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Abstract: This paper studies the effect of electricity on income, using the Nepal Living Standards Survey-III (NLSSIII), carried out in the years 2010-11. To account for endogeneity issues, we use Three Stage Least Squares (3SLS), and Two Stage Probit Least Squares (2SPLS) models. We find that causality runs both ways. That is, income explains whether a household is connected to electricity, but also, a household being connected to electricity has a very large and significant effect on income. A household being connected to electricity increases consumption per capita by 18% on average.

JEL Codes: O1; Q4

Keywords: Energy; Electricity; Income; Economic Development; Nepal

1. Introduction

Access to energy affects all aspects of life. In particular, access to abundant, reliable, and cheap energy is necessary for the unprecedented standard of living experienced by those residing in the developed world. Unfortunately, many in the developing world do not enjoy the same access to energy services that exists in high-income countries.

Energy poverty is defined as “the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development”(Masud et al., 2007). A narrower definition, given by the UNDP, describes energy poverty as the “inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other household and productive activities at sunset”(Gaye, 2007). According to the 2010 UNDP’s Human Development Report, 1.4 billion people around the world suffer from a complete lack of access to electricity.

A lack of access to modern forms of energy posits the development challenge of providing adequate education, schooling, access to information, clean water, sanitation, medical care, food, shelter, and income. It could be argued that a deficiency in energy access contributes to most problems facing the poor in the developing world.

A lack of access to modern energy sources may heavily impact education. Without electricity, children may not be able to extend the day to do school work. Schools that do not have access to electricity are not able to tap into modern technology, such as computers, which severely limits access to information.

Energy poverty may influence health outcomes in developing countries in several ways. Unpredictable electricity makes it difficult to power health centers and refrigerate medicines, greatly affecting the quality of health services available(Birol, 2007). Energy poverty affects health outcomes at the household level as well. Without electricity, households must turn to biofuels to cook their food and provide light and warmth for their homes. Not only is the collection of biofuels costly in time and danger of injury, but the indoor burning of biofuels is one of the greatest health concerns facing the developing world (Sagar, 2005). Indoor burning of biofuels is linked to tuberculosis, lung cancer, and respiratory infections. More people die from indoor air pollution than the use of drugs, alcohol, and tobacco, unsafe sex, and malaria combined (Sovacool, 2012). These health risks are by-and-large imposed on women and children, who traditionally spend much of their day gathering fuel and burning it indoors.

A predominant aspect of how a lack of access to modern energy may affect quality of life is through income, via labor productivity. Abundant, affordable energy defines nearly every aspect of daily work: no electric tools and machines for construction, farm work, or cottage industry; no illumination for any type of work after sunset; no cell phones to enhance communications; and no computers for acquiring information, organization, and book keeping, among others. Without modern energy, goods have to be transported either on foot or by animal labor. Without widespread, affordable energy, it may be difficult for households to climb out of the cycle of poverty.

Lately there has been growing interest in the field of energy poverty. Rubrics have been established to measure and define energy poverty (Gaye, 2007; Masud et al., 2007; Pachauri and Spreng, 2004; Reddy, 1999). Studies have been done exposing the health risks, educational detriments, and productivity challenges of energy poverty (Birol, 2007; Reddy, 1999; Sagar, 2005; Sovacool, 2012). The positive impact of per capita electricity consumption on macro-level growth has been established (Shahbaz et al., 2013). (Khandker et al., 2013) use 2002-2005 panel data for Vietnam to estimate the household-level effects of electricity on welfare. They use fixed effects methods, and find positive impacts of households connected to the grid on income, expenditures, and schooling.

This paper follows a similar approach to (Khandker et al., 2013), where we look at the effect of electricity on income, substituted by household consumption, in Nepal. To account for endogeneity issues, we use Three Stage Least Squares (3SLS), and Two Stage Probit Least Squares (2SPLS) models. We find that causality runs both ways. That is, income explains whether a household is connected to electricity, but perhaps more importantly, a household being connected to electricity has a very large and significant effect on income. On average, a household being connected to electricity increases consumption per capita by 18%.

The organization of this paper is as follows. Section II discusses the data, while section III lays out the econometric model. Section IV explains and discusses the results of the estimation strategy, while section IV concludes.

2. Data

Our data comes from the Nepal Living Standards Survey-III (NLSSIII), which was performed by Nepal's Central Bureau of Statistics (CBS) in 2010-11. The NLSSIII is a nationally representative survey that follows the Living Standards Measurement Survey (LSMS) methodology developed by the World Bank (CBS, 2011a).The cross sectional sample size for the NLSSIII is 5,988 households from 499 primary sampling units.

Our level of analysis for this study is a household, and we consider only those households which are in an area that has access to electricity. The survey provides electricity access information at the smallest geographical administrative unit, the Village Development Committee (VDC). As not all VDC's have access to electricity, we only include in our analysis observations from VDC's reporting electrification. Thus in our data, a household that has no electricity has the potential of being connected, since the VCD is connected to the electrical grid.

2.1. Variables and descriptive statistics

Poverty, and hence income and consumption levels in Nepal, are correlated with geographical region, household size, gender of the head of household, caste and ethnicity, education level, land holding size, occupation of the head of household, and the number of children under seven years of age in the family (CBS, 2011b). Therefore, we include these variables as controls in our econometric specification.

The caste system in Nepal is deep-rooted where Brahmin and Chhetri are the more privileged castes, while the Dalit caste is the most deprived in terms of income and opportunity. Dalits consume 25 percent less than Brahman/Cheetri households (Bennett, 2006). Thus, we also include Brahmin and Chhetri, and Dalit variables in the equation.

We also control for distance to the nearest market center and distance to the nearest paved road. These two variables may affect income and consumption negatively, since residing far from markets and roads may reduce the opportunity for trade (Rahman and Westley, 2001).

Other variables included are whether a household uses firewood in their home; and whether the household has a roof made from straw or wood. It is possible that a household may restrict using electricity due to the fear of fire if the roof is made of straw or wood. Similarly, a household may use less electricity if it uses firewood. The following table shows the descriptive statistics.

Table 1: Descriptive statistics of variables used

Variable	Description	Variable Type	Obs	Mean	Std Dev	Min	Max
cons_percapita	Consumption Per Capita, 1,000 NRs.	Continuous	2467	33.928	24.492	4.541	405.116
elec_percapita	Electricity consumption per capita	Continuous	2467	313.434	490.803	0	7968
ElectricityD	If the household has electricity	Dichotomous (Yes=1, No=0)	2467	0.772	0.420	0	1
land_pc	Land holding size per capita in hectares	Continuous	2201	0.154	0.262	0	6.789
Kids	Number of children younger than 7 in household	Continuous	2467	0.879	1.106	0	7
Caste	If caste is *Brahmin/Chhetri*	Dichotomous (Yes=1, No=0)	2467	0.300	0.459	0	1
Dalit	If caste is *Dalit*	Dichotomous (Yes=1, No=0)	2467	0.140	0.347	0	1
years_educ	Years of education of head of household	Continuous	2441	3.074	3.971	0	17

hh_gender	Gender of head of household	Dichotomous (Male=1, Female=0)	2467	0.728	0.445	0	1
hh_size	Household size	Continuous	2467	4.96	2.420	1	20
Roof	If roofing material is straw or wood	Dichotomous (Yes=1, No=0)	2467	0.209	0.407	0	1
Firewood	If household uses firewood	Dichotomous (Yes=1, No=0)	2467	1.067	0.251	1	2
dist_mkt_center	Distance to the nearest market center in kilometers	Continuous	2374	9.419	13.472	0	500.001
dist_paved_road	Distance to the nearest paved road in kilometers	Continuous	2117	13.143	22.879	0	210

Consumption is measured in Nepali Rupees (NRs), where the 2010 exchange rate for US$ 1 equaled NRs 73. This sheds some light on Nepal's poverty levels. We see that the average person sampled lived on 33,928 NRs of consumption. This translates into slightly more than one dollar per day. The standard deviation in per capita consumption is very large, representing a large degree of consumption inequality.

3. Econometric model

Our main objective in this paper is to study the effect of electricity consumption on income. Based on this, we need to estimate the following equation

$$income_i = \alpha_0 + \alpha_1 electricity_i + \boldsymbol{\beta}'\mathbf{X}_i + \varepsilon_i \, , \qquad (0)$$

where $\mathbf{X}_i$ is a vector of control variables, and ε_i is an error term.

Equation (1) could be estimated using Ordinary Least Squares (OLS) if there was not potential endogeneity between *income* and *electricity*. The presence of endogeneity is suspected on the basis of studies which reveal the significant impact of electricity on both income and consumption (Khandker et al., 2013), and the significant impact of income on access to electricity (Louw et al., 2008; Pachauri and Spreng, 2004).

Further, studies have found consumption per capita to be a more accurate measure of well-being than income. This is especially true in poor economies with large informal sectors, where income flows may be erratic and fluctuate during the year, and where households consume their own production (Ravallion, 1992). Because of this, we switch to consumption per capita as our dependent variable of interest.

One way of solving the endogeneity problem is to simultaneously estimate the system of equations

$$consumption_i = \alpha_0 + \alpha_1 electricity_i + \boldsymbol{\beta}'\mathbf{X}_{ci} + \varepsilon_{ci} \qquad (2)$$

$$electricity_i = \gamma_0 + \gamma_i consumption_i + \boldsymbol{\delta}'\mathbf{X}_{ei} + \varepsilon_{ei} \qquad (3)$$

where *consumption* is annual consumption per capita in NRs, and *electricity* is the per capita annual expenditure on electricity consumption. Equations (2) and (3) can be estimated using either the two stage least squares (2SLS) or three stage least squares (3SLS) method.

However, a potential issue with this approach is that households who are not connected will show as having zero expenditure on electricity. While correct, expenditures on electricity may thus not fully capture the difference between households that are and are not connected to electricity. In order to control for this issue, we also estimate the system of equations where we replace the continuous *electricity* variable by a dichotomous *electricityD* variable, which takes value 1 if a household has access to electricity and zero otherwise.

$$consumption_i = \alpha_0 + \alpha_1 electricityD_i + \boldsymbol{\beta}'\mathbf{X}_{ci} + \varepsilon_{ci} \tag{4}$$
$$electricityD_i = \gamma_0 + \gamma_i consumption_i + \boldsymbol{\delta}'\mathbf{X}_{ei} + \varepsilon_{ei} \tag{5}$$

Estimating (4) and (5) simultaneously via 2SLS or 3SLS is problematic due to the dichotomous endogenous variable *electricity,* since these methods are best suited for the dependent variables to be continuous. To solve this problem, we can use a Two Stage Probit Least Squares (2SPLS) estimation method as described in (Maddala, 1983) and (Keshk, 2003). First we rewrite equations (4) and (5) as

$$consumption_i = \alpha_0 + \alpha_1 \sigma_e electricityD_i^* + \boldsymbol{\beta}'\mathbf{X}_{ci} + \varepsilon_{ci} \tag{6}$$
$$electricityD_i^* = \frac{\gamma_0}{\sigma_e} + \frac{\gamma_1}{\sigma_e} consumption_i + \frac{\boldsymbol{\delta}'}{\sigma_e}\mathbf{X}_{ei} + \frac{\varepsilon_{ei}}{\sigma_e} \tag{7}$$

Where σ_e is the standard deviation of the error term in equation (5) which is normalized to 1 in a probit model, and the star superscript denotes this transformation.

Now in the first stage we estimate

$$consumption_i = \mathbf{\Pi}_1^{'}\mathbf{X} + v_1 \tag{8}$$

$$electricityD_i^* = \mathbf{\Pi}_2^{'}\mathbf{X} + v_2 \tag{9}$$

Here, $\mathbf{\Pi}_1$ and $\mathbf{\Pi}_2$ are vectors of parameters to be estimated, $\mathbf{X}$ is matrix of all exogenous variables in equations (6) and (7), and ν_1 and ν_2 are error terms.

In the first stage, Equation (8) is estimated using OLS, and equation (9) is estimated using a probit regression. Once these two equations are estimated, we obtain the respective predicted values and use them to replace the corresponding variables in equations (4) and (5), so that

$$consumption_i = \alpha_0 + \alpha_1 \widehat{electricityD}_i + \boldsymbol{\beta}'\mathbf{X}_{ci} + \varepsilon_{ci} \tag{10}$$

$$electricityD_i = \gamma_0 + \gamma_i \widehat{consumption}_i + \boldsymbol{\delta}'\mathbf{X}_{ei} + \varepsilon_{ei} \tag{11}$$

Where the hats over our variables of interest signify predicted values from equations (8) and (9). In the second stage, once the original endogenous variables are replaced by the predicted ones, we estimate the new equations using OLS and probit as before. Finally, standard errors are corrected.

4. Discussion and results

Poverty alleviation has been the primary objective of the Nepalese development effort since the eighth five year plan of 1992-97. Since then, poverty has declined from 42% to 25% for the 1993-2011 period (CBS, 2011a). Research points to various factors for this rapid decline: work related migration and remittances (Lokshin et al., 2010), access to public infrastructure such as rural roads (Dillon et al., 2011), and progress in school enrollment rates (Niimi, 2011).

Electricity generation and distribution received top priority in the 11th three year plan of 2007-2010. Access to electricity increased from 14% to 70% for the 1993-2011 period. Our regression results show that there is a positive impact of electricity consumption on per capita consumption in Nepal. Table 2 presents the first set of regression results from equations (2) and

(3). We see that both consumption positively explains electricity, and electricity positively affects consumption.

Table 2: Three stage least square estimate for consumption and access to electricity

	Electricity Per Capita	Consumption Per Capita
cons_percapita	12.532***	
	(1.404)	
elec_percapita		0.044***
		(0.009)
land_percapita	-143.785	18.369***
	(58.184)	(2.662)
Terai	16.082	-0.128
	(37.866)	(2.029)
Hill	-21.961	1.981
	(36.107)	(1.884)
Eastern	-170.562***	11.784***
	(35.650)	(1.8)
Central	-147.111***	12.153***
	(36.619)	(1.673)
Western	-78.873**	7.092***
	(33.588)	(1.642)
Midwestern	-99.818***	7.593***
	(36.904)	(1.866)
dist_mkt_center	0.265	-0.0306
	(0.573)	(0.03)
dist_paved_road	-0.734*	0.0326

	(0.407)	(0.023)
Caste	27.343	0.042
	(20.05)	(1.191)
Dalit	41.29*	-2.01
	(24.415)	(1.304)
Kids		-1.602***
		(0.485)
year_educ		0.509***
		(0.165)
Roof	-54.58**	
	(21.7)	
use_firewood	26.183	
	(19.481)	
hh_gender	-31.64*	-0.887
	(18.809)	(1.291)
Constant	6.41	7.921**
	(57.325)	(3.473)
Observation	1878	1878
R-Square	0.1809	0.0589

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3 displays our main regression results from equations (10) and (11).[1] The coefficients for our two main variables of interest, consumption per capita and electricity are

[1] In the regression we don't include the variables, *kids* and *year_educ* into *electricity* equation because we don't find any theory and empirical evidence that these variables explain access to electricity directly. Similarly, we exclude the variables *roof* and *use_firewood* from consumption per capita equation because these variables are

highly significant with the expected signs. An increase in per capita household consumption of 1,000 NRs (roughly $12 USD) results in an increase in the probability of electricity access by 2.4 percent. Similarly, on average, if a household, initially without electricity, gains access to electricity, then per capita consumption for that household increases by six thousand Nepali Rupees per capita (roughly $75 USD). For an average family size of 4.96, this means that a household with electricity consumes 30,000 NRs ($407 USD) more than a household without electricity. Since the average yearly household consumption is $2,277 USD, this implies that electricity accounts for an 18% increase in consumption.

We also find that households in the *terai* and *hill* belts consume more than their *mountain* counterparts. Similarly, households in all other development regions consume more than households in the *Far western* development region. We see that the consumption level decreases for a household far from the market and paved road. Other factors that determine household consumption significantly are education of the head of household, number of children less than seven years of age in the family, head of household gender, and caste. An interesting result shown is that a household headed by a female consumes more in Nepal than a household headed by a male. This is perhaps due to more remittances received by female headed household and some targeted development program for female headed household (Hunzai, 2010).

When the dependent variable is electricity, the coefficient of roof is significant. This means households with a straw or wood roof are 75.4% less likely to have electricity in their home than those without a straw or wood roof. While having a straw or wood roof is an indicator of low income, it may also be that in such houses the probability of the roof material catching fire due to short circuits. Similarly, households who use firewood in their home have a

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indicator rather than a cause for high or low level of consumption in Nepal. By excluding these variables from respective equation, we are able to avoid identification problem as well.

42% lower probability of having electricity. The only odd sign in the *electricityD* regression is the sign of the coefficient of *distance to the paved road.* We would expect a negative sign for the coefficient of this variable, though the magnitude is not very large.

Table 3: Two stage probit least squares result for consumption per capita and access to electricity

	I Consumption Per Capita	II Electricity
electricityD	6.064***	
	(0.786)	
consum_percapita		0.024***
		(0.006)
land_pc	24.609***	-0.374
	(1.63)	(0.270)
terai	2.742**	-0.191
	(1.23)	(0.14)
hill	3.011**	-0.184
	(1.25)	(0.134)
eastern	7.745***	0.09
	(1.094)	(0.136)
central	12.588***	-0.291
	(1.094)	(0.136)

western	6.871***	0.057
	(1.082)	(0.125)
midwestern	6.779***	-0.101
	(1.20)	(0.135)
dist_mkt_center	-0.033*	-0.001
	(0.019)	(0.002)
dist_paved_road	-0.05***	0.008***
	(0.016)	(0.002)
kids	-3.762***	
	(0.25)	
caste	1.59**	0.16**
	(0.720)	(0.079)
dalit	0.671	-0.173**
	(0.831)	(0.083)
year_educ	0.735***	
	(0.101)	
roof		-0.754***
		(0.079)
use_firewood		-0.424***
		(0.130)
hh_gender	-3.93***	0.014
	(0.664)	(0.070)
Constant	16.62***	0.806***

	(1.781)	(0.246)
N	1878	
R-square of OLS	33.24	
Pseudo R-Square for Probit	12.28	

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Corrected standard errors in parenthesis.

5. Conclusion

Nepal is a country that faces many development challenges. Particularly in the rural areas of the country, low incomes, poor health, and low education levels are problems that affect the majority of Nepal's inhabitants. Using both 3SLS and 2SPLS models, this paper accounts for endogeneity between electricity and consumption. We find a large and significant effect of electricity on income. In particular, it is worth noting that having electricity is about eight times more impactful on consumption expenditures than an additional year of education for the head of household.

These results are important in that they highlight the importance of energy on income, one of the main development indicators. These results should place energy poverty at the forefront of the policy discussion of development in Nepal and other areas of the world.

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