relatively close to other communities that were previously grid electrified – perhaps even for many years – then the impacts of microhydro may be larger.

8.1 Main Heterogeneity Results

To understand the heterogeneous impacts of microhydro, we estimate a regression in which we interact our instrumental variable with an indicator variable ("No Grid") that equals one if the municipality is comprised of no VDCs with electricity grid connections and zero if any of the VDCs within a municipality are connected to the grid. The absence of the national grid is our proxy for a municipality's lack of prior development.

Table 8, which mimics Table 3 and adds the interaction of MHP $\times$ No Grid, presents striking heterogeneity results for manufacturing establishments. In our main specification (column 2), one additional microhydro plant constructed within a municipality containing a grid connection results in a 56 percent increase in manufacturing establishments. Such municipalities would have, on average, 0.337 manufacturing establishments of 10 or more employees following the microhydro plant construction. In contrast, locations in which no part of the municipality was grid connected, the construction of a microhydro plant would lead to a 15 percent increase in manufacturing establishments, on average. This translates to only one in four of these ”no grid” municipalities having such a manufacturing establishment following the plant construction. Column 3 shows results are again robust to including municipality-year controls.

We perform analogous regressions with the census microdata to test for heterogeneities in employment impacts as well. Results in Table 9 show that the shift from self-employment to employee status is significantly muted in the ”no grid” locations. For example, among males, there is a 7 percentage point increase in the probability of being an employee in the ”no grid” locations. In contrast, those locations proximate to the grid experience an increase in the probability that males are employees of 61.6 percentage points, a difference of a factor of 10. Among females, the increase in employee status is similarly a factor of 10 larger among the grid proximate locations. These heterogeneities in employee status increases are mirrored by differences in decreases in self-employment.

Heterogeneous impacts for usual work activities, shown in Table 10, are consistent with these muted effects. Males in locations proximate to the grid are 41.9 percentage points more likely to report working for salary and wages, whereas those in locations not proximate to the grid are only 5.6 percentage points more likely with the construction of a microhydro mini-grid (column 2). Although the absolute increases in wage and salary work are smaller in magnitude with the construction of a microhydro mini-grid, the gap between the grid and no-grid locations is similar in magnitude to that among the males. Results are comparable for females.

8.2 Robustness Checks for Heterogeneity Results

For heterogeneity results, we conduct the same robustness checks performed for the main analyses. Results for manufacturing establishments (Table A11, column 2 for alternative IV and column 4 for OLS), employment status (Table A12, Panels C and D for alternative IV and Table A14, Panels C and D for OLS), and usual activities (Table A13 Panels C and D for alternative IV and Table A15, Panels C and D for OLS) are all qualitatively similar for both the alternative IV and OLS robustness checks; however, the OLS regressions produce coefficients that are substantially smaller in magnitude than the main and alternative IVs.

9 Conclusions

The results presented here provide several important contributions to our understanding of the economic impacts of electrification. First, it provides insights as to whether rural electrification, and decentralized renewable energy more specifically, can lead to structural transformation via changes in manufacturing and employment, shifting labor from the traditional sector to the modern. Electrification via microhydro mini-grids increased formal (i.e., government registered) manufacturing establishments. Even with the significant increase, the overall numbers remained relatively small. Informal enterprises also increased, likely also contributing to the shifts in labor. Individuals are more likely to be employees and less likely to be self-employed. Consistent with these findings, there is a shift from own agricultural work to salary and wage employment.

The shift away from agricultural work activities observed in Nepal differs from findings in historical studies of the United States. Loans provided by the Rural Electrification Administration starting in the 1930s, positively impacted agricultural employment, rural property values, and crop output as well as productivity, but had little non-agricultural economic impact (Kitchens and Fishback, 2015; Lewis and Severnini, 2020). Those loans, however, targeted rural farm cooperatives, which contrasts from the microhydro program in Nepal and provides a likely reason for differences in findings.

Second, we provide evidence that the site's location, particularly proximity to development, matters for electrification impacts. The impacts of microhydro on manufacturing establishments are significantly muted in more remote locations and labor outcomes are differentially impacted in remote versus non-remote sites.

Taken together, these results suggest that decentralized renewables such as microhydro need not necessarily (although they certainly can) be constrained by the technology; however, the location in which these systems are often constructed – remote and distant from other markets – may limit the opportunity for manufacturing development.

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Figures and Tables

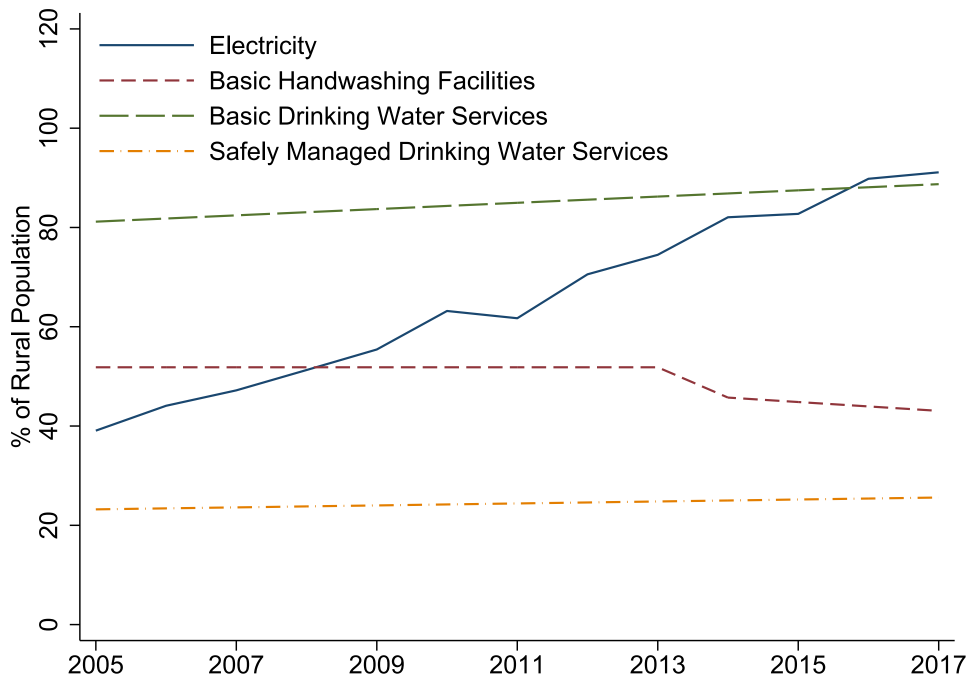

Figure 1: Rural Access to Electricity, Drinking Water, and Handwashing Facilities in Nepal, 2005 to 2017

Notes: Figure created using data from the World Development Indicators (World Bank, 2020).

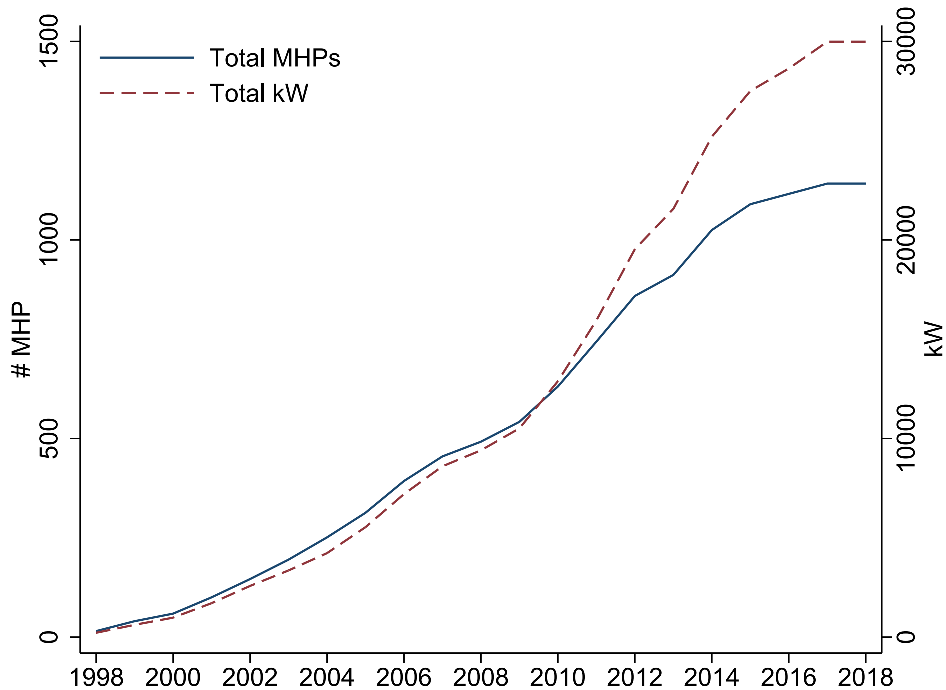

Figure 2: Microhydro Installed Capacity in Nepal Over Time

Notes: Figure created using data on microhydro plant construction over time from AEPC. The vertical access on the left depicts the number of microhydro plants constructed. The vertical access on the right shows the total installed capacity (kW) of those microhydro plants.

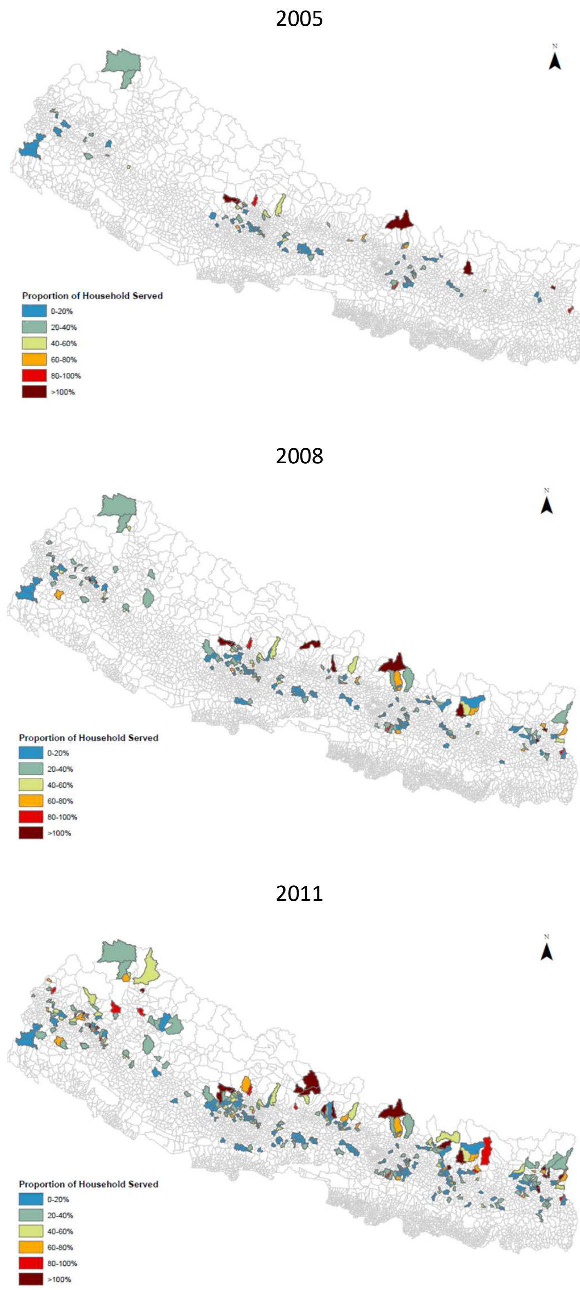

Figure 3: Microhydro Projects Completed Over Time (2005, 2008, 2011)

Notes: Map was created using data on microhydro plant construction from AEPC, the Transverse Mercator projection, and the Nepal Nagarkot TM Coordinate System. Color coding indicates the proportion of a VDC's population served by a microhydro plant.

Table 1: Correlates of GIS Carpet Study Identification of Geo-physically Appropriate Locations for Microhydro Plant Construction

	Carpet Study Identified
VDC Characteristics	
Hill or mountain regions	0.169***
	(0.019)
River slope bin [3, 20]	-0.020
	(0.015)
River slope bin [20, 30]	0.095***
	(0.022)
River slope bin [30, 50]	0.207***
	(0.033)
River Length (km)	-0.000
	(0.000)
Log distance to the nearest city (km)	0.037***
	(0.010)
Log distance to the nearest road (km)	0.072***
	(0.008)
Log distance to electric grid (km)	0.003***
	(0.001)
Population density	-0.002
	(0.004)
Household Characteristics	
Tap water access (2001)	-0.000
	(0.000)
Toilet access (2001)	-0.001***
	(0.000)
Electricity access (2001)	-0.000
	(0.000)
Home ownership (2001)	-0.031
	(0.094)
Households have television (2001)	0.001
	(0.001)
Constant	-0.185*
	(0.095)
Observations (VDCs)	3,852
R^2	0.284

Notes: The outcome variable is a binary variable equaling 1 if the VDC was identified as being geophysically appropriate for microhydro through the GIS carpet study and zero otherwise. ”Hill or mountain regions” is a binary indicator equaling 1 if the location is in the hill or mountains and 0 if located in the flat terai. The slope bins are binary indicators equaling 1 if the average river slope (in degree) within the VDC falls into one of the following categories: 3-20, 20-30, or greater than 30, and equaling 0 otherwise. The omitted group is between 0 and 3. Geographic data for distances are from ASTER Global DEM. Data on roads are from the Strategic Road Network. Data on household characteristics are from the 2001 census. Robust standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2: First-Stage Instrumental Variable Regressions

	Cumulative Number of MHPs in a Municipality/VDC		
	(1) CME Sample	(2) Census Sample: Male	(3) Census Sample: Female
Carpet × N_t	0.225***	0.070***	0.071***
	(0.030)	(0.010)	(0.010)
Individual Controls		✓	✓
VDC FE		✓	✓
Municipality FE	✓		
Province-Year FE	✓	✓	✓
K-P F-Stats	57.65	50.34	48.39
Observations	2,241	2,371,140	2,531,500
Adjusted R^2	0.851	0.735	0.746
#Regions	747	3,974	3,974
Observation Level	Municipality	Household	Household

Notes: "Carpet×N_t" is the interaction between: an indicator of carpet identification at the municipality/VDC level and the cumulative number of microhydro plants in Nepal in a year. Individual controls include the individual's age and education, the household size (number of people) and caste, and house amenities (toilet and water access). Standard errors are clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Impact on Manufacturing Establishments

	IHS(# Manufacturing Establishments)		
	(1)	(2)	(3)
MHP	0.427***	0.328***	0.330**
	(0.087)	(0.081)	(0.143)
Outcome Baseline Mean (Level)	0.216	0.216	0.216
K-P F-Stats	70.69	57.65	30.14
Observations	2,241	2,241	2,241
Municipality-Year Controls			✓
Municipality FE	✓	✓	✓
Year FE	✓		
Province-Year FE		✓	✓

Notes: These are second stage results. Observations are at the municipality level. MHP is the cumulative number of microhydro plants in a municipality from the first-stage regressions. The outcome variable is the inverse hyperbolic sine of the number of manufacturing establishments (employing 10 or more individuals) located within a municipality. Municipality-year controls include the logarithm of average elevation and slope in a municipality, both indicated with year fixed effects. The baseline mean is the outcome variable raw mean (i.e., not the inverse hyperbolic sine) for those locations where microhydro plants are later constructed. Data sources are further described in Data Appendix A3. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 4: Impact on Employment Status

	Reported employment status is:			
	Employer	Employee	Own Account Worker	Other
	(1)	(2)	(3)	(4)
A. Male				
MHP	-0.007	0.095***	-0.080***	-0.008
	(0.005)	(0.016)	(0.021)	(0.016)
Outcome Mean	0.018	0.219	0.365	0.395
K-P F-Stats	50.34	50.34	50.34	50.34
Observations	2,371,140	2,371,140	2,371,140	2,371,140
B. Female				
MHP	-0.010*	0.028***	-0.060**	0.042
	(0.006)	(0.006)	(0.029)	(0.027)
Outcome Mean	0.011	0.068	0.356	0.563
K-P F-Stats	48.39	48.39	48.39	48.39
Observations	2,531,500	2,531,500	2,531,500	2,531,500
#VDCs	3,974	3,974	3,974	3,974
Individual Controls	✓	✓	✓	✓
VDC FE	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓

Notes: MHP is the cumulative number of microhydro plants in a VDC from the first-stage regressions. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are responses to the individual's employment status. Additional variable descriptions provided in Data Appendix A4. Employment status can be as an employer, employee, own account work (i.e., self-employed), or other, which includes unpaid family work as well as those that do not report an employment status. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 5: Impact on Usual Activities

	Own Agriculture & Farming (1)	Salary & Wage (2)	Own Enterprise (3)	Extended Economic (4)	Household Work (5)	Study (6)
A. Male						
MHP	-0.109***	0.072***	0.008*	-0.009*	0.002	0.020*
	(0.022)	(0.014)	(0.005)	(0.005)	(0.003)	(0.011)
Outcome Mean	0.296	0.211	0.084	0.011	0.017	0.298
K-P F-Stats	50.34	50.34	50.34	50.34	50.34	50.34
Observations	2,371,140	2,371,140	2,371,140	2,371,140	2,371,140	2,371,140
B. Female						
MHP	-0.088***	0.019***	-0.006	-0.015	0.037**	0.030***
	(0.030)	(0.005)	(0.004)	(0.016)	(0.017)	(0.011)
Outcome Mean	0.285	0.057	0.034	0.032	0.28	0.239
K-P F-Stats	48.39	48.39	48.39	48.39	48.39	48.39
Observations	2,531,500	2,531,500	2,531,500	2,531,500	2,531,500	2,531,500
#VDCs	3,974	3,974	3,974	3,974	3,974	3,974
Individual Controls	✓	✓	✓	✓	✓	✓
VDC FE	✓	✓	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓	✓	✓

Notes: MHP is the cumulative number of microhydro plants in a VDC from the first-stage regressions. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are the individual's usual work in the past 12 months. Categories of usual work activities include: agriculture, wage or salaried work, small business activities (owning one's own enterprise), extended economic work (collecting fuel and water, preparing goods for consumption at home), household chores (cooking, cleaning, child care, etc.), and studies. Additional variable descriptions provided in Data Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 6: IV Cross-sectional Results: Employment Numbers and Financial Benefits

	(1) MHP	(2) #Employees	(3) Total Annual Benefits (thousand Nepali rupees)
Carpet × N_t	0.041***		
	(0.007)		
MHP		45.334**	3,550.041**
		(17.942)	(1,734.082)
Outcome Mean (Level)		46.996	3,851.07
K-P F Stats		33.03	33.03
Observations	3,942	3,942	3,942
VDC Controls	✓	✓	✓
District FE	✓	✓	✓
Regression	1st	2nd	2nd

Notes: These analyses use cross-sectional VDC-level data, collected via the Census of Manufacturing Establishments in 2011/2012. The variable MHP in these analyses is the cumulative number of microhydro plants in a VDC by the end of 2011 from the first-stage regressions. The "number of employees" is defined as the number of persons who work in or for the establishment and receive pay, in cash or in kind, at regular intervals. The "total benefits" is the sum of direct wages, salaries, and facilities, which includes both cash remuneration for work performed and time not worked due to holidays and for other reasons. The average exchange rate in 2011 was 1 Nepali Rupee to 0.0135 USD. Analysis is at the Village Development Committee (VDC) level, as the government change in boundaries had not yet occurred at the time of this CME iteration. VDC controls include the number of households as of 2001, the area of the VDC, if the VDC was already connected to the electrical grid as of 2001, the log elevation, distance to the grid in kilometers, the log distance to the nearest city, and the log distance to the nearest paved road. Standard errors in parentheses are clustered at the district level. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 7: Impacts on Household Enterprises

	MHP	Non-Agricultural Enterprises	Non-Agricultural Formal Enterprises	Non-Agricultural Enterprise Employees	Non-Agricultural Gross Revenue (NPR)	Non-Agricultural Net Revenue (NPR)	Farm Net Revenue (NPR)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Carpet × N_t	0.082***						
	(0.026)						
MHP		0.157**	0.016	0.218**	1.741**	1.724**	0.961
		(0.068)	(0.020)	(0.107)	(0.757)	(0.718)	(1.250)
Outcome Mean		0.360	0.083	1.208	183,782	99,273	37,178
K-P F Stats		10.16	10.16	10.16	10.16	10.16	10.16
#VDCs	575	575	575	575	575	575	575
Observations	9,756	9,756	9,756	9,756	9,756	9,756	9,756
VDC Controls	✓	✓	✓	✓	✓	✓	✓
District FE	✓	✓	✓	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓	✓	✓	✓

Notes: MHP is the cumulative number of microhydro plants in a VDC from the first-stage regressions. The outcome variables in columns 2 - 7 are transformed into the inverse hyperbolic sine. Outcome variables are collected through the Nepal Living Standards Survey (NLSS) in 2003 and 2010 in response to questions about non-agriculture enterprises. Formal enterprises are those enterprises that are registered with the government. Enterprise employees include non-farm employees, both household workers and hired workers. All revenues are in Nepali rupees (NPR). Village Development Committee (VDC) controls include the number of households, area, distance to the city, and distance to the road. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 8: Heterogeneous Impacts on Manufacturing Establishments

	IHS(# Manufacturing Establishments)		
	(1)	(2)	(3)
MHP	0.821***	0.560***	0.515**
	(0.166)	(0.133)	(0.203)
MHP × No Grid	-0.629***	-0.410***	-0.354***
	(0.147)	(0.111)	(0.125)
Outcome Mean (Level)	0.216	0.216	0.216
Observations	2,241	2,241	2,241
K-P F Stats	70.69	57.65	30.14
Municipality-Year Controls			✓
Municipality FE	✓	✓	✓
Year FE	✓		
Province-Year FE		✓	✓

Notes: MHP is the cumulative number of microhydro plants in a municipality from the first-stage regressions. "No grid" is an indicator for whether the municipality has no electric grid. The outcome variable is the inverse hyperbolic sine of the number of manufacturing establishments (employing 10 or more individuals) located within a municipality. Municipality-year controls include the logarithm of average elevation and slope in a municipality, both indicated with year fixed effects. The baseline mean is the outcome variable raw mean (i.e., not the inverse hyperbolic sine) for those locations in which microhydro plants are later constructed. Data sources are further described in Data Appendix A3. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 9: Heterogeneous Impacts on Employment Status

	Reported employment status is:			
	Employer	Employee	Own Account Worker	Other
	(1)	(2)	(3)	(4)
A. Male				
MHP	0.026	0.616***	-0.367**	-0.275*
	(0.031)	(0.218)	(0.174)	(0.139)
MHP × No Grid	-0.034	-0.546**	0.300*	0.280**
	(0.030)	(0.219)	(0.172)	(0.138)
Outcome Mean	0.018	0.219	0.365	0.395
K-P F-Stats	50.34	50.34	50.34	50.34
Observations	2,371,140	2,371,140	2,371,140	2,371,140
B. Female				
MHP	-0.033	0.253**	-0.311	0.090
	(0.050)	(0.100)	(0.234)	(0.219)
MHP × No Grid	0.023	-0.235**	0.261	-0.050
	(0.048)	(0.100)	(0.226)	(0.210)
Outcome Mean	0.011	0.068	0.356	0.563
K-P F-Stats	48.39	48.39	48.39	48.39
Observations	2,531,500	2,531,500	2,531,500	2,531,500
#VDCs	3,974	3,974	3,974	3,974
Individual Controls	✓	✓	✓	✓
VDC FE	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓

Notes: MHP is the cumulative number of microhydro plants in a VDC from the first-stage regressions. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. "No grid" is an indicator for whether a Village Development Committee (VDC) has no electric grid. The outcome variables are responses to the individual's employment status. The "other" group includes both unpaid family workers and those that did not state an employment status. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 10: Heterogeneous Impacts on Usual Activities

	Own Agriculture & Farming	Salary & Wage	Own Enterprise	Extended Economic	Household Work	Study
	(1)	(2)	(3)	(4)	(5)	(6)
A. Male						
MHP	-0.422**	0.419**	0.100	-0.011	-0.031	-0.181*
	(0.184)	(0.172)	(0.065)	(0.024)	(0.030)	(0.108)
MHP × No Grid	0.328*	-0.363**	-0.096	0.002	0.035	0.210*
	(0.184)	(0.172)	(0.065)	(0.023)	(0.030)	(0.108)
Outcome Mean	0.296	0.211	0.084	0.011	0.017	0.298
K-P F Stats	50.34	50.34	50.34	50.34	50.34	50.34
Observations	2,371,140	2,371,140	2,371,140	2,371,140	2,371,140	2,371,140
B. Female						
MHP	-0.384*	0.162**	-0.006	0.031	0.058	-0.087
	(0.227)	(0.072)	(0.042)	(0.175)	(0.140)	(0.123)
MHP × No Grid	0.308	-0.150**	0.000	-0.048	-0.022	0.121
	(0.225)	(0.072)	(0.041)	(0.173)	(0.138)	(0.124)
Outcome Mean	0.285	0.057	0.034	0.032	0.28	0.239
K-P F Stats	48.39	48.39	48.39	48.39	48.39	48.39
Observations	2,531,500	2,531,500	2,531,500	2,531,500	2,531,500	2,531,500
#VDCs	3,974	3,974	3,974	3,974	3,974	3,974
Individual Control	✓	✓	✓	✓	✓	✓
VDC FE	✓	✓	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓	✓	✓

Notes: MHP is the cumulative number of microhydro plants in a VDC from the first-stage regressions. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are the individual's usual work in the past 12 months: agriculture, salary/wage, own economic enterprises, extended economic enterprises, household work, and study. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

APPENDIX FOR ONLINE PUBLICATION:

Electrification to Grow Manufacturing? Evidence from Microhydro in Nepal

DATA APPENDIX

A1 Data on Sources of Electrification

A1.1 Microhydro plant construction data

In 1996, the country's Alternative Energy Promotion Center (AEPC) was created within the Ministry of Science, Technology, and Environment to promote and coordinate donors' renewable energy investments. Various multilateral and bilateral donors and development organizations funded the construction of microhydro plants and mini-grids during the study period. These funding institutions include the United Nations Development Programme (UNDP), the World Bank, the Global Environment Fund (GEF), Practical Action, and the Governments of Denmark (Danida), Norway (Norad), and Germany (KfW). Over the years the funding for microhydro from these entities was delivered through a few programs and projects representing various coordinated efforts, such as the Energy Sector Assistance Programme Phases I and II (ESAP I and II), the Rural Energy Development Programme (REDP), Renewable Energy for Rural Livelihood (RERL), and National Rural and Renewable Energy Programme (NRREP).

AEPC collected data on the microhydro plants constructed over time. From AEPC, we received detailed lists of plant construction through 2018, including location, date, capacity, and number of households served. We combined several lists provided by AEPC to ultimately identify the locations of microhydro plants. These locations can be identified at the Village Development Committee level (VDC), which is akin to a collection of villages.

Assigning a microhydro plant to a VDC: The AEPC data provide information on the location at which the microhydro plant was constructed; however, the service areas of the microhydro mini-grids do not necessarily perfectly correspond with boundaries of the Village Development Committees (VDC) in which the plants are constructed. For example, there may be a place with river slope that is appropriate for a microhydro plant that is located between two population centers. The plant may be constructed between the two population centers. It is feasible that the construction is within one VDC but serving the population center located within a neighboring VDC.

To ensure that we are assigning the microhydro plant and its mini-grid to the correct VDC, we map in GIS both the AEPC construction data and the household census microdata on electrification status. Data on the baseline electrification status are available through the 2001 National Population Census. The census asked what the usual source of lighting was for each household.[27] We use these maps to determine which VDCs were likely electrified by a plant in a neighboring VDC based on the available microhydro capacity, the populations of both VDCs, and whether there was another likely source of electrification nearby. This allows us to confirm which VDCs are electrified via microhydro mini-grids. We exclude any VDC with an electrification rate of less than 5%, as the proportion electrified is low enough that we do not consider the community to be electrified.

Determining whether a plant is still operating: Microhydro first began to be constructed in the country during the 1960s, so some of the microhydro plant in the dataset quite old. Given the expected 20-year lifespan of the microhydro plants, we do not expect the oldest systems to still be functioning and do not include them in the dataset. We therefore consider those microhydro plants with capacity recently installed, in other words, those constructed after 1990 per the AEPC records, as those still being active and operating during our study period.

A1.2 Grid extension data

We obtained data from the NEA and the National Association for Community Electricity (NACEUN) on the locations electrified through grid extensions via the Community Rural Electrification Programme (CREP) and with an established Community Rural Electrification Entity (CREE) through 2015. These data, however, did not include the year of CREE establishment. Therefore, similar to the microhydro mini-grids, we use census microdata to confirm data of electrification. We assume that if the VDC electrification rate is below 30% in the 2011 census, the CREE had not yet been established. We define a VDC as CREE-electrified if any part of it contains a CREE that was established as of 2011. These are admittedly basic measures, but sufficient to allow us to control for the locations involved in the CREP and to drop them from the analyses in our robustness checks.

A2 GIS and Remotely-sensed Data

To better understand the GIS carpet study and the correlates of the GIS study microhydro identification, we calculate river slopes using several publicly-available geospatial data files. Geospatial data on river in Nepal come from OpenStreetMap, which are ESRI compatible shapefiles that include various water bodies (e.g. rivers). Data are available at: https://download.geofabrik.de/asia/nepal.html.

[27]Potential responses included: electricity, kerosene, biogas, solar, and other.

To compute VDC-level elevation and slope statistics, we use high-resolution topographic data for Nepal that are generated from NASA's Shuttle Radar Topography Mission (STRM). A description of these data is available here: https://www2.jpl.nasa.gov/srtm/. These data, which were released publicly in late 2015, provide "a 1 arc-second, or about 30 meters (98 feet), sampling." These data can be downloaded from the SRTM Tile grabber through the following website: https://dwtkns.com/srtm/.

Together, these datasets are used to compute river statistics at the VDC level. These statistics include river length, river elevation, and river slope (in degrees). We calculate the river length within a VDC, the fraction of VDC area with elevation/slope falling in four different categories, and river gradient by restricting attention to cells in a district through which a river flows. We use these to compute the fraction of river area falling into the four gradient categories. The end result are VDC-level calculations of average river slope (in degrees) within the following bins: 0-3, 3-20, 20-30, or greater than 30.

A3 Data on Manufacturing Establishments

To create a panel dataset of manufacturing establishments in Nepal over time, we had to address differences between the two main datasets and changes in the country's administrative boundaries over time. We document the process of addressing both issues in the subsections that follow.

A3.1 Addressing Differences Across Data Sources

The panel dataset of manufacturing establishments that we created uses data from the 2006/2007 and 2011/2012 iterations of the Nepal Census of Manufacturing Establishments (Nepal Central Bureau of Statistics, 2014) and the 2017/2018 National Economic Census (Nepal Central Bureau of Statistics, 2019).

The data sources have a couple of differences that must be addressed. We accommodate them as follows. First, whereas the Census of Manufacturing Establishments collected data only on manufacturing, the National Economic Census collected data for other industries as well. We limit the 2017/2018 data to the subset covering manufacturing establishments, such that it is comparable to the counts in the 2006/2007 and 2011/2012 rounds. Second, the Census of Manufacturing Establishments collected data only for establishments employing 10 or more individuals; thus, we excluded establishments employing fewer than 10 individuals from the National Economic Census data. The end result is a panel dataset counting the number of manufacturing establishments that employ 10 or more individuals within a municipality in 2006/2007, 2011/2012, and 2017/2018.

A3.2 Addressing Changing Administrative Boundaries

Starting in 1990, Village Development Committees (VDCs) became the primary administrative unit for local governance in Nepal. At the level below provinces, the country was divided into 77 districts and those districts were comprised of 3,974 VDCs. The electrification data, which are described in Appendix A1 and used as our treatment and control variables in regressions, are at the VDC level.

The passing of a new national constitution in 2015 brought about changes in the administrative units comprising the country. The VDCs in Nepal were dissolved and replaced by a new system of administrative units – the Gaunpalika or municipalities. There were 747 municipalities created to replace the VDCs. Districts, the second-level administrative country sub-division, largely remained the same, except 2 of the smallest districts were subsumed by larger districts. As a result there are 75 districts after the 2015 constitution instead of 77. These changes in administrative units are summarized in the following table.

	Administrative units below Province	
	Before 2015	After 2015 constitution
sub-province unit	77 districts	75 districts
sub-district unit	3,974 VDCs	747 municipalities

Our analyses that only use data prior to 2015-2016 – prior to the passing and operationalization of the municipality system – do not require any spatial adjustments. Those analyses that include data after 2015-2016 do require adjustments to ensure appropriate spatial matching.

To incorporate the 2018 municipality-level Census of Manufacturing Establishments data into the analysis, we must address these changes in administrative units during our study period. We use GIS files mapping between VDCs to municipalities, and then aggregate the VDC-level data to the municipality level.

Most VDCs were combined into one municipality. Therefore, we aggregate the total number of enterprises in these VDCs and consider it as the municipality-level measure. For the treatment variable, we consider a municipality as having microhydro power or a Community Rural Electrification Entity (CREE) if one of its VDCs has microhydro power or a CREE in a certain year.

The matching of VDCs to municipalities is not perfect; 17 of the 3,974 VDCs were divided and assigned across multiple municipalities. For these VDCs, we employ three methods to construct the municipality-level outcome measure. First, we equally divide the number of enterprises in a VDC by its corresponding number of municipalities, and then sum up this adjusted number. Second, we drop all the VDCs that are matched with multiple municipalities and omit the enterprises in these regions. Third, we simply aggregate the number of enterprises to the municipality level by double counting those VDCs. We can perform our analyses utilizing each of these three approaches. We use the first approach as our primary specification and the other two approaches as robustness checks.

A4 Details on Census Microdata Variables

Two of our main outcome variables are from Nepal's census, implemented in 2001 and 2011. Here we provide additional detail from the publicly available documentation on the World Bank's microdata library. We have copied parts of the information. Full details are available here:

https://microdata.worldbank.org/index.php/catalog/523/related-materials

A4.1 Employment Status

The census question and response options are as follows: What was XXXXX employment status?
1. Employer
2. Employee
3. Own account worker
4. Unpaid family worker

The description of these 4 categories is given below.

1. Employer - An employer is a person who operates her/his own economic enterprises or engages independently in a profession or a trade and hires one or more employees. In other word, if the person is operating her/his own profession or business by hiring employees regularly in the reference period then the employment status of that person is employer. To mention the employment status of employer encircle the "employer" option given in the category 1. If the employer had done other activities than management at that time also the status is "employer". But, while operating own activity at the peak time of the season for example, planting, harvesting in agriculture related activities, at a person may hire some people for 2, 4 days only, at that time the status of person is not "employer"

2. Employees - An employee is a person who works for public or private employer and receives remuneration in terms of wage, salary, commission, piece rates or pay in kind. The status of the person becomes employees if she/he works in government office, non government office or corporation or private enterprises or office, private home at any profession in industry sector getting salary, wage. In the reference period, if the enumerated person was usually engaged in doing work for others by getting salary, wage then her/his employment status becomes employees. Employees are getting salary, wage but they are not directly related to the profit and loss of the industry

3. Own Account Worker - An own account worker is a person who operates her/his economic enterprises or engages independently in a profession or trade and hires no employees in the last 12 month. To mention the status of own account worker should be encircled in category 3. People, who are engaged in household work like servant, cook, and getting salary, wage regularly but they are not engaged regularly in economic enterprises, these people are only for the housework purpose and not for industry. So, their employment status is own account worker. The economic enterprises (Industry) which is conducted by any member of the household and other members also work there without taking the salary, wage then the status of other members is also like the main person who conducts the industry "own account worker". To denote this employment status encircle the category 3. But the profession which is adopted by any member of the household and other members only helps her/him partially (Morning, evening or other time) then the status of that persons will be the "unpaid family worker". To denote the unpaid family worker it should be encircled on category 4 not in category 3.

4. Unpaid family worker - An unpaid family worker is a person who works without pay in economic enterprises operated by a person living in the same household. The industry mentioned in column 18 (Agriculture or others) which is conducted by any household member and other members (husband, wife, son, daughter, brother, sister, brother in law, etc) can support the activity without taking salary, wage. Except the people who are included in the occupation of column 17, the main person, who conducts the industry and the full time engaged members, other members who help partially for that industry should be included in the category 4. To denote their employment status should be encircled the category 4 "unpaid family worker"

A4.2 Usual Work Activities

The census question and response options are as follows: What work usually doing during the last 12 months? (For all persons of age 10 years and above)
1 Agriculture/ own cultivation
2 Salary/ wage
3 Own non-agricultural enterprises
4 Extended economic activity
5 Job seeker
6 Household work
7 Student
8 Not working

Work is defined as the activities that may or may not generate income. There may be economic or non economic activities. The enumerated individual may do the activities from serial code ″1″ through ″7″ as mentioned above, or may not do any work (as serial code ″8″) in the 12 months preceding the census enumeration day. But in this question, the intention is to explore the most frequent activity done by the individual in terms of time spent. The enumerator should encircle or indicate the proper code of the activity that was done for most of the time during the last 12 months.

For the purpose of census enumeration, the above mentioned activities are further elaborated as following.

1. Own agriculture/farming: The category own agriculture/farming includes all activities related to agriculture. The activities included in the agricultural work are elaborated as following. Agricultural Activities: 1. All the activities like digging, plowing, planting, sowing, weeding, caring, cutting or chopping, harvesting, drying, sifting or removing impurities, packing, collecting seeds etc. in the course of production of crops (rice, wheat, maize, millet, barley, etc), cash crops, vegetables, fruits (orange, banana, mango, jackfruit, apple, peer, guava etc.) are known as the agricultural works or farming activities. 2. Similarly, all the activities like raising livestock: cow, buffalo, sheep, goat, pig, rabbit, etc., and raising poultry like chicken, duck and other birds with the purpose of meat or egg production are also included in the agricultural work or farming activities. 3. Activities like making of fish-ponds, breeding agricultural works. 4. The activities like planting of trees in the wood land and forest, weeding, planting the grass, weeding the grass, and related protection activities are also agricultural work. Similarly, bee-hiving, farming of silkworm are also included in the agricultural work. But agriculture works do not include the activities carried out in manufacturing industries like food stuff production industries, grinding industry, bamboo related materials or goods production industries, and saw-mill, etc. Own agriculture or farming means the agricultural works or farming activities that have been operated by the enumerated individuals investing their own capital in cash or kinds, or both, and labor, and who bear the profit or loss from their production. If the enumerated person has involved most of her/his time during reference period of last 12 months in own agricultural work or farming, then enumerator should mark or encircle the code 1 to indicate ″own agriculture or farming″. If the enumerated person has also invested most of her/his time in the agricultural activity operated by anyone of the household members, then the enumerator should encircle the code to indicate ″own agriculture work or farming″ for each person who is involved in agricultural activities. But if the enumerated person has involved most of her/his time in agricultural activities operated by others in charge of salary or wage or any kind of labor participation, then the enumerator should encircle code ″2″ to indicate the activity as salary or wage.

2. Salary/Wage Activity: The category includes the person who works for salary/wage most of time during the 12 months of the reference period. The enumerator should encircle code "2" to indicate salary/wage activity. If the enumerated person has spent most of the time in any kind of activities in the sectors like government or non-government institutions or manufacturing establishments or private home or business during the last 12 months of reference period, then the enumerator should encircle code "2" to indicate salary/wage. The domestic workers like gothala (shepherd or cowboy or herdsman), hali (ploughman), cook, or kamaiya (bondman) are kept for doing any activity in account of salary/wage, then for this case also the enumerator should encircle code 2.

3. Own non-agriculture enterprises or business: Non-agriculture enterprises include all kinds of business or enterprises operated by the household except one's own agriculture or farming activity. One's own non-agricultural enterprise is defined as any kind of business activities operated by household or member(s) investing capital (in terms of cash or kinds or labor) and bearing the profits or losses of the business. If the enumerated person has contributed most of her/his time in own any kind of non-agricultural enterprise or business in the reference period, then the enumerator should encircle code "3" to indicate her/his activity. Also if any of the household members has operated any kind of non-agricultural enterprise and the enumerated person has devoted most of her/his time in that enterprise during the reference period, then her/his activity should be encircled in code "3". But if enumerated person has worked in a non-agricultural enterprise or business receiving any kind of remuneration like salary, wage, or labor, then the activity of the person should be encircled in code "2". The activity of such person should not be encircled in code "3".

4. Extended Economic Work: Extended economic work is defined as activities like collecting firewood, fetching drinking water in the household for own consumption. Processing food and grinding grains in dhiki, janto (traditional grinding tools) or in a mill, or kelaune (picking grains) work; making pickle, titaura (rolled and dried fruit juices, tamarind), masyaura (dried preparation of the pulse for curry), or similar kinds of making food stuff for the consumption of the household. If any member(s) of household has contributed most of her/his time in such activities, then the activity of the person should be encircled in code 4.

5. Seeking Economic Work: Seeking job is defined as the activity of looking for or searching job- or work-related activities to generate income. In such conditions, the person seeking job should be actively involved in seeking a job or work and should be available for work.

6. Household Work: Household chores or work means the activities carried out by a person like cooking, feeding household members; taking care of children, aged persons, and ill member(s) of household; teaching their own children; cleaning the house and its courtyard, and washing related works. When the household member who often undertakes such activities for other household member(s) does so without any remunerations or wages, then such activities are called ″household chores″. Such activities carried out by the person for own self and family member(s) without any salary or wage is counted as not income generating work with economic perspective. If any of the enumerated male or female persons has contributed most of his/her time during the reference period in activities like cooking, feeding for household members; taking care of children, aged persons, and ill member(s) of household; teaching own children; cleaning the house and its courtyard, and washing related works, then her/his activity should be encircled in code ″6″ to indicate household chores. Similarly, if the person was not able to do any income generating work or has worked for short duration due to the reasons of pregnancy or Sutkeri (woman who has just given birth to a baby) or taking care of children, then the activity of such person should be encircled in code ″6″. But if any person undertakes these activities like cooking, feeding for household members; taking care of children, aged persons, and ill member(s) of household; teaching their own children; cleaning the house and its courtyard, and washing related works for any remuneration like salary, or wage (cash or kinds), then such activities are income generating works. As mentioned above if an enumerated male or female person has carried out such activities while receiving remuneration during the reference period, then her/his activity should be encircled in code ″2″ to indicate salary/wage but should not be encircled in code 6.

7. Study (student): Study (student) means the student (boy or girl) who has enrolled or not in school, college, university or other any academic institutes for achieving education or any kind of training during the reference period.

8. No work done: If a person has not undertaken any economic or income related activities (activities mentioned in codes ″1″, ″2″, ″3″, or ″4″), or not even sought any job or not doing non-economic work (activities mentioned in code 6 and ″7″), then the person's activity status is ″no work done″.

DETAILS ON ROBUSTNESS CHECKS

A5 Arbitrary Clustering

Our instrumental variables are constructed based on geographic characteristics, which might be highly correlated between nearby regions. In addition, as Adao et al. (2019) suggest, the regression residuals from a shift-share design could be correlated across regions with similar shares, and therefore making the typical robust or clustered standard errors too small. To address this issue, we employ the arbitrary clustering method proposed by Colella et al. (2019) for the inference in two different ways.

First, we account for spatial correlations among nearby regions using the distance between districts. Specifically, we construct a distance matrix based on the pair-wise distance among districts and use this matrix to define the correlation structure. We test two distance cutoffs, 50km and 100km, within which the error terms of two observations are assumed to be correlated.

Second, we account for correlations among regions with similar geographic characteristics. In the spirit of Gallea (2023), we leverage the Bray-Curtis index to measure the pairwise dissimilarity between two districts, which is mainly used for abundance data with continuous values. The dissimilarity between district i and j is defined as follows

$$BC_{ij} = 1 - \frac{2\sum_{k=1}^{K} \min(W_{ik}, W_{jk})}{\sum_{k=1}^{K}(W_{ik} + W_{jk})},$$

where W_{ik} is the k-th dimension of geographic characteristics for district i. Here, the series of geographic characteristics include average slope, average elevation, river length, the proportion of river with slope falling into each category (i.e., 0-3, 3-20, 20-30, 30-50 in degrees), and the proportion of river with elevation falling into each category (i.e., 0-250, 250-1000, 1000-3000, $\geq$3000 in meters). This index has the value between 0 and 1, and a higher value means less similarity between two districts. With all the pairwise Bray-Curtis index, we can create a dissimilarity matrix and use it to define the strength of the error dependence. We test two dissimilarity cutoffs, the median and the 3rd quartile of all the pairwise Bray-Curtis index values. Lastly, we also tried the Bartlett-kernal approach that assumes a distance linear decay in the correlation structure.

The arbitrary clustering method can be easily applied to our analyses on the manufacturing establishment data. However, we have difficulty in implementing this method directly on our individual-level census data due to the huge sample size. To mitigate the computation burdens, we aggregate the individual-level census data to the VDC level as follows. First, we regress the outcomes of interest, the independent variable (i.e., number of MHP), and the instrumental variable on the fixed effects and control variables. This is to partial out the controls and high dimensional fixed effects. Second, we obtain the regression residuals and aggregate them to the VDC level by taking the average. Third, we perform the weighted regression analysis using this VDC-level data where the weight is the number of individuals in each VDC in our sample.

The results of the estimates using the arbitrary clustering methods are presented in Table A4, A5, and A6. In the first two rows of each table, we report the coefficient estimates and the standard errors clustered at the district level. The standard errors computed from the arbitrary clustering method are reported below in parenthesis. As is shown in Table A5 and A6, the coefficient estimates from the aggregated VDC-level data are almost the same as those from the individual-level data. Our results are robust to this alternative inference method.

A6 Placebo Test with Randomization Inference

As Christian and Barrett (2017) suggest, the common spurious trends between the time-series part of the IV (i.e., microhydro construction budgets over time in our case) and the outcome variables might pose threats to the exclusion restriction assumption. To mitigate the concern, we perform a placebo test following Christian and Barrett (2017).

This test is based on a randomization inference method where we introduce randomness into the endogenous explanatory variable (i.e., the cumulative number of microhydro plants) while keeping everything else unchanged. Specifically, within a given year, the key variable of interest, the cumulative number of microhydro plants, are randomly assigned to regions (i.e., municipalities for the CME data or VDCs for the census data) that have microhydro plants. The randomization is without replacement and we generated 500 randomized allocations of microhydro plants. We then estimate the primary 2SLS model using these randomized microhydro variables. If the identification were unaffected by spurious time trends, the distribution of coefficients should shift towards zero relative to our main estimates.

Table A7 reports summary statistics of the coefficient estimates generated from the 500 randomizations for all the main outcome variables. In the last five columns, we report the mean, 10th percentile, median, 90th percentile, and the proportion of estimates that are closer to zero compared to our baseline estimates. Reassuringly, the distribution of these estimates shift towards zero.

APPENDIX of FIGURES

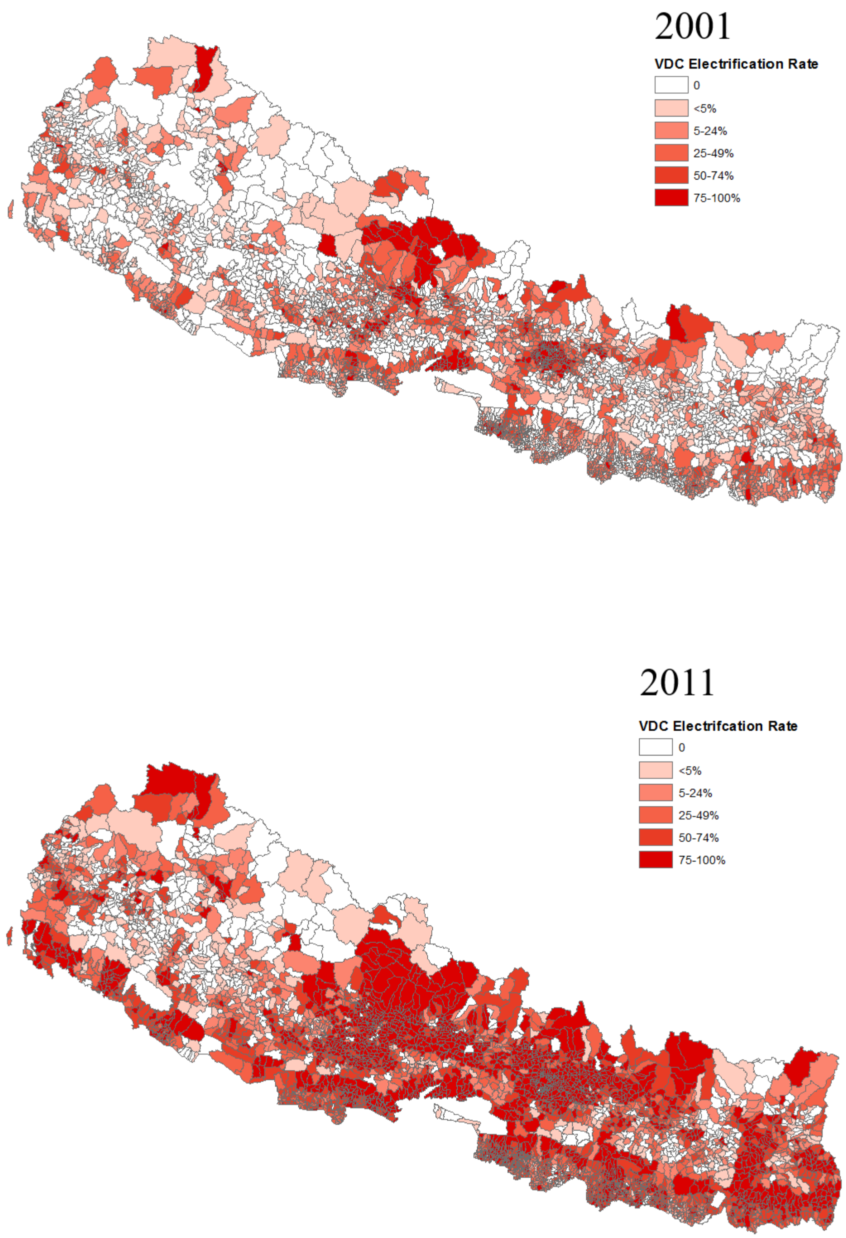

Figure A1: Electrification Rates at Village Development Committee (VDC) Level, 2001 and 2011

Notes: Map was created using the Transverse Mercator projection and the Nepal Nagarkot TM Coordinate System with data from the 2001 and 2011 Nepal Household Census. Blank spaces in the northwestern region were not sampled in 2001 due to unrest in those districts.

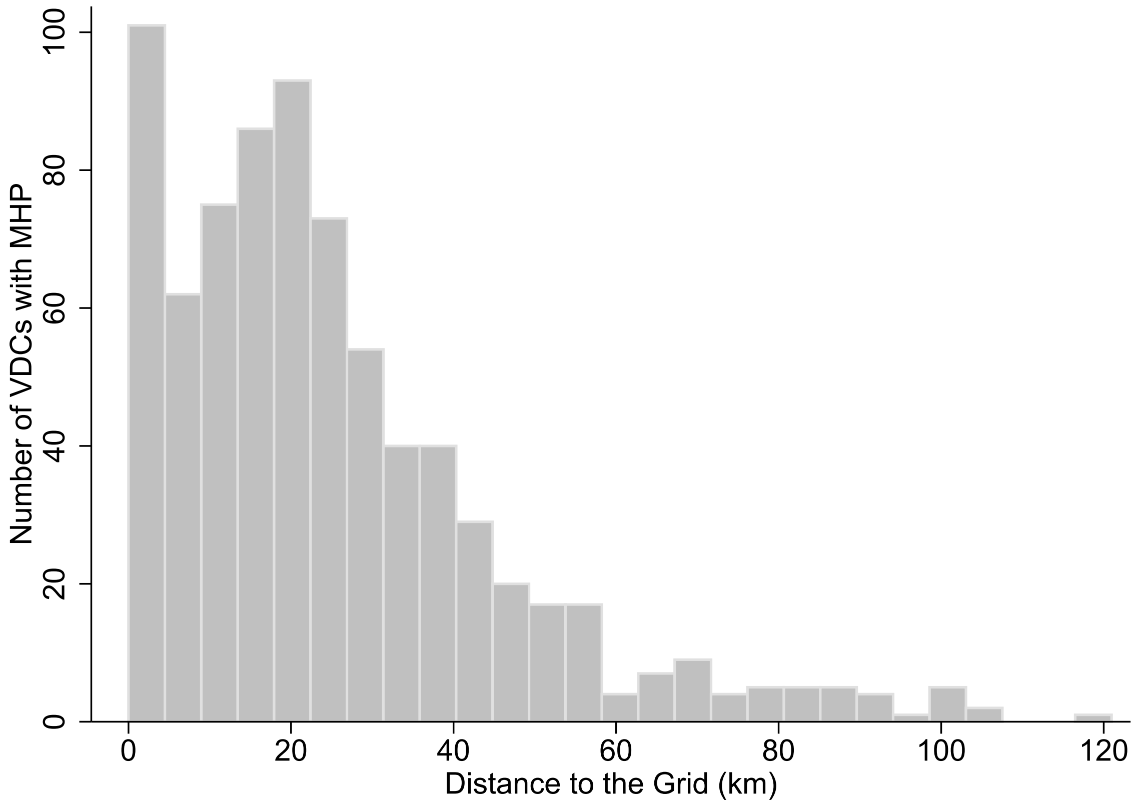

Figure A2: Proximity of Microhydro Sites to the Electrical Grid (km)

Notes: Figure uses data from Alternative Energy Promotion Center in Nepal.

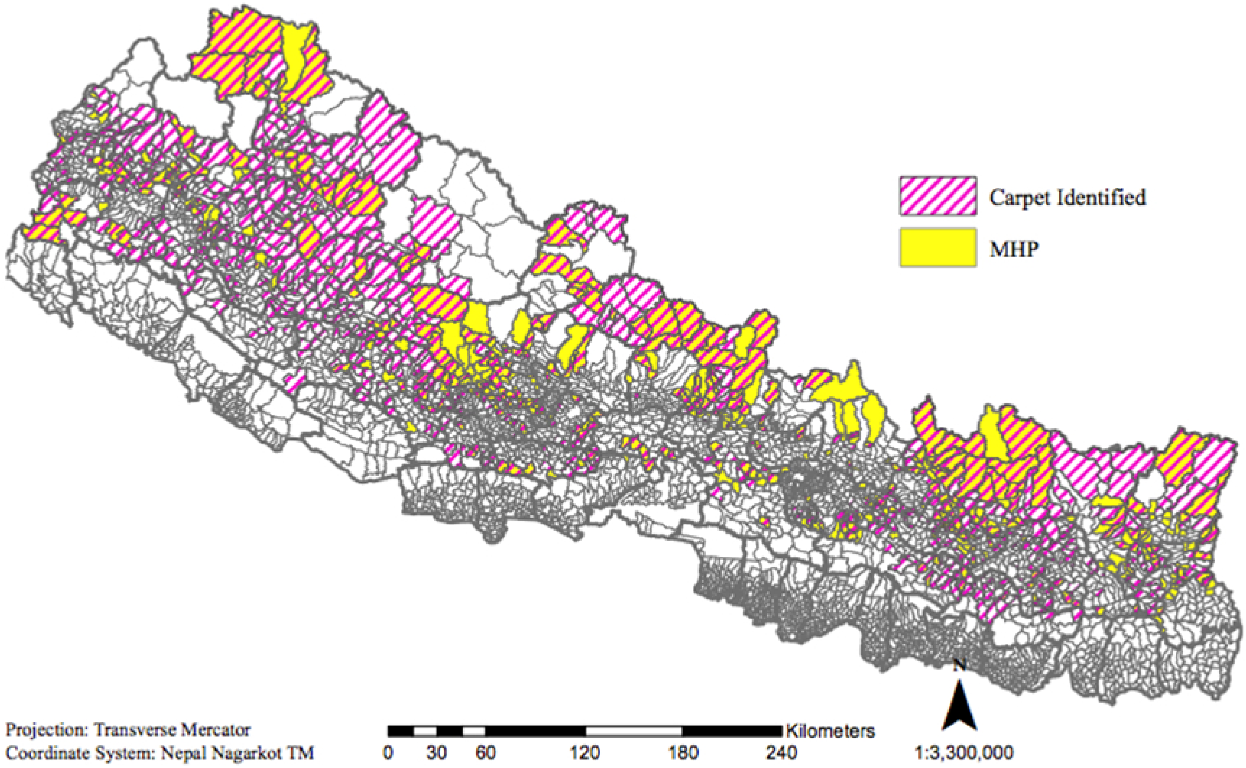

Figure A3: Village Development Committees (VDCs) Identified in GIS Study and VDCs Electrified with Microhydro Power (MHP) by 2011

Notes: Map was created using data on GIS study results and microhydro plant construction from AEPC, the Transverse Mercator projection, and the Nepal Nagarkot TM Coordinate System. The map shows that not all carpet-identified locations had microhydro plants constructed and microhydro could be constructed in locations not carpet-identified, outside of the AEPC process.

APPENDIX OF TABLES

Table A1: Employment Statistics in Locations Prior to Microhydro Plant Construction

Individual employment of:		Males	Females
Employment status is:			
	employer	0.017	0.018
	employee	0.098	0.028
	own account	0.543	0.609
	other	0.342	0.346
Usual work activity is:			
	agriculture	0.508	0.548
	salary & wage	0.087	0.020
	own enterprise	0.337	0.017
	extended economic	0.016	0.051
	household work	0.012	0.103
	study	0.285	0.206
Observations (individuals)		100,780	110,093

Notes: Baseline means are the variable raw means in Village Development Committees (VDCs) where microhydro plants will be constructed but were not yet at baseline. Employment variables are from the 2001 Nepal Population Census, which collected data for household members 10 years of age and older. Employment status can be as an employer, employee, own account work (i.e., self-employed), or other, which includes unpaid family work as well as those that do not report an employment status. Usual work activities consist of household chores (cooking, cleaning, child care, etc.), extended economic work (collecting fuel and water, preparing goods for consumption at home), studies, agriculture, wage or salaried work, and small business activities.

Table A2: Robustness Checks on Manufacturing Establishments

Dep. Var.:	IHS(# Manufacturing Establishments)		
	Exclude Duplicates (1)	Double Count (2)	Exclude CREP (3)
MHP	0.322***	0.331**	0.307***
	(0.080)	(0.081)	(0.081)
K-P F-Stats	57.65	57.65	58.79
Observations	2,241	2,241	1,842
Municipality FE	✓	✓	✓
Province-Year FE	✓	✓	✓

Notes: These are second stage results. Observations are at the municipality level. MHP is the cumulative number of microhydro plants in a municipality from the first-stage regressions. The outcome variable is the inverse hyperbolic sine of the number of manufacturing establishments (employing 10 or more individuals) located within a municipality. Municipality-year controls include the logarithm of average elevation and slope in a municipality, both indicated with year fixed effects. The baseline mean is the outcome variable raw mean (i.e., not the inverse hyperbolic sine) for those locations in which microhydro plants are later constructed. Data sources are further described in Data Appendix A3. Each column in this table presents a different way of addressing the changing spatial boundaries from VDCs to municipalities, as the administrative boundaries shifted from 2,974 VDCs to 747 municipalities and resulted in multiple VDCs per municipality. Most prior VDCs were cleanly encapsulated by one single new municipality; however, some VDCs were covered by new multiple municipalities (further explained in Appendix A3.2). We can exclude such VDCs (column 1) or double count them (column 2). In column 3, We exclude regions with any CREP grid connection as a robustness check. Robust standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A3: Robustness Checks on Correlations between IV and Other Economic Factors

VARIABLES	(1) Population Size	(2) #Male	(3) #Female	(4) #Schools	(5) #Students	(6) #Health Facilities	(7) Distance to Health Facilities
Carpet × N_t	0.000	0.001	-0.000	0.026	-0.041	-0.018*	0.001
	(0.003)	(0.003)	(0.003)	(0.020)	(0.044)	(0.011)	(0.029)
Observations	7,338	7,338	7,338	531	531	531	499
Adjusted R^2	0.957	0.956	0.957	0.479	0.277	0.809	0.559
VDC Controls	✓	✓	✓	✓	✓	✓	✓
VDC FE	✓	✓	✓				
District FE				✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓	✓	✓	✓

Notes: All the outcome variables are measured in inverse hyperbolic sines and are at the VDC level. Data on population size, number of males, females, and households are collected from the 2001 and 2011 iterations of the Nepal Population Census at the VDC level. Data on school and health facilities are collected through the Nepal Living Standards Survey (NLSS) at the community level in 2003 and 2010, and we aggregate the data to the VDC level. VDC controls include the number of households as of 2001, the area of the VDC, if the VDC was already connected to the electrical grid as of 2001, the log elevation, distance to the grid in kilometers, the log distance to the nearest city, and the log distance to the nearest paved road. We exclude locations with CREP grid extensions. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A4: Impact on Manufacturing Establishments: Arbitrary Clustering

	Dep. Var.: IHS(#Manufacturing Establishments)		
	Equal Divide (1)	Exclude Duplicates (2)	Double Count (3)
MHP	0.328	0.322	0.331
	(0.081)***	(0.080)***	(0.081)***
A. Arbitrary Clustering by Spatial Distance			
30 km	(0.082)***	(0.081)***	(0.083)***
60 km	(0.097)***	(0.095)***	(0.098)***
B. Arbitrary Clustering by Geographic Dissimilarity			
Median	(0.129)**	(0.127)**	(0.130)**
3rd Quartile	(0.140)**	(0.140)**	(0.140)**
Bartlett	(0.130)**	(0.128)**	(0.131)**

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. In the first two rows, we report the coefficient estimates and the corresponding standard errors clustered at the district level. In panel A, we report standard errors using the arbitrary clustering method with different thresholds on spatial distance among districts. In panel B, we report standard errors using the arbitrary clustering method with different thresholds (i.e., at the median, the 3rd quantile, or using the Bartless method) on geographic dissimilarity that is measured by district-level average elevation, average slope, river length, the proportion of river with slope falling into 0-3, 3-20, 20-30, 30-50 (in degrees); and with elevation falling into 0-250, 250-1000, 1000-3000, $\geq$3000 (in meters). *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A5: Impact on Employment Status: Arbitrary Clustering

Dep. Var.:	Reported employment status is:			
	Employer	Employee	Own Account Worker	Other
	(1)	(2)	(3)	(4)
A. Male				
MHP	-0.007	0.094	-0.080	-0.008
	(0.005)	(0.016)***	(0.021)***	(0.016)
A1. Arbitrary Clustering by Spatial Distance				
30 km	(0.005)	(0.016)***	(0.022)***	(0.016)
60 km	(0.005)	(0.017)***	(0.024)***	(0.018)
A2. Arbitrary Clustering by Geographic Dissimilarity				
Median	(0.003)**	(0.013)***	(0.017)***	(0.013)
3rd Quartile	(0.004)*	(0.012)***	(0.017)***	(0.012)
Bartlett	(0.004)*	(0.013)***	(0.018)***	(0.013)
B. Female				
MHP	-0.010	0.028	-0.060	0.043
	(0.006)*	(0.006)***	(0.029)**	(0.027)
B1. Arbitrary Clustering by Spatial Distance				
30 km	(0.006)	(0.006)***	(0.030)**	(0.028)
60 km	(0.006)*	(0.006)***	(0.033)*	(0.031)
B2. Arbitrary Clustering by Geographic Dissimilarity				
Median	(0.004)**	(0.005)***	(0.026)**	(0.025)*
3rd Quartile	(0.003)***	(0.005)***	(0.023)***	(0.021)**
Bartlett	(0.004)**	(0.005)***	(0.024)**	(0.023)*

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. In the first two rows, we report the coefficient estimates and the corresponding standard errors clustered at the district level. In panel A1 & B1, we report standard errors using the arbitrary clustering method with different thresholds on spatial distance among districts. In panel A2 & B2, we report standard errors using the arbitrary clustering method with different thresholds (i.e., at the median, the 3rd quantile, or using the Bartless method) on geographic dissimilarity that is measured by district-level average elevation, average slope, river length, the proportion of river with slope falling into 0-3, 3-20, 20-30, 30-50 (in degrees); and with elevation falling into 0-250, 250-1000, 1000-3000, $\geq$3000 (in meters). *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A6: Impact on Usual Activities: Arbitrary Clustering

	Own Agriculture & Farming	Salary & Wage	Own Enterprise	Extended Economic	Household Work	Study
	(1)	(2)	(3)	(4)	(5)	(6)
A. Male						
MHP	-0.108	0.072	0.008	-0.009	0.002	0.020
	(0.022)***	(0.014)***	(0.005)*	(0.005)*	(0.003)	(0.011)*
A1. Arbitrary Clustering by Spatial Distance						
30 km	(0.022)***	(0.014)***	(0.004)*	(0.005)*	(0.003)	(0.011)*
60 km	(0.025)***	(0.014)***	(0.004)**	(0.005)*	(0.003)	(0.013)
A2. Arbitrary Clustering by Geographic Dissimilarity						
Median	(0.018)***	(0.011)***	(0.004)**	(0.003)***	(0.003)	(0.008)**
3rd Quartile	(0.018)***	(0.010)***	(0.003)***	(0.004)**	(0.002)	(0.007)***
Bartlett	(0.018)***	(0.011)***	(0.004)***	(0.004)**	(0.002)	(0.008)**
B. Female						
MHP	-0.088	0.018	-0.006	-0.015	0.037	0.030
	(0.030)***	(0.005)***	(0.004)	(0.016)	(0.017)**	(0.011)***
B1. Arbitrary Clustering by Spatial Distance						
30 km	(0.031)***	(0.005)***	(0.004)	(0.015)	(0.018)**	(0.012)***
60 km	(0.034)***	(0.005)***	(0.004)	(0.015)	(0.018)**	(0.012)**
B2. Arbitrary Clustering by Geographic Dissimilarity						
Median	(0.024)***	(0.003)***	(0.003)*	(0.009)	(0.015)**	(0.007)***
3rd Quartile	(0.023)***	(0.004)***	(0.002)**	(0.013)	(0.014)***	(0.007)***
Bartlett	(0.023)***	(0.003)***	(0.003)*	(0.012)	(0.014)***	(0.008)***

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. In the first two rows, we report the coefficient estimates and the corresponding standard errors clustered at the district level. In panel A1 & B1, we report standard errors using the arbitrary clustering method with different thresholds on spatial distance among districts. In panel A2 & B2, we report standard errors using the arbitrary clustering method with different thresholds (i.e., at the median, the 3rd quantile, or using the Bartless method) on geographic dissimilarity that is measured by district-level average elevation, average slope, river length, the proportion of river with slope falling into 0-3, 3-20, 20-30, 30-50 (in degrees); and with elevation falling into 0-250, 250-1000, 1000-3000, $\geq$3000 (in meters). *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A7: Placebo Test with Randomization Inference

Variables	Baseline	Simulated Coefficients				
		Mean	p10	p50	p90	% Closer to 0
A. CME Sample						
# Manufacturing Establishments	0.328***	0.316	0.276	0.312	0.365	70.0%
B. Census Male						
Employment Status						
Employer	-0.007	-0.006	-0.007	-0.006	-0.006	97.8%
Employee	0.095***	0.088	0.081	0.087	0.095	89.0%
Own Account Worker	-0.080***	-0.074	-0.081	-0.074	-0.068	88.2%
Other	-0.008	-0.007	-0.008	-0.007	-0.007	88.0%
Usual Activities						
Own Ag. & Farming	-0.109***	-0.100	-0.109	-0.100	-0.093	90.0%
Salary & Wage	0.072***	0.067	0.062	0.066	0.073	87.6%
Own Enterprise	0.008*	0.008	0.007	0.008	0.008	81.0%
Extended Economic	-0.009*	-0.008	-0.009	-0.008	-0.008	85.6%
Household Work	0.002	0.002	0.002	0.002	0.002	23.4%
Study	0.020*	0.018	0.017	0.018	0.020	92.6%
C. Census Female						
Employment Status						
Employer	-0.010*	-0.010	-0.011	-0.010	-0.009	64.2%
Employee	0.028***	0.026	0.024	0.026	0.028	85.2%
Own Account Worker	-0.060**	-0.056	-0.061	-0.056	-0.052	85.4%
Other	0.042	0.040	0.037	0.040	0.043	100.0%
Usual Activities						
Own Ag. & Farming	-0.088***	-0.083	-0.090	-0.082	-0.077	84.8%
Salary & Wage	0.019***	0.017	0.016	0.017	0.019	91.8%
Own Enterprise	-0.006	-0.005	-0.006	-0.005	-0.005	97.4%
Extended Economic	-0.015	-0.014	-0.015	-0.014	-0.013	86.2%
Household Work	0.037***	0.034	0.032	0.034	0.037	89.6%
Study	0.030***	0.028	0.026	0.028	0.031	84.0%

Notes: We perform a placebo test using the randomization inference method following Christian and Barrett (2017), where we randomly assign the cumulative number of microhydro plants for each year among the regions that have microhydro plants. Column (2) duplicates our baseline estimates. The last five columns report summary statistics of the coefficient estimates from 500 randomizations, including the mean, 10th percentile, median, 90th percentile, and the proportion of estimates that are closer to 0 compared to the baseline estimates.

Table A8: Robustness Check of Excluding CREP Regions: Employment Status

Dep. Var.:	Reported employment status is:			
	Employer	Employee	Own Account Worker	Other
	(1)	(2)	(3)	(4)
A. Male				
MHP	-0.006	0.096***	-0.089***	-0.002
	(0.006)	(0.018)	(0.023)	(0.018)
K-P F-Stats	42.02	42.02	42.02	42.02
Observations	2,250,697	2,250,697	2,250,697	2,250,697
B. Female				
MHP	-0.011	0.029***	-0.071**	0.053*
	(0.007)	(0.006)	(0.032)	(0.030)
K-P F-Stats	39.43	39.43	39.43	39.43
Observations	2,389,391	2,389,391	2,389,391	2,389,391
Individual Control	✓	✓	✓	✓
VDC FE	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓

Notes: We exclude regions with any CREP grid connection as a robustness check. MHP is the cumulative number of microhydro plants in a VDC from the first-stage regressions. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are responses to the individual's employment status. The other group includes both unpaid family workers and those that did not state an employment status. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A9: Robustness Check of Excluding CREP Regions: Usual Activities

	Own Agriculture & Farming	Salary & Wage	Own Enterprise	Extended Economic	Household Work	Study
	(1)	(2)	(3)	(4)	(5)	(6)
A. Male						
MHP	-0.118***	0.074***	0.010**	-0.011**	0.003	0.026**
	(0.024)	(0.016)	(0.005)	(0.005)	(0.003)	(0.011)
K-P F-Stats	42.02	42.02	42.02	42.02	42.02	42.02
Observations	2,250,697	2,250,697	2,250,697	2,250,697	2,250,697	2,250,697
B. Female						
MHP	-0.102***	0.020***	-0.005	-0.013	0.041**	0.035***
	(0.033)	(0.005)	(0.004)	(0.017)	(0.019)	(0.011)
K-P F-Stats	39.43	39.43	39.43	39.43	39.43	39.43
Observations	2,389,391	2,389,391	2,389,391	2,389,391	2,389,391	2,389,391
Individual Controls	✓	✓	✓	✓	✓	✓
VDC FE	✓	✓	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓	✓	✓

Notes: We exclude regions with any CREP grid connection as a robustness check. MHP is the cumulative number of microhydro plants in a VDC from the first-stage regressions. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are the individual's usual work in the past 12 months: agriculture, salary/wage, own economic enterprises, extended economic enterprises, household work, and study. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A10: First-Stage Instrumental Variable Regressions: Alternative IV

	Dep. Var.: Cumulative #MHPs in a Municipality/VDC		
	(1) CME Sample	(2) Census Sample: Male	(3) Census Sample: Female
$[3, 20] \times N_t$	0.057*	0.003	0.004
	(0.032)	(0.003)	(0.003)
$[20, 30] \times N_t$	0.192***	0.030***	0.030***
	(0.020)	(0.004)	(0.004)
$[30, 50] \times N_t$	0.395***	0.066***	0.068***
	(0.043)	(0.014)	(0.015)
Individual Controls		✓	✓
VDC FE		✓	✓
Municipality FE	✓		
Province-Year FE	✓	✓	✓
K-P F-Stats	22.91	0.722	17.84
Observations	2,241	2,371,140	2,531,500
Adjusted R^2	0.854	0.735	0.746
#Regions	747	3,974	3,974
Observation Level	Municipality	VDC	VDC

Notes: There are three instrumental variables in these regressions, which are created by the following interactions: [a binary indicator variable equaling 1 if the average river slope falls into one of the following categories: 3-20, 20-30, or greater than 30, and equaling 0 otherwise] $\times$ [MHP number over year in Nepal]. The omitted group is the average river slope between 0 and 3. Individual controls include age, education, household size (number of people), house amenities (toilet, water), and caste. Standard errors are clustered at the district level and shown in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A11: Impact on Manufacturing Establishments: Alternative IV & OLS

Dep. Var.:	IHS(#Manufacturing Establishments)			
	Alternative IV		OLS	
	(1)	(2)	(3)	(4)
MHP	0.239***	0.532***	0.048***	0.078***
	(0.082)	(0.153)	(0.015)	(0.024)
MHP × No Grid		-0.407***		-0.050*
		(0.119)		(0.027)
K-P F-Stats	22.91	22.91		
#Municipalities	747	747	747	747
Observations	2,241	2,241	2,241	2,241
Municipality FE	✓	✓	✓	✓
Province-Year FE	✓	✓	✓	✓

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. "No grid" is an indicator for whether the municipality has no electric grid. The outcome variable is the inverse hyperbolic sine of the number of manufacturing establishments (employing 10 or more individuals) located within a municipality. Data sources are further described in Data Appendix A3. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A12: Impact on Employment Status: Alternative IV

Dep. Var.:	Reported employment status is:			
	Employer	Employee	Own Account Worker	Other
	(1)	(2)	(3)	(4)
A: Male Average Effect				
MHP	-0.019*	0.176***	-0.129***	-0.027
	(0.010)	(0.034)	(0.035)	(0.025)
B. Female Average Effect				
MHP	-0.028**	0.056***	-0.071*	0.042
	(0.011)	(0.011)	(0.040)	(0.040)
C: Male Heterogenous Effect				
MHP	-0.277	1.941**	-1.014	-0.650
	(0.191)	(0.914)	(0.664)	(0.467)
MHP × No Grid	0.270	-1.846**	0.923	0.654
	(0.189)	(0.910)	(0.654)	(0.465)
D. Female Heterogenous Effect				
MHP	-0.277	1.941**	-1.014	-0.650
	(0.191)	(0.914)	(0.664)	(0.467)
MHP × No Grid	0.270	-1.846**	0.923	0.654
	(0.189)	(0.910)	(0.654)	(0.465)

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. "No grid" is an indicator for whether the municipality has no electric grid. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are responses to the individual's employment status. The other group includes both unpaid family workers and those that did not state an employment status. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A13: Impact on Usual Activities: Alternative IV

	Own Agriculture & Farming	Salary & Wage	Own Enterprise	Extended Economic	Household Work	Study
	(1)	(2)	(3)	(4)	(5)	(6)
A: Male Average Effect						
MHP	-0.200***	0.149***	0.000	-0.013	0.008*	0.013
	(0.041)	(0.032)	(0.007)	(0.009)	(0.005)	(0.018)
B. Female Average Effect						
MHP	-0.166***	0.045***	-0.011*	-0.015	0.074***	0.027
	(0.047)	(0.010)	(0.006)	(0.025)	(0.027)	(0.020)
C: Male Heterogenous Effect						
MHP	-1.763*	1.608**	-0.004	-0.062	0.093	-0.341
	(0.908)	(0.804)	(0.156)	(0.134)	(0.079)	(0.358)
MHP $\times$ No Grid	1.634*	-1.530*	0.004	0.053	-0.088	0.373
	(0.899)	(0.800)	(0.156)	(0.133)	(0.078)	(0.356)
D. Female Heterogenous Effect						
MHP	-1.988*	0.670**	-0.130	0.046	1.015	-0.227
	(1.068)	(0.291)	(0.166)	(0.364)	(0.642)	(0.376)
MHP $\times$ No Grid	1.884*	-0.650**	0.119	-0.065	-0.968	0.267
	(1.057)	(0.289)	(0.165)	(0.360)	(0.636)	(0.372)

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. "No grid" is an indicator for whether the municipality has no electric grid. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are the individual's usual work in the past 12 months: agriculture, salary/wage, own economic enterprises, extended economic enterprises, household work, and study. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A14: Impact on Employment Status: OLS

Dep. Var.:	Reported employment status is:			
	Employer	Employee	Own Account Worker	Other
	(1)	(2)	(3)	(4)
A. Male Average Effect				
MHP	-0.001	0.019***	-0.012***	-0.005**
	(0.001)	(0.002)	(0.003)	(0.002)
B. Female Average Effect				
MHP	-0.002**	0.005***	-0.006	0.003
	(0.001)	(0.001)	(0.004)	(0.004)
C. Male Heterogeneous Effect				
MHP	-0.005	0.045	-0.035	-0.005
	(0.004)	(0.033)	(0.031)	(0.009)
MHP × No Grid	0.004	-0.027	0.023	-0.001
	(0.004)	(0.033)	(0.031)	(0.009)
D. Female Heterogeneous Effect				
MHP	-0.005	0.020***	-0.026	0.011
	(0.005)	(0.006)	(0.031)	(0.026)
MHP × No Grid	0.002	-0.015**	0.020	-0.007
	(0.005)	(0.006)	(0.031)	(0.026)

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. "No grid" is an indicator for whether the municipality has no electric grid. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are responses to the individual's employment status. The other group includes both unpaid family workers and those that did not state an employment status. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table A15: Impact on Usual Activities: OLS

	Own Agriculture & Farming	Salary & Wage	Own Enterprise	Extended Economic	Household Work	Study
	(1)	(2)	(3)	(4)	(5)	(6)
A. Male Average Effect						
MHP	-0.021***	0.015***	0.001	-0.000	0.001*	0.002
	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
B. Male Heterogenous Effect						
MHP	-0.063**	0.022	0.017	0.007	-0.001	0.020*
	(0.027)	(0.038)	(0.014)	(0.008)	(0.003)	(0.012)
MHP × No Grid	0.043	-0.007	-0.016	-0.007	0.002	-0.018
	(0.027)	(0.038)	(0.014)	(0.008)	(0.003)	(0.012)
C. Female Average Effect						
MHP	-0.014***	0.004***	-0.002**	-0.003	0.010***	0.003
	(0.004)	(0.001)	(0.001)	(0.002)	(0.004)	(0.002)
D. Female Heterogenous Effect						
MHP	-0.037	0.010	-0.001	-0.016	0.017	0.019
	(0.026)	(0.008)	(0.007)	(0.018)	(0.015)	(0.012)
MHP × No Grid	0.024	-0.007	-0.000	0.013	-0.006	-0.017
	(0.027)	(0.008)	(0.007)	(0.018)	(0.015)	(0.012)

Notes: MHP is the cumulative number of microhydro plants in a municipality from the alternative IV first-stage regressions. "No grid" is an indicator for whether the municipality has no electric grid. The outcome variables, which use microdata from the 2001 and 2011 iterations of the Nepal Population Census, are collected for household members 10 years of age and older. The outcome variables are the individual's usual work in the past 12 months: agriculture, salary/wage, own economic enterprises, extended economic enterprises, household work, and study. Additional variable descriptions provided in Appendix A4. The individual controls include the individual's age, the individual's education, the household size, and whether the household has a toilet. Standard errors are clustered at the district level and shown in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.