# *Econometric Analysis of the Effect of Economic Globalization, Energy Intensity, Urbanization, Industrialization and Growth on $CO_2$ Emissions of Bangladesh*

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This paper examines the effect of economic globalization, energy intensity, urbanization, industrialization and growth on per capita $CO_2$ emissions of Bangladesh employing techniques of Johansen co-integration, Vector Error-Correction Models (VECM) and VEC Granger Causality Tests. To analyse the impacts of innovations in all variables on $CO_2$ emissions, this study additionally employs variance decomposition (VDC) for robust findings. The result of long run and causality test postulates that growth stimulates energy consumption and consequently causes $CO_2$ emissions. VDC result posits that in the long run, energy intensity, urbanization, industrialization and growth contribute more than 60% of the $CO_2$ emission in Bangladesh. On the other hand, effect of economic globalization becomes stronger in the long run but in explaining fluctuations in $CO_2$ emissions it contributes only 9%. To avoid adverse effect of growth implementations of energy conservation policies are needed.

*Key Words:* Johansen co-integration, globalization, $CO_2$ emissions, urbanization, industrialization
JEL *Classification:* O44, Q20, Q43
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## Introduction

Since the last few decades of the preceding century there has been rising concern on the impact of economic growth spurring from energy consumption and its effect on environment. The synergy between the $CO_2$ emissions, economic development and globalization is wide-ranging. United Nations Convention on Climate Change postulates that by 2030 seventy five percent population of this planet will live in urban areas.

The Intergovernmental Panel on Climate Change (IPCC Report 2013) divulged that carbon dioxide absorption had increased by 40 percent since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The report included the global trends toward greater urbanization as one of the several important types of land use and land cover change. Besides, it brought to the fore that land use change had also contributed almost 30 percent of total anthropogenic $CO_2$ emissions since 1850. The Paris Climate Conference agreement also declared limiting emissions following national level environment policies which augmented an increase in the study regarding carbon emission, energy consumption and environmental pollution. In this backdrop, the prime objective behind exploring this study in the context of Bangladesh is that this kind of nexus has got immense potential to play on contemporary disputes on environmental conservation and sustainable development.

Bangladesh is one of the fastest growing emerging economies in Asia; averaging around 7.1% annual GDP growth and industrial sector is making the most impact on this projected growth (see https://www.bb.org.bd). According to Bangladesh Bureau of Statistics (see http://bbs.gov.bd) the contribution of industrial sector to the GDP is 33.71 percent that grew robustly by 11.1 percent in FY16, buoy by power, gas and water supply, and mining and quarrying subsectors. Available statistics further demonstrates that urban population of the country is 35.8% of total population (2017) and rate of urbanization is 3.19% (2015–2020 estimated). The rapid speed of urbanization and industrialization has led to serious environmental consequences for the developing economy like Bangladesh. Natural resource depletion due to urbanization, industrialization, energy consumption and growth and their subsequent pollution produce has elevated the spectre of environmental dilapidation threatening sustainable economic growth. A strong interactive connection between economic growth and energy supply and demand can be observed since Bangladesh's entrance to the global market. In any economy, sustainable economic growth could be achieved by sustainable environment development.

Climate change could spring from many environmental issues (i.e. anthropogenic pollutants emission from sulphur dioxide, oxides of nitrogen etc.), but this study focuses on $CO_2$ emission related problems that spur global warming. The general assumption is that intense energy consumption by city residents causes more fossil fuel burn and therefore causes large-scale of $CO_2$ emission. But the theories of ecological modernization and urban environmental transition clearly indicates that urbanization can have both positive and negative impacts on the environment despite the difficulties encountered in determining the net effect a priori. The compact city theory, on the other hand, emphasizes that urbanization improves the environmental quality. Be that as it may, since Bangladesh is still in the first stage of economic development, so it is highly likely that urbanization would lead more $CO_2$ emission, like other countries at this stage (Sadorsky 2014, 147).

The government of Bangladesh initiated an environmental policy in 1992 to control environmental degradation with sustained level of economic growth. The main objective of the National Environmental Policy was to protect, conserve and restore environment. As stated earlier that grasping the relationship between energy consumption and $CO_2$ emission is significant not only for resolving the energy sector crises, but also for long term sustainable development of the country. This paper intends to provide some policy options based on the study findings which relates to the country's national energy policy for sustainable development (Ministry of Power, Energy and Mineral Resources 2004). The policy postulates that energy should be for sustainable economic growth ensuring environmentally sound sustainable energy development program causing minimum damage to environment. This study has taken into account most of the sustainable development issues for instance, climate change, energy, urbanization (captures social development), environment with global concerns.

In this era of globalization, economies augment their interdependence through international cooperation. In order to reap the benefits of globalization, each economy needs to accelerate its growth to keep pace with global economy through trade, industrialization and social collaboration. Existing economic theories proclaim that trade between economies with different levels of environmental safeguard could lead pollution-intensive industry. Developing countries as they aspire for speedy growth have flexible environmental regulations compared to developed countries. Against this backdrop, the moot question is whether Bangladesh will be able to sustain economic growth using resources efficiently without ruining the environment?

In order to answer the question posed above this research have tied various issues like growth, energy intensity, urbanization, industrialization and economic globalization in a common thread and tries to find out the short and long-run relationships of energy intensity, urbanization, industrialization, per capita GDP growth (hereafter, growth) and economic globalization on $CO_2$ emissions. Thus the study has attempted to examine the causal relationships among energy intensity, urbanization, industrialization, growth and economic globalization on $CO_2$ emissions of Bangladesh as well.

One avenue of empirical research which remains unscathed for Bangladesh economy relates to the fact of possible asymmetries existing in the context of globalization, industrialization, energy and growth relationship. This study, probably for the first time contributes to the existing literature as it tries to see the effect of industrialization and economic globalization along with other variables on $CO_2$ emissions. Most importantly no prior study has been conducted on this issue specifically in the context of Bangladesh. The results may vary from country to country as the nature and comparative significance of energy sources of each economy is unique. Besides, the technological advancement may permit economies to enhance the use of environment friendly energy options over the time.

In order to keep the tenor of the above mentioned discourses this study is organized as follows: Introduction is presented in the first section. The next section briefly reviews the empirical evidence from the literature. The third section describes objectives of the study, the fourth section examines data sources and time series properties, the fifth section represents econometric methodology. Empirical results are analysed in the sixth section. The final section draws conclusion and policy recommendations.

## Existing Empirical Evidence

The literature on carbon emissions and economic growth is abundant and ample numbers of studies have attempted to analyse the link between energy consumption, growth and $CO_2$ emissions that examine the causal relationship among these variables. The recent stream of research has emerged, which examines the long-run co-integrating relationship and short-run dynamics among $CO_2$ emission, growth and energy consumption.

Stern (2000) investigated the relationship among income, energy use, labour, and capital stock in the US for the period 1948–1994 applying co-integration and vector error correction modelling. Findings suggest that there is mutual causality between energy consumption and GDP in the US. The study of Hossain (2011) included urbanization, $CO_2$ emissions, GDP (economic growth), energy consumption and trade of nine newly industrialized countries (Brazil, China, India, Malaysia, Mexico, Philippines, South Africa, Thailand and Turkey). The result specifies that higher energy consumption is causing more $CO_2$ emissions. But in respect of GDP, trade openness and urbanization the environmental quality are stable in the long-run. In their study of BRIC countries, Pao and Tsai (2010) found bidirectional causal relationship between pollutant emissions and energy consumption, and GDP and energy consumption in the long run but unidirectional causal relationship between energy consumption and GDP in the short run.

The study of Sharma (2011) found that urbanization has negative and significant impact on carbon emissions for a panel of 69 countries but this impact was considered insignificant in view of the size of the income-level group. Employing a STIRPAT model, Sadorsky (2014) examined the effect of urbanization on $CO_2$ emissions in 7 emerging economies. Using ARDL model he illustrates that augment in affluence, population, or energy intensity raise $CO_2$ emissions in the long-run. A study by Azam et al. (2015) on three ASEAN countries i.e. Indonesia, Malaysia, and Thailand spanning from 1980 to 2012 found that urbanization growth has significant positive effect on energy use for Thailand and Indonesia, while, population growth rate has significant positive impact on energy consumption in the case of Malaysia. The foregoing analysis reveals that urbanization growth may contribute to higher emissions, energy use through urbanization's links with industrialization process, where inhabitants move from agriculture sector to industry and services sectors. This transformation of people from rural to urban areas causes extensive energy use in many ways.

Further, the econometric estimation of Halicioglu (2009) and Zhang and Cheng (2009) includes trade, urbanization, and human development in order to avoid omitted variable bias. In the study of Zhang and Cheng (2009) the results show that neither carbon emissions nor energy consumption leads economic growth for China. York (2007) and Cole and Neumayer (2004) found a positive relationship between urbanization and $CO_2$ Emissions for a panel of 86 countries but Chen, Jia, and Lau (2008) and Liddle (2004) found that urbanization and urban density helps to increase the efficiency of public infrastructure use lowering energy consumption and emissions. Soytaş, Sari, and Ewing (2007) examine the effect of energy consumption and output on carbon emissions in the United

States. The findings suggest income does not Granger cause carbon emissions in the US in the long run, but energy use does. Hence, income growth by itself may not become a solution to environmental problems.

Employing the co-integration technique, Pao and Fu (2013) found unidirectional causal relationship between economic growth and energy consumption for Brazil from 1980 to 2010. Soheilakhoshnevis and Bahram (2014) examine the long and short run relation among carbon emissions, energy consumption, economic growth, urbanization, financial development and trade openness in Iran employing ARDL technique. Furthermore, Shahbaz and Lean (2012) incorporate the Vector Error Correction model and the findings holds the feedback hypothesis for Pakistan. Additionally, Shahbaz, Khanb, and Tahir (2013) examined the causal relationship between energy consumption and economic growth of China and finds energy consumption causes economic growth. The study of Shahbaz et al. (2013) supports the feedback hypothesis for Indonesia as well. Yang and Zhao (2014) used Granger causality tests and found that energy consumption causes carbon emissions and economic growth, but there is bidirectional causal link between $CO_2$ emissions and economic growth.

Few studies investigated the relationship among energy or electricity consumption and economic growth in the context of Bangladesh. Using time series data of South Asia including Bangladesh from 1972 to 2004 and applying ARDL technique, Khan and Qayyum (2007) found, both in the long and short-run the causality running from energy consumption to GDP in all concerned economies. Similarly, Asaduzzaman and Billah (2008) found positive relationship between energy consumption and economic growth for Bangladesh using data spanning from 1994 to 2004 and reported that higher level of energy use led to higher level of growth. Taking time series data from 1971 to 2008, Ahamad and Islam (2011) examines the energy consumption-growth nexus of Bangladesh applying the Vector Error Correction Model and found a bidirectional relationship running from electricity consumption to economic growth in the long-run. Recently Azam and Khan (2015) using STIRPAT model for 4 South Asian countries i.e. Bangladesh, India, Pakistan, and Sri Lanka from 1982 to 2013 found that urbanization has negative impact on $CO_2$ emission which leads to environmental improvement.

Above mentioned findings of different studies is a clear testimony that there exists relationship among economic growth, energy consumption and the other drivers of economic growth. Some observations deem economic growth as the prime mover of energy consumption. Others put emphasis on the significance of energy as an indispensable factor of production and consequently recommend that energy is necessary for economic growth. Some other analyses put forward that both energy consumption and economic growth affects each other. Finally, some postulates that there is no causal relationship between energy consumption and economic development.

To sum up from the above it can be concluded that available findings are not undisputed comparing their outcomes which direct to a conventional conclusion keeping it open to diverse rationalization. This study endeavours to examine the relationships among energy intensity, urbanization, industrialization, economic growth, economic globalization and $CO_2$ emission in the context of Bangladesh. We expect findings will carry a significant reference for the government of Bangladesh as well as to other developing economies to formulate their long-term energy policies for environmental sustainability without endangering their economic development.

## Objectives

The prime objective of this study is to empirically examine the impact of energy intensity, urbanization, industrialization, economic globalization and per capita GDP growth on per capita $CO_2$ emissions of Bangladesh. The specific objectives are:

- To investigate the long-run and short-run relationships among energy intensity, urbanization, industrialization, economic globalization and per capita GDP growth on per capita $CO_2$ emissions; and
- To look into the causal relationships among the variables.

## Data Sources and Time Series Properties

### DATA DESCRIPTION

This paper uses time series dataset of Bangladesh from 1980 to 2014 as the existing data period of World Development Indicator related to $CO_2$ emission and energy intensity is from 1980 to 2014. Compared to other available sources, it is the more reliable and easily accessible data source; in addition our key variables are $CO_2$ emission and Energy intensity. Annual data of all the variables except for economic globalization have been obtained from the World Development Indicators (see www.worldbank.org). Economic Globalization (EG) data have been collected from KOF. The KOF Index of Globalization (http://globalization.kof.ethz.ch) is a ranking of the most global countries based on three dimensions of globalization: economic globalization, social globalization and political globalization. The descriptions of variables with measurement are presented in the following paragraphs (all data are in the form of natural logarithm of the numbers hence their first differences approximate their growth rates):

- $CO_2$ is per capita carbon emissions (metric tons per capita)
- Y indicates GDP per capita (constant 2010 US$),
- EI signifies energy intensity (measured as energy consumption kg of oil equivalent per capita divided by GDP per capita),
- U denotes urbanization (urban population % of total),
- I is industrialization (industry, value added as % of GDP) and
- EG represents economic globalization.

Correlation matrix between variables of this study (table is not given to save space) show the highest $CO_2$ emissions correlation (99%) with urbanization followed by (97%) with per capita GDP and followed by Economic globalization (94%) and industrialization (93%) respectively. $CO_2$ emission correlates negatively with energy intensity but has positive correlation with per capita GDP growth, industrialization, urbanization and economic globalization.

#### STATIONARY FEATURE OF THE DATA

To observe some salient features of the data i.e. trend, structural breaks, seasonality and stationary quality, the graphical manifestation of the data taking natural log of both level and first difference data are used. A stationary time series of the graph always demonstrates a process of fluctuating around its mean whereas non-stationary series exhibits different mean in different periods (figures are not given to save space). From the graphs, it is evident that the variables are not stationary at level but after first differencing they become stationary and regarding the data point given the size of the observation there is no structural break. Later unit root test also confirm the same.

### Research Methodology

The model specification to investigate the effect of economic globalization, energy intensity, growth, industrialization and urbanization on $CO_2$ emissions of Bangladesh in the log-linear form is given below:

$$\ln\text{CO}_2 = \alpha + \beta_1(\ln\text{EI}) + \beta_2(\ln\text{EG}) + \beta_3(\ln\text{I}) + \beta_4(\ln\text{U}) + \beta_5(\ln\text{Y}) + \mu_t, \quad (1)$$

where $CO_2$ is the dependent variable and Energy Intensity (EI), Economic Globalization (EG), Industrialization (I), Urbanization (U) and Per Capita GDP Growth (Y) are explanatory variables. Theoretical expectation of the model is $\beta_1 > 0, \beta_2 > 0, \beta_3 > 0, \beta_4 > 0$ and $\beta_5 > 0$.

Several steps are followed to estimate the link among the variables of this study. Firstly, Augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979) unit root tests are carried out to test the stationarity of the series to get rid of spurious results. The ADF test has been carried out based on:

$$\Delta y_t = \mu + \beta_t + \sigma y_{t-1} + \sum_{j=1}^{k} \alpha_j \Delta y_{t-j} + \varepsilon_t, \quad (2)$$

where $\Delta$ is the difference operator, $t$ is the time trend, $\varepsilon$ is the error term considered as a white noise error, $y_t$ is the series and $k$ is the number of lags. Secondly, after doing the ADF test, VAR lag order selection criteria are carried out to find out the number of lags selected by the criterion.

Thirdly, co-integration tests are performed based on ADF test results using Johansen multivariate co-integration techniques proposed by (Johansen 1988) and (Johansen and Juselius 1990) to investigate the existence of long-run relationships among the variables. Fourthly, as co-integration is confirmed among the variables, Vector Error Correction Model (VECM) is used to see both the short run and long-run effects. The VECM specifications are as under:

$$\begin{aligned}\Delta\ln\text{CO}_{2\,t} = {} & \alpha_1 + \sum_{i=1}^{p}\beta_{11i}\ln\text{CO}_{2\,t-1} + \sum_{i=1}^{p}\beta_{12i}\Delta\ln\text{EI}_{t-1} + \sum_{i=1}^{p}\beta_{13i}\Delta\ln\text{EG}_{t-1} \\ & + \sum_{i=1}^{p}\beta_{14i}\Delta\ln\text{I}_{t-1} + \sum_{i=1}^{p}\beta_{15i}\Delta\ln\text{I}_{t-1} + \sum_{i=1}^{p}\beta_{16i}\Delta\ln\text{U}_{t-1} \\ & + \sum_{i=1}^{p}\beta_{17i}\ln\text{Y}_{t-1} + \gamma\text{ECT}_{t-1} + \varepsilon_{1t} \qquad (3)\end{aligned}$$

$$\begin{aligned}\Delta\ln\text{EI}_{t} = {} & \alpha_2 + \sum_{i=1}^{p}\beta_{21i}\ln\text{CO}_{2\,t-1} + \sum_{i=1}^{p}\beta_{22i}\Delta\ln\text{EI}_{t-1} + \sum_{i=1}^{p}\beta_{23i}\Delta\ln\text{EG}_{t-1} \\ & + \sum_{i=1}^{p}\beta_{24i}\Delta\ln\text{I}_{t-1} + \sum_{i=1}^{p}\beta_{25i}\Delta\ln\text{I}_{t-1} + \sum_{i=1}^{p}\beta_{26i}\Delta\ln\text{U}_{t-1} \\ & + \sum_{i=1}^{p}\beta_{27i}\ln\text{Y}_{t-1} + \gamma\text{ECT}_{t-1} + \varepsilon_{1t} \qquad (4)\end{aligned}$$

$$\begin{aligned}\Delta \ln \mathrm{EG}_t = {} & \alpha_3 + \sum_{i=1}^{p} \beta_{31i} \ln \mathrm{CO}_{2\,t-1} + \sum_{i=1}^{p} \beta_{32i} \Delta \ln \mathrm{EI}_{t-1} + \sum_{i=1}^{p} \beta_{33i} \Delta \ln \mathrm{EG}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{34i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{35i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{36i} \Delta \ln \mathrm{U}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{37i} \ln \mathrm{Y}_{t-1} + \gamma \mathrm{ECT}_{t-1} + \varepsilon_{1t} \end{aligned} \tag{5}$$

$$\begin{aligned}\Delta \ln \mathrm{I}_t = {} & \alpha_4 + \sum_{i=1}^{p} \beta_{41i} \ln \mathrm{CO}_{2\,t-1} + \sum_{i=1}^{p} \beta_{42i} \Delta \ln \mathrm{EI}_{t-1} + \sum_{i=1}^{p} \beta_{43i} \Delta \ln \mathrm{EG}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{44i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{45i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{46i} \Delta \ln \mathrm{U}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{47i} \ln \mathrm{Y}_{t-1} + \gamma \mathrm{ECT}_{t-1} + \varepsilon_{1t} \end{aligned} \tag{6}$$

$$\begin{aligned}\Delta \ln \mathrm{U}_t = {} & \alpha_5 + \sum_{i=1}^{p} \beta_{51i} \ln \mathrm{CO}_{2\,t-1} + \sum_{i=1}^{p} \beta_{52i} \Delta \ln \mathrm{EI}_{t-1} + \sum_{i=1}^{p} \beta_{53i} \Delta \ln \mathrm{EG}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{54i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{55i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{56i} \Delta \ln \mathrm{U}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{57i} \ln \mathrm{Y}_{t-1} + \gamma \mathrm{ECT}_{t-1} + \varepsilon_{1t} \end{aligned} \tag{7}$$

$$\begin{aligned}\Delta \ln \mathrm{Y}_t = {} & \alpha_6 + \sum_{i=1}^{p} \beta_{61i} \ln \mathrm{CO}_{2\,t-1} + \sum_{i=1}^{p} \beta_{62i} \Delta \ln \mathrm{EI}_{t-1} + \sum_{i=1}^{p} \beta_{63i} \Delta \ln \mathrm{EG}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{64i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{65i} \Delta \ln \mathrm{I}_{t-1} + \sum_{i=1}^{p} \beta_{66i} \Delta \ln \mathrm{U}_{t-1} \\ & + \sum_{i=1}^{p} \beta_{67i} \ln \mathrm{Y}_{t-1} + \gamma \mathrm{ECT}_{t-1} + \varepsilon_{1t} \end{aligned} \tag{8}$$

Here, $CO_2$, EI, EG, I, U and Y represents $CO_2$ emissions, energy intensity, economic globalization, industrialization, urbanization and per capita GDP respectively. The symbol $\Delta$ signifies first differences and ECT indicates error correction terms and the coefficients of ECT determine the speeds of adjustment. The sign $\alpha_1$ to $\alpha_6$ are intercepts and $p$ refers to lag lengths.

TABLE 1 ADF Unit Root Test

| Variables | Level | | 1st Difference | | |
|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (3) |
| $\ln CO_2$ | 0.431838<br>(0.9812) | −1.893040<br>(0.6340) | −5.067460<br>0.0003) | −5.031633<br>(0.0017) | I(1) |
| lnY | 7.138111<br>(1.0000) | 0.747788<br>(0.9995) | −2.398586<br>(0.1498) | −7.422360<br>(0.0000) | I(1) |
| lnEI | −0.587421<br>(0.8605) | −2.001101<br>(0.5799) | −7.325253<br>(0.0000) | −7.722324<br>(0.0000) | I(1) |
| lnU | 1.499809<br>(0.9990) | −0.379022<br>(0.9843) | −9.975108<br>(0.0000) | −9.633819<br>(0.0000) | I(1) |
| lnI | −0.322522<br>(0.9112) | −2.459462<br>(0.3448) | −5.087616<br>(0.0002) | −5.000243<br>(0.0016) | I(1) |
| lnEG | −1.340764<br>(0.5991) | −2.883777<br>(0.1800) | −5.522193<br>(0.0001) | −5.507705<br>(0.0004) | I(1) |

NOTES Column headings are as follows: (1) intercept, (2) intercept and trend, (3) order of integration. *p*-values in parenthesis.

In the fifth step, VEC Granger Causality/Block Exogeneity Wald Tests are employed to see the causal relationship among the variables. Granger (1988) implies that if two time-series variables are co-integrated, then at least one-directional Granger causation exists. Granger causality test between the variables is examined using the equations (3) to (8).

Finally, innovation accounting methods for instance, forecast error variance decomposition (VDC) is carried out. Furthermore, to determine rigorousness and stability of the estimation Breusch-Godfrey Serial Correlation LM test, Heteroskedasticity test, Jarque-Bera Normality test, Stability Diagnostic tests and Inverse Roots of AR are carried out.

## Empirical Results and Discussion

Augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979) technique is used to validate the unit root property of the series since usually the time series data provide spurious results. The ADF test is carried out both at level and at first difference. Table 1 exhibits the results:

The results presented in the table above show that all the variables are found to be non-stationary at level but after first difference all the variables become stationary and found to be integrated in the same order. At 5 percent level of significance the order of integration is I(1) implying that all series has to be differenced once in order to be stationary.

TABLE 2 VAR Lag Order Selection Criteria

| Lag | logL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 19.43317 | NA | 0.023817 | −0.902073 | −0.673052 | −0.826159 |
| 1 | 51.26215 | 51.72210* | 0.003475 | −2.828884 | −2.554059* | −2.737788 |
| 2 | 52.66904 | 2.198268 | 0.003397* | −2.854315* | −2.533685 | −2.748036* |
| 3 | 53.03951 | 0.555693 | 0.003546 | −2.814969 | −2.448535 | −2.693507 |

NOTES Endogenous variables: $\ln CO_2$, lnEI, lnU, lnI, lnY, lnEG. LR: sequential modified LR test statistic (each test at 5% level), FPE: final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion. * Indicates lag order selected by the criterion.

TABLE 3 Unrestricted Co-Integration Rank Test (Trace and Maximum Eigenvalue)

| Trace | | | Maximum Eigenvalue | | |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (1) | (2) | (3) |
| None* | 199.0195 | 0.0000 | None* | 96.20702 | 0.0000 |
| At most 1* | 102.8124 | 0.0000 | At most 1* | 38.60867 | 0.0126 |
| At most 2* | 64.20378 | 0.0007 | At most 2* | 28.07790 | 0.0432 |
| At most 3* | 36.12588 | 0.0082 | At most 3 | 19.94793 | 0.0725 |
| At most 4* | 16.17795 | 0.0394 | At most 4* | 16.10970 | 0.0253 |
| At most 5 | 0.068252 | 0.7939 | At most 5 | 0.068252 | 0.7939 |

NOTES Column headings are as follows: (1) hypothesized number of CE(s), (2) statistic, (3) probability. * Denotes rejection of the hypothesis at the 0.05 level.

The first step in the construction of a VAR model is to determine the appropriate lag length using multivariate information criterion. Table 2 summarizes the results of VAR lag order selection.

Table 2 shows that most of the criteria chooses lag 2, hence it was incorporated throughout this study as selected by FPE, AIC and HQ.

The results of co-integration test of the pertinent variables are displayed in table 3.

Johansen Co-integration Trace statistics test results identifies five co-integrating equations and maximum Eigen value results show three co-integrating equations at 5% levels of significance. As a result, the null hypothesis of no co-integration is rejected. This indicates that there have indeed long-run co-integrations in the model. The co-integration results also indicate the existence of error correction term in the model. For good measure, the long-run co-integration should be checked. Sign is reversed in the long-run in the normalization process. The significant positive relationship also implies there is truly long-run relationship among the variables and VECM long-run equation also gives the same result.

As there is co-integration VECM needs to be tested to see the short as well as long-run dynamics of the co-integrated series. The error correction model shows the speed of adjustments to reach equilibrium. The term error-correction, relates to the fact that last period deviation from long-run equilibrium influences the short-run dynamics of the dependent variable.

Conventional VECM for co-integrated series is given below:

$$\Delta y_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta y_{t-1} + \sum_{i=0}^{n} \delta \Delta x_{t-1} + \varphi z_{t-1} + \mu_t. \tag{9}$$

Results of VECM long-run and short-run are demonstrated in table 4. Estimated VECM with $CO_2$ as target variable:

$$\begin{aligned}\Delta \ln CO_{2\,t} = &-1.69 ect_{t-1} + 0.65 \ln CO_{2\,t-1} + 0.44 \ln CO_{2\,t-2} - 1.93 \ln EI_{t-1} \\ &- 0.87 \ln EI_{t-2} + 3.21 \ln U_{t-1} - 2.09 \ln U_{t-2} - 0.89 \ln I_{t-1} \\ &- 0.04 \ln I_{t-2} - 2.61 \ln Y_{t-1} + 0.17 \ln Y_{t-1} + 0.15 \ln EG_{t-1} \\ &+ 0.08 \ln EG_{t-2} + 0.029,\end{aligned}$$

where $ect_{t-1} = \varphi = 1.69$ and $\beta_0 = 0.029$. $\varphi$ is the speed of adjustment towards long-run equilibrium which is significant and negative. The economic interpretation is that as being negative it implies that if there is a departure in one direction the corrections will have to pull back to the other direction to ensure the equilibrium. VECM with $CO_2$ as target variable shows about 169% of the departure in the long run is corrected each period. As the coefficient is negative and significant it indicates the process will converge in the long run. It can also be said that depending on the speed of adjustment the explanatory variables granger causes the dependent variables.

Long-run model is given below:

$$\begin{aligned}ect_{t-1} = &\ 1.0000 \ln CO_{2\,t-1} - 1.51 \ln EI_{t-1} - 1.56 \ln U_{t-1} - 0.10 \ln I_{t-1} \\ &- 0.69 \ln Y_{t-1} - 0.09 \ln EG_{t-1} + 9.517.\end{aligned}$$

The outcome of the normalized co-integration coefficients of the VECM long-run model indicates energy intensity, urbanization, industrialization, economic globalization and per capita GDP growth have significant positive relationship with per capita $CO_2$ emissions. In the short-run urbanization, growth and economic globalization is positively

TABLE 4 VECM Long-Run and Short-Run Output

| | Variables | Coefficient | Std. error | *t*-statistics |
|---|---|---|---|---|
| Long-run | $\ln CO_2(-1)$ | 1.000000 | | |
| | $\ln EI(-1)$ | −1.515083 | 0.08452 | −17.9262 |
| | $\ln U(-1)$ | −1.566547 | 0.06361 | −24.6291 |
| | $\ln I(-1)$ | −0.105926 | 0.06682 | −1.58534 |
| | $\ln Y(-1)$ | −0.697303 | 0.05307 | −13.1403 |
| | $\ln EG(-1)$ | −0.091785 | 0.03117 | −2.94477 |
| | C | 9.517586 | | |
| Short-run | CointEq1 | −1.694896 | 0.48025 | −3.52916 |
| | $D(\ln CO_2(-1))$ | 0.659612 | 0.27361 | 2.41074 |
| | $D(\ln CO_2(-2))$ | 0.445900 | 0.24387 | 1.82843 |
| | $D(\ln EI(-1))$ | −1.932464 | 0.55170 | −3.50272 |
| | $D(\ln EI(-2))$ | −0.872762 | 0.50944 | −1.71318 |
| | $D(\ln U(-1))$ | 3.219596 | 2.39173 | 1.34614 |
| | $D(\ln U(-2))$ | −2.098407 | 1.40470 | −1.49384 |
| | $D(\ln I(-1))$ | −0.894141 | 0.34951 | −2.55827 |
| | $D(\ln I(-2))$ | −0.048883 | 0.38139 | −0.12817 |
| | $D(\ln Y(-1))$ | −2.616522 | 0.86134 | −3.03772 |
| | $D(\ln Y(-2))$ | 0.179221 | 0.80085 | 0.22379 |
| | $D(\ln EG(-1))$ | 0.150063 | 0.11367 | 1.32017 |
| | $D(\ln EG(-2))$ | 0.084669 | 0.11494 | 0.73662 |
| | C | 0.029967 | 0.04132 | 0.72522 |

related whereas, energy intensity and industrialization is negatively related with per capita $CO_2$ emissions.

To analyse the short-run and long-run causal relationship, Granger Causality in the VECM framework is estimated and table 5 illustrates the outcomes of causality test based on VECM framework. Significance at 10% level is also considered for causality test.

The existence of co-integration among the series implies that causality must be present at least in one direction. The result of the short-run causality shows energy intensity, industrialization, has unidirectional causal relationship; whereas per capita GDP has bidirectional causal relationship with $CO_2$ emission. The unidirectional causal flow from energy intensity to $CO_2$ emission, industrialization to $CO_2$ emission suggests en-

TABLE 5 Results of VEC Granger Causality/Block Exogeneity Wald Tests

| Sources of causation (ind. variable) | Dependent variable | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Short-run | | | | | | Long-run | |
| | Δ(ln$CO_2$) | Δ(lnEI) | Δ(lnU) | Δ(lnI) | Δ(lnY) | Δ(lnEG) | ECT | $t$-statistics |
| Δ(ln$CO_2$) | – | 0.160627 | 3.333069 | 2.783056 | 5.756685*** | 2.392543 | −1.694896* | −3.529163 |
| Δ(lnEI) | 12.80913* | – | 6.088729*** | 1.044411 | 2.639817 | 0.502815 | 0.075882 | 0.226237 |
| Δ(lnU) | 2.451642 | 3.169901 | – | 2.793278 | 2.035825 | 0.102226 | 0.036237*** | 1.791462 |
| Δ(lnI) | 6.898195** | 2.364208 | 1.386473 | – | 2.227114 | 0.423973 | −0.058850 | −0.157899 |
| Δ(lnY) | 10.51404* | 4.602450 | 5.167526*** | 2.462578 | – | 0.007889 | −0.275176** | −2.439649 |
| Δ(lnEG) | 2.025724 | 0.745742 | 4.433306 | 3.113987 | 4.952127*** | – | 0.509649 | 0.448521 |

NOTES *, **, and *** denotes statistical significance at the 1%, 5% and 10% level, respectively.

TABLE 6 The Variance Decompositions of $CO_2$ Emission

| Forecast horizon | For. std. error | ln$CO_2$ | lnEI | lnU | lnI | lnY | lnEG |
|---|---|---|---|---|---|---|---|
| 1 | 0.035295 | 100.0000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 2 | 0.043847 | 70.05371 | 3.220817 | 11.05283 | 7.754620 | 6.961760 | 0.956264 |
| 3 | 0.047245 | 60.53196 | 8.175865 | 13.17536 | 10.69231 | 6.575468 | 0.849034 |
| 4 | 0.050943 | 53.15406 | 8.949648 | 13.84393 | 14.42429 | 5.761196 | 3.866882 |
| 5 | 0.055409 | 45.14530 | 18.10473 | 13.10687 | 12.76269 | 5.027498 | 5.852907 |
| 6 | 0.058723 | 40.19379 | 23.33816 | 13.05944 | 11.99218 | 4.708704 | 6.707735 |
| 7 | 0.060852 | 37.47685 | 23.93401 | 14.01842 | 12.92560 | 4.398883 | 7.246234 |
| 8 | 0.062953 | 35.03783 | 24.12733 | 15.29934 | 13.64236 | 4.180135 | 7.712999 |
| 9 | 0.065456 | 32.41362 | 25.55480 | 16.22067 | 13.63348 | 3.928468 | 8.248966 |
| 10 | 0.068278 | 29.84189 | 27.57163 | 16.74752 | 13.22355 | 3.610412 | 9.004998 |

ergy intensity and industrialization lead to $CO_2$ emission. The long-run causality on the other hand is supported by the lagged error correction term which is negative and statistically significant in per capita $CO_2$ emission [$\Delta(\ln CO_2)$], and per capita GDP [$\Delta(\ln Y)$] equation. This result implies that economic growth stimulate energy consumption and consequently causes $CO_2$ emissions for Bangladesh.

To analyse the impacts of innovations in all variables on $CO_2$ emissions, this study employs variance decomposition (VDC) to get some useful insights about the short run. Variance decompositions trace out the proportion of the movements in the dependent variables that are due to their own shocks versus shocks to the other variables (Brooks 2014, 342–343). The variance decomposition is useful in evaluating how shocks reverberate through a system due to external shocks to each economic variable showing relative importance. Forecast from error variance decompositions helps to determine the proportion of variation of the dependent variable explained by each of the independent variables in the same VAR system. The variance decompositions are summarized in table 6.

The forecast horizon is yearly in the table 6. The influence on past $CO_2$ emission shocks dominates in the short-run but eventually becomes less dominant in the long-run. In the long-run energy intensity, urbanization, industrialization and growth contribute more than 60% of the $CO_2$ emission in Bangladesh. Economic globalization becomes stronger in the long-run but in explaining fluctuations in $CO_2$ emissions it contributes only 9%.

Finally, in order to verify rigorousness of the models, Breusch-Godfrey Serial Correlation LM test, Heteroskedasticity test, Jarque-Bera Normality test, Stability Diagnostic tests (CUSUM and CUSUM of Squares) and Inverse Roots of AR are carried out (table 7). From the diagnostic tests no anomalies are found. Residuals are normally distributed; there is no evidence of serial correlation and the model is dynamically stable.

## Conclusion and Policy Recommendations

This paper empirically examines the relationships among $CO_2$ emissions, energy intensity, urbanization, industrialization, economic globalization and growth in a multivariate setting. Findings postulates economic globalization, industrialization, urbanization, growth and energy intensity causes $CO_2$ emissions resulting in global warming and consequently climate change. Furthermore, it is also a widely accepted fact that energy intensity, urbanization, industrialization, economic globalization and

TABLE 7 Diagnostic Tests

| | | |
|---|---|---|
| Breusch-Godfrey Serial Correlation LM Test | *F*-statistic | 0.3339 |
| | Prob. *F*(2,16) | 0.7210 |
| | Prob. Chi-Square(2) | 0.5267 |
| Heteroskedasticity Test: Breusch-Pagan-Godfrey | Prob. *F*(18,13) | 0.8360 |
| | Prob. Chi-Square(18) | 0.6851 |
| | Prob. Chi-Square(18) | 0.9998 |
| Jarque-Bera Normality Test | Jarque-Berra | 3.0077 |
| | Prob. | 0.2222 |
| CUSUM and CUSUM of Squares Test | Stable | |
| Inverse Roots of AR | Satisfactory | |

growth are the principal forces driving the increase in energy demand; this increase in energy demand has profound effect on growth of $CO_2$ emission leading to global warming. Findings of the study also confirm the same result therefore it is assumed that in the long run, energy intensity, urbanization, industrialization and growth contribute more than 60% of the $CO_2$ emission in Bangladesh. Besides, causality test result postulates energy intensity, urbanization, globalization and growth are *raison d'être* for $CO_2$ emission. Therefore, this study opens up new insights for policy makers to formulate a comprehensive economic, financial and trade policy for continuation of growth, industrialization and urbanization by improving the environment quality. As a result, there is relatively more scope for energy conservation measures as a feasible policy for Bangladesh.

To rise above unpleasant situation of the contemporary debate of global warming and climate change, the government of Bangladesh needs to be cautious in formulating its national energy development policies, emphasizing the environment and the sustainability of energy resources. For optimal utilization of energy and to lessen $CO_2$ emissions the country could do the following. The country has many options for energy policy reform for a sustainable energy use. It is imperative to comprehend the vast human and economic potential of this country with a more balanced concern of political and economic criteria as most of the eye-catching energy options are the cause of higher carbon emissions. Hence, the composition of energy use and technological innovation should be carefully chosen for preservation of environment.

Moreover, in recent past there was a global tendency of depending more on the use of fossil fuels and non-renewable energy sources causing $CO_2$ emissions. In this backdrop, to ensure the accessibility of green and affordable energy sources has been deeply acknowledged globally keeping energy as the seventh Sustainable Development Goal (SDG) of the United Nations. Thus, use of cleaner energy sources i.e. solar, water, biogas, tidal and wave power and nuclear energy instead of fossil fuels could help decreasing $CO_2$ emissions but further research on viable composition of energy sources in the country context is needed for efficient energy use. In particular, the country could extend bio-energy usage practice for as a cleaner energy option, which can augment energy supply and reduce the trouble of waste disposal and solid waste management.

Sustainable, clean and affordable energy as a part of the SDGs, the country might preferably consider viable energy options that will contribute not only to its macroeconomic indicators but also establish harmony with the ecosystem reducing $CO_2$ emissions consequently global warming. Emerging economies like Bangladesh are on the trajectory of increasing growth. Hence, for energy efficiency, pricing on polluters could help maintaining equilibrium both in growth and environmental preservation. Finally, to facilitate the transition towards cleaner options, government's firm intervention is needed to finance the projects and the development of the country's energy infrastructures. Encouragement of urbanization with decentralization of urban population with low-carbon urban infrastructure and transportation system is desirable to reduce $CO_2$ emissions. Economic growth of the country could be accelerated through globalization and proper utilization of global technological advancement and innovation in energy sector for preserving the environment.

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