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CO_2 Emission, Energy Consumption and Economic Development: A Case of Bangladesh

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Abstract

Environmental awareness and its relation to the development of economy has garnered increased attention in recent years. Researchers, over the years, have argued that sustainable development warrants for minimizing environmental degradation since one depends on the other. This study analyzes the relationship between environmental degradation (carbon emission taken as proxy for degradation), economic growth, total energy consumption and industrial production index growth in Bangladesh from year 1998 to 2013. This study uses Vector Autoregression (VAR) Model and variance decomposition of VAR to analyze the effect of these variables on carbon emission and vice-versa. The findings of VAR model suggest that industrial production and GDP per capita has significant relationship with carbon emission. Further analysis through variance decomposition shows carbon emission has consistent impact on industrial production over time, whereas, industrial production has high impact on emission in the short run which fades in the long run which is consistent with Environmental Kuznets Curve (EKC) hypothesis. Carbon emission rising along with GDP per capita and at the same time having low impact in the long run on industrial index indicates there may be other sources of pollution introduced with the rise in income of the economy over time.

Keywords: Energy consumption, CO_2 emission, Environment degradation, Economic development, Bangladesh.

JEL Classification Code: O13, P48, Q56.

1. Introduction

Researchers have argued that the development of an economy is directly related to environmental awareness which gained significant attention in recent years (Teodorescu, 2012; Muhyidin, Saifullah, & Fei, 2015). In the long run, development of an economy may have significant impact on environment. On the other hand, environmental changes are also expected to have impact on the economy. Energy has been one of the driving force of economic development. A number of researchers have argued that the growing consumption of energy has been the core reason of increased carbon emission, thus resulting in environmental degradation. Hence, climate change and its impact has been a growing concern all over the world.

In a recent report by International Energy Agency (2016) it was mentioned China alone contributes 28% of global carbon emission and sector wise electricity and heat contributes 42% of the carbon emission. CO_2 emission in Bangladesh has increased from 9,123 (kt) in 1984 to 57,070 (kt) in 2011 which places the nation at 53rd position among the top 60 with CO_2 emissions from gaseous fuel consumption country (The World Bank, 2017). If the trend persists, Bangladesh may continue to move up the ranking despite the implementation of new green energy policies since the nation still largely depend on fossil fuels (crude oil, natural gas, coal and coke) energy sources.

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There has been enormous demand for electricity, oil gas and natural resources in the agriculture, industry, service sector alongside the daily life of people in Bangladesh. According to Ministry of Finance (2016) currently 76 percent of the total population of the country has access to electricity (including renewable energy) and, natural gas has almost met 72 percent of the country's total commercial use of energy. The share of gas, hydro, coal, import and oil based energy generation were 68.63 percent, 1.84 percent, 1.62 percent, 7.32 percent and 20.58 percent respectively.

From historical data, it is found that in FY1995-96 maximum electricity generation was 2,087 MW which has increased to 9,036 MW on 30st June 2016. With increasing industrialization, extensive urbanization, growing population and rising standard of living - demand for electricity has been growing extensively. However, to what extent consumption of electricity has detrimental effect on the environment is yet to be measured. In recent years there has been growing concern regarding this relationship between energy consumption and environmental awareness and sustainable economic development.

Consumption of energy depends mostly on the stage of economic development. This paper attempts to investigate the long-run relationship between environment degradation (emission of CO_2, responsible for climate change), income, energy consumption and industrial production index growth in Bangladesh from year 1998 to 2013. One of the main limitation of this study is the availability of data beyond the selected time period.

2. Literature Review

As world population is increasing, industrialization is spanning - a number of studies have been carried out to see the linkages between CO_2 emission, energy consumption and economic growth around the world. Energy consumption plays an important role in economic growth. Kraft and Kraft (1978) were the pioneers in this field of study where they investigated the relationship between energy consumption and economic growth by using various econometric methods for different time periods. The pioneering work of inverted U-shaped relationship between economic growth and income inequality has been later reformulated to test similar inverted U-shaped relationship between economic growth/income and environmental quality (Kuznets, 1955). According to the reformulated hypothesis, as initial per capita income rises, there is increasing environmental degradation. However, after reaching a critical level of economic growth it tends to decrease. Thus, on a similar note, Rothman and De Bruyn (1998) argue that economic growth may become a solution rather than a source of the problem.

Dinda (2004) in his report reviews some of the empirical studies on Environmental Kuznets Curve (EKC) hypothesis. He found that the evidences of EKC are questionable with different types of pollutants. The study proposed that further studies on income level and pollutant emission to incorporate proper economic modeling. Structural and decomposition analysis is promoted to have better results than reduced-form model analysis. Also, the addition of time series analysis is to complement existing panel data analysis - as it provides a better understanding of a country's development and its pollution level over time.

Chen (2009) detected the existence of co-movement between environmental degradation and income in China. China's economic growth and export trade significantly elevated its carbon emissions, and the rapid economic growth is the main determinant of increased carbon emissions (Yue, Long, Chen, & Zhao, 2013; Wang, Fang, Guan, Pang, & Ma, 2014). Investigation by Lee (2005) found long-run and short-run causalities from energy consumption to GDP, however there no evidence of reverse causality. This finding suggested that economic growth might have adverse effects on energy conservation, which may be a temporary or a permanent trend in developing countries. Halicioglu (2009) found bidirectional Granger causality in the long run and short run between economic growth and carbon emissions while Soytas, Sari, and Ewing (2007), and Soytas and Sari (2009) found unidirectional Granger causality running from energy consumption to carbon emissions in the long run.

Zhang and Cheng (2009) analyzed causality between economic growth, energy consumption and carbon emission. In their analysis, they found uni-directional causalities running from economic growth to energy consumption and energy consumption to carbon emissions in the long run. A study by Belke, Dobnik, and Dreger (2011) provides a new insight on the relationship between total energy use by the population and income development level for 25 OECD countries. Cointegration analysis and dynamic panel causality method was applied in their study indicating a two-way causality through Granger method testing between total energy use by the population and income development level. Stolyarova (2009) established short-run relationship between CO_2 emissions and its determinants by analyzing the relationship between CO_2 emissions and economic growth, using a panel data set of 93 countries for 1960-2008. In her analysis, it was found that the growth rate of per capita GDP has a strong positive impact on the growth rate of per capita CO_2 emissions while it has an inverse relationship with the growth rate of the energy mix. According to Islam, Shahbaz, Ahmed, and Alam (2013)

research on the effect of South Africa's economic growth and coal consumption on CO_2 emissions over the period 1965–2008 showed that with increasing economic growth energy emissions also increases, coupled with coal consumption, making a significant contribution towards deterioration of the environment.

In an analysis by Al-mulali, Fereidouni, Lee, and Sab (2013) it was found that about 60% of Latin American and Caribbean countries maintained a positive bidirectional long-run relationship between energy consumption, CO_2 emissions, and economic growth, the remaining 40% yield mixed results. Further study by Saboori, Sapri, and bin Baba (2014) explores the long-run causality among the total energy use by transportation industry, environmental degradation and income development level for OECD countries. The authors conduct a fully modified OLS estimation to explain the cointegration equation in the series. Also, shock to total energy use by transportation industry, environmental degradation and income development level are analyzed in the study through impulse response function. A study by Islam et al. (2013) also incorporated financial development in their study. They found evidence indicating that an advancement in financial sector lead to a decline in pollution level due to increase in efficiency within the industries. They employed the VECM estimation to estimate the Granger causality between the variables. Results from their two-time period estimation indicate that total energy use by the population in Malaysia is influenced by its financial development and GDP growth. In a more recent study, Muhyidin, Saifullah, and Fei (2015) suggested that the economic sustainability will not be affected by pollution abatement policies for CO_2 emission. Moreover, current energy use policies should be complimented with renewable energy resources such as, wind, bio-fuel and solar energy.

Industrial outputs are known to emit high level of pollution especially from developing countries. Chen (2009) conducts a test between industrial output and input of Chinese industries, income development level, pollutant emission and total energy use by the population. The author found a positive relationship between total energy use by the population and capital to the industrial production index growth. However, industrial production index growth is negatively affected by pollutant emission and employment level. The author suggests technology-driven policies to control for emission while maintaining positive income development.

3. Research Methods and Data Source

This research adopts a similar technique used by Islam et al. (2013) and Muhyidin, Saifullah, and Fei (2015) to study the relationship between per capita CO_2 emissions (E), per capita gross domestic product (GDP), per capita energy consumption within the country (EC) and industrial production index growth (IPI).

Where,

$E = f (GDP, EC, IPI)$

$Et = \alpha 0 + \alpha 1GDPt + \alpha 2ECt + \alpha 3IPIt + \mu t$

This study uses data from the year 1998 to 2013 of Bangladesh economy from the World Bank Data Bank. In this study, all variables are transformed into log-linear forms except industrial production index growth (IPI) because IPI data is already in percentage. This study uses Phillips-Perron (PP) test for unit root test. Followed by Johansen cointegration test. To study the relationship between the variables this study used VAR model and variance decomposition of VAR.

4. Result Analysis and Discussion

Unit root tests are conducted for the full sample period with two lags in order to determine the stationarity characteristics of the individual variables. These test results are summarized in Table 1. The result of PP unit root test indicates that all selected variables are stationary and integrated at 2nd difference, and the result is not consistent with Azlina and Mustapha (2012), Saboori and Sulaiman (2011), and Muhyidin, Saifullah, and Fei (2015). However, those studies also used PP unit root test.

Table 1: Phillips-Perron (PP) unit root result

	Level	1st difference	2nd difference
Variable	P-value	P-value	P-value
EC	0.9972	0.0140**	0.0001***
E	0.9840	0.0182**	0.0001***
GDP	1.0000	0.7534	0.0947*
IPI	0.0371**	0.0005***	0.0003***

Notes: *** indicates 1%, ** indicates 5% and * indicates 10% level of significance.

The evidence of cointegration in the series is analyzed by applying the Johansen cointegration test. Table 2 summarized the result from trace statistics and maximum eigenvalue of Johansen cointegration test with null hypothesis of no presence of cointegrating equations among the variables.

Table 2: Johansen cointegration tests result

Hypothesized No. of CE(s)	Trace Statistics	Maximum Eigenvalue
r = 0	90.12667***	46.04756***
r ≤ 1	44.07911***	21.53421**
r ≤ 2	22.54490***	16.75833**
r ≤ 3	5.786564**	5.786564**

Notes: *** indicates 1% and ** indicates 5% level of significance

The result shows that at every rank for the both trace statistics and maximum eigenvalue values are significant at 5% level. Therefore, there is no evidence of cointegrating equation among the four variables. Since there is no cointegration, study proceeds to unrestricted VAR model (Ali, Saifullah, & Kari, 2015).

4.1. VAR Model Estimates

The VAR model is estimated by using E, GDP, EC and IPI. Unrestricted VAR in level has been performed to understand the effects and relationships. In the vector autoregression estimates, two lags have been used with a constant for each variable. Table 3 shows the regression result of the model. The high values of adjusted R-squared suggest that the fit is good for each variable of the model. The F-statistic is very high for each variable of the model which means it is a good fitted model and independent variables of each model explains the variation of dependent variable. Table 3 also shows that both lag of GDP and 1st lag of IPI is significant at 5% confidence level. Hence, CO_2 emissions in Bangladesh are stimulated by its per capita gross domestic product and industrial production growth. The VAR result is consistent with Stolyarova (2009), Yue et al. (2013) and Wang et al. (2014), however, in Malaysian industrial production growth and economic growth stimulates energy consumption (Muhyidin, Saifullah, & Fei, 2015).

Table 4 shows the variance decomposition results for the VAR model for the next 10 years. Variance decomposition of E shows that, GDP has a weak effect on E in the short run, but in the long run GDP has stronger effects on Lee (2005) came to a similar conclusion; on the other hand, Stolyarova (2009) found that E has a stronger relationship with GDP in short run. The table shows that GDP has a weak effect on E until year three, but it increases to 55.58 in year five. Then it drops slightly over the next two years to 51.62 and eventually go up to 55.68 by the 10th year. Similar analysis shows the effect of E to GDP is very small but somewhat consistent over time. The results indicate higher emission associated with rise in income. On the other hand, IPI has a strong short run effect to E and the effect is weaker in long run and the effect of E to IPI is weak but consistent over time which is supported by the hypothesis of EKC (if the assumption of development reliant on industrialization is taken); environmental degradation occurs in the early stage of development and subsequent turning point which leads to better environmental condition (Grossman & Krueger, 1991; 1995; Galeotti, Lanza, & Pauli, 2006; Fodha & Zaghdoud, 2010; Puzon, 2012). In case of Bangladesh increased carbon emission (having weak relation with Industrial production) with increase in GDP could possibly arise from other sources created, which calls for attention. Further investigations can be undertaken to identify the potential sources and mitigate the problems to achieve sustainable development.

Similarly, variance decomposition shows the impact of EC on E does not vary much between short and long run. The effect of E on EC is observed to decrease with passage of time. The findings differ slightly with Soytas, Sari and Ewing (2007), Soytas and Sari (2009), Zhang and Cheng (2009).

Table 3: VAR Estimates

	E(-1)	E(-2)	GDP(-1)	GDP(-2)	EC(-1)	EC(-2)	IPI(-1)	IPI(-2)	C
	0.07	0.63	-0.76**	1.43**	-0.23	-0.35	0.00**	-0.00	-1.23
R-squared	0.996								
Adj. R-squared	0.989								
Sum sq. resids	0.000								
S.E. equation	0.008								
F-statistic	147.74								
Log likelihood	54.96								
Akaike AIC	-6.56								
Schwarz SC	-6.16								
S.D. dependent	0.076								

Notes: ** indicates 5% level of significance

Table 4: Variance Decomposition of VAR Models

Variance Decomposition of E					
Period	**S.E.**	**E**	**GDP**	**EC**	**IPI**
1	0.007159	100.0000	0.000000	0.000000	0.000000
2	0.009993	63.24150	3.357793	22.55720	10.84350
3	0.011589	51.86421	2.876199	23.97942	21.28018
4	0.015201	33.36009	31.24760	21.76006	13.63225
5	0.020475	19.11642	55.58323	17.76950	7.530845
6	0.021557	18.13781	52.12301	22.74510	6.994077
7	0.022954	20.21424	51.62206	20.33861	7.825088
8	0.024960	17.44065	56.43903	18.33459	7.785734
9	0.026089	17.08192	57.65971	17.99305	7.265317
10	0.026958	16.11901	55.67884	21.37719	6.824957
Variance Decomposition of GDP					
Period	**S.E.**	**E**	**GDP**	**EC**	**IPI**
1	5.616059	1.187668	98.81233	0.000000	0.000000
2	10.97521	1.261428	97.41281	1.211638	0.114125
3	15.04684	0.738519	98.28302	0.878488	0.099974
4	17.94862	0.836717	97.86867	1.224148	0.070461
5	20.01408	1.523960	97.30595	1.113415	0.056671
6	21.40629	1.739825	96.71840	1.486746	0.055024
7	22.91618	1.980732	96.43068	1.528995	0.059589
8	24.99818	1.776210	96.53650	1.631834	0.055458
9	27.53206	1.628940	96.84087	1.484424	0.045763
10	30.19821	1.468346	96.86606	1.627099	0.038499
Variance Decomposition of EC					
Period	**S.E.**	**E**	**GDP**	**EC**	**IPI**
1	2.220639	42.70781	13.33983	43.95236	0.000000
2	3.159622	31.75171	8.622308	51.41105	8.214940
3	3.500724	30.28786	8.922192	44.03496	16.75500
4	4.794142	19.16561	42.52552	28.37014	9.938728
5	6.267350	12.29160	60.57490	21.31578	5.817724
6	6.604486	11.51221	57.42904	25.57063	5.488119
7	7.012896	13.98678	56.95170	22.95560	6.105912
8	7.554786	12.32021	60.48140	21.07629	6.122102
9	7.956735	12.17877	62.23006	19.93094	5.660230
10	8.276817	11.37905	61.17443	22.16797	5.278551
Variance Decomposition of IPI					
Period	**S.E.**	**E**	**GDP**	**EC**	**IPI**
1	2.729765	7.656510	43.37781	32.60065	16.36503
2	2.845250	8.264732	41.08499	31.37828	19.27200
3	2.960043	8.866042	38.53278	30.97897	21.62220
4	3.608757	7.644613	50.57110	25.15140	16.63288
5	3.755104	7.546043	52.43489	23.38325	16.63582
6	4.424155	6.649095	60.26395	18.15001	14.93695
7	4.475845	6.552753	61.00946	17.74522	14.69256
8	4.737869	6.165267	60.82359	19.20238	13.80876
9	4.855905	6.086262	60.74827	19.95025	13.21521
10	4.890160	6.660286	59.90107	19.77527	13.66337

5. Conclusion and Recommendation

This paper investigates the relationship between environmental degradation (through carbon emission), income, energy consumption and industrial production index growth in Bangladesh. This topic deserves special attention since the growth of any developing economy is associated with degradation of the environment due to heavy reliance and consumption of pollutant emitting energy sources (Ueta & Mori, 2007). At the same time, substantial economic growth can help achieve better quality of the environment which could ensure sustainable economic development.

Findings from VAR analysis suggest that in the case of Bangladesh, GDP per capita and industrial production have significant relationship with CO_2 emission. Further analysis through variance decomposition shows carbon emission has consistent impact on industrial production over time, whereas, industrial production has high impact on emission in the short run which fades in the long run which is in consistence with EKC hypothesis (Grossman & Krueger, 1995; Galeotti, Lanza, & Pauli, 2006; Fodha & Zaghdoud, 2010; Puzon, 2012). This is an indication that Bangladesh may be nearing the turning point where further development could be achieved with low carbon emission if other sources of emission can be tackled.

CO_2 emission rising along with GDP per capita and at the same time having low impact in the long run on industrial index growth indicates that there may be other potential source of carbon emission created with development which can be looked into in further studies. Also, consistent impact of CO_2 emission on energy consumption indicates that investment in environment friendly technology is something which can be addressed with more importance to ensure sustainable development.

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