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Energy Use and Fertility Rate: A Developing Country Perspective

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Energy keeps an economy functioning. It is evident that energy is required for the development of a nation. Many researchers have discussed about the relationship between energy use and fertility rate. For a developing country like Bangladesh which has a very high population growth, the relationship between energy use and fertility rate may have a more prominent effect. This paper investigates the relationship between energy consumption and fertility rate in Bangladesh. Increasing consumption of energy among the Bangladeshi population might result in decreasing fertility which in turn could lead to a stable population growth. To implore this relationship, Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests have been used. Moreover, Johansen and ARDL cointegration methods have also been used. Finally, the Granger causality test has been applied to study this relationship. From an economic point of view, it could be expected that there is a relationship between energy use and fertility. On the other hand, the tests used have revealed that there is no such causal relationship between the variables in Bangladesh.

Field of Research: Economics

1. Introduction

Energy is considered as the life blood of an economy. An economy's growth and prosperity is directly interlinked with its growth in energy. Energy resources are required critically to fulfill everyday human activities. It is a significant factor in determining the quality of lives. Moreover, energy usage is paramount for any economy: developing or developed. Energy resources are vital for every country even more so for developing countries.

Energy use and economic growth have a proven causal relationship and this particular relationship have been a popular debate issue for years. Energy is undeniably one of the most important factors of production. Increased energy use should result in a rise in economic production which in turn can lead to economic growth. Stern (2010) had mentioned that energy cannot be substituted in production. Energy has an irreplaceable role in production. Thus, the importance of energy consumption for every country is pivotal. Moreover, the energy sector is important because it is responsible for creating jobs in the economy. Extraction, transportation and distribution of energy require a good number of people. Countries which are energy rich like Venezuela and Kuwait can reap more employment benefits from this industry. Venezuela and Kuwait's energy industry account for 35% and 57% of GDP respectively.

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If there is an existing causality running from energy consumption to income, then this indicates an energy-dependent economy such that energy is an impetus for income. It implies that a shortage of energy may negatively affect income (Masih & Masih 1998). On the other hand, a reverse chain of causality from income to energy denotes a less energy-dependent economy. Energy conservation policies may be implemented in these countries with little adverse or no effects on income (Jumbe 2004). Chiang- Lee (2005) had mentioned that developing countries are energy dependent. Energy conservation policies can hurt the economy of growing countries like Argentina, Mexico, Malaysia, Philippines, Pakistan, India and many more. Access to energy is crucial for any country's development. It is excruciatingly important for third world Asian countries where poverty is imminent. Bangladesh is among one of those developing countries where the recent expansion of energy use can take the development of the country to new heights.

Countries like Bangladesh in South East Asia are subject to energy poverty. It is often said that poverty in reality is a woman's face. Women are poorer compared to men. This is because women have a far weaker voice in household matters. The relationship between energy poverty and gender inequality has been addressed in several publications. Moreover, Halves (2012) and O'Dell *et al.* (2014) had looked upon impacts of energy consumption on women empowerment. Furthermore, they had mentioned that energy consumption can lead to a decreasing fertility rate in women through empowerment. A healthier and socially forward female population is expected to engage themselves more in education and entrepreneurship which in turn will divert their attention from producing or taking care of children. Cosio- Zavala (1999) had found that autonomy among women does have an effect on the choice of contraception among women in three Asian countries. Moreover, she further determined a positive relationship between social empowerment among women and fertility rate in Mexico.

For a country like Bangladesh, population growth is a matter of great concern. Bangladesh is a rapidly developing country with rising population growth. The small country is home to about 160 million people and it is by far one of the most densely populated countries in the world. The population growth in Bangladesh had decreased from 1990 because of use of contraception. However, the population growth rate is still very high for Bangladesh. The population will likely reach 251.45 million in the year of 2061 if the fertility rate remains the same (BBS 2015). 31.5 % of the population of Bangladesh is living below the national poverty line which is higher than its neighboring countries like Nepal, Bhutan, India and Srilanka (Asian Development Bank 2016). In fact, poverty in Bangladesh has become more pronounced rising from 40 million people in 1981 to 77 million in 2005 (*Bauer et al.* 2008). The country immediately needs to address its population growth rate if it wants to witness sustainable economic growth. Robert Solow in his growth model had mentioned that a high population growth rate would lead to a reducing capital stock. Decreasing capital accumulation will in turn result in decreased economic output thereby affecting the economic growth of a country. Not to mention, Ashraf *et al.* (2013) had noted that a reducing fertility rate might result in economically significant rising per capita income.

80% of the population is still living in rural areas. Bangladesh has its own social norms. The women of the country are expected to only engage in household chores and childbirth. About 58% of the rural households were energy poor in the year 2004 (Khandker *et al.* 2011). Over the years, energy consumption has slowly climbed in Bangladesh because of the availability of natural gas. Increased used of energy can empower the female population of the country. A more forward female population will help the country in controlling its high population growth rate. Similarly, Fujii and Shonchoy (2015) observed that the adoption of electricity can actually lead to decreasing fertility in Bangladesh using panel data. However, to the best of the authors' knowledge, there are no empirical time series studies which explicitly address the causal relationship between energy consumption and fertility rate in women. This paper detects that there is no long run causal relationship between the two concerned variables. The following two questions are addressed in this paper

1. Is there a long run economic relationship between energy consumption and the fertility rate in women?
2. Is there any causal relationship between the two variables- energy use and fertility rate?

This paper has shown that there is a long-term relationship between energy use and fertility rate although no causal relationship exists between the two variables. This is a new finding for Bangladesh and therefore energy use should be given utmost priority while the country is still developing. By looking at this relationship and filling in the gaps, Bangladesh can work towards limiting the growth in population. If the country can become successful in controlling its population, it will definitely witness sustainable economic growth in the future.

The paper continues with section 2 providing a review of the literature. Sections 3 and 4 are followed by an overview of the energy sector and fertility rate in Bangladesh, and methodology. The rest of the paper includes results, conclusion and references in sections 5, 6 and 7.

2. Literature Review

The relationship between energy consumption and fertility rate in Bangladesh has not been explicitly studied upon in any research. However, many studies have found a relationship between energy consumption and women empowerment. It is through women empowerment that the fertility rate in women will likely drop. Poverty and women are deeply connected. According to UNDP (1995), about 1.3 billion people were living under the poverty line and about 70% of these people were women. Energy is a key ingredient to eliminating poverty and gender discrimination among men and women. Access to energy can change the lives of rural women for good.

Harbison and Robinson (1985) addressed the relationship between rural electrification and fertility change. Data from six countries was collected and reviewed which showed a link between electrification and fertility. The study showed that the higher the level of electrification, the higher will be the level of contraception use which in turn resulted in a greater fertility reduction.

Another way to look at it can be through female employment. Women will be more likely to get involved in employment if they have spare time. Dinkelman (2007) had found that the presence of electric lights and cooking in rural homes of South Africa had led to a 9.5% point increase in female employment. However, no increase was seen in male employment because of electrification. Electrification in rural homes freed up women's time which in fact led them to get involved in home production of goods or micro enterprises. Similarly, a 9% point increase was also seen in female employment with no change in male employment in Guatemala (Grogan *et al.* 2009). This study showed that electrification in high fertility homes can result in increased time in labor markets and decreased time in home production by women.

In the same way, ADB (2010) ,Chowdhury (2010) and Barkat *et al.* (2002) had found that electrification did in fact decrease the amount of time spent on collecting fuel wood by women in Bhutan and women in Bangladesh utilized this extra time to generate some sort of income. In addition to that a study by O'Dell *et al.* (2014) showed that the wage of self-employed rural women with access to energy was almost twice as the wage of self-employed rural women in Brazil. The average rural income of men and women who had access to energy was 10% higher.

Barkat *et al.* (2002) had also found that electrified homes had a higher literacy rate for both men and women compared to non-electrified Bangladeshi homes. Moreover, women in electrified homes re-allocated their time to get involved in income generation. Most of the women had agreed that availability of electricity freed up their time after sunset for income generating activities. Furthermore, 68% of married women who had access to electricity use one type of contraceptive method. On the other hand, only 62% women in non-electrified homes used contraception.

A study conducted in rural Peru said that children whose homes had solar power systems had higher chances of staying in school (Arraiz & Carero 2014). This is because children in SHSs homes were more likely to study at home. In contrast, this study also found that women in SHSs homes were more involved in looking after children and household chores rather than income generating activities.

As a matter of fact, Khandker *et al.* (2012) had looked upon the benefits of electrification on both poor and rich households in India. The benefits included increased supply of both male and female labor, attendance in schools, studying time by boys and girls, per capita income and household expenditure. At the same time, consumption of electricity culminated to reduced time for fuel wood collection and poverty. In fact, another study of Khandker *et al.* (2009) looked into the benefits that households reap from electrification. This study found that rich households enjoyed more benefits than poor households in Bangladesh. The benefits can be in terms of household income, educational outcome and so on.

Winther (2008) had critically examined the relationship between electricity and female empowerment. In the village of Zanzibar, Tanzania, women and girls saved 25 hours on average because of electricity. Almost an equal number of young girls got to attend schools as the boys. Moreover, women and girls got an ample amount of free time in the evening to get involved in productive activities. According to Grimm *et al.* (2014), access to electricity did affect fertility among women through exposure to television. This in turn led to use of contraception in rural families. Rural electrification led to a decline of about 18% to 24% in fertility among women in Indonesia. Peters and Vance (2010) investigated the effect of electrification on fertility rate using house-hold level survey in Cote D'Ivoire. A positive relationship was found between electricity and fertility rate in urban households. This meant that electrification actually improved fertility in urban women. On the other hand, there was a negative relationship between electrification and rural fertility. Thus, access to electricity negatively affected fertility in rural households.

Some studies have implicitly showed the effect of electrification on fertility rate. Jensen and Oster (2009) had found that rural women in India who had access to television were less likely to accept physical abuse and had a greater likelihood of sending their girls to school. Rural women who had gained access to television were more open minded and socially empowered. Moreover, these women were more likely to get involved in work too. Burlando (2013) studied fertility rate in Zanzibar after a month long blackout between May and June of 2008. By using a difference in differences strategy, 15% to 18% increase in births after the blackout was shown. However, this trend was observed for villages which already consumed electricity. Villages without any access to electricity did not show any increase.

A study was conducted by Isfahani and Taghvatalab (2014) in Iran to study the relationship between electricity use and fertility rate. This study used both difference in differences and instrumental variables methods to check the relationship. The difference in differences method showed that development of electricity facilities in rural areas of Iran after the 1979 revolution led to a decrease in fertility rate in women. The result from the instrumental variable method, however, disagreed. Fujii and Shonchoy (2015) had looked explicitly at the relationship between fertility rate and rural electrification in Bangladesh. A panel data set from Bangladesh was used to reach to a conclusion. The use of electricity reduced fertility among rural Bangladeshi women. However, the effect of rural electricity was more significant if the family already had two or three children. The gender of existing children also plays a role in family planning decisions among Bangladeshi rural couples.

It is clearly evident from the above discussions that there was no country specific causal relationship between energy use and fertility rate. Moreover, no empirical study using these two variables has been conducted in lower middle income countries. It must be noted that such a relationship can expedite the development process in developing countries.

3. Overview of the Energy Sector and Fertility Rate in Bangladesh

Energy is the driving source of all economic activity of a country. The per capita income of Bangladesh is US $ 1211.7 (FY 2015). This makes it one of the poorest nations in the world. According to Asian Development Bank (2009), the real GDP of Bangladesh has been growing at a rate of 6% during the past five years. The growth in GDP is accompanied by increasing demand for energy. The average growth of the electricity sector has been about 7% since 1990. However, during the fiscal year of 2010, the electricity sector had grown by 10%. Bangladesh could generate only about 5936 MW of power during early 2011 and only about 49% of its population of 160 million had access to electricity (Azad 2011). In contrast, the insufficient power generation of Bangladesh can be held responsible for output losses over US $ 1 billion (UK Trade and Investment 2011).

The two main consumers of electricity in Bangladesh are mainly industries and households. The proportion of electricity consumed by households had increased from 40% in the year 2001 to 49.94% in 2013. In contrast, the percentage of electricity consumed by commercial industries went down from 47 to 35 during the same period. Among the industrial sector, the agricultural sector requires energy only seasonally and accounts for only 4.61% of total energy consumption in Bangladesh. Other sectors like street lights, water pump in public places and so on comprise of only a very small share of electricity consumption. In the year of 2005, this sector had a share of 5% in the overall energy consumption of Bangladesh. However, the annual growth of electricity in this sector grew at a rate of 11.5% between 1995 and 2005.

Bangladesh is a third world country. About 48% of rural households in Bangladesh are income poor while 58% of rural households are energy poor (Khandker *et al.* 2010). In 2016, 78% of the population gained access to electricity. Over half of the population of Bangladesh is still dependent on traditional energy sources: wood, animal waste, crop residue and so on. According to Wadud *et al.* (2011), biomass comprised of about 54% energy consumption in the rural areas. However, the proportion of biomass used for energy decreased to only about 35% in the year 2005. Bangladesh Bureau of Statistics (2009) stated that kerosene was used for providing lighting to 65% Bangladeshi homes in 1996 whereas diesel was used for operating irrigation pumps in the agricultural sector. Animal waste, agricultural remains and firewood were commonly used as biomass (Miah *et al.* 2010).

This is because the energy infrastructure of the country is relatively insufficient for its massive population. Moreover, the infrastructure is very poorly managed. The service quality provided by the energy sector is very low. There is considerable theft of energy in the country. This in turn is acting as a barrier for socio economic development, regional development and attracting foreign direct investment. The life standard of the people of Bangladesh could be greatly improved if energy were provided to all the energy deprived households.

Natural gas is undoubtedly the primary source of energy for Bangladesh. It accounts for about 75% of the total commercial energy sector. 37% of natural gas is used for generating electricity. The country is over dependent on imports of petroleum. Bangladesh does not have its own reserve of petroleum. Thus, it heavily relies on petroleum imports. Bangladesh is also blessed with reserves of bituminous coal. The country is not technologically competent enough to extract these recourses. Only 5% of consumable energy was produced by using coal in the years of 2005 and 2006.

Petroleum prices are rising quickly and natural gas reserves are depleting. Bangladesh needs to find a way to substitute to renewable sources of energy for electricity generation. Quick fixes and development are needed in the renewable energy sector of Bangladesh. Less than 5% of power generation is possible using renewable energy sources mainly hydropower. Solar photovoltaic is popular in rural areas. Availability of micro credit has made PVs affordable for people living in rural Bangladesh. Moreover, wind energy provides about 2MW of power. Wind turbines have been installed in Muhuri Dam and Kutubdia Island in the districts of Khulna and Cox's Bazaar respectively.

Existing literature has shown that existing gas reserves will be able to meet the energy demand of the country till 2016. Moreover, the country does not have an adequate production capability to meet its energy demands. Bangladesh has always witnessed a lack in the supply of electricity. In the year 1992, the installed capacity was 2350 MW although the derated capacity was only 1719 MW. The installed capacity climbed to 10416 MW in 2014 while the corresponding derated capacity was 9821 MW. This is a clear indication that the increase in installed capacity is not properly reflected by an increase in power generation. The following table shows the difference between installed and derated electricity capacity.

Table 1: Electricity Generation in Bangladesh

Year	Installed Capacity	Derated Capacity
2009	5719	5166
2010	5823	5271
2011	7264	6639
2012	8819	8149
2013	9151	8537
2014	10416	9821
Source: Bangladesh Power Development Board (BPDB), 2015		

The difference between installed and derated capacity exists because of many reasons. Firstly, a few power plants are out of operation for maintenance or overhauling. Secondly, some power plants are old and cannot perform as expected. Lack in discovery of new gas reserves can be another reason. This means that the supply of natural gas is not as unlimited and unrestricted as in the early 2000s.

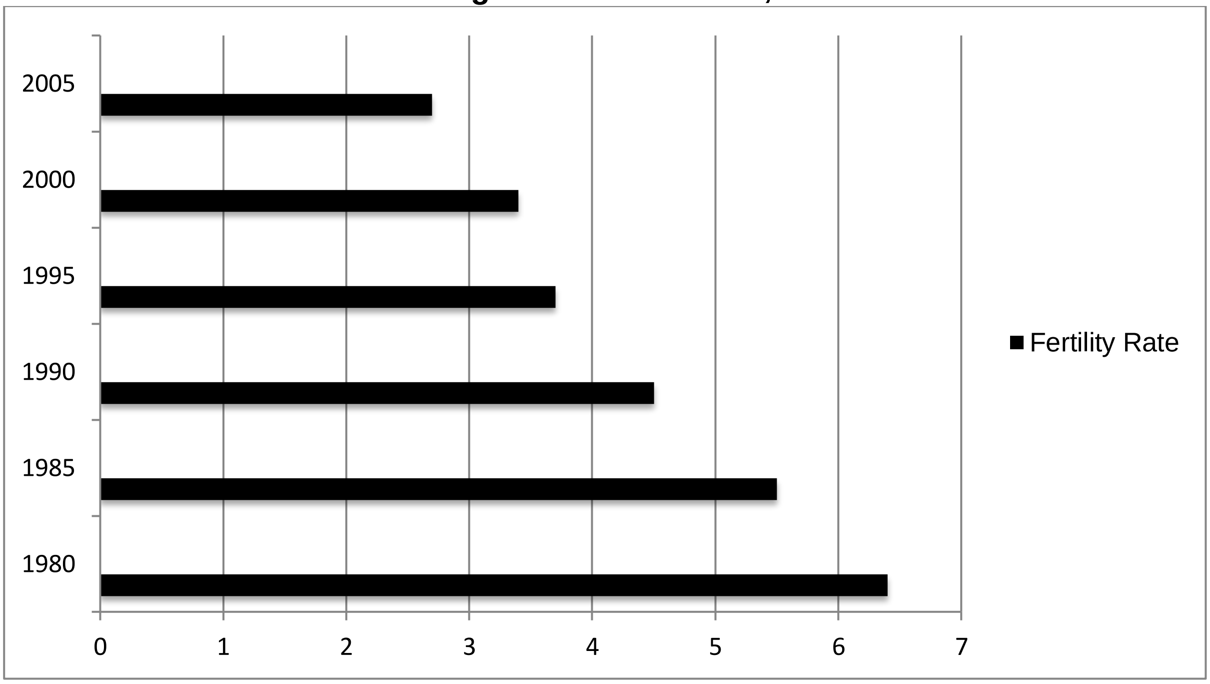
While the country's demand for energy is growing, its limited non-renewable energy sources are getting used up every day. Studies have shown that energy demand will rise to 5.6 cubic billion feet in the year 2025 and the existing reserves of natural gas is inadequate to meet the demand. The country is home to around 3.3 billion tons of coal at depths which range from 118 to 1158 meters. Bangladesh can extract coal till the depth of 509 meters. The nation has also been involved in hydro-electric power generation. The use of solar electric power is also gaining popularity and biogas production is also possible in Bangladesh. If only the country could form effective plans and commit to it; the nation would have transformed into a medium earning country. Energy is the key behind solving Bangladesh's most pivotal problem which is poverty.

The government of Bangladesh aims to address the energy shortage within 2010 to 2016. It plans to generate about 14773 MW within the given time period. About 42% of the targeted energy generation will be provided by the public sector. On the other hand, 58% of the total power generation will be produced by the private sector. To make this possible, the government has even signed with 19 private rental power companies. These companies can provide up to 1745 MW of power. In addition to that, the government has also approved 15 public sectors projects which will provide about 1564 MW of power. The government of Bangladesh is also interested in producing renewable energy. Numerous plans have been jotted down to develop solar and wind power stations across the country. Furthermore, the government has also updated a lot of policies to encourage the private sector to take part in power generation since 1996.

Yet another major concern of Bangladesh is its rapidly increasing population. Participating in child bearing is a very common trend among women in underdeveloped and developing countries. Women in Bangladesh become mothers even before the age of 20 (Singh 1998). Moreover, child bearing in adolescent women is the highest in Bangladesh compared to Asian countries. Asaduzzaman and Khan (2008) had shown that women in their twenties had 3 children on average between 1999 and 2000. This number further increased to 4 when those women jumped to the age group of over 30. This is mainly due to lack of family planning, discouraged female education and early marriages. The total fertility rate of Bangladeshi women have decreased from 6.3 births per woman between 1971 and 1975 to 3.3 births per woman in 1994 to 1996 (Kamal & Chaudhury 2003). However, the total fertility rate had stopped declining from 1994 onwards even though the contraceptive prevalence rate had increased from 44.6% between 1993 and 1994 to 53.8% between 1999 and 2000 (World Health Organization 2016). The most common methods of contraception in Bangladesh are the pill, female sterilization, injectable and condoms. According to the WHO, the uses of these contraceptive methods have increased drastically over the last twenty five year. This might have led to the sharp decrease in fertility rate in women.

Mitra *et al.* (2000) had found that between 1999 and 2000, the total fertility rate among rural Bangladesh women was about 3.5 births per woman whereas it was 2.5 births per urban woman. Moreover, the total fertility rate was the highest in Chittagong and Sylhet divisions of Bangladesh. Education can have a strong impact on fertility among women. Women who had access to education had a fertility rate of 2.4 births per woman. This number is 1.7 births per woman lower than women who have no schooling. Moreover, women who have an access to media are more likely to have fewer children than those who are not exposed to mass media. Moreover, women who know about contraception are more likely to want fewer children than women who have never used contraception. Figure 1 shows the trend of fertility rate from 1980 till 2005 among Bangladeshi women (World Bank 2015).

Figure 1: World Bank, 2015



Despite Bangladesh being one of the poorest countries in the world, the substantial decrease in fertility reflects the success of early family planning programs. However, the decline in fertility rate among Bangladeshi women has almost plateaued after 2000. This can be a serious problem for an over-populated nation like Bangladesh.

4. Methodology and Data

To check for stationary variables, the existence of unit root has been tested in this paper. Macro variables are well known for being non-stationary. Augmented Dickery fuller and Phillips-Perron (PP) tests are performed to check for the existence of unit root. Some of the variables are found to be non-stationary and thus regression is not possible without making them stationary. Moreover, cointegreation test is performed to check for possible linear combinations among stationary variables. It has to be noted that Johansen and ARDL tests are widely used in empirical literature to address the issue of cointegration and Granger causality test deals with the direction of causality. If cointegretion can be found then the Granger Casualty test will be run to check the probable direction of causality.

In a time series analysis, existence of non-stationary data can possibly lead to deceptive regression unless there is at least one cointegretion relationship. For cointegration, the Johansen procedure can be applied. The Johansen procedure provides a combined framework for testing and estimating cointegretion relations in the context of Vector Autoregressive (VAR) error correction models. To apply this approach, an Unrestricted Vector of Autocorrelation of this form needs to be estimated:

$$\Delta x_t = \alpha + \theta_1 \Delta x_{t-1} + \theta_2 \Delta x_{t-2} + \theta_3 \Delta x_{t-3} + \cdots\cdots + \theta_{k-1} \Delta x_{t-k+1} + \theta_k \Delta x_{t-k} + u_t \quad \text{--- (i)}$$

Where Δ is the difference operator, x_t is a $(n \times 1)$ vector of non-stationary variables (in levels) and u_t is also the $(n \times 1)$ vector of random errors. The matrix θ_k contains the information on long run relationship between variables. If the rank of $\theta_k = 0$, the variables are not cointegrated. On the other hand, if rank (usually denoted by r) is equal to one, there exists one cointegrating vector and finally if $1 < r < n$, there are multiple cointegrating vectors.

Johansen and Juselius (1990) have derived two tests for cointegration. Those are the trace test and the maximum Eigen value test. The trace test assesses the null hypothesis with at most *r* cointegrating vectors. On the other hand, the maximum Eigen value test looks at the null hypothesis which has exactly *r* cointegrating vectors in x_t.

Pesaran *et al.* (1996) and Pesaran and Shin (1995) introduce the ARDL approach of cointegration. This approach has recently gained a lot of popularity in econometric analysis. Recent empirical studies have shown that the new ARDL approach to cointegration is more convenient and preferable than conventional approaches like Johansen and Jusilas (1980) and Engle and Granger (1987).

The chief benefit of using the ARDL approach is that it can be applied regardless of whether the variables are I (0) or I (1). This, in turn, fends off the problems of pre-testing which are associated with standard cointegraton analysis which usually requires the classification of the variables into I (0) or I (1). Moreover, the ARDL approach also produces more robust results when dealing with a smaller sample size. Therefore, the ARDL approach of cointegration avoids the use of ADF unit root tests and autocorrelation functions tests for testing the order of integration. On the other hand, some researchers state that this approach will not work in the presence of I (2) series. Ouattara (2004) says that the implementation of unit roots tests might be necessary in the ARDL approach in order to confirm that none of the variable is integrated for order 2 or beyond.

The ARDL approach consists of two stages. In the first stage, the long run relationships between the variables under observation is tested using the F-statistics for testing the significance of the lagged levels of the variables in the error correction form of the underlying ARDL model (Pesaran & Pesaran 1996). Two sets of values for different number of regressors have been tabulated irrespective of an intercept and / trend. One of the sets assumes that all the variables in the ARDL procedure are I (1). In contrast, the other set assumes that all the variables are I (0).

If the computed F-statistics is lower than the upper critical value then the main hypothesis of a non-existing long run relationship can be rejected without needing to know the orders of integration for the time series. Similarly, if the computed F-statistics falls below the lower critical value then the rejection of the null hypothesis is not possible. Finally, if the computed F-statistics falls within the range of the critical value band then the result comes out as inconclusive.

The second stage of the ARDL procedure is to estimate the long and short run coefficients and their inferences provided that there is already a long run relationship between the variables.

The ARDL framework takes the following form:

$$\Delta Y_t=\beta_0+\sum\beta_1\Delta Y_{t-i}+ \sum\beta_2\Delta X_{t-i}+ \beta_3 Y_{t-1}+ \beta_4 X_{t-1}+\varepsilon_t \qquad \text{--- (ii)}$$

The ARDL model can be very sensitive when it comes to choosing the order of the distributed lag function and during the inclusion of trend in the model. In Microfit 4.0, there is an automatic choice of selecting the appropriate model. However, the significance of the trend variable has to be taken into consideration and checked.

Narayan and Smyth (2006) argues that “in spirit of the bounds test, a model with a time trend is invalid because for the model to be valid there should be only one long run relationship. If someone includes time trend in the model one may end up with more than one possible cointegration relationship: one with a time trend and one without a time trend. However, in this very study, the time trend has been included just to check whether the cointegration tests are sensitive towards trend. In addition to this a clear indication of trend is observed from the plotted level variables.

The cointegration analysis says that there is at least one direction of causality when two variables are cointegrated. The Granger-causality introduced by Granger (1969, 1980, 1988) studies empirical macroeconomics and finance. Engle and Granger (1987) have indicated that the presence of non-stationary variable can result in wrong conclusions in the Granger causality test. A causal long run relationship between non-stationary time series is only possible when the variables are cointegrated.

If y and x are the variables of concern, the Granger causality test determines whether current explanation of current values of x as provided by information in past values of x can be explained by past values of y. If past values of y does not explain current changes in the values of x then y does not Granger cause x. Similarly, investigation needs to be carried out whether x Granger causes y by repeating the process. Four likely outcomes are possible in the Granger causality test (1) neither of the two variables Granger cause each other, (2) y causes x but not otherwise, (3) x causes y but not otherwise and (4) both x and y Granger cause each other. In this study, the causality test between energy consumption and fertility rate has been conducted. Two sets of equations have been estimated for conducting this study:

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots\cdots + \alpha_l x_{t-l} + \beta_1 y_{t-1} + \cdots\cdots + \beta_l y_{t-l} + u_t \qquad \text{--- (iii)}$$

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots\cdots + \alpha_l y_{t-l} + \beta_1 x_{t-1} + \cdots\cdots + \beta_l x_{t-l} + v_t \qquad \text{--- (iv)}$$

For all possible pairs of (x, y) series in the group, the reported F-statistics are the Wald statistics for the joint hypothesis $\beta_1 = \beta_2 = \beta_3 = \cdots\cdots = \beta_l = 0$

As mentioned earlier, this paper looks at the long run relationship between energy consumption and fertility rate and the direction of causality. A simple relationship in this study has been used. However, this relationship is at a high level of aggregation (between total energy use and fertility rate) and takes a much simpler functional form such that one principle variable, energy use, is capable of explaining variation in the other which is fertility rate.

5. Results

Unit root tests have to be run in order to inspect the order of integration of the data series for all the variables. ADF statistics and corresponding critical values for all the variables in their level and first difference forms are indicated in **Table 2**.

Table 2: Augmented Dickey Fuller Unit Root Test for the Variables

Panel 1: Levels			
	ADF Statistics (Only Constant)	ADF Statistics (Constant & Trend)	Decision
Fertility Rate	-1.834386	-1.705918	Non Stationary
Energy Use	-5.686139	-5.846115	Stationary
Panel 2: First Differences			
	ADF Statistics (Only Constant)	ADF Statistics (Constant & Trend)	Decision
Fertility Rate	-5.540371	-6.149633	Stationary
Note: All regression is estimated with and without trend. Selection of the lag is based on Schwartz Information Criterion (SIC).			

Phillips Perron test has been run to obtain more robust and uniform results for the variables. This is because the variable 'fertility rate' is non-stationery at levels. Thus, it is important to further check and verify the nature of this variable. The results of the Philips Perron test are shown in **Table 3**.

Table 3: Phillips Perron Unit Root Test for the Variables

Panel 1: Levels			
	PP Test Statistics (Only Constant)	PP Test Statistics (Constant & Trend)	Decision
Fertility Rate	-3.815826	-1.395609	Stationary with constant but without trend constant; Non-stationary with constant and trend
Energy Use	3.671	-0.901009	Stationary with constant but without trend constant; Non Stationary with constant and trend
Panel 2: First Differences			
	PP Test Statistics (Only Constant)	PP Test Statistics (Constant & Trend)	Decision
Fertility Rate	-	-11.59910	Stationary
Energy Use	-	-6.556188	Stationary
Note: All regression is estimated with and without trend. Selection of bandwidth is based on Newey-West Bandwidth Criterion.			

An important issue to consider while conducting the unit root test is to select an appropriate lag length. One approach is inclusion of a relatively long lag length and to select the model by the usual t-test. If the t-statistics using lag p comes out insignificant at some specified critical value then the regression could be estimated repeatedly using a lag length of p-1 until the lag becomes significantly different from zero. Different lags have been taken to check whether the variables are stationary. All lags yield homogeneous results which mean that fertility is stationary at level whereas the variable energy consumption is stationary in the first difference form.

The unit root tests have non-standard and non-normal asymptotic distribution. This in turn is highly influenced by the inclusion of deterministic terms, e.g, constant, time trend etc. The inclusion of an extraneous regressor like the time trend can decrease the power of the test. On the other hand, if true data generating process is trend stationary then failure of inclusion of a time trend can also lead to a reduction in the capability of the test. In addition, the loss in power because of exclusion of a time trend is more severe than a decrease in the power of the test due to including a time trend when it is extraneous (Lopez *et al.* 2005).

It can be seen from the unit root tests that the variable ‘Fertility Rate’ is non-stationary in its level and stationary in the first difference form whereas ‘Energy Use’ is stationary in level. The above results also imply that the variables would yield false results unless the variables are cointegrated. These results, however, allow proceeding to the next stage of testing for cointegration. The Johansen cointegration test indicates that two series have one cointegrating relationship for both 1 and 2 orders of VAR. Both the maximal Eigen value test and the trace test indicated one cointegrating relationship at 95% significance level. The Johansen test result of this study is insensitive to the inclusion of intercept and/or trend. Results of Johansen test for cointegration (VAR order 2 and no intercept; no trend) is given in the following table:

Table 4: Johansen Test for Cointegration (Maximum Eigen value Test)

	Null Hypothesis	Alternative Hypothesis	Statistics	95% Critical Value	Conclusion
Energy Use and Fertility Rate	None	At Most One	13.30913	11.22489	One Cointegrating Relationship

Using ARDL method, the order of lags on the first differenced variables was obtained from unrestricted VAR model by means of AIC. In this paper, lag 4 is considered as an optimal level. Though results from lag 2 and 3 are included to increase the robustness of the tests. Lag 1 has been excluded. This is because as a rule of thumb, we should incorporate more than one lag for the annual data. The F-statistics for each order of lag is given in Table 6. The f-statistics is highly significant in lag 2 and lag 4 but the result obtained from lag 3 in inconclusive.

Table 5: ARDL Cointegration Test (F-Statistics)

Order of Lag	F Statistics without Trend
2	F(2,25)= 4.6962
3	F(2,22)=3.0417
4	F(2,18)=6.9446

Since one cointegrating relationship exists between the variables, the Granger Causality test can be conducted. The Granger Causality test has been run for 4 different lag intervals (lag 1, lag 2, lag 4 and lag 4). The results of the test for lag 2 are reported in **Table 6**. As the main purpose of the study is to examine the causal relationship between the concerned variables, to avoid complicacy, a simple equation has been regressed by omitting the other exogenous variables which has been reflected by a high coefficient and intercepts value. At the same time, the inclusion of other variables tend to give us more than one cointegrating relationships.

Table 6: Granger Causality Tests

Hypothesis	F-Statistics	P-Value	Granger Causality
Fertility rate does not Granger Cause Energy Use	0.64656	0.5315	No Causality Found
Energy Use does not Granger Cause Fertility Rate	0.00896	0.9911	

The results of the Granger Causality test confirm that no causal relationship runs from energy use to fertility rate or vice versa. Before this paper, there was no clear indication of such a relationship in Bangladesh. The results clearly prove that energy use and fertility rate have a long term relationship, however, the relationship lacks causality.

6. Conclusion

Firstly, from the ADF and the Phillips Perron test, it can be seen that not all variables are stationary. On the other hand, the first difference form in both ADF and Philips Perron show that all the variables are stationary. Reliable results cannot be achieved without checking for cointegration. Thus, to check for cointegration, it is important to observe whether the variables are stationary in the first difference form. Tests for cointegration show that the variables are cointegrated at lag 2 and 4 although there is no cointegration at lag 3. Finally, the Granger Causality test depicts that there is no causal relationship between energy consumption and fertility rate. This paper is the first empirical approach to detect causal relationship between energy use and fertility rate and it has been found that although there is a long run association between the variables in other countries, there is a very weak link between the two variables in Bangladesh. As a result, this paper provides new knowledge regarding the causal relationship between the two concerned variables and in the area of energy and urban economics.

By looking into previous literature, it can be said that an economic relationship between energy use and fertility rate can be expected in Bangladesh. This is because countries like Iran, India and Tanzania did show a relationship between energy use and fertility rate. Through energy use, women get free time in their hands. With an ample amount of free time in their hands, women get involved in education or small scale entrepreneurship. In addition to that women are socially empowered by watching a diversified culture on television by using energy. Exposure to television can highly motivate women towards using contraception. As a result, electrification can lead to declining fertility rate among women. This paper started with the hope that the relationship of energy use and fertility rate would exhibit any one of four hypotheses. The first two hypotheses were that a unidirectional causal relationship runs from energy use to fertility and vice versa. The third hypothesis was that a bi-directional causal relationship existed between the two variables. The last hypothesis states that no causal relationship runs between the two variables. This empirical paper has provided evidence in support of the fourth hypothesis and does not support previous literature.

A causal relationship between the two variables may exist in other countries. However, the empirical outcomes of this study show no such relationship in Bangladesh. This is quite astonishing because a country like Bangladesh would have been able to control its expanding population through rural electrification and increased energy generation. Since data shows no proof of such a relationship, the Government of Bangladesh needs to focus on other policies to further bring down the fertility rate in women.

This of great concern that gathered data of Bangladesh does not reflect such a relationship in Bangladesh. This indicates that problems exist in root levels in Bangladesh. Organizations working particularly in the development sector should pay attention and identify these problems. According to the Solow model, a high population growth rate can lead to economic instability. Bangladesh has a very high population growth rate and the only way to get it under control is to push the fertility rate downwards. The government of Bangladesh has stopped promoting contraceptive awareness among women after the great fall in fertility rate in the late 1990s. It is important to remember that social awareness is effective only when done continuously. Thus, the government should continue putting rigorous efforts in raising social awareness among both men and women in the Bangladesh society.

The high population growth rate cannot be controlled in Bangladesh just by increasing the supply of electricity in rural areas. The government of Bangladesh needs to focus and come up with restrictive policies to control the high fertility rate in Bangladeshi women. The plateauing of the fertility rate in Bangladesh can lead to drastic effects on the future economy. Thus, it is crucial for the government to implement new and potent policies to address this issue.

It must be taken into consideration that this study faced a lot of limitations. Firstly, the sample size is very small. Secondly, a bivariate model has been used for this study. Finally, other factors such as education, social empowerment, employment could have been taken into account. These factors can affect the fertility rate among women. Future research can focus on a multivariate model to study the causal relationship between energy use and fertility rate in Bangladesh and other developing Asian countries to come up with effective policies.

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