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RELATIONSHIP OF RENEWABLE AND NON-RENEWABLE ENERGY UTILIZATION WITH CO2 EMISSION OF BANGLADESH

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ABSTRACT

This paper attempts to find out the relationship of renewable and non-renewable energy utilization with CO_2 emission in Bangladesh. The analysis is done using the Autoregressive Distributed Lag (ARDL), Dynamic Ordinary Least Squares (DOLS), Fully Modified OLS (FMOLS) and Canonical Cointegrating Regression (CCR) techniques to observe the robustness of the findings. Results postulate that non-renewable energy and GDP has statistically significant positive association with CO_2 emission whereas, renewable energy is negatively associated. From all estimation techniques, it is found that 1% augment in non-renewable energy utilization will boost CO_2 emission by on an average more than 0.75%. Moreover, Toda -Yamamoto (TY) and vector autoregression impulse response procedure have been employed and the findings confirm that non-renewable energy is causing CO_2 emission but renewable energy is not causing CO_2 emission. The paper adds value to the present energy-emission study in a way that in Bangladesh context there are paucity of studies that concentrate on the effect of both renewable and non-renewable energy utilization on CO_2 emission and there exists no study with multiple estimation techniques with a view to get robust findings. Another contribution is the dynamic effects of impulse response function also complement the ARDL, DOLS, FMOLS and CCR findings. As findings are responsive to the methodology used, therefore, for robust results, multiple techniques are employed. This study recommends increasing the share of renewable energy will play a critical role to reduce CO_2 emission consequently global warming.

Contribution/ Originality: The study is one of the few studies on Bangladesh context that examines the effect of both renewable and non-renewable energy utilization on CO_2 emission with multiple estimation techniques. Moreover, dynamic effects of Impulse Response Function and findings from the ARDL, DOLS, FMOLS and CCR complement each other.

1. INTRODUCTION

Bangladesh is one of the rapidly rising emerging economies in Asia. Average annual GDP growth of the economy is around 7.3% (WDI, 2019). According to "Energy Efficiency and Conservation Master Plan up to 2030" (Efficiency, 2015) the quantity of primary energy supply of the country is 33,172 ktoe[1]. The distributional percentage of the energy supply is 55% from domestic natural gas, trailed by 27% from biomass and waste in pastoral area and imported oil contributes 15%. The present dearth and insufficiency in the accessibility of utilizable

[1]Kilotonne of Oil Equivalent.

fossil fuel energy directs to the search of innovative and modern energy resources. Even though there exists a substantial gas reserve in the country but the present withdrawal pace is alarming and by 2031 this reserve will be desiccated (Amin & Rahman, 2019). According to The Power Sector Master Plan (Plan, 2016) by 2021 more than fifty percent of the entire power production will utilize coal of which the contribution of imported coal and domestic coal will be 21.71% and 29.07% respectively. To achieve the country's anticipated vision 2021, sustainable development goals (SDGs) 2030 and becoming a developed country by 2041 requires uninterrupted energy supply which needs more energy consumption resulting in more CO_2 emission leading towards global warming. Moreover, environmentally the country is the most susceptible to climate change as well and for this reason the study related to energy and environment are pertinent in the country context.

The energy production from renewable sources is relatively low in Bangladesh. For instance, according to the World Bank (2017) the electricity production using renewable resources was merely 1.2% of overall electrical energy generation in 2015 which was 11.4% in 1990. The share rate of renewable electricity production to total electricity production is decreasing each year. Renewable energy resources i.e. solar, wind, biogas and hydroelectric power are the most popular renewable sources in Bangladesh till now (Rahman, 2011). Karnaphuli Hydro Power Station is the sole power plant which produces 230 MW of electricity for the country. Wind energy is prevalent mainly in coastline vicinities and off seashore areas having powerful wind domination. At present two places of the country i.e. Feni and Kutubdia have 2MW of established wind energy production turbine. An additional 50-200 MW capacity wind energy production is under planning at Parky Beach as well. There are other sources of renewable energy of the country, among them biogas has potential and largely collected from animal and urban waste as a part of sustainable waste management. Another potential source can be the solar energy.

The energy production sector is considered to be the main contributor to the human induced greenhouse gases (GHG), in particular CO_2 emission into the environment (Ritchie & Roser, 2020). Against this backdrop, Bangladesh necessitates depending on unconventional substitute of energy sources to avoid climate change related predicaments. In this regard, introduction of more fossil fuel development venture to get electricity at a lower price poses challenge to the environment. Keeping this in mind, it would be impossible to think about 100% clean energy right now. Neither the country can shift overnight nor can she rely on a particular supply of energy to meet the increasing demand.

In this context, the prime objective of this study is to find out the relationship of renewable and non-renewable energy utilization, economic growth with CO_2 emission in Bangladesh. Findings are identical therefore, remains robust using several econometric techniques showing non-renewable energy is the reason of spurring CO_2 emission while renewable energy is not causing CO_2 emission in Bangladesh. To the best knowledge of the author, no study in the context of Bangladesh has concentrated on both renewable as well as non-renewable energy utilizing multiple estimation techniques. Moreover, the dynamic effects of impulse response function also complement the ARDL, DOLS, FMOLS and CCR findings.

The remainder of the paper is prearranged as follow: After the introductory section (Section 1), Section 2 is designed to present a brief overview of energy, growth and environment scenario of Bangladesh. It is followed by existing empirical evidence (Section 3). Section 4 illustrates research methodology. Observed findings and discussions are analyzed in Section 5. Finally, in Section 6 conclusion are drawn with policy implications.

2. A BRIEF OVERVIEW OF ENERGY, ENVIRONMENT AND GROWTH NEXUS IN BANGLADESH

Statistics show Table 1 globally Bangladesh is one of the smallest per capita energy consuming economies that produces in larger quantity with smaller amount of energy consumption in comparison to other high income economies (WDI, 2019). In this respect, she has huge potential to be an energy efficient economy without disturbing the economic growth.

Table-1. GDP per capita and Energy utilization scenario.

Country	GDP per capita US$ (2017)	Electric power consumption (kWh per capita) (2014)	Energy use (kg of oil equivalent per capita) (2014)
Bangladesh	1093	310	222
India	1963	806	637
Pakistan	1222	471	485
Sri Lanka	3842	531	515
Nepal	728	139	412
Lower Middle Income	2189	767	646
Middle Income	4992	2064	1395
World	10634	3127	1920

Source: WDI (2019)

Energy has a pivotal role to play in sustaining economic growth. The below graphs (Figure 1) show that with the increase in GDP (LY) taken as economic growth, CO_2 emission (LCO_2) representing environmental quality and non-renewable energy utilization (LNRE) is also increasing in Bangladesh. Therefore, for uninterrupted growth we need more efficient energy sources that will reduce emission. Here renewable energy utilization (LRE) could play a vital role. Use of renewable energy portends to make energy utilization clean as well as sustainable.

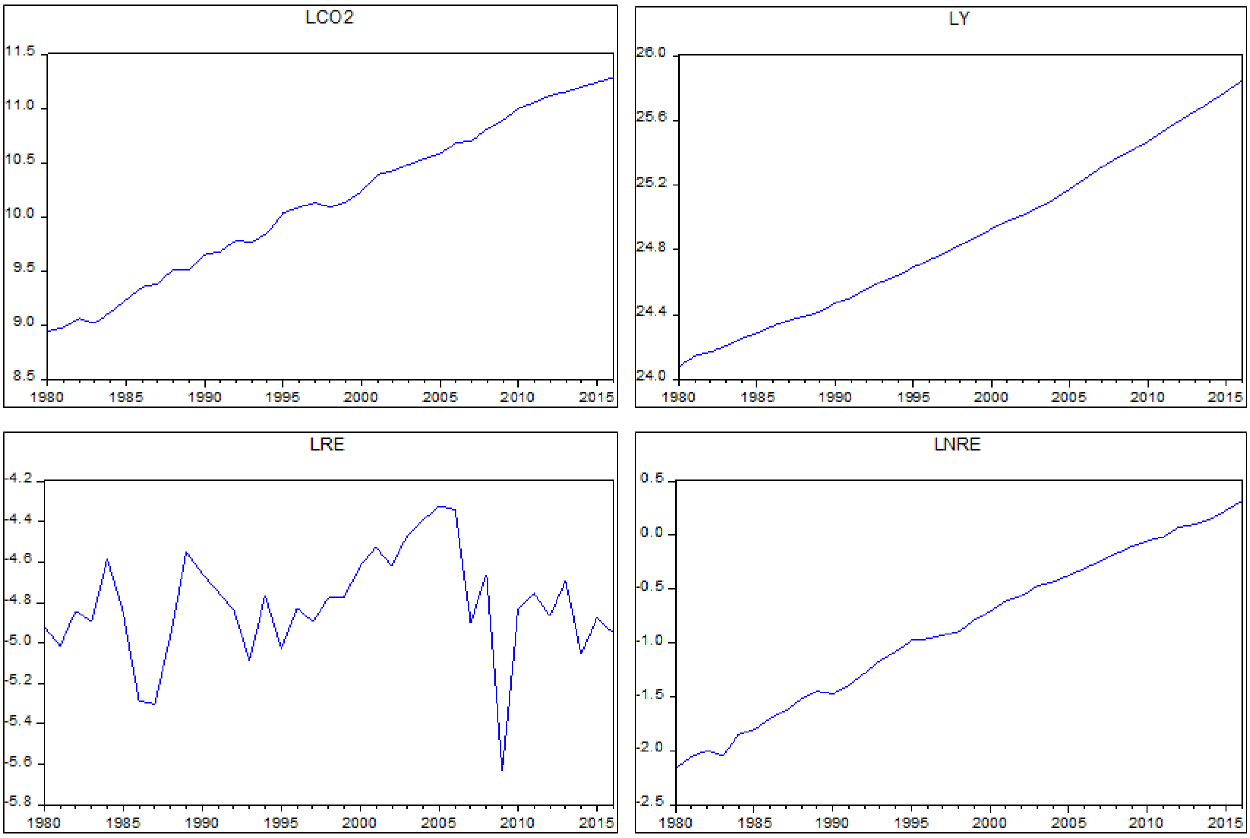

Figure-1. GDP, renewable and non renewable energy utilization and CO_2 emission of Bangladesh.

Due to global temperature rise the country becomes vulnerable to climate change. Rise of sea level, high tide and wave and recurring floods and cyclones are the impacts caused by global greenhouse gas (GHG) emission specially CO_2 emission spurring from fossil fuel consumption leading towards global warming. Bangladesh has less contribution in the production of the GHG emissions in comparison with the key CO_2 releasing economies. Therefore, we need to address climate change issues in our national policies to be acknowledged globally as a victim of global development course of action.

Table-2. Studies on Growth, renewable and non renewable energy utilization and CO_2 emission.

Author (s)	Variables Used	Method	Findings
Baek and Kim (2013)	CO_2 emissions, economic growth, energy consumption and FDI	Cointegration test, Autoregressive Distributed Lag (ARDL)	Energy consumption results in a harmful long-run impact on CO_2 emissions
Al-Mulali (2014)	Nuclear energy consumption, GDP growth and CO_2 emission	Fully Modified OLS (FMOLS) and Granger Causality	Nuclear energy consumption shows no consequence on CO_2 emission
Narayan and Smyth (2005)	Electricity consumption Employment and Real income	Granger Causality	Real income causes electricity consumption
Apergis and Payne (2010)	Economic growth, renewable energy consumption	Cointegration test	Causality connecting energy consumption and growth exists with feedback impact
Alam, Begum, Buysse, Rahman, and Van Huylenbroeck (2011)	CO_2 emissions, Income and Energy Consumption	Toda-Yamamoto (TY) approach , Granger Causality	Bi-directional causal association exists amid energy use and CO2 emissions
Soytas, Sari, and Ewing (2007)	Income, Energy consumption, Carbon emissions, labor, gross fixed capital formation	Granger causality, TY, Generalized VDC, Impulse Response	Energy utilization causes CO_2 emissions however income does not cause CO2 emissions
Zhang and Cheng (2009)	Growth, Energy use, CO_2 emissions, Capital, Urban population	Granger causality	Neither CO_2 emission nor energy use leads economic growth
Chang (2010)	Carbon dioxide emissions, Energy consumption and Economic growth	Multivariate co-integration and Granger Causality	Economic growth will increase both energy consumption and carbon emission
Ang (2007)	Pollutant emissions, Energy consumption, and Output	Cointegration and Vector Error Correction (VECM) model	Economic growth wields causal relationship with energy consumption and emission
Baek and Kim (2013)	Economic growth, Energy consumption, Fossil fuels and nuclear energy in electricity production	Dynamic cointegration framework and ARDL	Nuclear energy is beneficial whereas fossil fuels energy consumption is detrimental for environment
Ang. (2008)	Output, Pollutant emissions, and Energy consumption	Johansen cointegration and Causality tests	Emission and energy utilization encourage output
Sharma (2011)	Trade openness, per capita GDP, per capita electric power consumption, total primary energy consumption,	Arellano and Bond GMM estimator	All the variables used have positive effects on CO_2 emissions
Soytas and Sari (2009)	Economic growth, CO_2 emissions, energy consumption, gross fixed capital formation and labor	Granger Causality	CO_2 emission causes energy use, but not the other way round
Pao, Yu, and Yang (2011)	Pollutant emissions, energy use, and Real output	Cointegration and Granger Causality	High energy use has causal association with emissions
Halicioglu (2009)	Carbon emissions, Energy consumption, Income, and foreign trade	ARDL and Granger Causality	Carbon emissions is significantly caused by income
Hossain (2012)	CO_2 emissions, Energy consumption, Economic growth, Foreign trade and Urbanization	Dynamic Causality, ARDL Bound Test, and VEC Model	Excessive energy use is the reason behind more CO_2 emissions
Sadorsky (2014)	CO_2 emissions, Energy intensity, Affluence, Urbanization and Population	Mean group, Common correlated effects and Augmented Mean Group estimators	Calculated simultaneous effect on the variables i.e. energy intensity and affluence shows positive association
Akhmat and Zaman (2013)	Nuclear and Commercial energy consumption, Economic growth	Bootstrap panel Granger Causality method	Causal relationship exists connecting nuclear energy use and economic growth for majority of the economies
Sharif, Raza, Ozturk, and Afshan (2019)	CO_2 emissions, GDP, non-renewable and renewable energy and financial development	CIPS unit root test, Westerlund bootstrap cointegration, Pedroni co-integration, FMOLS and panel causality	Non-renewable energy consumption shows positive impact but renewable energy consumption exerts negative impact on CO_2 emissions

3. EXISTING EMPIRICAL EVIDENCE

The impact of economic growth on environment due to energy consumption is vastly studied since the previous few decades of the past century. The Paris Climate Conference 2015 accord stated to condense emissions pursuing country level environment policies (Rhodes, 2016). Stern et al. (2006) calculate that the economic outcome of global warming could cause a reduction of overall GDP approximately by 25% worldwide whereas greenhouse gas lessening would outlay nearly 1% GDP of the world. The Intergovernmental Panel on Climate Change (IPCC) report (2013) (Stocker, 2013) reveals that CO_2 emission has amplified near about 40% ever since pre-industrial period. According to the information it is principally occurred due to fossil fuel stimulated discharge and secondarily emission coming from total land exploitation alteration. The statement includes the worldwide drift headed for larger urbanization being one of the numerous significant forms of land use and land face transformation. More to the point, it opines that land utilization alteration has caused roughly 30% of entire human induce CO_2 release ever since 1850. At present it is comprehensively acknowledged that except far-reaching measures to reduce global warming are introduced, the earth could be directing near lesser amount of augmentation of growth as well as towards ecological catastrophe Stern et al. (2006).

Summary table of existing studies focusing on global and Bangladesh perspective is given in Table 2 and 3.

Table-3. Studies Focusing on Bangladesh.

Author (s)	Variables Used	Method	Findings
Alam., Begum, Buysse, and Van Huylenbroeck (2012)	Energy consumption, electricity consumption, carbon emissions and economic growth	Cointegration, ARDL, VECM	Causality running from energy utilization to economic growth but it shows one way causality
Dey (2019)	Per capita electricity consumption and per capita gross national income	VECM	Bidirectional causality exists amid electricity consumption and Income
Mozumder and Marathe (2007)	Growth, Energy consumption	VECM, Granger Causality	Growth causes Energy utilization
Ahamad and Islam (2011)	Per capita GDP and Per capita electricity consumption	VECM, Granger Causality	Energy consumption has causal association with growth
Sharmin and Tareque (2018)	Economic globalization, Energy intensity, Urbanization, Industrialization, Growth, per capita CO_2 emission	VECM and Granger Causality	Growth stimulates energy use that consequently increases CO_2 emissions

In pooling together, from the above existing empirical evidence it can be observed that fossil fuel is the dominating source of carbon emission globally and Bangladesh is not exception to that. Solar, wind, and biomass energy generating technologies are still the finest affordable solutions to reduce the dependencies on fossil fuel. The energy production from renewable sources is relatively low in Bangladesh. For instance, according to the World Development Indicators (WDI) data, the electricity production from renewable energy resources was only 1.2% of total electricity production in 2015 which was 11.4% in 1990. The share rate of renewable electricity production to total electricity production is decreasing each year.

4. RESEARCH METHODOLOGY

4.1. Model Specification and Data Description

The following log-linear regression model has been incorporated in the paper to address the objective of this study-

$$LCO_2 = \alpha + \beta_1(LRE) + \beta_2(LNRE) + \beta_3(LY) + \mu_t \quad (1)$$

In Equation 1 CO_2 is the dependent variable shows environmental quality and renewable energy utilization (RE), non-renewable energy utilization (NRE) and GDP[2] (Y) depicting economic growth are explanatory variables/indicators. All data are in natural logarithm and unit of renewable and non-renewable energy utilization is Quad Btu (Quadrillion British Thermal Unit) and collected from Energy Information Administration (EIA). CO_2 emission is in Kt and GDP (Y) is in constant 2010 US$) taken from World Development Indicators (WDI). Equation 1 indicates α as the intercept term where β_1 , β_2 and β_3 are the coefficients of the independent indicators and μ_t expressed the error term.

Theoretical expectations from the incorporated indicators are: ($\beta_1 < 0$; $\beta_2 > 0$; $\beta_3 > 0$). Expected signs of the indicators are also relevant to the existing body of literature and goes with pertinent economic theory.

4.2. Methods of Analysis

The study have done the Unit root tests to check the unit root property of the series employing Augmented Dickey- Fuller (ADF) and Phillips-Perron (PP) techniques to get rid of spurious results and to get stationary quality of the indicators. Both the ADF and PP test was carried out based on the following model:

$$\Delta y_t = \mu + \beta_t + \delta y_{t-1} + \sum_{j=1}^{k} \alpha_j \Delta y_{t-j} + \varepsilon_t$$

Here, Δ represents the difference operator, t portrays the time trend, ε denotes the error expression termed as a white noise error, y_t signifies the series and k shows the number of lags used.

Upon satisfactory result of ADF and PP unit root check analysis, Autoregressive Distributive Lag (ARDL), Fully Modified OLS (FMOLS), Dynamic OLS (DOLS) and Canonical Cointegrating Regresion (CCR) techniques are used to find out the effect of both the renewable and non-renewable energy utilization on CO_2 emission in Bangladesh. Along with ARDL approach multiple estimation procedures are used to check the validity of long-run outcomes.

Further Toda -Yamamoto (TY) procedure (Toda & Yamamoto, 1995) and Impulse response analysis in vector autoregression process have been conducted to see the causal association, direction of causal relationship and how the indicators behave under shocks.

Finally, to see the reliability and goodness of fit of the model Breusch-Godfrey Serial Correlation LM test, Heteroskedasticity test, Jarque-Bera Normality Test, Stability Diagnostic tests and Inverse Roots of AR techniques are employed.

[2] GDP and growth are synonymously used in this study.

5. RESULTS AND DISCUSSION

5.1. ARDL, FMOLS, DOLS and CCR Estimation

After ensuring unit root properties[3] a multivariate framework is applied in the paper to examine the connection between CO_2 emission, renewable energy (RE) utilization and non renewable energy (NRE) utilization. Multiple estimation techniques for instance, ARDL, FMOLS and DOLS techniques are used to get robust findings as results are responsive to the methodology used Table 4.

Table-4. Results of ARDL, FMOLS, DOLS, CCR.

Variable	ARDL	FMOLS	DOLS	CCR
LNRE	0.797***	0.816***	0.764***	0.816***
LRE	-0.013	-0.032	-0.012	-0.037
LY	0.267**	0.238**	0.314***	0.242**
ECT	-1.024056***			
Diagnostic Tests				
Breusch-Godfrey Serial Correlation LM Test	0.526 (0.597)			
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.590 (0.776)			
Jarque-Bera normality test	1.542 (0.462)			

Note: ***, **, and * show significance at 1%, 5%, and 10% level respectively. Diagnostic tests results are based on F-statistic, and figures in ( ) represents probability-values respectively.

Results from all the four techniques used, postulate that renewable energy is negatively related whereas non-renewable energy and GDP is positively related with CO_2 emission. Findings indicate renewable energy sources is not the reason behind CO_2 emission, on the contrary non-renewable sources generate high carbon emission as the coefficients of non-renewable energy are also relatively high compared to renewable energy. From all estimation techniques, it is found that 1% raise in non-renewable energy utilization will augment CO_2 emission by on an average more than 0.75%. The Error correction term (ECT) is negative and significant as found from the ARDL results. It indicates any kind of disequilibrium will be corrected due to certain shocks. Moreover, the findings from FMOLS, DOLS and CCR conintegration results complement the ARDL findings.

5.2. Diagnostic Tests for Robustness Check

To determine the robustness of the models, Breusch-Godfrey Serial Correlation LM test, Heteroskedasticity test, Jarque-Bera Normality Test (Table 4), Stability Diagnostic tests (Figure 2 and 3) and Inverse Roots of AR (Figure 4) techniques are employed. As the inverse roots of the AR characteristic polynomial are inside the unit circle it shows the stationary quality of the model with dynamic stability. Stable AR root result portrays the validity of the Impulse Response Function result as well. The other diagnostic tests show the model is dynamically stable and free from serial correlation referring the goodness of fit of the model.

[3] Unit root results are not tabulated to save space

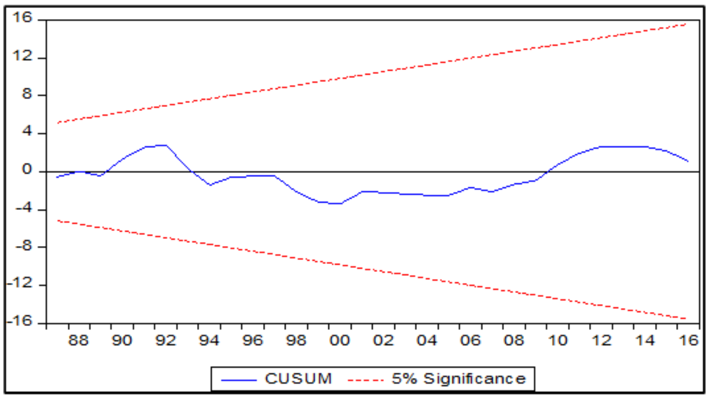

Figure-2. CUSUM.

5.3. Results of Toda -Yamamoto (TY) Procedure

To check the existence of casual relationship with path of causal association, modified Wald test (MWALD) proposed by Toda and Yamamoto (1995) has been employed. This technique entails VAR form with level variables (unlike the first differences in Granger causality tests) hence; no information is lost during the first differencing process and can be estimated without pre-testing for cointegration. Principally, this method augments the appropriate VAR order, k, by the maximum order of integration, i.e. d_{max}. Later a $(k + d_{max})^{th}$ order of VAR is calculated and the coefficients of the previous lagged d_{max} vector are disregarded. The TY procedure ensures that the normal test statistic for Granger causality has the usual asymptotic χ^2 distribution with k degrees of freedom for making valid inferences. This study finds that all likelihood ratios indicate to an optimal lag length of (1). Therefore, for estimation purpose the study employed a VAR (2) in levels.

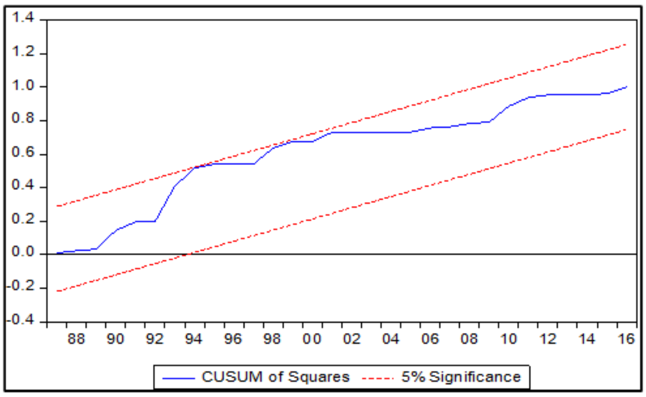

Figure-3. (CUSUM of Squares).

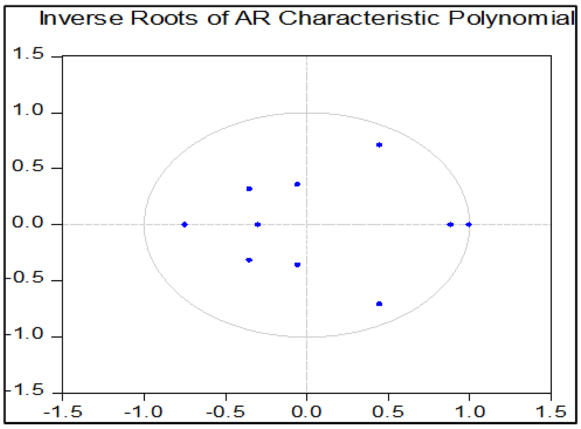

Figure-4. Inverse Roots of AR.

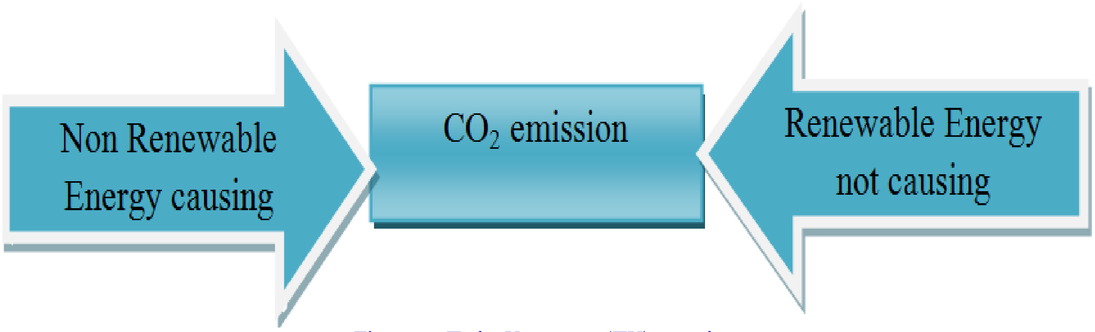

Figure-5. Toda -Yamamoto (TY) procedure.

Result of Toda -Yamamoto (TY) procedure (Figure 5) postulates that there is unidirectional causal connection between CO_2 emission and non renewable energy utilization and no causality between CO_2 emission and renewable energy utilization. This implies that renewable energy is not the reason for CO_2 emission. Findings of the causality result encourage utilizing more renewable energy and discourage exploiting excessive non-renewable energy to ensure environmental quality.

5.4. Results of Impulse Response

The graph (Figure 6) of impulse response also confirms that non-renewable energy utilization shows positive shock whereas renewable energy has negative shock on CO_2 emission.

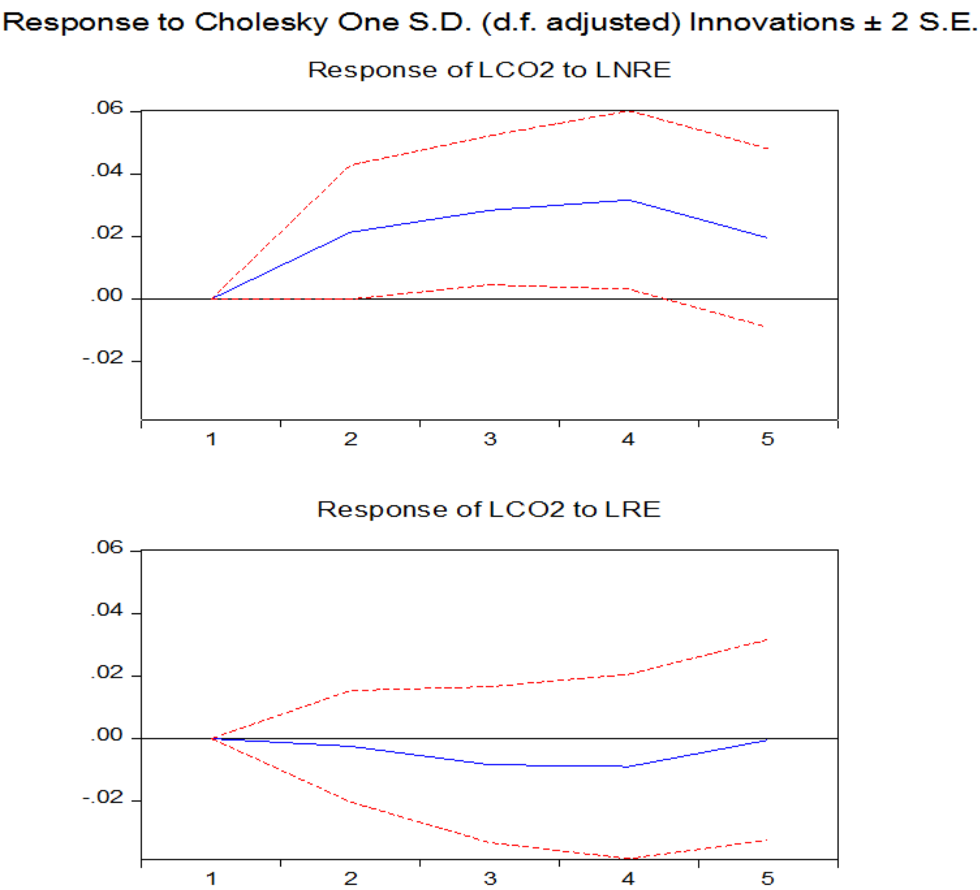

Figure-6. Impulse response function.

The findings postulate that renewable energy causes less CO_2 emission compared to non-renewable energy. Therefore, renewable energy utilization has less harmful impact on environment quality in comparison with non-renewable energy utilization. This result harmonizes the results found from other estimation techniques applied in this study as well.

6. CONCLUSION AND POLICY RECOMMENDATIONS

This paper endeavors to find out the relationship of renewable and non-renewable energy utilization with CO_2 emission of Bangladesh. Results put forward that non-renewable energy utilization and growth has statistically positive association with CO_2 emission but renewable energy is negatively associated. From the findings of multiple estimation techniques it is discernible that the exploitation of renewable energy resources can make energy utilization clean as well as sustainable in Bangladesh. It is now commonly accepted that without far-reaching actions taken for trimming down CO_2 emission that cause global warming, growth as well as environmental scenario will deteriorate in the coming future. In this respect, to keep the growth process of Bangladesh in an expected pace, the country policy should address environmental issues to arrive at a sustainable path both regarding economic growth and environmental efficacy measured by CO_2 emission in the coming future.

This paper recommends raising the contribution of renewable energy utilization in the development process will play a key role to reduce CO_2 emission. Combining asymmetric and unconventional renewable energy sources, for instance, photo voltaic (PV) and wind energy to reduce CO_2 emission is getting precedence globally. But renewable energy resources have high introduction cost and low utilization rate. There are also some off-grid vicinities where Solar Home System (SHS) or small-scale diesel production supply electricity sources are prevailing. Those are costly and have fuel running cost along with initial cost. To deal with this type of problems, the boosting of renewable energy incorporation is necessary along with safe energy storage technology for maintaining and securing stable power supply. Renewable energy sources with improved technologies are becoming more cost competitive in some countries and conditions, but incentives like government subsidy are still necessary to go for the renewable options.

As utilization of renewable energy source poses elevated introduction price and low deployment pace, for that reason, government should encourage going for renewable options. Hence, government should invest more in the inception phase of new technologies to ensure efficacy of energy production and utilization. Change in the energy utilization behavior of all stakeholders for environmental sustainability could be a prospective area to make further inquiries to judge the sustainability of the energy consumption, growth and environment.

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