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The Case of Mountain Areas in Bangladesh

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Abstract

This paper examines the relationship between electricity access, gender disparity, and green finance in the mountain areas of Bangladesh. We use a novel new micro-level survey data collected for the purpose of this study. We develop unique weighted indices and applying robust instrumental generalised method of moment estimation. The findings indicate that increase in electricity access (hours) is beneficial to empowerment of women in the Chittagong Hill Tracts (CHT) districts in grid-connected and off-grid areas. Using a quasi-experimental framework, we find no significant evidence suggesting that women from grid-connected households tend to enjoy greater gender parity than women from off-grid areas. This is likely due to increase in adoption of renewable energy devices such as Solar Home System (SHS). Using a probabilistic random utility model, we show that a surge in different expenditures tends to supress adoption of renewable energy in poor households more than in non-poor households, given the high prices and lack of financial schemes to support the purchase of renewable device. The expansion of green financial tools and strategies at the household and macro level is necessary to advance the outreach of renewable energy in the CHT districts to continue achieving gender parity.

Keywords: Women Empowerment, Gender Disparity, Green Energy, Electricity, Green Finance, Mountain, CHT, Bangladesh.

JEL Classification: D10, D13, D14, D40, D63, H42, Q41, Q43

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1 Introduction

The economy of Bangladesh, once deemed a “bottomless basket with no hope of survival”, is now globally perceived as a “development miracle”. The country has made significant strides in economic growth as well as socioeconomic sectors over the years (Mujeri et al., 2020; Mahmud et al., 2018; Asadullah et al., 2014). The country has shown an increase of average GDP growth rate of over 6.7% in the last decade (Amin et al., 2020). Prior to the pandemic in 2020, GDP growth rate had reached over 8%. Although the World Bank had predicted Bangladesh to be severely impacted, statistics from the BBS showed a growth rate of 3.5% instead of the estimated 2-3%; we expect a V-shaped recovery to 5.5% in 2021. The country has also made substantial progress in improving socioeconomic factors such as life expectancy, child mortality rate, literacy rate, poverty reduction, and per capital income level. Achieving such remarkable feats in growth and development led Bangladesh to be known as the new Asian Tiger. According to ALOnaizi and Gadhoum (2017), Bangladesh has been identified as one of “The Next 11” or N-11 economics of the world by Goldman Sachs given its fast growth and potential.

Energy plays a crucial role in the economic development of Bangladesh as both existing and emerging sectors rely on energy to operate. The government, in recognising and prioritising this sector as a part of sustainable development, has increased coverage of electrification from 47% in 2009 to almost 100% (BPDB, 2020). Achieving a stable and sustained growth rate in recent years, Bangladesh has decided to aim towards becoming an advanced economy by 2041 according to Vision 2041. In many studies, “women” have been stated to be “key enablers” in developing a society (Nandan and Mallick, 2020; Todaro and Smith, 2012; Momsen, 2008; Gill et al., 2007). Thus, the focus of development has shifted towards the reduction of inequality as well as equitable distribution of the benefits of economic growth, especially to women and the vulnerable.

Also, according to the United Nations, “achieving gender equality and empowering all women and girls” emphasises that equal gender participation is required for an economy to achieve its potential, therefore, gender equality is a “critical element” in the goal of development. It has been argued, however, that a substantial gap still exists in gender participation due to lack of policy implementations (Sedai et al., 2022; Hendriks, 2019; Duflo, 2012). In order to promote gender equality, certain initiatives have been focusing on women's economic engagement, i.e. empowerment. These include financial inclusion, political participation, and property rights among others.

Energy and gender equality are linked as recent literature points to the positive impact of energy access on women empowerment, especially in the case of developing countries (Sedai et al., 2022; Bajo-Buenestado, 2021; Samad and Zhang, 2019; Gould and Urpelainen, 2018; Winther et al., 2017; Khandker et al., 2014). According to Dinkelman (2011) and Rao (2013), the effect of energy access disproportionately favours women because women in developing countries spend more time in the household than men. As a result, we expect that gaining access to energy will empower women through increase in labour supply in non-household activities, such as reliable lighting or energy appliances that extend workday availability and productivity, decisions regarding children's education, household income and expenditure, as well as other decision-making autonomy regarding resources and mobility of women. However, certain aspects of the empowerment process through reliable and adequate energy access still remains elusive. For instance, Winther et al. (2017) argue that little is known about how energy access alters gender relations within households compared to substantial evidence of the impact of energy on women's economic welfare.

Furthermore, literature shows how access to energy impacts both women and men positively through marginal effects although they do not primarily account for how or why energy access results in a given set of gendered outcomes. Few empirical designs focusing on the effect of energy access on intra-household resource allocation, given gender preference, bargaining power, and time allocation on activities currently exist (Sedai et al., 2022). Moreover, the concept of women empowerment itself is a broad spectrum, and analysis of such kind would not bring any desirable outcome for policy implications without first constructing a clear framework to define women empowerment given context, culture, norm, societal heterogeneity (Winther et al., 2017).

Bangladesh has significantly progressed in enhancing grid-connectivity for electricity for all. However, it is challenging to provide the mountain areas of Bangladesh such as Chittagong Hill Tracts (CHT) (Bandarban, Rangamati, and Khagrachari) full grid coverage within the next 20-25 years due to the combinations of steep hills and narrow valleys. This has been a major factor in causing communities in these regions to remain relatively underdeveloped compared to the flat terrains of the country. Attempting to find a solution to aid such communities, brings focus to the idea of the access to and usage of alternatives, such as small and medium scale renewable based electricity generation.

Gender equality worsens when the inaccessibility of energy in mountain areas is considered. It has been long observed that women and girls in the Indian sub-continent face inequality due to existing social norms. From being less educated than men and boys and having less access to information, skills, training, and labour markets to facing greater risks of violence and harmful practices, the results of discrimination prove to be multifaceted. Together, these factors constraint women's chances of success as entrepreneurs in different sectors. In mountain regions such as the CHT of Bangladesh, it is expected that women face even larger disadvantages than those in flatlands due to the added factor of inadequate access to energy.

The government and private entities have taken initiatives to generate renewable electricity from devices such as Solar Home System (SHS) in the CHT. These projects work to improve access to service and increase the quality of basic social services for women and children. Some notable ways in which women have been empowered through income-generating activities at night, such as sewing clothes, making handicrafts, knitting, processing turmeric, other non-household activities, etc. Household income also increased as a result; such initiatives have improved the living standards of marginalised women by uplifting their social and economic conditions. Nevertheless, issues of high price, lack of appropriate financial scheme, and maintenance costs restrict the multiplier effect of such initiatives in the CHT districts, contributing to the gender disparity to persist.

Against the backdrop, the main objective of this household-level analysis is to explore the relationship between electricity access, green finance, and gender disparity in the mountain areas of Bangladesh (i.e., CHT). The novelty of this paper is threefold. First, to our knowledge, this is the first theory-driven empirical analysis that investigates interlinks between electricity access and women empowerment in the CHT districts of Bangladesh. Second, it shows the empirical evidence on the need of facilitating green finance to increase acceleration of green energy devices in the off-grid areas of CHT districts. Third, it provides some key policy suggestions.

We find that electricity access in the CHT districts has strong positive impact on women empowerment at aggregate and disaggregate levels (total, rural, and urban samples). We further show that women from the grid-connected households face gender parity similar to women from the off-grid areas. On the other hand, we also find evidence that renewable energy adoption likelihood tends to cap by income-expenditure dynamics.

The remainder of the paper is organised as follows. Section 2 is a brief literature review. Section 3 presents the methodology and description of primary survey and data. Section 4 presents the results and relevant discussions. Section 5 concludes and offers policy recommendations.

2 Review of Literature

Energy plays a crucial role in the development progress of any economy as every sector of economy relies on it. A society deprived of access to energy resources faces a multitude of consequences, such as ill health, lack of literacy, and gender discrimination (Acharya and Sadath, 2019). Providing and ensuring access to affordable, reliable, sustainable, and modern energy universally is a Sustainable Development Goal (SDG 7) that countries now hope to achieve. Households lacking energy due to accessibility and affordability suffer from energy poverty, and this need for quality energy impacts several aspects of social wellbeing as well as daily activities, such as cooking and lighting (Phoumin and Kimura, 2019). Electricity leads to effective education, transportation, security, and improves many other factors (Opoku et al., 2021). Electrification of households, in particular, is imperative to living and working in the modern age. Lack of electricity acts as a barrier to achieving higher education levels, increased income, better health, more equitable gender relations, etc., thereby limiting development of a specific region (Polansky and Laldjebaev, 2021).

Alongside the realisation of the importance of reliable and quality energy, it has also been recognised that gender equality is essential for holistic economic development. Women's empowerment is considered a process towards gender equality, and it is understood as equal rights of women and men, access to resources and control over them, and the power to influence matters that affect or concern them (Winther et al., 2017).

Electrification disproportionately affects women and girls as they spend more time in the households doing chores, especially when access and electricity is not available. In contrast, in households with electricity, women can partake in income-generating activities to increase household income and girls can attain education through schooling (Samad and Zhang, 2019; Van de Walle et al., 2013). Therefore, electrification enables empowerment through causal channels such as employment and education (Samad and Zhang, 2019; Samad and Zhang, 2017). As a result of electrification, the financial and social status of women are improved. Although the effect of electrification differs due to location, living standards, education, and deficiency, the quality of electrification has a significant positive impact on all empowerment indices (Sedai et al., 2022).

However, while having access to electricity benefits the welfare of women as well as men, the impact on gender relations remains unclear (Winther et al., 2017). In Bangladesh, women spend a large share of evening hours in income-generating activities. Electrification in Bangladesh has contributed to developing women's socio-economic status; the impact of electrification on women can be seen in many aspects of their lives, including but not limited to their mobility, decision-making, freedom in using income and savings, household work planning, awareness of legal and gender inequality issues, preference of sending girls to school, and knowledge of the negative impact of dowry (Barkat et al., 2002).

Rural electrification not only helps reduce poverty but improves other factors that reduce poverty; it reduces time allocated for the collection of fuel wood and allows schooling of children, increases labour supply of men and women, and increases household per capita income and expenditure (Khandker et al., 2014). In rural marginalised households, electricity enables increase in assets as well as consumption, and helps in moving out of poverty (Sedai et al., 2021). Energy poverty is experienced by those living in mountain regions of developed countries as well. Katsoulakos et al. (2014) state that a high percentage of households in mountainous Greece is vulnerable to energy poverty due to higher energy needs than urban areas and insufficiency in the fulfilment of those energy needs.

In terms of achieving equal electrification, renewable energy has played a significant role in developing countries. With the help of SHSs, off-grid electrification has been done quite significantly (Yadav et al., 2019; Amin et al., 2023). Several studies have shown that implementation of renewable based electricity generation devices such as SHSs have indeed improved different socio-economic indicators. Among others, Samad and Zhang (2017) highlight that it increases children's evening study time, lowers kerosene consumption, and provides health benefits for household members, in particular for women. Zahnd and Kimber (2009) critically discuss how augmentation of a simple renewable energy system to generate in the off-grid areas of Nepal accelerated the development progress. Urmee and Harries (2011) show that renewable energy device generated electricity is used by households in different types of income-generating activities in Bangladesh. In a similar fashion, Kurata et al. (2018) find that micro-enterprises also use SHS devices for running their production or service activities in Bangladesh.

Furthermore, Amin et al (2021a) show that renewable energy devices like SHS use is considered a coping mechanism against natural disaster induced electricity disruption by disaster-prone households. Besides, Groh et al. (2016) reveal that those SHSs, on average, have performed better in terms of electricity service quality than the national grid if measured against the multi-tier framework to measuring energy access quality as introduced by the World Bank's Energy Management Assistance Programme.

Even though renewable energy based electrification has achieved commendable outcomes, there are still some issues that need attention (Palit and Bandyopadhyay 2016; Ojong, 2021); otherwise the notion of achieving gender parity by empowering women through electricity access in off-grid areas would face slow momentum in the long-term. Among others, pricing affects renewable energy augmentation and the rate is slow. For instance, Foley and Logarta, 2007; Samad and Zhang (2017); Amin et al (2021b) argue that since in most developing countries household income is limited, purchase of renewable energy devices like SHSs becomes difficult, especially for the poor and near-poor households.

Samad and Zhang (2017) recommend that there should be support toward reducing the cost of SHS purchase. Amin et al. (2021b) advocate that cost of such devices could be reduced by lowering operating costs, reducing price risk, and financing. Furthermore, for renewable energy investment, it is still perceived as a risky venture by private investor, which needs to be mitigated by introducing new schemes of green finance. Amin et al. (2021b) assert that the first lump sum payment for the installation of renewable energy devices (like SHS) is significantly higher compared with their regular expenditure and income dynamics. As a result, the poorer segment of the off-grid population is of greater need of customised credit schemes; however, such credit schemes are nearly invisible in countries Bangladesh and other neighbouring countries.

Due to lack of payment mechanism, it has been observed that a certain share of households do not think of getting a renewable energy device, leading to loss in expected welfare in many instances (Ojong, 2021). Ojong (2021), through a literature review, show that only upper- and middle-income households are likely to install renewable energy devices to meet the electricity demand in India, Pakistan and Nepal. Moreover, evidence shows that due to lack of proper payment schemes, many poor households buy renewable energy devices since they do not meet the criteria for loans. Even if they fulfil the requirement, sometimes it becomes difficult to arrange the instalment money since the instalment is relatively high (Sovacool and Drupady, 2011; Amin et al., 2021b). Besides, maintenance costs coupled with availability of skilled maintenance personnel increases running costs.

As discussed before, energy access is difficult in mountain areas, however, it is being tackled by alternatives such as augmentation of renewable energy device. Green microfinance may be a sustainable initiative that will allow further empowerment of women in the CHT areas. Green finance refers to financial investments in sustainable development projects (Lindenberg, 2014). According to Atahau et al. (2021), there exists a direct relationship of RE on green microfinance institutions (MFIs) and that renewable energy has a mediated effect on women empowerment via green MFIs. Lee and Huruta (2022) state that the relationship between women empowerment and green microfinance is partially mediated by financial literacy. Therefore initiatives to bring electrification to households in mountain areas to empower women and those initiatives need to incorporate renewable energy and green microfinance to further aid in women empowerment.

3 Methodology and Data

3.1 Econometric Methodology

Following theoretical and analytical framework of Sedai et al. (2022); Samad and Zhang (2019); Winther et al. (2017); and Van de Walle et al. (2013), we consider the following model for investigating the impact of electricity access on women empowerment in the CHT districts of Bangladesh.

$$WEm_i = \alpha_i + \vartheta E_i^{hr} + \beta X_i^h + \psi D_i^\eta + \theta M_i + \varepsilon_i \qquad (1)$$

Where, WEm_i is the outcome of interest. This measures the degree of women empowerment in household i in the CHT districts. E_i^h is the hours of electricity access by the household i. X_i^h includes essential household characteristics such as real income, household size, household head sex, women age, number of children, and women marital status of women surveyed. D_i^η captures all the district level fixed effects, household type fixed effects, and locality fixed effect (rural or urban). M_i controls for ethnicity (indigenous or migrant) within the surveyed mountain areas. Finally, ε_i is the error term and assumed to be random and normally distributed with a constant mean and variance. ϑ, β, ψ, and θ are unknown parameters of interest estimated using the cross-sectional household-level data.

For the estimation purpose of equation (1), we use Instrumental Variable-Generalised Method of Moments (IV-GMM). Choosing IV-GMM has numerous reasons. Apart from achieving consistent estimations, it can address endogeneity in the model. Endogeneity is likely to occur in equation (1) because according to the existing literature, E_i^{hr} tends to be endogenous. Sedai et al. (2022) argue that if households are randomly chosen, then the issue of endogeneity is ruled out from the modelling framework; nevertheless, at the Primary Sampling Unit (PSU) (or village/ward) level, households sometimes may not be chosen randomly due to some degree of self-section bias coupled with sorting issue.

On the other hand, electricity access also depends on several other observed and unobserved characteristics. In our case, apart from the household dynamics, some of the crucial characteristics are geographic terrain, area specific household behaviour, certain norms and culture, income opportunities, local education facilities, tourism market, inter-district migration, etc. therefore, we instrument E_i^{hr} with formerly mentioned instrumental variables. It should be noted that the idea of geographic terrain instrument is well acknowledged in the earlier studies (Samad and Zhang, 2017; Duflo and Pandey, 2007; Khandker, et al., 2013; Van de Walle et al., 2013). Furthermore, the error variance of the model is constructed by utilising clustering method to address unobserved heterogeneity at the household-level.

To obtain Average Treatment Effect (ATE) on the grid-connected households for comparing changes in the degree of women empowerment is carried by using Propensity Score Matching (PSM) method discussed by Becker and Ichino (2002) and Rosenbaum and Rubin (1983). PSM is an approach that corrects the treatment effect estimation by controlling for the presence of the some confounding determinants given the notion that the bias spirals down when the evaluation of objective is performed using treated and control subjects who are as similar as possible. If propensity score of receiving grid connection in the CHT area is $p(E_{grid})$, then given pre-treatment dynamics, we can write the following:

$$p(E_{grid}) = \Pr(\Psi = 1|E_{grid}) = E(\Psi|E_{grid}) \qquad (2)$$

In equation (2) $\Psi = \{0, 1\}$. This is an indicator for treatment effect. E_{grid} is, as per the definition of Rosenbaum and Rubin (1983) a multidimensional vector of pre-treatment variables. If Ψ is random within the cells of E_{grid}, it is also considered as random within cells defined by one-dimensional $p(E_{grid})$. Therefore, given the sample population households, the PSM is known. Hence, the ATE on the treated can be found by following expression:

$$ATE \equiv E\{WEm_{grid,i} - WEm_{non-grid,i}|\Psi_i = 1\}$$

$$\geqslant ATE = E[E(WEm_{grid,i} - WEm_{non-grid,i}|\Psi_i = 1, p(E_{grid,i})]$$

$$\geqslant ATE = E[E\{WEm_{grid,i}|\Psi_i = 1, p(E_{grid,i})]\} -$$
$$E\{WEm_{non-grid,i}|\Psi_i = 0, p(E_{grid,i})\}|\Psi_i = 1] \quad (3)$$

Keeping this formal expression in mind, we use the Radius Matching (RM) ATE method to conduct our analysis. The main reason for using RM ATE is that it has advantages over Nearest-Neighbour (N-N) and Stratified ATE methods. Among others, one of the major drawbacks of the stratified ATE method is that it ignores observations in blocks where treated or control units are absent. This sometimes distorts the ATE consistency when sample tends to be at moderate level. On the other hand, since the N-N ATE method finds a match for all treated units, and as a result some of the matches are relatively poor given some nearest neighbour may have a very different propensity (Becker and Ichino, 2002). The RM ATE method addresses these issues. By design, each treated unit is matched only with the control units whose propensity score falls into a predefined neighbourhood or radius of the propensity score of the treated unit. RM ATE can be found by following, where T=treatment, C= control, w=weight, and N^T=number of treated units.

$$ATE^{RM} = \frac{1}{N^T}\sum_{i\epsilon T}\left(WEm_i^T - \sum_{j\epsilon C(i)} w_{ij} WEm_j^c\right) \quad (4)$$

Following Amin et al. (2021a), we use a random utility binary probit model to understand the likelihood of renewable energy device adoption by the households situated in the off-grid areas of the CHT districts. The objective is to empirically pinpoint the crucial determinants that are key to widen the door for renewable energy device adoption, especially financial perspectives. Similar to the IV-GMM, we use cluster based error variance structure to remove unobserved heterogeneity as much possible.

$$RED_i = \beta X_i + \varepsilon_i \ \sim N(\bar{\vartheta}, \overline{\sigma^2}\,) \qquad (5)$$

$$Prob(RED_i = 1|X_i) = Prob(RED_i{}^* > 0|X_i) = \phi(\beta X_i)$$

$$RED_i{}^* = \beta X_i + \varepsilon_i \sim \begin{cases} if\ RED_i{}^* > 0, RED_i\ = 1 \\ if\ RED_i{}^* < 0, RED_i\ = 0 \end{cases}$$

Here, RED_i= Propensity to adopt renewable energy device for electricity generation (1, 0) for all households, X_i= Regressors varying with respect to households.

3.2 Data

The analysis of this paper was based on micro-level data, obtained from a holistic survey conducted by the research team for the purpose of the present study. There were three phases of the survey: (i) preparation, (ii) implementation and fieldwork, and (iii) analysis and validation. The preparation phase included sampling design, developing the questionnaire, training the enumerators and the data entry operators, and piloting the draft questionnaire. The field data was collected in the implementation phase, followed by data entry and data cleaning operations. In the last phase, the information obtained from the quantitative data were visualised along with empirical analysis.

Sample data needs to be sufficiently large to have at least a near normal distribution (if not portray complete normal distribution) to be population representative.[1] Therefore, to obtain a population representative sample, the sampling design in this research adopted a stratified sampling technique in three stages: (i) calculation of approximate sample size with Cochran's formula, (ii) selection of PSUs, and (iii) selection of households within each PSU following the sampling methodology developed by the 2011 population census of Bangladesh and recent household-level surveys such as Household Income Expenditure Survey (HIES) of 2016 and Study on Employment, Productivity, and Investment in Bangladesh of 2019.

Following the sampling framework mentioned above, the minimum number of households (from each CHT district, shown in Figure 1 below) from which data needs to be collected is found to be 175, given 10% Margin of Error (ME) and 95% Confidence Level (i.e., Z-score=1.96). Assuming 3%-5% non-response and considering the issue of spurious survey information, 180 households was the targeted to be surveyed from each of the CHT districts. Hence, the total number of households targeted to be surveyed was 540. However, field enumerators found different response rates in the CHT districts, and therefore, we introduced additional weights to collect sample households from each district. Based on the weights, field enumerators surveyed 539 households, where 216 households from Rangamati (40.1%), 213 households from Khagrachari (39.5%), and 110 households from Banarban (20.4%).

Given the conventional practice, each PSU contains survey information of 20 households, making the number of PSUs to be 27. These 27 PSUs then distributed among the CHT districts (shown in Figure 2 below) based on rural-urban household distribution dynamics and other criteria such as geographic location, energy access (grid and off-grid), poverty dynamics, etc.[2] Within each PSU, 20 households were chosen randomly (i.e. SRS method) to avoid as many as unobserved attributes possible that could potentially contribute biasedness in the empirical analysis.[3]

[1] By population we are referring to households within the survey areas.

[2] The PSU distribution dynamics is consistent with HIES 2016.

[3] A Simple Random Sample (SRS) of size 'n' consists of 'n' individuals from the population chosen in such a way that every set of 'n' individuals has an equal chance to be the sample actually selected.

Figure 1: CHT Districts of Bangladesh

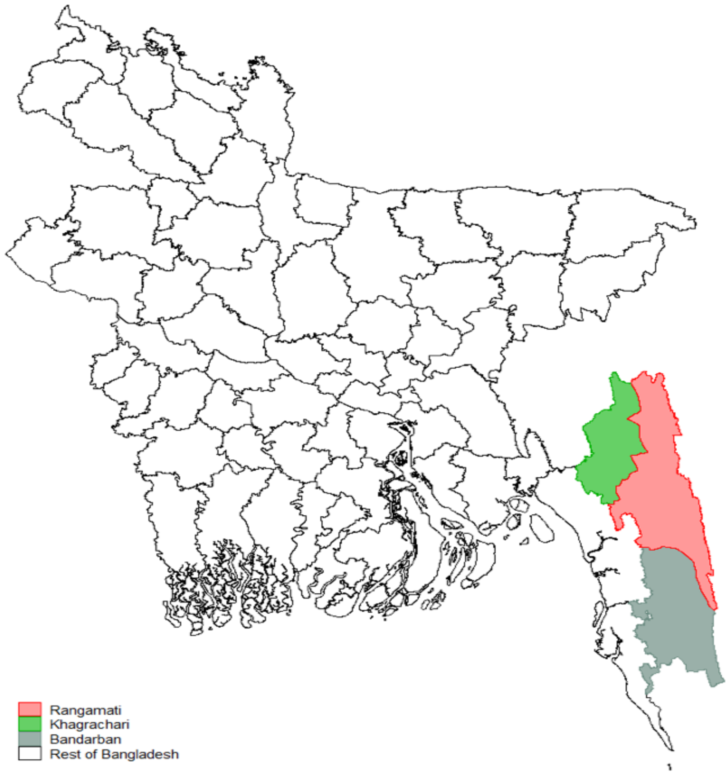
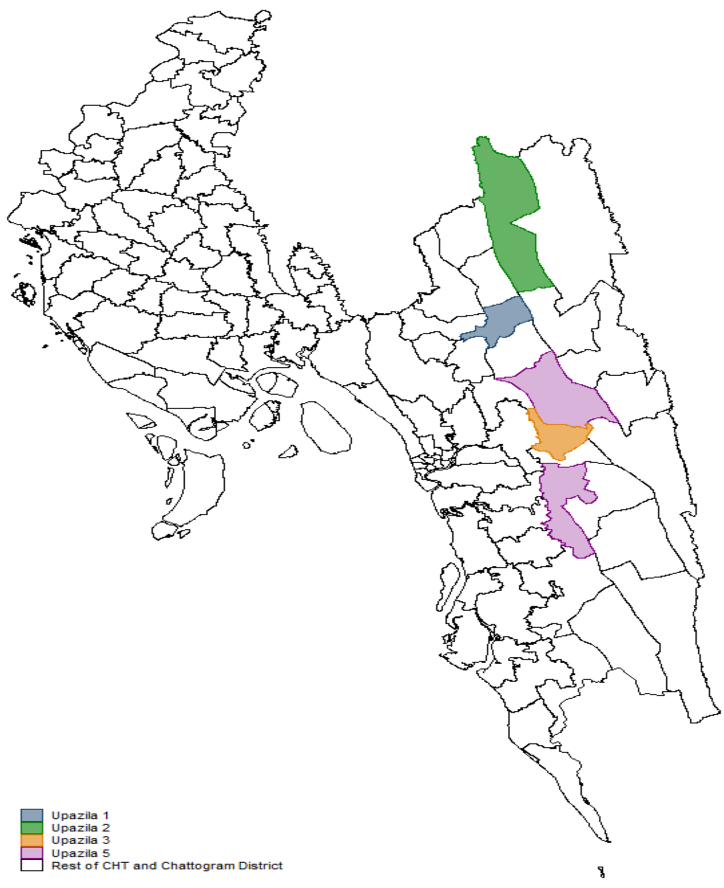


Figure 2: Chosen Upazilas from the CHT Districts



We further created several women empowerment indices by combining the empowerment variables shown below in Table 1 by using the Principal Component Analysis (PCA). There are 4 women empowerment indices in total, namely household decision, economic freedom, economic decision and mobility and agency. The components for each of the indices were chosen by the eigenvalue greater than 1 rule (Wold et al., 1987). The use of indices allows multiple indicators to be used in the analysis without the necessity of including all the variables in the regression models.

Table 1: PCA of Women Empowerment Variables

Indices	Empowerment Variable (0,1)	Obs.	Weight PCA	Interval
Household Decision	Family expenditure record	539	0.49	(-3.1,0.47)
	Decision for household appliances	539	0.48	
	Cooking decision	539	0.88	
	Children schooling decision	539	0.80	
Economic Freedom	Engaged in non-household activities	539	0.99	(-1.7,0.35)
	Decision to save	539	0.84	
	Authority over extra cash	539	0.93	
Economic Decision	Decision for household appliances	539	0.45	(-2.6,0.7)
	Decision for buying assets/expensive items	539	0.47	
	Decision for household necessity items	539	0.72	
Mobility and Agency	Decision in absence if household head	539	0.65	(-1.3,0.6)
	Decision for household necessity items	539	0.97	
	Participate in household budget	539	0.98	

Note: Factor loads are the score of individual variables in the empowerment indices and all indices are standardised with mean zero and standard deviation one. Estimation method: maximum likelihood.

4 Results and Discussion

We start this section by investigating the impact of electricity access and women empowerment indicators in the CHT districts of Bangladesh. It should be worth mentioning that improvement in the women's empowerment indicators from different aspects indicates progressive gender parity. Table 2 presents the IV-GMM estimation results for different women empowerment indicators at the aggregate level. We find that access to electricity has a strong positive impact on women empowerment indicators, namely economic freedom, economic decision, and household decision. This finding is consistent with the literature on electricity access and women empowerment (Sedai et al., 2022; Samad and Zhang, 2019; Khandker et al., 2014 Van de Walle et al., 2013).

Table 2: IV-GMM Estimation Results on the Nexus of Electricity Access and Women Empowerment

Variables	Economic Freedom	Economic Decision	Household Decision	Mobility and Agency
Electricity (Hrs)	0.0313***	0.0506**	0.0539***	-0.0107
	(0.00870)	(0.0225)	(0.0164)	(0.0102)
Log(Income)	1.011	-2.221	-0.261	-0.549
	(1.600)	(3.590)	(1.110)	(0.493)
Log $(\text{Income})^2$	-0.0533	0.0902	-0.00315	0.0281
	(0.0795)	(0.178)	(0.0559)	(0.0241)
Household Size	-0.0214	-0.00453	0.00202	0.0134
	(0.0141)	(0.0351)	(0.0249)	(0.0151)
Household Head Sex (Female=1)	0.117***	0.380***	0.156*	0.364***
	(0.0421)	(0.0930)	(0.0956)	(0.0452)
Woman Age	0.0199**	0.0190	0.0215	0.00267
	(0.00919)	(0.0211)	(0.0184)	(0.00865)
Woman Age^2	-0.000194*	-0.000146	-0.000181	-1.23e-05
	(0.000106)	(0.000250)	(0.000210)	(0.000105)
Ethnicity (Local=1)	0.0810*	0.133	0.221**	0.101*
	(0.0563)	(0.130)	(0.102)	(0.0778)
Number of Children	0.0739	0.166	0.0916	0.0522
	(0.0466)	(0.103)	(0.0910)	(0.0528)
Married (Yes=1)	0.181*	0.141*	0.222	-0.00400
	(0.0969)	(0.212)	(0.160)	(0.0785)
FE Controls				
Locality FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Household Type FE	Yes	Yes	Yes	Yes
Instruments	76	76	76	76
Constant	-6.162	11.44	3.276	4.086
	(8.073)	(18.12)	(6.852)	(3.322)
N	539	539	539	539

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.15

In terms of changes in the women empowerment indicators, we observe that increase in electricity access by 1 hour leads to improvement in economic freedom by 0.0313 standard deviation. On the other hand, women's economic and household decisions improve by 0.0506 and 0.0539 standard deviations, respectively, as electricity access increases by 1 hour in the households of the CHT districts. However, we also find that mobility and agency is not significant, indicating this indicator does not correlate with access to electricity.

Looking at the household characteristics, it is evident that household income does not determine variation in the weighed women empowerment indicators prepared with the PCA approach. The result is slightly different from the case of India, where Sedai et al. (2022) observe that household income somewhat positively impacts economic freedom and mobility, among others. For the CHT's case from Bangladesh, we argue that the insignificancy arises because these women empowerment aspects are skewed toward area-specific socioeconomic and geographical dynamics. We also find that household size is not a significant indicator for women empowerment indicators, which is consistent with the findings of Van de Walle et al. (2013) and different from Sedai et al. (2022).

There is a significant positive impact on all indicators of women empowerment when the household head is female. We find that compared to male-headed households, economic freedom, economic decision, household decision, and mobility and agility are 0.117 standard deviation, 0.38 standard deviation, 0.156 standard deviation, and 0.364 standard deviation higher than that of male-headed households. Intuitively this result is plausible in the CHT districts, given the mountain culture, religion, and norms, many households are headed by females. As a result, we also find that ethnicity changes the indicators of women empowerment. Women from indigenous households tend to be in a better position in terms of gender parity since their economic freedom (0.0810 standard deviation), household decision (0.221 standard deviation, and mobility and agility (0.101 standard deviation) are higher compared to women from the non-indigenous households.

The results suggest that women's age plays a role in achieving economic. The relationship is, in fact non-linear; yet we observe a trivial effect in the second derivative. This indicates the positive effect of women's age dominates the relationship for a long time. On the contrary, married women tend to have more intra-household bargaining power in terms of economic freedom, economic decisions, and household decisions. Besides, the number of children does not significantly impact women empowerment indicators.

The above discussion confirms that indicators of women empowerment correlate with the accessibility of electricity in the CHT districts of Bangladesh. Next, we further disaggregate the data and examine the impact in urban and rural areas. Tables 3-4 show the estimation results for urban and rural. We find that electricity access increases women empowerment indicators in urban and rural areas; yet the magnitude is slightly higher for urban areas. Standard deviation changes in economic freedom, economic decision, and household decision are 0.0336, 0.0572, and 0.0550 in urban areas, respectively, whereas 0.021, 0.044, and 0.038, respectively in rural areas. Comparing the disaggregated results, apart from the significance level, it is clear that heterogeneity is a trivial issue in the case of electricity access and women empowerment across the locality. This is because the degree of unobserved heterogeneity is well controlled by applying a cluster-based robust error structure.

Table 3: IV-GMM Estimation Results on the Nexus of Electricity Access and Women Empowerment in Urban Areas

Variables	Economic Freedom	Economic Decision	Household Decision	Mobility and Agency
Electricity (Hrs)	0.0336***	0.0572*	0.0550***	-0.0272
	(0.0108)	(0.0300)	(0.0199)	(0.0204)
Log(Income)	0.590	-5.159***	-0.440	-0.589
	(2.195)	(1.755)	(1.259)	(0.949)
Log $(\text{Income})^2$	-0.0293	0.244***	0.00974	0.0306
	(0.107)	(0.0850)	(0.0628)	(0.0462)
Household Size	-0.0267	-0.0133	0.00913	-0.0264
	(0.0220)	(0.0497)	(0.0324)	(0.0280)
Household Head Sex (Female=1)	0.237***	0.567**	0.480***	0.696***
	(0.0890)	(0.223)	(0.160)	(0.152)
Woman Age	0.0517***	0.0627*	0.0844***	0.0113
	(0.0139)	(0.0320)	(0.0229)	(0.0228)
Woman Age^2	-0.000562***	-0.000662*	-0.000906***	-0.000164
	(0.000167)	(0.000384)	(0.000270)	(0.000268)
Ethnicity (Local=1)	-0.0138	-0.201	0.0290	-0.240
	(0.170)	(0.331)	(0.241)	(0.223)
Number of Children	0.122	0.188	-0.0128	-0.0776
	(0.0969)	(0.263)	(0.169)	(0.153)
Married (Yes=1)	0.0239	-0.263	-0.0163	-0.135
	(0.134)	(0.292)	(0.203)	-0.0776
Controls				
District FE	Yes	Yes	Yes	Yes
Household Type FE	Yes	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes	Yes
Instruments	76	76	76	76
Constant	-4.960	28.87***	0.539	1.799
	(11.23)	(10.47)	(6.810)	(5.611)
N	221	221	221	221

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.15

Disaggregation reveals that ethnicity does not have impact on urban areas; however, it has positive impact on economic freedom, household decision, and mobility and agency for the rural indigenous women. This is because the proportion of indigenous households is higher in the rural areas of the CHT, and according to our sample, about 89.6% indigenous households are from rural areas. Keeping the ethnicity aspect in mind, it is also plausible to see that married women in rural areas tend to have more intra-household bargaining power compared to their urban counterpart generated from economic freedom, economic decision, and household decision.

Table 4: IV-GMM Estimation Results on the Nexus of Electricity Access and Women Empowerment in Rural Areas

Variables	Economic Freedom	Economic Decision	Household Decision	Mobility and Agency
Electricity (Hrs)	0.021*	0.0444*	0.0383*	0.0276**
	(0. 012)	(0.0321)	(0.0220)	(0.0123)
Log(Income)	0.106	0.666	1.191	-0.614
	(1.023)	(2.109)	(1.531)	(0.834)
Log $(\text{Income})^2$	-0.012	-0.0608	-0.0743	0.0254
	(0.041)	(0.106)	(0.0778)	(0.0412)
Household Size	-0.003	-0.0165	-0.0302	0.0349**
	(0.041)	(0.0430)	(0.0294)	(0.0171)
Household Head Sex (Female=1)	0.0524	0.162	0.0496	0.275***
	(0.0413)	(0.109)	(0.0955)	(0.0520)
Woman Age	0.004	-0.0334*	-0.0229	0.00756
	(0.0067)	(0.0192)	(0.0141)	(0.00954)
Woman Age^2	1.12e-06	0.000452*	0.000306*	-3.59e-05
	(7.8e-05)	(0.000231)	(0.000162)	(0.000114)
Ethnicity (Local=1)	0.082*	0.228	0.490***	0.194**
	(0.061)	(0.189)	(0.124)	(0.0936)
Number of Children	0.054	0.115	0.126	0.0724
	(0.050)	(0.114)	(0.108)	(0.0692)
Married (Yes=1)	0.233**	0.438*	0.478**	0.115
	(0.115)	(0.264)	(0.227)	(0.113)
Controls				
District FE	Yes	Yes	Yes	Yes
Household Type FE	Yes	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes	Yes
Instruments	76	76	76	76
Constant	0.821	-1.312	-5.558	2.370
	(4.268)	(10.28)	(7.396)	(4.118)
N	318	318	318	318

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.15

The IV-GMM estimation results lead us to a convincing conclusion that electricity access indeed improves women empowerment indicators generated from PCA. Therefore, we now aim to focus on another concern. Since electricity access leads to women empowerment though different channels, we generally would like to conceptualise a scenario where the grid system supplies the electricity. Therefore, a common hypothesis here would be that access to electricity improves women empowerment indicators where grid connectivity is available compared to the areas where grid connectivity is absent. However, such conceptualisation may only provide half of the picture, or, it may lead to many spurious outcomes. In both cases, there is a possibility of policy inconsistency. Hence, it is imperative to analyse the concern. In this paper, we choose the quasi-experimental path for investigating the concern.

We apply the PSM method to investigate whether access to grid electricity increases women empowerment compared to households where grid electricity is unavailable. In other words, our treatment group will have households that get grid electricity, while the control group will comprise households outside of the CHT districts' grid coverage. The ATE on the treated will be the determining factor of the earlier stated hypothesis. Table 5 depicts the ATE for the grid-electricity-connected households with robust standard errors and significance levels. The ATEs of the grid-electricity-connected households indicate that women's economic freedom, economic decision, household decision, and mobility and agency do not significantly differ from households outside the grid coverage. Therefore, the hypothesis we discussed can be rejected because ATE indicates there is no meaningful difference in the indicators of women empowerment between treatment and control groups. So, this finding leads us to another avenue of discussion. Now, the question is if there is no significant difference between grid-connected and non-grid-connected households in terms of women empowerment, then how are non-grid-connected households ensuring reliable access to electricity?

Table 5: ATE on the Treated for Women Empowerment

Criteria	ATE	Std. Err.	T Statistics
Economic Freedom	-0.016	0.082	-0.188
Economic Decision	-0.235	0.157	-1.495
Household Decision	-0.127	0.145	-0.874
Mobility and Agency	-0.162	0.093	-1.822

Note: t statistics for N=539; DF=488. All reported values are based on 500 bootstrap replications. ATE is calculated with radius approach. Matching regression and all the benchmark results are available on request.

From the survey results, 240 households (44.5%) do not have access to grid electricity. Out of 240, 232 households (96.7%) have access to renewable energy device that can generate adequate electricity for the households. Further investigation from the survey data indicates that these households mainly use SHSs as renewable energy device. It is worth mentioning that Bangladesh is one of the leading countries to deploy SHSs (Samad and Zhang, 2017). According to the arguments of Amin et al. (2023) and Groh (2014), SHSs are providing solar-powered electricity access to more than 25 million rural households, which has arguably helped in reducing energy poverty and alleviating over all development. Given this background, we next focus on the probability of renewable energy device adoption in the CHT districts. In doing so, we apply a random utility probit model for renewable energy device adoption in off-grid areas. The results are shown in Table 6.

Table 6: Renewable Energy Device Adoption in Off-Grid Areas

Variables	Full Sample		Poor		Non-Poor	
	Probit	Margin	Probit	Margin	Probit	Margin
Log(Income)	6.125***	0.219***	5.846**	0.529**	45.72**	0.804**
	(1.595)	(0.059)	(2.697)	(0.264)	(22.54)	(0.406)
Log(Food Expenditure)	-1.507***	-0.054***	-2.087	0.144	-6.429*	-0.113*
	(0.542)	(0.022)	(1.468)	0.163	(3.361)	(0.060)
Log(Non-Food Expenditure)	-2.835***	-0.101***	-3.570**	-0.323**	-14.31**	-0.252**
	(0.938)	(0.032)	(1.718)	(0.163)	(7.217)	(0.123)
Household Size	0.596**	0.021**	0.616*	0.056*	1.463*	0.026*
	(0.232)	(0.009)	(0.323)	(0.033)	(0.983)	(0.018)
Household Type (Farm=1)	1.253**	0.045**	-1.974***	-0.179**	-0.149	-0.003
	(0.498)	(0.021)	(0.669)	(0.081)	(0.923)	(0.016)
Children Schooling (Yes=1)	0.805	0.029*	0.820	0.074	5.210***	0.092**
	(0.526)	(0.017)	(0.737)	(0.065)	(1.988)	(0.034)
Household Head Sex (Female=1)	1.252**	0.045**	2.024**	0.183*		
	(0.589)	(0.027)	(0.911)	(0.106)		
Controls						
Locality & District	Yes	Yes	Yes	Yes	--	--
Household Chores	Yes	Yes	Yes	Yes	--	--
Fuel Collection	Yes	Yes	Yes	Yes	--	--
Non-Household Work	Yes	Yes	Yes	Yes	--	--
Leisure	Yes	Yes	Yes	Yes	--	--
Log Pseudo Likelihood	-13.86		-10.05		-4.72	
Wald Chi^2	91.79***		91.67***		16.89***	
Area Under ROC	0.966		0.944		0.990	
Correctly Classified	97.66		91.67		97.89	
N	214	214	60	60	60	60

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.15

The probit estimates reveal that income is a major factor for renewable energy device adoption in the households of the CHT districts, which is consistent with the findings of Aarakit et al. (2021); Lay et al. (2013); Samad et al. (2013). According to our estimates, a 1% increase in income raises the probability of renewable energy device in the off-grid areas of CHT districts by 21.9%. The adoption probability for poor households is 52.9 %, while non-poor households have a probability of 80.4%. On the other hand, household expenditures have a negative effect on renewable energy device adoption in the CHT districts. Overall, an increase in both food and non-food expenditures lead to 5.4% and 10.1%, respectively.

Similarly, rise in non-food expenditures reduces renewable energy adoption probability 32.3% for poor households. The probability of renewable energy adoption in off-grid non-poor households reduces by 11.3% and 25.2%, respectively, as food and non-food expenditures increase by 1%. Apart from the income and expenditure aspects, we also find that children's schooling, sex of household head, and household type significantly influence the decision of renewable energy device adoption across poor and non-poor households.

Findings from the income and expenditure perspectives have some intuitive underpinnings. At first glance, it is evident that there is a good amount of observed heterogeneity when it comes to income and expenditure effects on the likelihood of renewable energy device adoption among poor and non-poor households. As per the growth hypothesis, income surge in non-poor households leads to higher demand for electricity, which then pushes up the probability of renewable energy device adoption. The same explanation is valid for poor households; however, given the market price of renewable energy devices the likelihood of renewable energy device adoption gets constrained. Apart from the economic reasons, social differences also improve the likelihood of renewable energy adoption for non-poor households, as discussed by the literature (Ojong, 2021; Aklin et al., 2018; Khan et al., 2019; Bhattarai et al., 2018; Sovacool and Drupady, 2011; Sovacool, 2018).

On the other hand, when household expenditures are considered, poor households in the off-grid areas of the CHT districts are less likely to adopt any renewable energy device compared to non-poor households in the same cohort. Given that poor households generally tend to save less to meet the present consumption pattern, a sudden change in the expenditure account make them less attracted toward renewable energy device adoption. Such behaviour is observed due to two critical reasons.

First, the price is relatively high for poor households compared to non-poor households. Our survey data suggests that the average price of a renewable energy device (SHS) is around 22,000 Bangladeshi Taka (BDT), which is much above the $5 per day definition for defining poor households in our analysis. As most of the households tend to buy renewable energy device by direct cash payment (72.1%), abrupt changes in expenditure puts a cap on the likelihood of getting a renewable energy device, especially for the poor and near-poor households compared to non-poor households. Also, we argue that this behavioural aspect is expected to be higher in present time because of the current economic crisis in the world commodity market, resulting in higher prices in both food and non-food commodities in Bangladesh.

Second, the issue of instalments and cost of maintenance. Even though most of the households tend to buy renewable energy device through direct cash payment to the seller, about 36% of the households are found to be using instalment payment method, where monthly incomes of these households are skewed toward the poverty line. The monthly instalment varies immensely and ranges between 1,000-5,000 BDT with an average of about 2,400 BDT, which is high considering the monthly income of poor households. Findings from the data thus indicate that available financing schemes are not very optimal in reaching all types of households. Our survey data further suggests that, unlike flat lands, the access to microfinance or microcredit is minimal in the CHT districts through which relatively poor households could buy renewable energy device compared to flat land districts.

According to Khan et al. (2019), approximately 63% of the Noakhali and Sriajgang districts' rural households use SHS financed through microcredit. On the contrary, only 20% of the sample households used microfinance schemes to finance their renewable energy device. So, there is a clear indication that at the household-level, there is not enough variety of attractive financing schemes though which households can finance renewable energy device with any upward pressure in their consumption pattern. The maintenance cost is also high for SHS-type renewable devices, which sometimes demotivate the adoption of such device. From the Focus Group Discussion (FGDs), we find that some households has stopped using SHS due to high maintenance cost after 1-2 visits of maintenance personnel.

5 Conclusion

The main objective of this paper has been to explore the relationship between electricity access, gender disparity, and green finance in the mountain areas of Bangladesh. For the empirical analysis, we have conducted a survey to gather household-level data from three CHT districts, namely Bandarban, Rangamati, and Khagrachari. The survey was conducted following the sampling method developed by following national level survey done by the government of Bangladesh. The survey data itself is unique in the sense that no other study in our knowledge has used or developed a dataset that is able to capture in-depth information on household energy dynamics, social and cultural aspects, district-level market structure of different commodities, income and consumption dynamics, CHT development issues, gender perspectives, education, information and technology, etc.

Following the literature, we first empirically established that access to electricity is beneficial to women empowerment in the CHT districts both in the grid and off-grid areas (across locality). We used the PCA method to construct weighted women empowerment indices that allowed to capture the degree of intra-household gender parity through economic freedom, economic decision, household decision, and mobility and agency. Furthermore, using a quasi-experimental framework, we show that, given there is an issue of grid expansion in these mountain districts, there is no significant evidence that women from the grid-connected households enjoy gender parity than the women from the off-grid areas. According to our holistic survey data, such observation is the result of higher degree of renewable energy devices (mainly SHSs) adoption in the households from the off-grid areas.

While investigating the renewable energy adoption likelihood among the off-grid households with a random utility model, we found that apart from the household characteristics such as children's education, household head sex (i.e. male/female), and household type (i.e. farm/non-farm), household income-expenditure has a very strong influence on the renewable energy device adoption and is subject to heterogeneity. We found that income enhancement by 1% tends to increase adoption likelihood by 21.9%-80.4% depending on whether the household is below or above the poverty line. From the expenditure perspective, the surge in non-food expenditure tends to suppress renewable energy adoption more in poor households than non-poor households. We argued that such income-expenditure outcome is the result of high average market price of SHSs, limited options to finance the buying of SHSs, direct cash payment, and high maintenance cost.

Evidently, the expansion of renewable energy devices to meet electricity demand has been impressive in the CHT districts; however, the outcome is still constrained by financing issues as mentioned earlier. Therefore, we argue in favour of more innovative financial schemes to facilitate renewable energy device adoption in the non-grid areas of CHT districts. We recommend that initiatives should be taken to increase the outreach of the microfinance organisations in the CHT areas similar to the districts in the flat lands. Not only just outreach, we also advocate in favour of bringing customised financial schemes for CHT households to optimise their finance without hurting their consumption pattern and other non-household activities. Since geographical issues hinder financial institutes' operational activities, innovative mobile banking schemes could be launched in collaboration with microfinance instructions and other banking platforms. Renewable energy device providers (both public and private) also need to change their available financing schemes.

Besides, since FinTech firms are emerging in Bangladesh, the government can promote FinTech firms to bring innovative green financing mechanisms for the CHT districts to expand renewable energy coverage, which will eventually work as an enabler for women empowerment. On the other hand, we assert that the government must continue the distribution of renewable energy devices to poor households from the remote areas of the CHT districts as a part of the CHT development programme. We believe the process could be further strengthened by collaborating with renewable energy market players, resulting in acquiring adequate level of green funds. It is also advisable that green finance guideline and the spectrum of Bangladesh Bank should be strengthened. This will promote private commercial banks and foreign commercial banks to invest in the renewable energy market of Bangladesh.

Price is another issue for renewable energy device adoption. Even though SHS-type renewable energy device price has reduced over the time; however, thinking from the marginalised, it's still somewhat out of reach. Among others, a prime reason is the levied tax on importing solar inverters and panels. Currently, a 37% tax is levied on solar inverters coupled with 26% tax is imposed on solar panels. We emphasise that this needs to be reduced in order to reduce the prices of solar energy devices side by side to accelerate development projects and also attract investors. Additionally, more interdisciplinary reach is needed to identify indigenous solutions on how to reduce prices and increase the efficiency of renewable energy devices so that maintenance costs can be minimised.

This paper can be extended by investigating the same objective in the coastal areas such as districts close to the Sundarbans (i.e., one of the largest mangrove forests) to compare the results for better policy implications. We also aim to design randomised control trial (RCT) studies to get a better understanding of the heterogeneity dynamics of women empowerment and its link with electricity access in different parts of Bangladesh. Besides, another extension avenue could be to develop a theoretical modelling framework for green finance that could be used by policymakers to design an efficient green finance market in developing countries like Bangladesh.

References

Aarakit, S. M., Ntayi, J. M., Wasswa, F., Adaramola, M. S., & Ssennono, V. F. (2021). Adoption of solar photovoltaic systems in households: Evidence from Uganda. *Journal of Cleaner Production*, 329, 129619.

Acharya, R. H., & Sadath, A. C. (2019). Energy poverty and economic development: Household-level evidence from India. *Energy and Buildings*, 183, 785-791.

ALOnaizi, B., & Gadhoum, Y. (2017). The next 11: emerging investment market. In *1st International Conference on Advanced Research (ICAR-2017), Manama, Bahrain* (pp. 53-62).

Aklin, M., Cheng, C. Y., & Urpelainen, J. (2018). Geography, community, household: Adoption of distributed solar power across India. *Energy for Sustainable Development*, 42, 54-63.

Amin, S., Mansur, A. H., Kamal, S. M., & Groh, S. (2023). Powering up a Country into the Middle-Income Club. In *Electricity Access, Decarbonization, and Integration of Renewables* (pp. 21-52). Springer VS, Wiesbaden.

Amin, S. B., Chowdhury, M. I., Ehsan, S. A., & Iqbal, S. Z. (2021a). Solar energy and natural disasters: Exploring household coping mechanisms, capacity, and resilience in Bangladesh. *Energy Research & Social Science*, 79, 102190.

Amin, S. B., Chowdhury, M. I., Ehsan, S. A., & Iqbal, S. Z. (2021b). Solar energy sustainability in Bangladesh: tackling the management challenges. In D*esign, Analysis, and Applications of Renewable Energy Systems* (pp. 705-734). Academic Press.

Amin, S. B., Al Kabir, F., & Khan, F. (2020). Energy-output nexus in Bangladesh: A two-sector model analysis. *Energy Strategy Reviews*, *32*, 100566.

Asadullah, M. N., Savoia, A., & Mahmud, W. (2014). Paths to development: Is there a Bangladeshsurprise? *World Development*, 62, 138-154.

Atahau, A. D. R., Sakti, I. M., Huruta, A. D., & Kim, M. S. (2021). Gender and renewable energy integration: The mediating role of green-microfinance. *Journal of Cleaner Production*, *318*, 128536.

Bajo-Buenestado, R. (2021). The effect of blackouts on household electrification status: Evidencefrom Kenya. *Energy Economics*, 94, 105067.

Barkat, A., Khan, S. H., Rahman, M., Zaman, S., Poddar, A., Halim, S., & Islam, S. (2002). Economic and social impact evaluation study of the rural electrification program in Bangladesh. Report to *National Rural Electric Cooperative Association (NRECA) International*, Dhaka.

Becker, S. O., & Ichino, A. (2002). Estimation of average treatment effects based on propensity scores. *The Stata Journal*, 2(4), 358-377.

Bhattarai, D., Somanathan, E., & Nepal, M. (2018). Are renewable energy subsidies in Nepal reaching the poor? *Energy for Sustainable Development*, 43, 114-122.

BPDB (2020). *Recent Statistics*. Ministry of Power, Energy and Mineral Resources. People'sRepublic of Bangladesh.

Dinkelman, T. (2011). The effects of rural electrification on employment: New evidence fromSouth Africa. *American Economic Review*, 101(7), 3078-3108.

Duflo, E., & Pande, R. (2007). Dams. *The Quarterly Journal of Economics*, 122(2), 601-646.

Duflo, E. (2012). Women empowerment and economic development. *Journal of Economic Literature*, 50(4), 1051-79.

Foley, G., & Logarta, J. (2007). The challenge of rural electrification: strategies for developing countries. *Resources for the Future*, 45-73.

Gill, K., Pande, R., & Malhotra, A. (2007). *Women deliver for development*. The Lancet, 370(9595), 1347-1357.

Gould, C. F., & Urpelainen, J. (2018). LPG as a clean cooking fuel: Adoption, use, and impact inrural India. *Energy Policy*, 122, 395-408.

Groh, S., Pachauri, S., & Rao, N. D. (2016). What are we measuring? An empirical analysis of household electricity access metrics in rural Bangladesh. E*nergy for sustainable Development*, 30, 21-31.

Groh, S. (2014). The role of energy in development processes—The energy poverty penalty: Case study of Arequipa (Peru). *Energy for Sustainable Development*, 18, 83-99.

Hendriks, S. (2019). The role of financial inclusion in driving women's economic empowerment. *Development in Practice*, 29(8), 1029-1038.

Katsoulakos, N., Papada, L., & Kaliampakos, D. (2014). The problem of energy poverty in mountainous areas. In IISA 2014, *The 5th International Conference on Information, Intelligence, Systems and Applications* (pp. 222-226), July. IEEE.

Khandker, S. R., Samad, H. A., Ali, R., & Barnes, D. F. (2014). Who benefits most from rural electrification? Evidence in India. *The Energy Journal*, 35(2).

Khandker, S. R., Barnes, D. F., & Samad, H. A. (2013). Welfare impacts of rural electrification: A panel data analysis from Vietnam. *Economic Development and Cultural Change*, 61(3), 659-692.

Khan, T., Khanam, S. N., Rahman, M. H., & Rahman, S. M. (2019). Determinants of microfinance facility for installing solar home system (SHS) in rural Bangladesh. *Energy Policy*, 132, 299-308.

Kurata, M., Matsui, N., Ikemoto, Y., & Tsuboi, H. (2018). Do determinants of adopting solar home systems differ between households and micro-enterprises? Evidence from rural Bangladesh. *Renewable Energy*, 129, 309-316.

Lay, J., Ondraczek, J., & Stoever, J. (2013). Renewables in the energy transition: Evidence on solar home systems and lighting fuel choice in Kenya. *Energy Economics*, 40, 350-359.

Lee, C. W., & Huruta, A. D. (2022). Green Microfinance and Women's Empowerment: Why Does Financial Literacy Matter? *Sustainability*, *14*(5), 3130.

Lindenberg, N. (2014). Definition of green finance. German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE). DIE mimeo, 2014 https://papers. ssrn. com/sol3/papers. cfm.

Mahmud, M., Otsuka, K., Sawada, Y., & Yamada, E. (2018). Development transformation in Bangladesh: An overview. *Economic and Social Development of Bangladesh*, 3-26.

Momsen, J. (2008). *Women and Development in the Third World*. Routledge.

Mujeri, M. K., & Mujeri, N. (2020). *Bangladesh at Fifty: Moving beyond Development Trap*s. Springer International Publishing.

Nandan, A., & Mallick, H. (2020). Does gender equality matter for regional growth and income inequality? An empirical analysis for the Indian States. *Journal of International Development*, *32*(4), 439-469.

Ojong, N. (2021). Solar home systems in South Asia: Examining adoption, energy consumption, and social practices. *Sustainability*, 13(14), 7754.

Opoku, E. E. O., Kufuor, N. K., & Manu, S. A. (2021). Gender, electricity access, renewable energy consumption and energy efficiency. *Technological Forecasting and Social Change*, 173, 121121.

Palit, D., & Bandyopadhyay, K. R. (2016). Rural electricity access in South Asia: Is grid extension the remedy? A critical review. *Renewable and Sustainable Energy Reviews*, 60, 1505-1515.

Phoumin, H., & Kimura, F. (2019). Cambodia's energy poverty and its effects on social wellbeing: Empirical evidence and policy implications. *Energy Policy*, 132, 283-289.

Polansky, J., & Laldjebaev, M. (2021). Gendered energy relations at the crossroads of Asia: Electrification, empowerment, and mixed outcomes in northeastern Afghanistan. *Energy Research & Social Science*, 73, 101928.

Rao, N. D. (2013). Does (better) electricity supply increase household enterprise income in India? *Energy Policy*, 57, 532-541.

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70(1), 41-55.

Samad, H. A., & Zhang, F. (2019). Electrification and women's empowerment: evidence fromrural India. *World Bank Policy Research Working Paper, (8796)*.

Samad, H. A., & Zhang, F. (2017). Heterogeneous effects of rural electrification: Evidence from Bangladesh. *World Bank Policy Research Working Paper*, (8102).

Samad, H. A., Khandker, S. R., Asaduzzaman, M., & Yunusd, M. (2013). The benefits of solar home systems: an analysis from Bangladesh. *World Bank Policy Research Working Paper*, (6724).

Sedai, A. K., Jamasb, T., Nepal, R., & Miller, R. (2021). Electrification and welfare for the marginalized: Evidence from India. *Energy Economics*, 102, 105473.

Sedai, A. K., Nepal, R., & Jamasb, T. (2022). Electrification and socio-economic empowermentof women in India. *The Energy Journal*, 43(2).

Sovacool, B. K., & Drupady, I. M. (2011). Summoning earth and fire: The energy development implications of Grameen Shakti (GS) in Bangladesh. *Energy*, 36(7), 4445-4459.

Sovacool, B. K. (2018). Success and failure in the political economy of solar electrification: Lessons from World Bank Solar Home System (SHS) projects in Sri Lanka and Indonesia. *Energy Policy*, 123, 482-493.

Todaro, M. P., & Smith, S. C. (2012). *Economic Development 11th Edition*. Addision-Wesley. ISBN 10: 0-13-801388-8.

Urmee, T., & Harries, D. (2011). Determinants of the success and sustainability of Bangladesh's SHS program. *Renewable Energy*, 36(11), 2822-2830.

Van de Walle, D. P., Ravallion, M., Mendiratta, V., & Koolwal, G. B. (2013). Long-term impacts of household electrification in rural India. *World Bank Policy Research Working Paper*, (6527).

Winther, T., Matinga, M. N., Ulsrud, K., & Standal, K. (2017). Women's empowerment through electricity access: scoping study and proposal for a framework of analysis. *Journal of Development Effectiveness*, 9(3), 389-417.

Wold, S., Esbensen, K., & Geladi, P. (1987). Principal component analysis. *Chemometrics and Intelligent Laboratory Systems*, 2(1-3), 37-52.

Yadav, P., Davies, P. J., & Sarkodie, S. A. (2019). The prospects of decentralised solar energy home systems in rural communities: User experience, determinants, and impact of free solar power on the energy poverty cycle. *Energy Strategy Reviews*, 26, 100424.

Zahnd, A., & Kimber, H. M. (2009). Benefits from a renewable energy village electrification system. *Renewable Energy*, 34(2), 362-368.