Determinants of Electrification in India: A Cross Sectional Analysis of Socioeconomic Inequities

Need a new title

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Abstract

On what?

This study sets out to understand the effects of village level electrification. Electrification has shown to be a key requisite for the reduction of poverty through mechanisms such as increases in efficiency, productivity and education. ~~Examining which~~ villages gain electrification presents policy makers with an opportunity to scrutinize the effect of electrification on welfare. Using the Socioeconomic High Resolution Urban Geographic (SHRUG) data set this paper ~~will utilize~~ a ~~cross sectional analysis~~ to examine to what extent there is an increase in consumption for villages that have gained access to electricity. The findings aim to inform policymakers about inequities in electrification and assess to what extent electrification improves outcomes for low income populations.

Introduction

Puzzle: most research says electirification reduces poverty, but so and so say it doesn't. This research uses novel data from here to better understand this issue

Access to electricity is critical for development. For populations to prosper, access to critical infrastructure such as electricity increases various socioeconomic indicators of development. Educational attainment, income, and health increase as additional households are powered by electricity (Cabraal, Barnes, and Agarwal 2005); Shahidur R. Khandker, Barnes, and Samad (2009). If electrification is a tool for development, there should be an observable increase in welfare for villages that receive access to electricity.

In Burlig and Preonas (2024) researchers have found that there is a decrease in welfare for small populations that obtain access electricity. What observations exist at the village level to support this? Is it true that governments should re prioritize electricity as a tool for development for small villages, and instead focus on other tools to welfare between villages of different sizes? This study seeks to examine if there is a positive impact at the village level when villages have access to electricity.

Households that don't have access to electricity lose efficiency and have to spend more time on tasks that they otherwise could be spending doing income generating work.

The (SHRUG) Platform for India provides a comprehensive data set for India. The data set includes a compilation of population census data, SECC data and various other modules that are linked using shared location ID's for ease of merging data.

First this paper will discuss relevant literature and variables used in past studies to examine effects of electrification. Second, the paper will outline theory and the hypothesis. Then it will discuss methodology and data. The analysis will present the model used in the regression analysis, then display the results, followed by a discussion of the results. The paper will then make conclusions based on the results.

Literature Review

Existing research has examined outcomes of electrification. Scholars have found discrepancies in outcomes. Burlig and Preonas (2024) finds differences in accumulated benefits between small and large populations that receive electrification. In their study Burlig and Preonas (2024) uses SHRUG data to examine the impacts of India's RGGVY (Rajib Gandhi Grameen Vidyutikaran Yojana) program. Their study uses regression discontinuity and difference in differences models to estimate impacts of electrification on economic well being. The researchers find statistically significant evidence that for smaller populations, access to electrification causes a welfare decrease, and for larger populations it causes welfare to almost triple.

In Shahidur R. Khandker et al. (2012) researchers argue that the impact of electrification across income and expenditure vary with higher income house-

holds receiving more benefits from electrification. In their study Shahidur R. Khandker et al. (2012) say that it can be argued income and expenditure don't depend on proportion of households with electricity, rather, it depends on household size and age composition of the household. In their study they find that electrification increases weekly study time by 1 hour for school aged children, increases employment hours by 17% for women and increases per capita income by 38.6%.

In Sedai et al. (2021) researchers examine the probability of electrification and the effect of electrification for marginalized communities compared to dominant communities using the IHDS II data set. They find that marginalized communities benefit less from electrification than dominant communities.

Researchers in Rathi and Vermaak (2018) examine the impacts of rural electrification on labor market outcomes through a gendered lens. The study finds that on average when rural Indian communities receive access to electricity, women are more likely to work at least 240 hours, and men are less likely to work. The study argues this is because access to electricity frees up time by reducing time spent collecting fuel and making household tasks more efficient. In Rathi and Vermaak (2018) argues the extent that electrification improves the labor force depends on supporting policies, labor absorption capacity and willingness to participate in income generating activities which may be related to local norms. The Rathi and Vermaak (2018) study concludes that policy makers should consider local social and political structures, gender roles, and labor absorptive capacity to realize benefits of rural electrification programs. Singh (2016) and Auerbach (2019) provide evidence showing that social, cultural and political structures have important effects on development.

Theory and Hypothesis

Studies that examine electrification in India scrutinize effects of electrification. But what are the key determinants of electrification in India? Existing studies examine benefits households experience after gaining access to electricity, but an apt question to answer is what effect does electrification have on low income villages. Answering this question is valuable for developing countries that are attempting to provide electricity to their populations.

India provides value in studies that explore impacts of electrification on development. In 1947, 1500 villages in India had access to electricity. India contributed to 80% of global gains in new household grid connections between 2000 and 2016 (Burlig and Preonas 2024). Since 1951 India has had at least 10 programs with the goal of increasing electrification (Rathi and Vermaak 2018). The most major efforts include the Rajiv Gandhi Grameen Vidyutikaran Yojna (RGGVY) which had a target of achieving 100 percent rural electrification, and the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) which succeeded the RGGVY program and is focused on providing more consistent power supply to rural areas of India.

What years?

In Thomas et al. (2020), researcher's argue there is a positive association between electrification and total household expenditure and this can be used as a proxy for disposable income. This paper attempts to examine this effect. Confusing.

This study attempts to recreate the effects found in previous research with different data. Many past studies use IHDS or other data sets that use the individual level of analysis. This paper uses the SHRUG dataset and aggregates at the village level of analysis. Justify this. Or explain how different

In India, the population census uses different definitions to determine a village's electrification status. This study uses a cross sectional analysis utilizing data from India's 2011 population Census and the Socio-Economic and Caste Census (SECC) for 2011. The population census includes village level data for access to electricity, population size, and village demographics. The SECC includes socioeconomic data at the village level.

Based on the available literature the study expects to see an increase in average consumption per capita based on electrification status. Villages that have electricity have been found to have increases in labor market outcomes as a result of freeing up more time to work, increasing income. In cases that women are unable to work as a result of time spent collecting fuel and completing household chores that are decreased with electricity, women are able to enter the labor force and bring additional income into the household. Thomas et al. (2020) posits that the positive effect on household expenditure comes through increased ability to work at night, positive effect on productivity, and lower cost of electricity compared to fuel. This should be in lit review. Not here

This paper expect to find that villages that have access to electricity have higher levels of consumption per capita. This still makes little sense to me.

The paper also expects that villages that have higher average levels of consumption, are on average more likely to have access to electricity. Shahidur R. Khandker, Barnes, and Samad (2009) argues that households that have higher levels of education, greater land assets, and better housing conditions are more likely to adopt electricity. Which way is causal arrow going?

In Appendix A, a logistic regression is included that demonstrates this relationship.

Methodology

Almost one billion people lack access to electricity (Burlig and Preonas 2024). In 2018 28 countries had a lower per capita GDP than India's per capita GDP in 2011 (Burlig and Preonas 2024). doesn't belong here.

The extent electrification increases estimated monthly consumption was examined using a simple linear regression model. In this paper cross sectional analysis was chosen as it can be most effective for observational studies like this one.

Using a multiple linear regression we are able to simulate a ceterus peribus effect, holding other factors fixed. By controlling for for other factors such as the proportion of people in the household that had an income of at least 5,000 Rs, how many hours of electricity the village has in the summer, the rate of poverty in the village, the proportion of the population that is female, the proportion of the population that is female and in poverty, and the proportion of people in the village that own land, the analysis controls for other factors that may affect consumption.

But measures are at village level

The data was collected by various other researchers and the villages in India gained access to electricity in a non random order. The unit of analysis used in this paper is the village. In the SHRUG data set, you are able to aggregate at the village, district, sub-district and state level. The population census and SECC data was collected at the household level, but it can be useful to perform an aggregate analysis to analyze the combined effect.

Should probably be controlling for state.

The various types of electricity access signify if a village had access to electricity for that sector. According to 2011 population census documentation, if 10% of households were electrified, the variable for domestic access to electricity was coded as a 1. If the village had access to electricity for agriculture, the electricity for agriculture variable was coded as a 1. If the village had access to electricity for commerical purposes, the variable for commercial electricity was coded as a 1. The SECC records earnings for the highest earning member of the household in three bins, 0 to 4,999 rupees, 5,000 to 9,999 rupees, and 10,000 or more rupees. According to Asher and Novosad (2019) 85% of households report being in the lowest bin. This analysis used the 5,000 to 9,999 rupee bin to estimate the impact for lowest and highest earners.

Again, you are looking at village

Data

Repetitive

This paper uses data from the SHRUG data set. Shrug is an open source repository of Indian village-level datasets Asher et al. (2021) . The data set includes population census data from 2001 and 2011, and Socioeconomic and Caste Census (SECC) data from 2011. Researchers Asher et al. (2021) create a measure of estimated consumption per capita and estimated poverty level. To create the variables Asher et al. (2021) use data from the Indian Human Development Survey (IHDS-II) and combine it with data from the SECC. They regress household consumption from the IHDS data set with SECC data that includes household level enumeration of assets. The IHDS consumption expenditures are based on 47 questions about household consumption. The total average total expenditure per household is used as a measure of each household's economic level. They include variables for consumption of food items such as rice, wheat, sugar and meat. The consumption metric also includes average amount spent on fuel and kerosene. The monthly consumption based on and aggregate up to the village level to construct estimated consumption per capita and estimated poverty level. This paper uses village-level data from the population census and SECC.

for each village?

Is this your measure of poverty?

Which is the index variable described above?

Estimated consumption per capita is the outcome of interest for exploring the welfare impacts of electrification. It can be assumed that people who gain electricity will have better welfare outcomes and will consume more. If consumption increases for villages that have electricity, having electricity is a significant indicator for development.

The Popoulation Census of India collects data about India's population on a decennial interval. In Vasudha Foundation (2013) it is estimated that 34,887 villages are yet to be electrified. The population census Census 2011 - concepts & definitions used in town and village amenities (2023) includes dummy variables for whether there is access to electricity for agriculture use, commercial use, and domestic use. If 10% of households in a village have electricity, it is coded as a 1 (Vasudha Foundation 2013). The data includes a dummy variable that indicates if all 3 sectors have access to electricity.

In India the population census is collected by the Registrar General. Enumerators are sent to visit every household across the country (Government of India n.d.). Information about each individual is gathered using a questionnaire and captures demographic information.

The SECC is conducted in the same way in a survey conducted by India's Ministry of Rural Development. The SECC aims to document the socioeconomic status of all households in urban and rural areas. The survey documents the material of the walls and roof individuals are living in, demographic information, education level, disabilities, caste status, and ownership of assets such as cell phones, motor vehicles, and land.

The survey data used for this analysis was collected in 2011, at the end of the RGGVY program. The program started its initiative towards 100% electrification in 2004 and villages that were selected for electrification in the first wave received funding between 2005 and 2008 (Burlig and Preonas 2024). Villages that were selected in the second wave received funding between 2008 and 2011 (Burlig and Preonas 2024).

Integrate this with data descriptions above.

Descriptive Statistics

Table 1 shows descriptive statistics for the covariates. There were 57% of villages in rural areas in 2011 that had electricity for domestic, agriculture, and commercial purposes, 90% of villages had electricity for at least 10% of households.

So little variation here. I would just use this 90% as the sample and then the use the 57% variable as the IV.

According to the data, 210,297 villages do not have electricity access for all three documented sectors, and 274,568 villages have electricity for all three sectors.

The bar graph below shows the raw data for access to power for each sector as they are coded for each village. Access to domestic electricity is the highest with 90% of villages being coded as having domestic electricity access, however it is unclear what percentage of households in these villages have access to electricity.

How do 57% have access to domestic, agg, and commercial when only 53% have access to commercial?

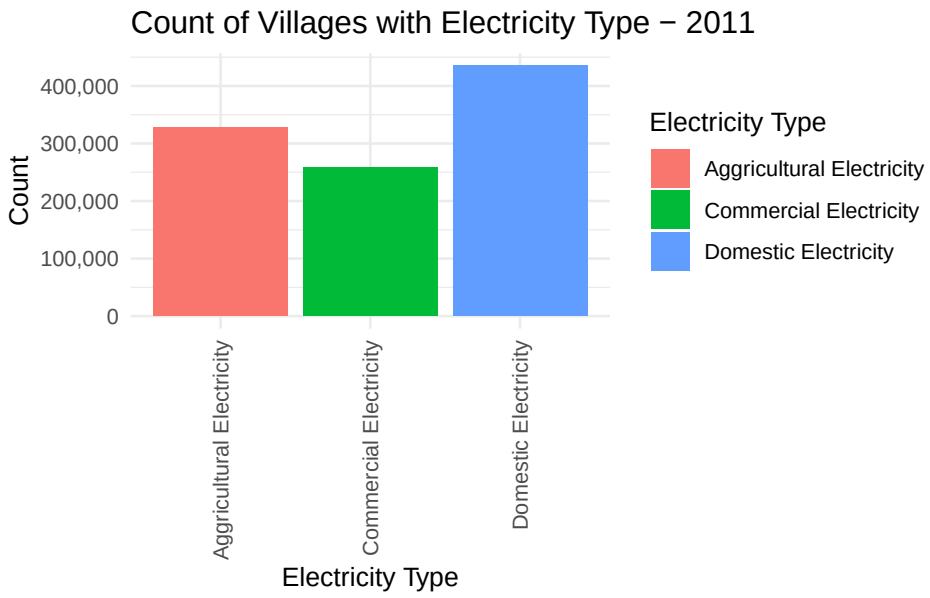
Table 1: Summary Statistics

Statistic	Mean	St. Dev.	Min	Max
Electricity Access - All	0.57	0.50	0	1
Electricity - Domestic	0.90	0.30	0	1
Electricity - Agg	0.68	0.47	0	1
Electricity - Commercial	0.53	0.50	0	1
HH Income - 5k	0.24	0.23	0.00	1.00
Summer Power (Hours)	6.94	7.72	0.00	24.00
Poverty	0.35	0.22	0.00	1.00
Proportion Female	718.32	978.90	0	192,721
Proportion Own Land	0.54	0.29	0.00	1.00

Table 2: Count of Villages with access in all 3 sectors

Electricity Access	Count
All sectors - No	210286
All sectors - Yes	274344

Percentages would be better



The map below shows estimated average monthly consumption per capita for sub districts in India that are classified as rural in the data set. Yellow areas represent sub districts that have an estimated monthly consumption of 10,000 INR or below, green is 20,000 or below, dark green is 30,000 or below, blue is 40,000 or below, and purple is 40,000 or more.What is the unit here?

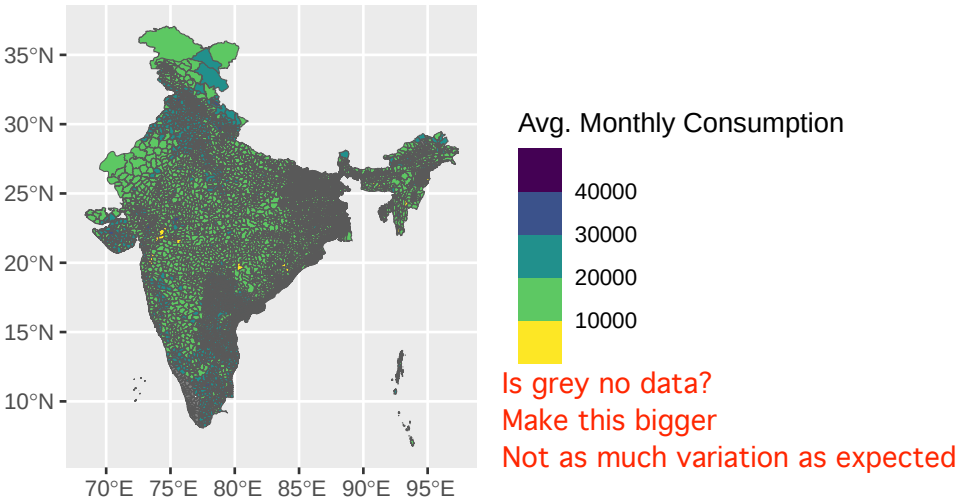


Fig. 1: This map shows estimated average consumption per capita at the sub district level in INR.

The map below shows a breakdown of sub districts by whether villages in the sub district have access to power in all 3 sectors. Over 75% of villages in sub districts that are yellow had all 3 types of power in 2011, a sub district that is green had between 50% and 75% of villages that had all 3 types of electricity, a sub district that is blue has between 25% and 50% of villages that had access to all types of electricity, and a sub district that is purple had less than 25% of villages that had access to all 3 kinds of electricity.

Rephrase

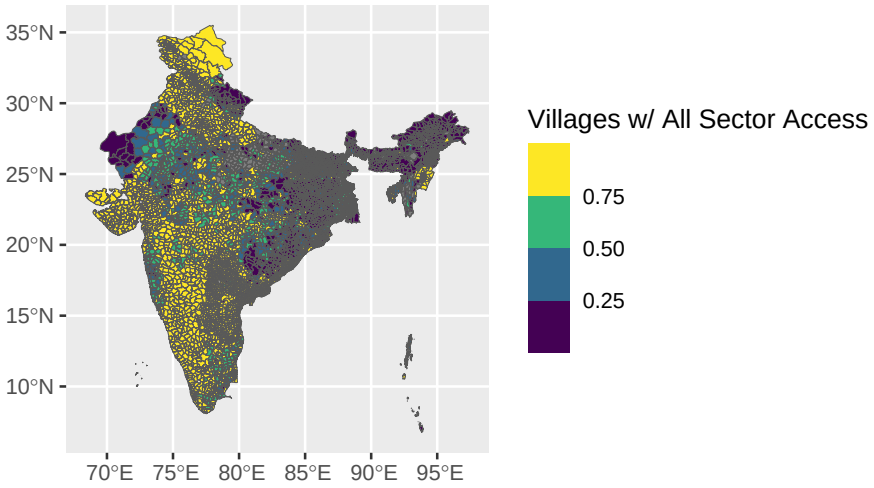


Fig. 2: This map shows the average percentage of villages in each subdistrict that had access to elec

Model

The model used to explore the welfare impacts of electrification is as follows.

consumption?

Multicollinearity issue

$$(log)Y_i = \beta_0 + \beta_1 AccesstoElectricity + \beta_2 Income5k + \beta_3 HoursofElectricityinSummer + \beta_4 RateofPoverty + \beta_5 ProportionofFemaleinVillage + \beta_4\beta_5 RateofPovertyxProportionFemale + \beta_6 OwnLand + u$$

Show histogram to see if need to be logged

Poverty is also your DV. Need to redo this model

In this model Y_i is the outcome of interest, log of estimated monthly consumption. A log linear model also reduces the impacts of possible heteroscedasticity. The main independent variable β_1 is access to electricity. The covariate β_2 is share of households that the income of the highest earning member is greater than 5k Rs. β_3 is the number of hours electricity is available during the summer. β_4 is the estimated rate of poverty in the village. β_5 is proportion of the population that is female, $\beta_5 x \beta_5$ is an interaction term between rate of poverty in the village and proportion that is female, and β_6 is share of households that own land. The error term u contains unexplained variance in the model.

This makes no sense

Results

When the primary independent variable is access to electricity in all three sectors, consumption decreases by 1%. This result is shown in Table 3. This is likely

a result of the dummy variable for the commercial sector. Since this data is based on the SECC census for rural populations, commercial access to electricity is arguably ineffective at increasing the welfare of a population. Rathi and Vermaak (2018) estimated 64% of employment in rural areas is agriculture. The covariants measuring if the household head made more than 5,000 Rs, hours of electricity in the summer, poverty rate, proportion of a population that is female, and the proportion of the population that owns land were centered in the models by subtracting each value from the average value.

Table 3: Regression Results

	Dependent variable:
	log(Consumption Per Capita)
Electricity Access - All	-0.010^{***}
	(0.001)
HH Income - 5k	0.148^{***}
	(0.001)
Summer Power (Hours)	0.003^{***}
	(0.00004)
Poverty	-1.210^{***}
	(0.001)
Proportion Female	-0.00001^{***}
	(0.00000)
Proportion Female x Poverty	-0.00002^{***}
	(0.00000)
Proportion Own Land	-0.055^{***}
	(0.001)
Constant	9.707^{***}
	(0.0004)
Observations	484,630
R^2	0.826
Adjusted R^2	0.826
Residual Std. Error	0.130 (df = 484622)
F Statistic	$328{,}504.900^{***}$ (df = 7; 484622)
Note:	*p<0.1; **p<0.05; ***p<0.01

The results in Table 4 show that consumption increases when villages have access to domestic electricity. If households have access to electricity, there is a 1.6% increase to estimated monthly consumption per capita. There is a 14% increase in estimated monthly consumption per capita if the highest earner in a household makes at least 5,000 Rs. Every extra hour of electricity in the summer leads to a 2% increase in estimated monthly consumption. Consumption decreases by 5.4% as the proportion of the population in the village that owns land increases.

This result is unexpected. Possible explanations for this may include differences in expectations when households are wealthier. In the US, the expectation is that households that earn more money have higher expenditures. In India, it is possible that this is not the case. It is also possible that the argument posed by Shahidur R. Khandker et al. (2012) that consumption is based on the size and makeup of a household explains this outcome. Consumption also decreases by 120% for every unit increase in a village's poverty rate. All of the coefficients in the model are statistically significant lower than the 1% level.

Table 4: Regression Results

	Dependent variable:
	log(Consumption Per Capita)
Electricity Access - Domestic	0.016^{***}
	(0.001)
HH Income - 5k	0.149^{***}
	(0.001)
Summer Power (Hours)	0.002^{***}
	(0.00003)
Poverty	-1.207^{***}
	(0.001)
Proportion Female	-0.00001^{***}
	(0.00000)
Proportion Female x Poverty	-0.00002^{***}
	(0.00000)
Proportion Own Land	-0.054^{***}
	(0.001)
Constant	9.686^{***}
	(0.001)
Observations	484,630
R^2	0.826
Adjusted R^2	0.826
Residual Std. Error	0.130 (df = 484622)
F Statistic	$328{,}791.600^{***}$ (df = 7; 484622)
Note:	*p<0.1; **p<0.05; ***p<0.01

To test how the regression performed with different types of electricity access each type of electricity access was inserted into the model as the primary independent variable. Table 5 displays the results of these models. All variables indicating access to electricity had a positive and statistically significant impact on average consumption per capita except for the commercial electricity access variable.

Table 5: Regression Models

	Dependent variable:		
	log(Consumption Per Capita)		
	(1)	(2)	(3)
Commercial Sector	−0.007***		
	(0.001)		
Domestic		0.016***	
		(0.001)	
Aggriculture			0.010***
			(0.0005)
Electricity Access	0.147***	0.149***	0.148***
	(0.001)	(0.001)	(0.001)
HH Income - 5k	0.003***	0.002***	0.002***
	(0.00003)	(0.00003)	(0.00003)
Summer Power (Hours)	−1.210***	−1.207***	−1.208***
	(0.001)	(0.001)	(0.001)
Poverty	−0.00001***	−0.00001***	−0.00001***
	(0.00000)	(0.00000)	(0.00000)
Proportion Female	−0.00002***	−0.00002***	−0.00002***
	(0.00000)	(0.00000)	(0.00000)
Proportion Female x Poverty	−0.055***	−0.054***	−0.053***
	(0.001)	(0.001)	(0.001)
Constant	9.705***	9.686***	9.695***
	(0.0003)	(0.001)	(0.0004)
R^2	0.826	0.826	0.826
Adjusted R^2	0.826	0.826	0.826
Note:			*p<0.1; **p<0.05; ***p<0.01

need to change scale – to move decimal point

Discussion

The results of the linear regression model show that on average welfare for villages in India increased as a result of having access to electricity for domestic purposes.

Limitations to this analysis include possible overestimation due to model selection and choice of method. A preferable method would have used an instrumental variables or fixed effects regression model. Previous research on the impact of electrification outline that electrification is not randomized, therefore there may be unaccounted endogeneity in the model. Rathi and Vermaak (2018) outlines three ways that access to electricity may be endogenous to labor market outcomes. Sedai et al. (2021) asserts that consumption and distribution of electricity are endogenous. A cross sectional analysis is limited in its ability to make claims about the direction of the effect.

The second limitation of the analysis in this paper is that the scope is not narrow enough to make substantive claims about the effect of electrification. If the study was done with a more limited focus, such as the impact of electrification for previously un-electrified villages, there would be potential to make more substantial claims. Burlig and Preonas (2024)'s cites that by 2011, the RGGVY had connected 17.5 million households and connected 1 in 5 previously un-electrified households. A study similar to the one by Burlig and Preonas (2024) that examines the data using panel data and narrowing the scope to include homes that were previously un-electrified has greater policy implications for developing countries.

A necessary assumption for MLR is that the error term is not correlated with the explanatory variables. In this case It is possible that there is omitted variable bias, with unmeasured factors in the error term having high correlation with the predictors.

Future studies would benefit from combining the ideas of development research. Existing work has examined the impact of electrification in both directions and explored various causal mechanisms for benefits that result from electrification. It would be interesting to examine these effects across various political structures and areas. Singh (2016) points to Kerala's development indicators as an outlier compared to the development indicators of surrounding states. The study points to linguistic sub-nationalism as a causal factor in Kerala's development. Studies that seek to examine what factors have the greatest positive effect on development should include variables that account for variation in development such as sub-national solidarity.

Conclusion

This study examined the determinants of electrification in rural India using cross-sectional data from the SHRUG dataset. The finding reveal significant socioeconomic inequities in access to electricity, with higher-income households

more likely to benefit. While access to domestic electricity positively impacts welfare by increasing estimated monthly consumption, the results highlight that commercial electrification alone has limited utility in improving rural well being.

The analysis underscores the importance of targeted policies to address disparities in electrification. Programs must consider challenges such as poverty, gender and land distribution, to ensure equitable access to energy infrastructure. These finding align with previous research that stresses the interplay of social and economic factors in determining development outcomes. However, they also suggest that rural electrification policies need greater integration with broader development strategies, such as gender empowerment and income distribution.

This study has limitations, such as the reliance on cross-sectional data and the potential for unobserved confounders influencing results. Future rsearch should employ longitudinal methods to better isolate causal relationships. Exploring the role of political, cultural, and instituional factors in shaping access to electricity could provide richer insights into how development policies can be optimized.

By shedding light on the inequities in electrification, this paper contributes to a growing body of literature emphasizng the need for inclusive energy policies in developing countries. Policymakers must prioritize marginalized communities to ensure that electrification serves as a catalyst for sustainable development.

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