IMPACT OF ENERGY USE ON WOMEN EMPOWERMENT IN BANGLADESH: AN EMPIRICAL ANALYSIS

Anta Atalantia[1] and Sakib Bin Amin[2]

ABSTRACT

Bangladesh achieved significant progress in the energy sector from 2009 to 2019, and it has helped the country to improve the socio-economic conditions of women**.** However, to the best of our knowledge, there are no empirical time-series studies that explicitly address the relationship between electrification and women's empowerment. For an emerging country like Bangladesh, where women's work is often undervalued and society seems to be biased towards men, the demonstrated relationship between electrification and women's empowerment may have unveiled the immense impact that this might have had on the society. Hence, this paper investigates and quantifies the impact of electrification on women's empowerment, taking the general view that increasing electrification in Bangladesh results in empowering women in a community. Augmented Dickey-Fuller (ADF), Dickey-Fuller- GLS (DF-GLS), Johansen Cointegration methods have been used in this paper to explore this relationship. Moreover, the Granger-causality-test, Vector-Error-Correction Model (VECM) tests have also been applied to quantify this relationship. Our results support the view that energy use has a potential impact on the female laborforce in Bangladesh's both in the long and short run. Moreover, it also has a statistically significant effect on the female literacy rate in the long run**.** The Dynamic OLS (DOLS) results show that a 1-unit increase in energy consumption can lead to a 0.20 percent increase in female labor force participation in the long run other things remain unchanged. So, access to adequate electricity can provide the opportunity for employment creation to the poor female. To do so, the Bangladesh government should pay more attention to the development of off-grid electrification to better the socio-economic conditions of the unprivileged rural women in Bangladesh.

JEL codes: O11, Q43
Key Words: Macroeconomic development, energy, and macroeconomy
Field of Research: Economics

1. INTRODUCTION

In modern economics, energy is considered as the most vital strategic fuel for developing the socio-economic conditions of a nation. The industrial revolutions, exceptional economic growth, and major improvements in the standards of living all are, one way or the other, influenced by energy consumption facilitating the uptake of better technologies (Amin & Khan, 2020). The holds dispute the fact that the energy sector diversely constitutes a modest share of GDP in Bangladesh. The growth of an economy is directly related to the energy sector of the economy. Adequacy of electricity and development of the energy sector is a driver for the sustainable development of Bangladesh.

[1] *BS Graduate (Economics) North South University, Bangladesh, Email: antaatalantia123@gmail.com*
[2] *Associate Professor (Economics) and Corresponding Author, School of Business and Economics, North South University, Bangladesh; Email: sakib.amin@northsouth.edu*

At the same time, there is a nexus between women empowerment and usage of electricity. Women empowerment means creating an environment for women to exercise their capability, power and power and authority. According to Sundström et al. (2017), women's empowerment is as a universal standard term rather than the relative term of women to males in a society; is the capacity for women to make a better choice as an agency at home, and for social decision making. According to Kabeer (2005), empowerment is defined by three interrelated qualities. First of all, agency is the method through which wise decisions about one's future are made. Secondly, empowerment includes people's ability to make decisions as well as their sense of agency and self-worth. Thirdly, it entails how a society's institutions and relationships allocate power resource and opportunities. The successes made as a result of individual efforts to achieve empowerment are the result of resources and agency. Today it is known that women empowerment is one of the keys to economic growth. However, in today's world women from many countries face barriers to use electricity (Alstone, *et al.,* 2011). So, the increase of the electricity usage is paramount for socio-economic development of Bangladesh.

Women participation in the work place has significantly increased in Bangladesh; however, it is still severely less than the other developed countries. For example, in 2018 the labor force participation rate by female (15yr+ age) in Bangladesh is 35.85% whereas in the other developed countries like in Australia and The United States, the participation rate is 59.64% and 56%, respectively (World Development Index, 2018).

The development process of a country gets hampered for lack of energy sectors (Amin, 2015)**.** The overburden of women works, and their lack of power and influence makes them miserable by lowering their health status and well-being. There are many vehicles through which women empowerment can be achieved. One of the main vehicles is energy use. Use of energy and electricity can be an instigator for economic growth and human development. Energy use and women empowerment can be closely related to the development of a country. Energy consumption can be the main source of empowering women, for which access to the energy for female of this country is also essential.

After the independence of Bangladesh in 1971, only 3% of the total population had access to electricity. This number has gone up to 59.6% in 2012 and 88% in 2018 (World Development Index 2018). As gender inequality is considerably high in Bangladesh, electrification specifically in women's daily and working life can eradicate gender inequality and, hence will empower women.

Barkat (2002) found out that women play a greater role in running a business than men in many cases. In this research, there are evidences for women empowerment and better household decisions making instances in the villages with electricity compared to the villages without electricity. There are many indicators of women empowerment among those; the main indicators will be described and examined in the context of a relationship among women empowerment and energy usage

Energy poverty is common phenomenon in countries like Bangladesh and, also in South Asia. It is often deduced that, poverty has a woman face. Khandker et al. (2009) studies the impact of electrification in rural area. The study finds that, access to improved lighting ensures extra hours of study and, as a result, better educational outcomes. Lighting also improves other household activities such as sewing by women, social gatherings and so on. Moreover, radios and television increase the accessibility of information to rural households. Besides electricity facilitates household's economic activities both from inside and outside the house hold.

In this paper, we will try to address the relationship between energy use and women empowerment in the Bangladeshi context. Through this research work, we would like to examine whether energy use can empower women. We are taking this hypothesis for Bangladesh because energy is a significant determinant for economic development. Since Bangladesh is looking forward to achieving its Sustainable Development Goals, energy is one of the important determinants to fulfill the goals. This paper detects if there is any relationship between the variables considered and women empowerment. As well as, how energy use can affect female empowerment in Bangladesh. Research results show that energy use has a potential impact on the female labor force both in the long run and short run in Bangladesh. It has also had an effective impact on the female literacy rate in the long run. These results support the previous result findings which we get from the literature review. And the results are different in case of women empowerment ensuring by energy usage. There are three main research questions:

I. Is there any causal relationship between energy use and women empowerment in Bangladesh?
II. Is there any long-run cointegrating relationship between energy use and women empowerment in Bangladesh?
III. Is there any short-run relationship between energy use and women empowerment in Bangladesh?

We consider three variables: female literacy rate, female labor force participation rate, and fertility rate as the proxy variables of women empowerment. The rationale for using these variables is as follows.

Berik (2022) in her discussion paper for UNDP, proposed for replacing the United Nations Development Program's (UNDP) gender inequality index (GII) with two other gender index which are Global Gender Parity Index (GGPI) and Women's Empowerment Index (WEI). In WEI index there is dimension of female education and their reproductive choices to measure women empowerment. And in GII index there is dimension of female opportunities for paid work or financial inclusion which is also related to women empowerment as reflects the gender gap. That is why we measured the fertility rate as a measurement of women's freedom of reproductive choice, educational attainment to measure their capabilities to seek education and female labour force participation to study opportunities for paid work for women in to explore the impact of women's empowerment on the economic development of Bangladesh.

Data for variables are collected from the Data Bank of World Bank and from Bangladesh Bureau of Statistics (BBS). The variables are Energy use by women, Fertility rate, Female literacy rate, Female labor force. The rest of this study is organized as follows: Section 2 presents the literature review of energy use and women empowerment concept; Section 3 describes the energy scenario in Bangladesh; Section 4 presents an overview the women empowerment status in Bangladesh; Section 5 presents the methodology from various estimations. In Section 6, we undertake some robustness checks and present the results; Section 7 lays out the path from energy use to women empowerment in the society; and then finally we conclude the study in Section 8.

2. LITERATURE REVIEW

It is important to point out that there is lack of studies in Bangladesh where the impact of electrification and women empowerment have been explicitly discussed. UNDP (1995) mentions

that 70% people living under the poverty line are found to be women. Energy is considered as one of the vital components for alleviating poverty as well as gender discrimination. Besides, lives of the rural women also change as they start getting the access to adequate electricity.

Harbison and Robinson (1985) address the linkage between electrification and fertility rate in are India, Bangladesh, Thailand, Korea, Indonesia, Philippines, and the U.S. The study results show that higher level of electrification results in increase level of contraception prevalence. This relationship promotes women empowerment.

Dinkelman (2011) observes that women participation in the workplace in rural South Africa increases significantly 9.5% after 5 years of increase level of electrification. The study shows that female employment is South Africa increases by 13.5% with accessibility of electrification in the treated areas but the effect is insignificant for men. Although electrification is not directly related in generating new labor demands.

Grogan and Sadanand (2013) find that women in Rural Nicaragua are 23% more likely to work outside with the availability of electricity. The result findings show us that electrification increases the working time for both spouses. Similarly, Dasso and Fernandez (2015) indicate that women in Peru are more likely to be educated and employed after having electricity. Also, Van de Walle *et al.* (2013) observes that household electrification results in significant level on rise in consumption and earnings in rural India. On the contrary, Salmon and Tanguy (2016 find that electrification has positive impact only on husband's working time, on the other hand wives tend to increase leisure and household work. The number of unpaid work of women did not reduce with increased level of electrification. However, electricity has reduced the time allocation for specific household activities like firewood collection and others outside activities. Women would use this saved time to increase time for paid work. Barket *et al.* (2002) come up with the similar result in Bangladesh and Bhutan. Electrification helps the women from these countries to allocate their spare time from household work to generate income. This study also finds that electrified houses have higher literacy rate than non-electrified Bangladeshi houses both for women and men. In addition, a study by O'Dell shows that self-employed women with access to energy get twice of wage compared to the self-employed women without access to energy. The findings also indicate that average rural income of men and women is 10% higher with the accessibility of energy. Also a study conducted in Peru shows that children having solar energy at home are more likely to study in schools (Arraiz & Carero 2014).

Khandker *et al.* (2009) look upon many cases to elucidate the impact of electrification and energy use on household income, expenditure and education in Bangladesh. It shows positive impact of energy use on household income, expenditure and education. The household income raises 21% with 1.5%-point reduction in poverty per year. Khandker *et al*. (2012) compares the impact of electrification on poor and rich households in India. The study shows that rich households enjoy higher return in income and also higher level of educational output.

Winther (2008) examines the nexus between electricity and female empowerment in the village of Zanzibar, Tanzania. By the results of this we get to know that young girls and women save 25 hours on average with access of electricity. There is also equal number girls and boys attending schools. Also women save enough time to dedicate the time in income generating work. A study (UNDP/ESMAP 2004) on women in India finds that women are likely to spend 40 min less in household work like cooking and collecting firewood with electricity compared to households without electricity. Isfahani and Taghvatalab (2014) show that in Iran increase level of electrification results in decrease in fertility rate. We learn that after development in electricity took

place in 1979 in Iran it causes reduction in fertility rate and also it let to increase the literacy rate of women. Similarly, Fuji and Shonchoy (2015) also find that increasing electricity availability results in reducing fertility rate in rural area of Bangladesh.

Fuji and Shonchoy (2015) look explicitly at the relationship between fertility rate and rural electrification. This study shows that the use of electricity reduced the fertility rate among rural Bangladeshi women. From these two studies, we can implement that as electrification had successfully reduced fertility rate. And electrification is also related to women empowerment as decreasing fertility rate reflex the empowerment of women. So electrification and empowerment are related to each other. Jensen and Oster (2009) find that women in rural India who have access to television are less likely to face domestic violence. They are more likely to send their girls to schools and also intend to involve in income generating works.

From the above mentioned literature review, we clearly know that there is no such research which precisely studies the impact of energy use on women empowerment with time series analysis**.** In addition to that, there is a lack of variables added to each study for the determination of the impact on women empowerment. On the contrary, in this paper three proxy variables are taken as the measurement of women empowerment and to inspect the impact of energy use on it.

Granger Causality Test is used in this paper to see if there is any causal relationship between energy use and women empowerment. The findings support the hypothesis as a relationship is observed between energy consumption and women empowerment. We set our hypothesis relevant to our research questions. A set of null hypothesis is as follows,

H_1: Energy consumption cause women empowerment

H_2: Energy consumption has a potential impact on female labor force

H_3. Energy consumption has a potential impact on literacy rate

All the study and outcome from the literature review are combined in **Table 1.**

Table 1: Key Features of the Empirical Literature on Energy Use and Women Empowerment Revised

Author	Topic	Country	Methodology used	Key findings
Harbison and Robinson (1985)	Rural Electrification and Fertility Change	India, Bangladesh, Thailand, Korea, Indonesia, Mindanao Island, U.S	Panel regression analysis	The higher the level of electrification, the higher will be the level of contraception prevalence
Dinkelman (2011)	The Effects of Rural Electrification on Employment: New Evidence from South Africa	Africa	Instrumental variables strategy and a fixed effects approach	Instrumental variables strategy and a fixed effects approach
Grogan and Sadanand (2013)	Rural Electrification and Employment in Poor Countries: Evidence from Nicaragua	Nicaragua	Bivariate model structure	Nicaragua is 23 percent more likely to work outside of the home when there is electricity in the household
Dasso and Fernande z (2015)	The effects of electrification on employment in rural Peru	Peru	The difference in differences and fixed effect structural model	Electrification increases the labor demand more than labor supply
Van de Walle et al. (2013)	Long-Term Impacts of Household Electrification in Rural India	India	Time series econometrics analysis.	Household electrification brought significant gains to consumption and earnings, the latter through changes in market labor supply
Chowdhury (2010)	Impact of infrastructures on paid work opportunities and unpaid work burdens on rural women in Bangladesh	Bangladesh	Time series regression analysis by ordinary least squares estimation	Infrastructures expand the paid work opportunities for women in the non-farm sector.
Salmon and Tanguy (2016)	Rural Electrification and Household Labor Supply: Evidence from Nigeria	Nigeria	Copula-based bivariate hurdle model	Electrification only has a positive impact on the husband's working time
ADB (2010), Chowdhury (2010)	Impact Evaluation of Rural Electrification in Bhutan	Bhutan	Qualitative research with experimental, quasi-experimental and non-experimental methods	Electrification decrease the amount of time spent on collecting fuelwood by women

Author	Topic	Country	Methodology used	Key findings
Jensen and Oster (2009)	The Power of TV: Cable Television and Women's Status in India	India	A three-year, individual-level panel data set regression	Cable television connection in a rural area significantly decrease the domestic violence towards women
Fuji and Shonchoy (2015)	Fertility and Rural Electrification in Bangladesh	Bangladesh	Contemporaneous and retrospective panel data consumption model prediction	Electricity reduced fertility rate among rural Bangladeshi women
Winther (2017)	Women's empowerment through electricity access	Zanzibar, Tanzania	A qualitative oriented study	Women and girls save 25 hours on average because of electricity
Arraiz & Calero 2014	From Candles to Light: The impact of Rural Electrification	Peru	Panel data participation model	Children in SHS homes are more likely to study at home
Khandker et al. (2012)	Who Benefits from the Rural Electrification? Evidence in India	India	Cross-sectional survey analysis	Rich households enjoy more benefits than poor households
O'Dell et al. (2014)	Women, energy, and economic empowerment: Applying a gender lens to amplify the impact of energy access	Brazil	Posttest-only Control Group Operations Research Design	The average rural income of men and women who has access to energy is 10% higher
Barket *er al.* (2002)	Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh	Bangladesh	Qualitative study	Electrified homes have a higher literacy rate for both men and women compare to non-electrified
Khandker et al. (2009)	Welfare Impacts of Rural Electrification: A Case Study from Bangladesh	Bangladesh	Cross sectional survey and analysis	Electrification increase 21 percent in income, reduces 1.5 percentage of poverty per year
Isfahani and Taghvata lab (2014)	Rural Electrification and Female Empowerment in Iran: Decline in Fertility and Rise in Literacy	Iran	A difference-in-difference method, instrumental variables to account for the potential endogeneity of electrification	Development in electricity decrease in fertility rate in women and also increase the literacy rate of women.

Source: Compiled by the authors

3. ENERGY SECTOR IN BANGLADESH: AN OVERVIEW

Bangladesh is an emerging country with a middle-income status. The per capita income of Bangladesh is 1203.03 USD (FY 2018). The GDP per capita of this country is 10% of the world's average. It wanted to decrease import bill after oil shock 1973 and as a consequence government of Bangladesh substituted natural gas as the main energy source (Amin at al., 2012). Bangladesh extracted about 722 million cubic feet natural gas in 2012 which is mainly consumed by internal markets.

According to International Trade Administration of USA the demand for electricity of Bangladesh is projected to be 34,000 megawatts (MW) by 2030. The estimated total investment to the nest 15 years is $70 billion. While as of June, 2018 installed generation capacity has increased to 18,753 MW. Bangladesh Power Development Board (BPDB) has implemented programs to expand generation capacity to 24,000 MW by 2021 and 40,000 MW by 2030.

The energy sector of Bangladesh is thriving. The country has started the plant called "Rooppur Nuclear Power Plant" which has the capacity of 2.4 gigawatt (GW) is expected to operate in 2023. According to BPDB in July 2018, 90% of the population had access to electricity. Still per capita energy consumption in Bangladesh is considered to be low. In November 2019, seven new power plant project has taken under consideration for future establishment. The details are in the chart below.

Table 2: New Power Plant Projects in Bangladesh 2019

Anwara Power Plant	Rangpur Power plant	Karnaphuli Power Plant	Shikalbaha Power Plant	Patia Power Plant	Tetulia Solar power plant	Gazipur Power Plant
300 MW	113 MW	110 MW	105 MW	58 MW	8 MW	100 MW

Source: The Daily Star, November 13, 2019

According to the statistics of Petro Bangla, the remaining reserved gas will last 2031 (Petro Bangla, 2015). The total installed generation capacity was 15821 MW whereas the total demand was 9479 in September 2017. To achieve 100% of electricity across Bangladesh only grid electricity is not enough. The government is now encouraging off-grid electricity production, for example, Solar Home systems, Micro Hydropower Plants, and Biomass energy can be a very productive way to lessen the shortage of electricity. In December 2018, a renewable energy policy passed and according to that policy, 10% of electricity generation will be done by 2020.

The main reasons for the shortage of access to electricity in Bangladesh are lack of proper distribution, poor quality of service and maintenance. The living standard of the country will be greatly improved if there is proper distribution of electricity to the energy deprived households. There is always a huge difference between the installed capacity and derated capacity of the electricity generation of Bangladesh mainly because some plants are out of function and some plants are out of maintenance. Finding new gas reserves can be a solution to this problem. We can compare the installed and derated capacity of electricity generation by showing a chart below.

Table 3: Electricity Generation in Bangladesh

Year	Installed Capacity (MW)	Derated Capacity (MW)
2014	10416	9821
2015	11534	10939
2016	12365	11170
2017	13555	12771
2018	15953	15410
2019	19290	18767

Source: Bangladesh Power Development Board, 2019

Electricity demand in Bangladesh expected to increase to 34,000 MW by 2030. In the country households and industries are the prime consumers. In 1971 only 3% of the population had access to electricity and this number has gone up to 88% in 2019. World Bank revealed that in 2018, 62% of total population of the country was rural people. And in 2015, 92% of urban and 67% of rural people had access to electricity. We can see a clear lack of energy distribution according to this data.

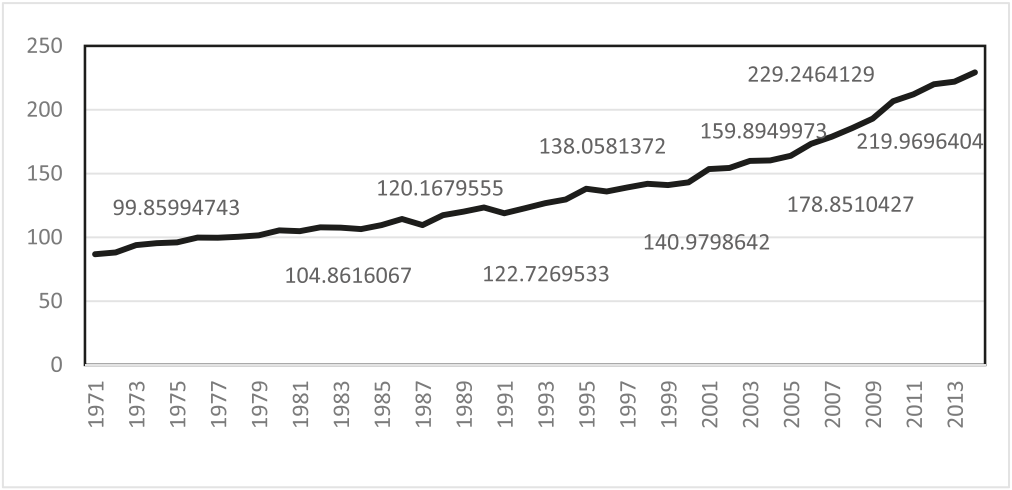
Table 4: Electricity Access in Bangladesh

Rural Access	Urban Access
2016	2016
94%	69%

Source: The Energy Progress Report, 2018

Gender equality is prerequisite for sustainable development of a country. However according to At Stone *et al*., 2011 women from many countries still face discrimination to energy use. Rural women of Bangladesh are conceived in doing households works like burning fuels, dung crop residues etc. which causes air pollution and serious health hazards (Amin, 2015). So in this regard rural women should use renewable energy. And also saving time can be regenerated in income generating work. As Groote *et al.,* 2017, shows that lighting by electricity can help women to enterprise with the available spare time. From world development data we can see the consumption of energy use in Bangladesh in **Figure 1**.

Figure 1: Energy Use (*Kg of oil equivalent per capita*)-Bangladesh



Source: World Development Index, 2018

4. WOMEN EMPOWERMENT STATUS IN BANGLADESH: AN OVERVIEW

According to the Bangladesh Institution of Health Science (BIHS) and International Food Policy Research Institution (IFPRI), only half of all the women in our country are empowered. On a national level, there has been a noticeable gain from 27.1 to 47.2 percent in women empowerment in the three or half-year (IFPRI, BIHS 2011/12 to 2015).

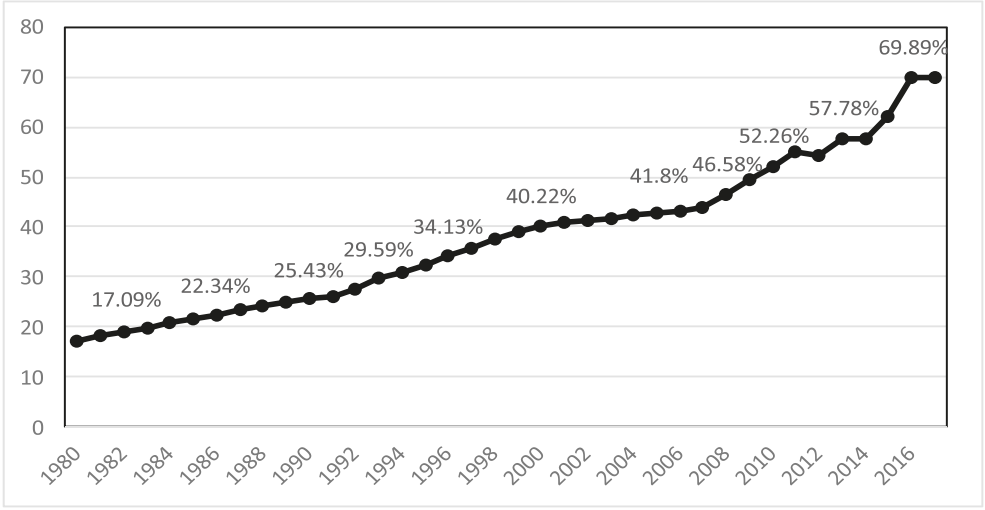
Figure 2: Empowerment Status in Bangladesh

Source: IFPRI (2017), Abbreviated Women's Empowerment in Agricultural Index

For empowerment conditions in Bangladesh, we can see some results from a research based study. IFPRI designed the agriculture, nutrition, and gender Linkages (ANGeL) project, a two-year effort piloted by the Bangladesh Ministry of Agriculture through its Department of Agricultural Extension.

In this research paper for the measurement of the status condition of women in Bangladesh as mentioned earlier, we have taken three variables as the proxy variables for women empowerment conditions in Bangladesh. Literacy is one of the prime factors that ensure economic development in a nation. No country can achieve sustainable development by ignoring education

Figure 3: Female Literacy Rate Adults Percentage (age15+) Female-Bangladesh

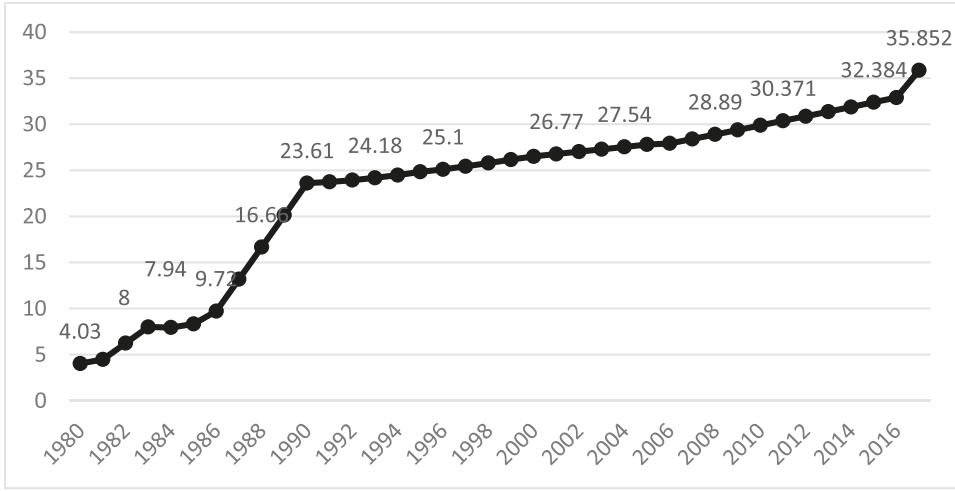


Source: World Development Index, 2018

According to the world development data index in 2018 the adult female (15+) literacy rate is 71.182%. Whereas in a developed country like China this number is 95%. This indicates that we are lacking behind the other developed countries in the female literacy rate. Even in developing countries like Ghana and Kenya, the female literacy rate is higher than in Bangladesh. To be a developed country Bangladesh government needs to provide the same facilities for rural areas and as well as for big cities. Rural people should be given access to Wi-Fi, electricity, and other energy resources.

Female labor force steadily grew between 2010 and 2017 because of the higher growth of the garment sector in Bangladesh (Asia-Pacific Employment and Social Outlook 2018). According to International Labor Organization Female participation in workplace has increased to 36.3 percent in 2017 from 33.2 percent in 2016. World development data shows that in 2019 the female labor force of the total labor force in Bangladesh is 30.52%. Though there is an increasing pace of female literacy rate from 2015 to 2019 still this number is severely poor than the other developed countries. For example, in a developed country like Australia in 2019 according to WDI the female labor force of total labor force is 46.418% which indicated the level of lacking in female labor force participation in Bangladesh.

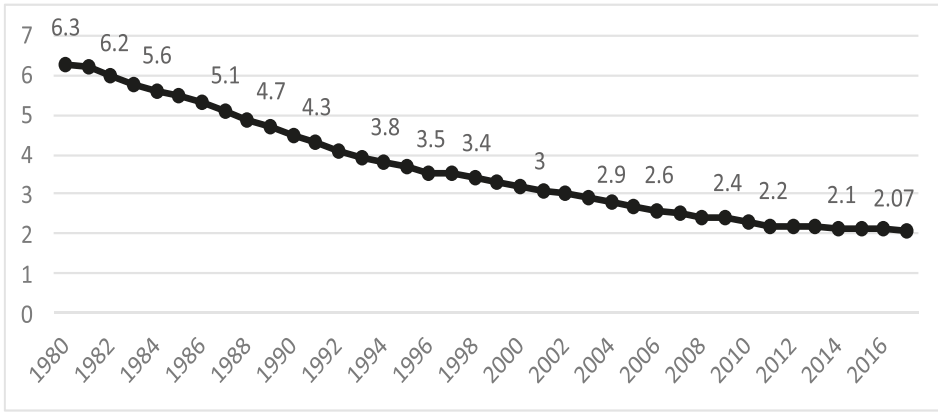
Figure 4: Female Labor Force participation (%) of Total Labor Force



Source: World Development Index, 2018

The total fertility rate has been stagnant in Bangladesh for the past ten years. In 2019, according to the World Development data fertility rate in Bangladesh was 2.01 children per woman. Over the last 50 years, the fertility rate of Bangladesh was declining at a moderating rate to shrink from 6.95 children per woman in 1970 to 2.01 children per woman in 2019. From the past year, the fertility rate has been decreased drastically in Bangladesh but still, the fertility rate is comparatively high then the other developed countries.

Figure 5: Fertility Rate Total (births per women) – Bangladesh



Source: World Development Index, 2018

For example, in a developed country like Australia, the fertility rate in 2017 according to the world development index was 1.765 births per woman whereas the number was 2 births per woman in

Bangladesh. From figure 4 we can see that the fertility rate in Bangladesh has decreased severally from 1080 to 2017. As the fertility rate is decreasing in Bangladesh it can be an important indication that the female literacy rate is affecting to empower the women of this country. This decreasing fertility rate is a good sign to encourage female labor force participation. So energy can play an important role to motivate the women through literacy, employment, and hence the fertility rate will further decrease.

According to the World Economic Forum Index, Bangladesh is leading the entire south Asian region in terms of gender equality. "Global Gender Gap Report 2020" shows that an overall score of 72.6% made Bangladesh the most gender equal country in South Asia (except Philippine). However, from the Global Gender Report of 2006 to 2020, the gender gap of Bangladesh increased in economic participation, educational attainment, health, and survival sectors. On the other hand, women's participation in political sectors increased from 2006 to 2020 according to the global report.

Table 5: Rank of Bangladesh in "Global Gender Gap Report 2020"

Sector / Year	Economic Participation by Women	Educational Attainment	Health and survival	Political Empowerment
2006	107^{th}	95^{th}	113^{th}	17^{th}
2020	14^{th}	120^{th}	119^{th}	7^{th}

Source: World Economic Forum, Countries: 153, 2020

From the chart, we can see that besides being 50^{th} ranking worldwide in the global gender gap index ranking gender inequality is on the rise in Bangladesh. According to the 2017-18 Global Gender Gap Report, Bangladesh is falling behind in terms of female reprinting in parliament. Female representation in this case is only 10.7 percent as opposed to male participation which is 89.3 percent. Female health disparity is another sore point in Bangladesh.

5. METHODLLOGY AND DATA

This study employed series from 1985 to 2010 which were obtained from the World Development Index (WDI) and Bangladesh Bureau of Statistics. In providing the causal and cointegrating relationship between energy use by women and women empowerment, fertility rate (births per woman), female labor force participation rate (aged of 15+ female), female literacy rate (aged of 15+ in percentage) are considered as proxy variables for women empowerment.

5.1 The Models

In providing the theoretical framework for the relationship between energy use and women empowerment, standard functional models are specified bellow. Within this framework the impact of energy use on empowerment is usually modelled in three ways. Firstly how the energy consumption lead to increase in female labor force; secondly the impact of fertility deduction in

female labor force and thirdly how increasing literacy rate increase the labor force participation by women.

$$FLF_t = f(EUSE_t, FR_t) \quad (1)$$
$$FLF_t = f(EUSE_t, FLR_t) \quad (2)$$
$$FLF_t = f(EUSE_t, FR_t, FLR_t) \quad (3)$$

Here, FLF: Female labour force participation rate, EUSE: Energy use by women, FR: Fertility rate, FLR: female literacy rate.

5.2 Unit Root Test

To check for stationary variable Augmented Dickey-Fuller (ADF) has been conducted in this paper. Testing stationary properties of the variables is important because estimating regression using non stationary variable based on Ordinary Least Squares (OLS) results in spurious and inconsistent outcome (Gujarati, 2004). Macro-economic data are well known for being non-stationary. To solve this problem Augment Dickey Fuller test (ADF) is used for unit root testing of the variables.

5.3 Cointegration Test

In the case of non-stationary time-series process, where mean and variance change simultaneously overtime, cointegration tests allow us to check the long-run equilibrium. A well-known cointegration test is the Johansen test. The test uses linear combinations of the variables to estimate all the cointegrating vectors, generally if there are "n" numbers of variables with unit root process, then exists most n-1 number of unique cointegration vectors.
To apply this approach, an Unrestricted Vector of Autocorrelation of this form needs to be estimated:
$\Delta x_t = \alpha + \theta_1 \Delta x_{t-1} + \theta_2 \Delta x_{t-2} + \theta_3 \Delta x_{t-3} + \cdots\cdots + \theta_{k-1} \Delta x_{t-k+1} + \theta_k \Delta x_{t-k} + u_t$ **(1)**
In this equation,
Δ = difference operator,
x_t = (n-1) vector of non-stationary variables in levels
u_t= (n-1) vector of random errors.
θ_t= information on the long-run relationship between variables.
θ_t= 0 means, the variables are not cointegrated.
Rank, r = 0 means, there is the existence of one cointegrating vector.
1<r<n means, there are multiple cointegrating vectors are available.

5.4 Causality Tests

One of the most used hypothesis tests in the time series analysis is the Granger casualty. Broadly speaking, Granger causality determines whether one variables has the predictive power to describe other variable suggesting policy implications, especially in the area of macroeconomics.

Two sets of the equation have been used for conducting this study:
$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots\cdots + \alpha_i x_{t-i} + \beta_1 y_{t-1} + \cdots\cdots + \beta_i y_{t-i} + u_t$ **(2)**
$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots\cdots + \alpha_i y_{t-i} + \beta_1 x_{t-1} + \cdots\cdots + \beta_i x_{t-i} + v_t$ **(3)**

All possible (x,y) series in the group represents that the F-statistics are the Wald statistics for the joint hypothesis, $\beta_1=\beta_2=\beta_3=\cdots\cdots=\beta_1=0$.

An alternative to Granger causality is the VECM approach, which takes into account both short- and long-term effects. The vector error correction model (VECM) that adjusts for both short-run changes in variables and deviates from equilibrium when one or more cointegrating vectors are detected for a set of variables. Causality hypothesizing in a multivariate framework can be estimated by the following VECM equations:

$$\Delta Y = \alpha + \sum_{i=1}^{m} \beta_i \Delta Y_{t-i} + \sum_{j=1}^{n} \gamma_j \Delta x_{t-j} + \sum_{k=1}^{0} \delta \Delta M^s + \sum_{l=1}^{p} \zeta \Delta N + \theta Z_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta X = \alpha + \sum_{i=1}^{m} b_i \Delta Y + \sum_{j=1}^{n} c_j \Delta x_{t-j} + \sum_{k=1}^{0} d \Delta M^s + \sum_{l=1}^{p} e \Delta N + f Z_{t-1} + \varepsilon_t \quad (5)$$

Here, $\mathbf{Z}_{t-1}$ = error-correction term.

The error-correction term measures the deviations of series from long-run equilibrium relation. Error correction term avails the adjustment of Y and X towards their respective long-run equilibrium. VECM test represents the difference between the long run and short run dynamic relationship.

DOLS test helped us in this study to deal with small sample size and biases. It corrects the regressor endogeneity by lags and leads. DOLS test estimates long run equilibrium with the same or different ordered variables. As in this paper our sample size is limited we applied DOLS test to avoid faulty estimation.

$$Y_t = \beta_0 + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \ldots + \beta_k X_{k,t} + \sum \alpha_{1\Delta} X_{1,t-1} + \sum \gamma_{1\Delta} X_{2,t-1} + \ldots + \sum \delta_{1\Delta} X_{k,t-1} + \varepsilon_t$$

Here in the aforementioned equation,
Y_t = dependent variable where regressors X_t, t i=1,2,3…..n.
We also performed the **CUSUM** test to look for any systematic changes or movements that might indicate structural instability.

6. RESULTS

6.1 Unit Root Results

Augmented Dickey Unit Root statistics and corresponding the critical values for the variables in their level and first difference forms are written below in **Table 6A**.

This study uses a time series model. One method is to include a relatively long lag length to select by t-statistics. If the t-statistics using lag P comes out insignificant at some specific critical value, then the regression can be established using a lag length of p-1 until the lag can become significantly different from zero. Different lags have been taken to check whether the variables are stationary or not. The variables are stationary at the first difference except the rate of female literacy and female labor force. Dickey Fuller- GLS (DF-GLS) Unit Root test. **Table 6B** shows that above variables are stationary at the first difference.

Table-6A: Augmented Dickey-Fuller Unit Root Test for the Variables

Panel 1: Levels

Variable	ADF Statistics (Only Constant)	ADF Statistics (Constant & Trend)	Decision
EUSE	1.61696(0.9969)	-1.494334 (0.8043)	Non Stationary
FLF	1.677246 (0.991)	-0.026623 (0.995)	Non Stationary
FR	-0.35770(0.901)	-2.27137(0.432)	Non Stationary
FLR	-1.506(0.513)	-1.899997(0.624)	Non Stationary

Panel 2: First Differences

Variable	ADF Statistics (Only Constant)	ADF Statistics (Constant & Trend)	Decision
EUSE	-6.221542(0)	-7.095622(0.0)	Stationary
FLF	-1.66147(0.437)	-1.727299(0.04)	Non Stationary
FR	-2.145260(0.23)	-2.022114(0.5)	Non Stationary
FLR	-5.40991(.0002)	-5.896111(.0004)	Stationary

Table-6B: DF-GLS Unit Root Test

Panel 1: Levels

Variable	DF-GLS Statistics (Only Constant)	DF DLS Statistics (Constant & Trend)	Decision
FLR	0.557576 (0.25)	-3.394816 (0.03)	Non Stationary
FLF	-1.096390(0.55)	-1.902962 (0.95)	Non Stationary

Panel 2: First Differences

Variable	DF-GLS Statistics (Only Constant)	DF DLS Statistics (Constant & Trend)	Decision
FLR	-1.736960(0.02)	-3.196571(0.00)	Stationary
FLF	-3.299543(0.01)	-3.540138(0.06)	Stationary

6.2 Cointegration Results

The cointegration test results show that all the variables used in this paper are cointegrated in the long run (**Table 7A, 7B and 7C**)

Cointegration Test for Model 1

Hypothesized No. of CE(s)	Trace Statistic	Probability	Max-Eigen Test	Probability
None	52.35558	0.00	35.31510	0.00
At most 1	17.04048	0.03	15.21036	0.04
At most 2	1.830124	0.17	3.841466	0.17

Cointegration Test for Model 2

Hypothesized No. of CES	Trace Test	Probability	Max-Eigen Test	Probability
None	45.90721	0.00	35.31396	0.00
At most 1	10.59325	0.10	10.15287	0.10
At most 2	0.440378	0.27	0.440378	0.57

Cointegration Test for Model 3

Hypothesized No. of CES	Trace Statistic	Probability	Max-Eigen Test	Probability
None	93.05777	0.00	37.19963	0.01
At most 1	55.85814	0.00	28.83685	0.02
At most 2	27.02129	0.10	17.19803	0.11
At most 3	9.823259	0.13	9.823259	0.13

The Johansen cointegration test results indicate that our variables have cointegrating relationship.

6.3 Granger Causality Results

Table 8 shows a unidirectional causality from female labor force participation to energy use. That means the higher the rate of female labor force the higher the energy use by women. From table 8 we can see that probability is significant and we cannot reject the null hypothesis that the female labor force does not granger cause energy use to increase or decrease. The result shows that the causality direction runs from energy use to female labor force participation. It goes hand in hand with the concept that energy use directly increases the rate of labor force participation rate. With the help of the energy, the female will be able to get the opportunity to work more hence participation in the female labor force will increase. There is unidirectional granger causality from female energy use to female literacy rate as we can see that the probability for the direction. As energy consumption rises, for example, the female will be able to study for extra hours daily.

Lugauer et al. (2010) show that the increased level of married women using energy through household appliances has a positive significant effect on female labour force participation in U.S. states. This also aligns with the findings of this research paper.

Granger causality test reveals that there is no causal relationship between energy use and fertility rate. This relationship may not be seen due to the indirect relationship between them by other variables that are not included in this research task.

There is a unidirectional Granger causality between female literacy rate to female labor force participation. As females get literate and the female literacy rate increases, it encourages them to get involved in the labour force sector for earning and doing productive work. As a result, female labor force participation rate increases. There is enormous literature to support these results. Likewise, Ince (2010) shows that increasing female education results in decreasing fertility rate and mortality rate while it positively affects the female labor force and literacy in Turkey.

Table 8: Granger Causality Test Results

Hypothesis	F-Statistic	P-Value	Granger Causality
FLF → EUSE	0.62933	0.5437	Unidirectional
EUSE → FLF	9.70809	0.0012	
FLR → EUSE	0.31085	0.7365	Unidirectional
EUSE→ FLR	2.54798	0.1046	
FR →EUSE	0.55597	0.5826	No Causality
EUSE → FR	0.49013	0.6201	
FLR → FLF	8.18984	0.0027	Unidirectional
FLF → FLR	0.99946	0.3866	
FR → FLF	8.81044	0.0020	Unidirectional
FLF→ FR	0.20807	0.8140	
FR → FLR	4.76903	0.0210	Bidirectional
FLR → FR	4.55771	0.022	

The fertility rate and female literacy rate have a bidirectional Granger causality. As female get more literate, it affects the fertility rate. With the increasing literacy rate fertility rate tends to decrease and thus emerge women empowerment.

6.4 VECM Results

After conducting the Granger causality test we have inspected VECM test. **Table 9** shows the results of VECM test. Energy use has a potential impact on the female labor force in the long and short run in Bangladesh. It has also an effective impact on the female literacy rate in the long run.

Our results show a causal relationship between the female literacy rate and the female workforce. The results show that energy consumption has a long-term and short-term impacts on Bangladesh's female work force.

A recent study by Amin and Mahmud (2017) examined the link between energy usage and fertility changes in rural areas. Findings from the current study confirm those of the previous study in which there is no causal relationship between fertility rate and women's energy usage. Because of this paper's focus on energy usage in Bangladesh, the overall conclusions differ from those of Amin and Mahmud (2017).

Table-9: VECM test results

Variable (Logarithm Transformation of the variable)	**Null Hypothesis**	**Chi-square statistic**	**P-Value**	**Conclusion**
FLF	FLF→ EUSE	1.060036	0.5886	No Causality found
FLR	FLR →EUSE	0.590556	0.7443	No Causality found
FR	FR→ EUSE	7.013741	0.0300	**Causality found**
EUSE	EUSE→ FLF	10.97352	0.0041	**Causality found**
FLR	FLR →FLF	9.237167	0.0099	**Causality found**
FR	FR →FLF	3.420787	0.1808	No causality found
EUSE	EUSE→ FLR	1.438826	0.4870	No causality found
FLF	LNFLF→ LNFLR	0.523422	0.7697	No causality found
FR	LNFR →LNFLR	0.348164	0.8402	No causality found
EUSE	EUSE→FR	2.022113	0.3638	No causality found
FLF	FLF→ FR	2.234887	0.3271	No causality found
FLR	FLR →FR	3.694301	0.1577	No causality found

From VECM results we can see that energy use has significant correlation with female labor force and fertility rate. Added to that beside widely established relationship between female labor force and fertility rate our research findings shows contradictory results that female fertility rate and female labor force has no causality because it shows that the causality runs from female literacy rate to female labor force. Primarily the main driver force for female labor force is female literacy but not fertility rate. Hence fertility rate and female labor force has no causal relationship regarding VECM test results.

6.5 DOLS Results

In this section, as per the three models, we can see that increase in one unit of energy consumption can lead to an increase in female labor force participation by 0.13-0.20 percent, one unit change in fertility rate can lead to a decrease in the female labor force by 0.60- 1.28 percent, one-unit literacy rate can lead into increase labor force participation rate by 0.14-0.26 percent, keeping all other things constant. From **Table 10**, all the regression diagnostics tests (Adj-R2, J-B, A-C, long run variances) show that all three models represent the relationships between the dependent and the independent variables. Samad and Zhang (2019) elucidate that energy consumption by women can increase women's empowerment through increased labor force participation which supports DOLS results.

Table 10: DOLS Estimation Results

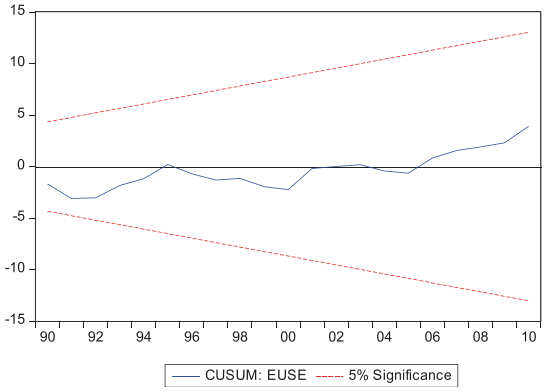
Variables	Model 1	Model 2	Model 3
EUSE	0.13 (0.02)***	0.10 (0.02)**	0.20 (0.02)**
FR	-0.60 (0.25)**		-1.28 (0.20)**
FLR		0.14 (0.02)***	0.26 (0.03)*
C	19.56***	15.08***	16.04***
Adj-R^2	0.99	0.99	0.98
J-B	1.24	1.63	0.31
A-C	3.38	1.52	4.40
LRV	0.02	0.01	0.14

Note: Standard errors are in parenthesis. ***, **, and * show significance at 1 and, 5 and 10 percent respectively. J-B and AC refer Jarque-Bera ad Autocorrelation tests, respectively. Both tests have been done in the residuals of the regressions. The optimal lag for each model is selected by AIC Criterion.

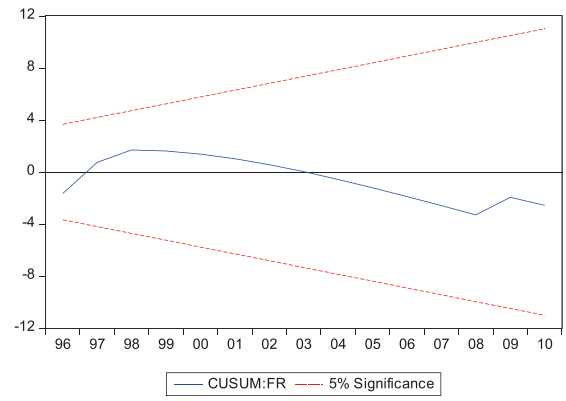
6.6 The CUSUM Test Results

The CUSUM test results of each variable show that the plots stay within 5 percent critical value, indicating that the variables used in this empirical analysis are stable both in terms of systematic and sudden movements.

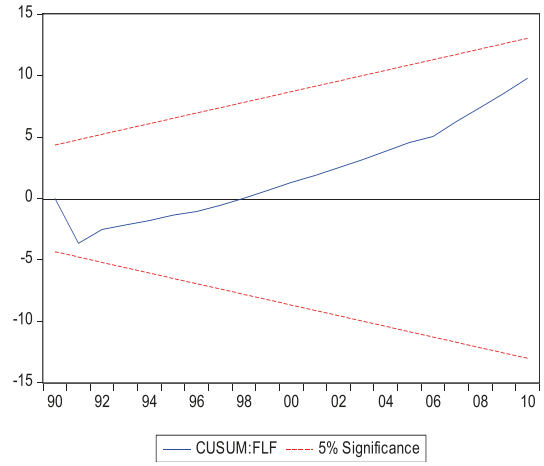
Figure 6: Stability of the Variables



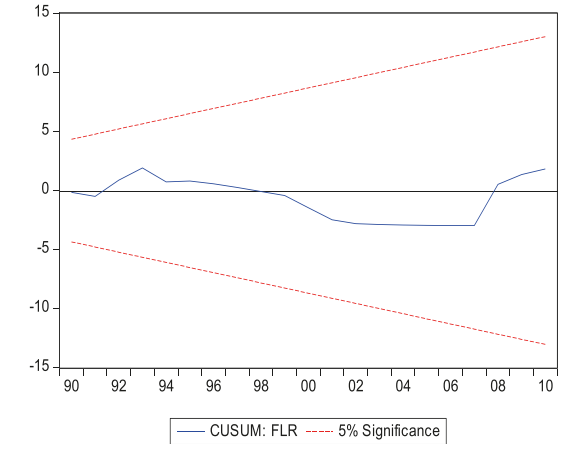
Graph 1: CUSUM Test for Energy use by female



Graph 2: CUSUM test for Fertility Rate



Graph 3: CUSUM test for Female labor force

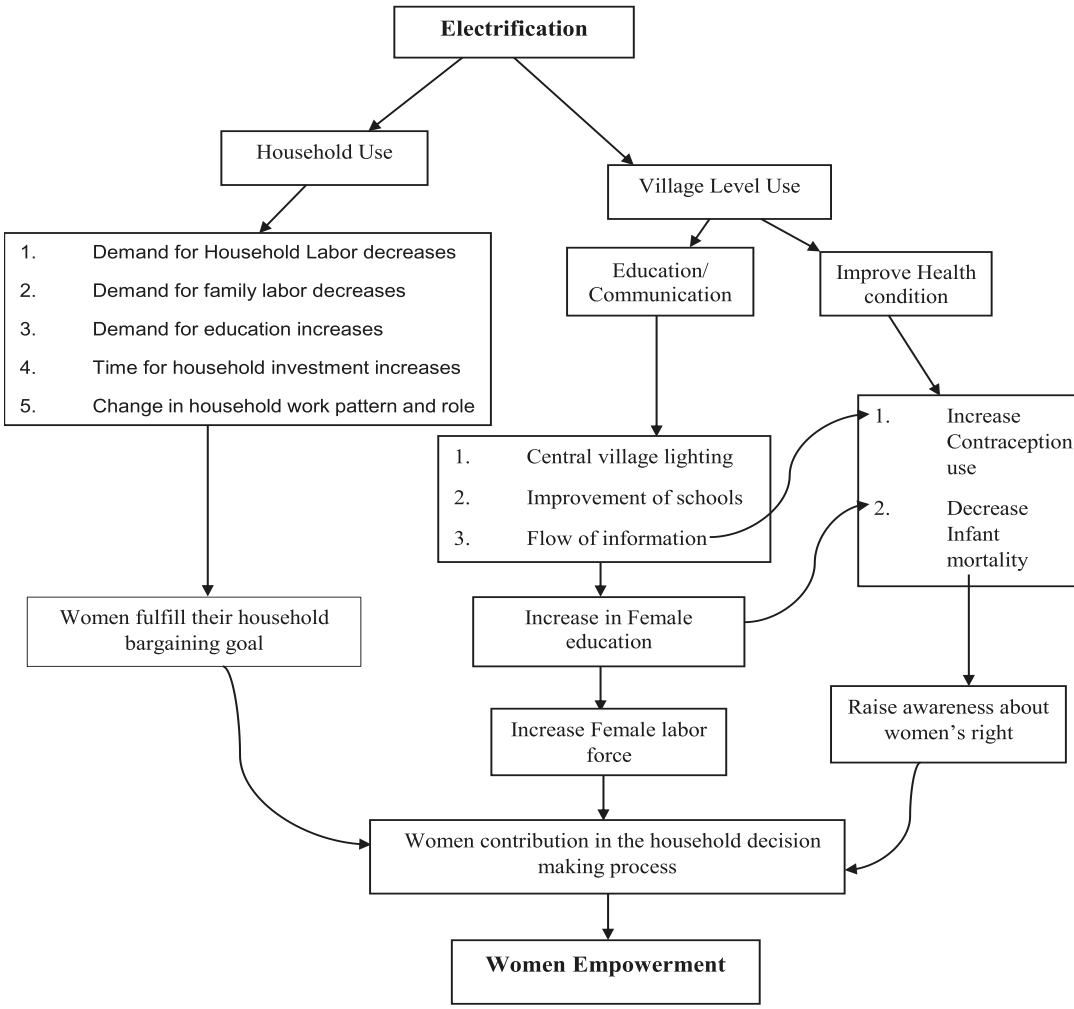


Graph 4: CUSUM test for Female literacy rate

7. A FRAMEWORK OF THE IMPACT OF ENERGY USE ON WOMEN EMPOWERMENT

Harbison and Robinson (1985) provide a useful foundation to the development of a framework. The framework is about the impact of energy use on fertility rate. According to this research paper, energy consumption is both a community level and houseful level variable. **Figure 7** presents a preliminary version of the framework which includes directions of impacts on women empowerment from both of these levels. This is a slightly different and extended version of a framework than that of Harbison and Robinson (1985).

Figure 7: The Impact of electrification on women empowerment



***Source**:* Combined by Author

According to the figure, there are two main pathways through which energy consumption impacts women's empowerment.

1. Household Use: Energy consumption at the household level reduces the time for household chores hence women can invest their time in literacy and labour force participation. This will create confidence in women for greater bargaining power. The well-being of families increases, and children's educational and health outcomes are better when women have more negotiating power in household decisions.

2. Village Level Use:

i) Education:
In the village level, through electrification, like central village lighting, the improvement of schools can increase the communication outcome by the flow of information in the school. This creates awareness of household bargaining power among teenage girls in the school. Increasing education will increase women's participation in labor force (VECM test results, Table-9). As a result, women's contribution to the family will increase household decision-making power.

ii) Improved Health Condition:
As electrification at the village level increase, the educational attainment of women. It creates health awareness through communication and the flow of information in the school. As a result, the fertility rate and mortality rate of women decrease through household decision-making power. Women's agency develops through this process results in women's empowerment.

8. CONCLUSIONS

In this paper, we have analyzed the impact of energy use on women empowerment. We found that energy use has a potential impact on the female 'laborforce' both in the long run and the short run in Bangladesh. It also had considerable impact on the female literacy rate in the long run. These findings support the previous results drawn from our literature review. That is this paper validates that energy consumption can ensure women's empowerment, which also supports the previous literature. Energy use can ensure development in the remote and rural areas of Bangladesh. Rural women can take advantage of the accessibility of energy and electricity to complement their family income. Energy can have the potential to affect female empowerment.

Our research findings indicate that energy can play a vital role in ensuring female empowerment. Especially in terms of the female laborforce participation, energy use can increase this causality and contribute to the development of our country. It can also increase the female literacy rate for which we can have a bright literate generation. Electrification can enhance the literacy rate and thus can stimulate the rate of female labor force participation. For future economic development, our country needs to empower women. Although the government is doing well in energy access, the government should consider more rigorous efforts to keep this momentum going. In addition to that, from an energy review of Bangladesh 2019, we get to know that 79% of the connected consumers suffer from a lack of electricity supply. So the government can encourage and can focus on the off-grid electrification so that all the female of Bangladesh can be empowered through energy usage.

One of the main limitations of this research paper is that there is a small number of variables and data availability from 1980 to 2010. This paper can be further expanded in the future by analyzing the research work with more variables. On the other hand, this paper can even be more expanded by modeling energy use and women empowerment for other South Asian countries with the help of panel data set. Having an insight into the aggregate energy use and women's condition of the South Asian countries can reveal immense scopes for achieving collective goals both in terms of economic and social outcomes.

There should be well crafted measured policies to ensure women empowerment in the country. The policy's objective should be to promote women's financial freedom, development, and

empowerment. The Policy should be extensively applied in order to promote active engagement from all stakeholders in order to achieve its objectives.

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Appendix

Statistical Description

	Fertility Rate	Energy use by women	Female labor Force	Female literacy Rate
Mean	3.638684	66.89469	23.13063	37.89621
Median	3.350000	67.05770	25.97500	38.28000
Maximum	6.300000	113.5196	35.85200	70.08000
Minimum	2.070000	0.000000	4.030000	17.09000
Std. Dev.	1.341077	26.83382	8.860237	14.75751
Skewness	0.567413	-0.721747	-0.978557	0.464302
Kurtosis	2.042786	4.107230	2.703789	2.340619
Jarque-Bera	3.489809	5.240257	6.203562	2.053721
Probability	0.174662	0.072794	0.044969	0.358130
Sum	138.2700	2541.998	878.9640	1440.056
Sum Sq. Dev.	66.54403	26641.99	2904.641	8058.014
Observations	38	38	38	38

AUTHORS' BIOGRAPHY

Anta Atalantia is currently working on agricultural innovation research project as a research associate at North South University (NSU), in Dhaka Bangladesh. She has completed her Bachelor of Science (BSc) in Economics from North South University. She also has completed her Master's in Economic Development from the University of Glasgow and awarded prestigious "*Adam Smith Scholar Award*" for her excellence. She is enthusiastic about the intricacy and density of multidimensional economic development, as well as the methods used by other eminent economists in their research and formulation of anti-poverty initiatives. She believes that poverty reduction and development of a country cannot take place without gender equality and women empowerment.

Dr. Sakib Bin Amin is an Associate Professor in Economics and the Director of the Accreditation Project Team (APT) at the School of Business and Economics, North South University. He holds a Ph.D. in Economics from Durham University (UK). Dr. Sakib was awarded the prestigious UK Alumni Award 2022-2023 in the Science and Sustainability category. He also received the Commonwealth Rutherford Fellowship (2017-2018) for conducting postdoctoral research in energy economics at Durham University (UK). In addition to being an Assistant General Secretary of the Bangladesh Energy Society, Dr. Sakib is a fellow of the Higher Education Academy, a member of the International Association for Energy Economics, and a life member of the Bangladesh Economic Association.