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Testing the Environmental Kuznets Curve Hypothesis in Bangladesh

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Abstract

The environmental Kuznets curve (EKC) indicates an inverted U-shaped relationship between economic growth and environmental degradation. It implies environmental degradation or pollution rises at the early stage of economic growth but will tend to decrease at the level of high income. The aim of this study is to investigate the existence of the EKC for an emerging economy in Asia, Bangladesh, over the 1971-2014 period using the Johansen cointegration technique and vector error correction model (VECM). For this purpose, this study used two different pollutants: carbon dioxide (CO_2) emissions per capita and nitrous oxide (N_2O) emissions per capita as the environmental indicator and GDP per capita as the economic indicator. Energy use per capita and trade openness are also used in this study to avoid omitted variable bias. The empirical result indicates a statistically significant long run relationship between the per capita emissions of two pollutants and the GDP per capita. The empirical result also confirms the existence of the inverted U-shaped EKC for both the pollutants (CO_2 and N_2O). The income turning points equal to 727 US$ per capita and 554 US$ per capita have been found for CO_2 and N_2O, respectively. This study suggests that Bangladesh should formulate sustainable economic policies to control environmental degradation. In particular, development plans should have specific policies and guidelines to reduce carbon emissions.

Keywords: *GDP per capita, CO_2 emissions, EKC, Cointegration, VECM*

1. Introduction

Bangladesh is one of the fastest-growing economies and one of the next eleven emerging economies globally. According to the International Monetary Fund (2019), Bangladesh is the 39th largest economy in the world in terms of nominal GDP and the 29th largest in terms of purchasing power parity (PPP). It is the second-largest economy in South Asia after India. According to the United Nations Department of Economic and Social Affairs (2019), Bangladesh has a population of 165 million. Over the last ten years, Bangladesh has maintained an average GDP growth rate of 7 percent. Once upon a time, Bangladesh was known

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as an agricultural country. In recent years, the contribution of agriculture to the country's GDP has been declining, while the industrial sector's contribution has been increasing. Currently, the contribution of agricultural, industrial, and services sectors to GDP in Bangladesh is 13.31 percent, 31.31 percent, and 55.38 percent, respectively (2020). The economic growth of Bangladesh has accelerated in the last two decades due to its industrial growth. In this case, trade liberalization is the key driving force for higher economic growth and development.

At present, many developing countries have adopted the "grow first, clean up later" approach, where higher economic growth is considered as the primary goal, regardless of its environmental impact (Waluyo and Terawaki, 2016). The concept of higher economic growth is associated with the issue of higher energy consumption and environmental degradation in most developing countries. Intensive use of energy resources, on the one hand, plays a crucial role in economic growth; on the other, it creates more significant pressure on the environment through either the rapid depletion of natural resources or the creation of by-product pollutants (Sugiawan and Managi, 2016). According to scientific research, it is clear that human activities are highly responsible for global warming. Global warming and air pollution have been considered the most severe environmental problems for the last three decades. The emission of greenhouse gases is the leading cause of global climate change, and excessive emissions of CO_2 are compounding the problem. Higher economic growth, increasing people's living standards, and their economic activities can be attributed to the gradual increase in worldwide emission of greenhouse gases and global warming (Ali et al., 2017). The contribution of Bangladesh to global CO_2 emissions is still relatively low. In 2016 per capita CO_2 emission was only at 0.46 metric tons, which was much lower than the OECD average of 9.6 tons in 2014 and the rest of the world average of 4.8 metric tons in 2016 (OECD, 2015; JRC, 2016). However, CO_2 emissions by Bangladesh have been increasing rapidly since 2010 because of more reliance on coal and oil, especially for power generation and industrial production. As Bangladesh is in the very early stages of economic development, it can be said with certainty that as economic activities increase, CO_2 and other greenhouse gases emissions will increase further in the future.

At present, an important public policy agenda for the authorities of any developed and developing countries is to assess and analyze the impacts of higher economic growth on the environmental quality and set policy. Researchers have empirically modeled the relationship between environmental quality and economic growth through the emissions-income nexus. The outcome of most of these empirical studies is known as the so-called environmental Kuznets curve (EKC) hypothesis (Jalil and Mahmud, 2009). The main objective of this paper is to test the validity of the EKC hypothesis in Bangladesh empirically. Bangladesh is one of the fastest growing economies in the world; an answer to this important relationship can be of interest to the policymakers of the country.

The rest of the paper is organized as follows: Section Two explains the Environmental Kuznets Curve hypothesis, Section Three reviews the existing empirical literature on this issue, Section Four highlights the trends of GDP per capita and environmental variables, Section Five represents the methodology of the study, Section Six demonstrates the results of econometric analysis, and finally, Section Seven concludes the study.

2. Environmental Kuznets Curve (EKC) Hypothesis

Economist Simon Kuznets (1955) proposed a hypothesis relating to income inequality and economic growth. According to this hypothesis, income inequality increases at an early stage of economic growth, then peaks and declines as economic growth proceeds. This relationship was later named after Simon Kuznets as an inverted U-shaped Kuznets curve (Stern, 2004). Afterward, this hypothesis was extended to the relationship between environmental degradation and economic growth and turned to the name "environmental Kuznets curve" (EKC). Environmental degradation rises at the initial stage of economic growth, but it will tend to decrease (environmental improvement) at the level of high income. It also implies that environmental degradation (pollution) is an inverted U-shaped function of economic growth.

The EKC was first proposed by Grossman and Krueger (1991) in their study of the potential impacts of the North American Free Trade Agreement (NAFTA) and the concept's popularization through the World Bank Development Report 1992 (Islam and Shahbaz, 2012; Stern, 2004). In the first phase of economic growth, trade and investment liberalization expand economic activities that cause an increase in demand for energy. Excessive energy use in the production process generates harmful pollutants, known as a scale effect. In the second phase, a composition effect arises from a change in trade policy. The composition effect will damage the environment if a substantial competitive advantage stems from differences from environmental regulation. Finally, the production of output shifts from energy-intensive industries to technology-intensive industries as income rises. This shift in production reduces harmful pollutants, which refers to a technique effect (Grossman and Krueger, 1991).

On the other hand, the N-shaped EKC occurs if the original Grossman and Krueger's EKC hypothesis does not hold in the long run. Environmental degradation may increase again in the long run instead of declining beyond a certain income level. The N-shaped EKC emerges because the domination of scale effects may be bigger than the composition and technical effects (Allard et al., 2018).

3. Review of Empirical Literature

There are so many empirical studies that have been done focusing on the existence of the inverted U-shaped relationship between environmental indicators (e.g., CO_2, SO_2, N_2O, etc.) and economic growth. There is a considerable variation in the results of empirical studies regarding the existence of the EKC hypothesis. Many researchers have found evidence for the inverted U-shaped EKC in their studies. By applying the autoregressive distributive lag (ARDL) model to cointegration for the period 1971-2010, Sugiawan and Managi (2016) confirmed the existence of an inverted U-shaped EKC relationship between economic growth and CO_2 emissions for Indonesia. They also found an estimate of income turning point equals to 7729 US$ per capita. Kanjilal and Ghosh (2013) revisited the cointegrating relationship between CO_2 emissions, energy use, and economic activity using the data from 1971 to 2008. They found the presence of 'regime-shift' cointegration among the variables and confirmed the validity of an inverted U-shaped EKC for India. Hao et al. (2016) investigated the existence of the EKC for per capita coal consumption in China utilizing panel data of 29 Chinese provinces during 1995 and 2012. Using a spatial Durbin model (SDM) to control potential spatial dependence, they found evidence of the inverted U-shaped EKC relationship between per capita coal consumption and the GDP per capita. By applying the cointegration technique with the time series data for 1968-2007, Tutulmaz (2015) confirmed an inverted U-shaped EKC relationship between CO_2 emissions and GDP per capita in Turkey.

Some researchers examined the EKC hypothesis using more than one environmental indicator such as sulfur dioxide (SO_2), nitrous oxide (N_2O), Methane (CH_4), and ecological footprint (EF) as an alternative to CO_2 emissions (Mrabet and Alsamara, 2017). Fodha and Zaghdoud (2010) investigated the EKC hypothesis for Tunisia from 1961 to 2004 using CO_2 emissions and SO_2 emissions as the environmental indicators and GDP per capita as the economic indicator. Their results demonstrated a long-run cointegrating relationship between per capita emissions of two pollutants and the GDP per capita. They confirmed an inverted U-shaped EKC relationship only between SO_2 emission and GDP per capita. They calculated an income turning point approximately equal to 2000 US$. Mrabet and Alsamara (2017) examined the presence of the environmental Kuznets curve using two different environmental indicators: CO_2 emissions and the ecological footprint (EF) in Qatar from 1980 to 2011. By employing the ARDL method with the presence of unknown structural breaks, they did not find evidence of the inverted U-shaped EKC hypothesis for the case of CO_2 emissions. Still, they confirmed the existence of this hypothesis when using ecological footprint.

On the other hand, some empirical studies did not support the inverted U-shaped EKC hypothesis. Robalino-Lopez et al. (2015) tested the validity of the EKC hypothesis for Venezuela between 1980 and 2025, and they did not find the validity of the inverted U-shaped EKC hypothesis for Venezuela when using CO_2 emissions. By applying panel cointegration tests, Azomahou et al. (2006) rejected the inverted U-shaped EKC hypothesis for a panel of 100 countries during the period 1960-1996. Ozcan (2013) investigated the EKC hypothesis for 12 Middle East countries from 1990-2008 using panel data methods. The results of his study did not support the inverted U-shaped relationship between environmental degradation and income per capita. Furthermore, Wang (2012) examined the relationship between CO_2 emissions and GDP per capita employing panel data of 98 countries from 1971 to 2007. He argued that a threshold effect between the two variables exists and also rejected, based on empirical results, the inverted U-shaped EKC hypothesis.

In the case of Bangladesh, the majority of the researchers have tried to find out the impact of energy consumption on economic growth. To best of my knowledge, only a few empirical studies have been done focusing on this issue without applying advanced econometric techniques. For example, Sharker et al. (2010) examined the EKC hypothesis for

Bangladesh using time series data from 1972 to 2000. By employing both classical and bootstrap techniques, they confirmed that an increase of CO_2 emission per capita did not have a self-limiting point linked to increasing GDP per capita in Bangladesh, as noted in the EKC hypothesis. Alam (2014) revisited the presence of the EKC relationship using one environmental indicator in Bangladesh during the period 1972 to 2010. By applying trend analysis of CO_2 emissions according to GDP per capita, he did not find evidence of inverted U-shaped EKC for the case of CO_2 emissions. Using the ordinary least squares (OLS) method and data from 1981 to 2011, Husain (2016) investigated the EKC hypothesis for Bangladesh. The results of her study confirmed the existence of the EKC relationship in Bangladesh, but this result is not robust to using a dynamic model. An analysis of these previous studies has shown that no sophisticated econometrics techniques have been used. The present study uses advanced empirical techniques, and includes a number of control variables compared to the previous studies, thus providing more updated information about the relationship between economic growth and environmental degradation in Bangladesh.

4. Trends in GDP Per Capita and Environmental Variables

Bangladesh has been experiencing an upward trend in real GDP per capita for the last five decades. The per capita real GDP in Bangladesh was USD 380.94 in 1971, increasing to USD 951.31 in 2014 (Table A2 in Appendix). Figure 1 shows the trend of the per capita real GDP for 1971 and 2014. The per capita GDP continuously incremented over the five decades with some minor fluctuations. From 1971 to 1990, it increased very slowly. After 1990, the per capita GDP continued to overgrow, never declining until 2014. Figure 2 demonstrates the trends in two different emissions: CO_2 and N_2O. The per capita CO_2 emissions (tons) also continuously incremented over the five decades with some minor fluctuations. The per capita CO_2 emissions in 1971 were 0.047 tons which increased almost nine times in 2014 to 0.41 tons. On the other hand, the per capita N_2O emissions (tons) were almost constant over the last five decades. One thing is clear from the two figures that the real GDP per capita increased two and half times during the period, but the CO_2 emissions per capita increased almost nine times.

Figure 1: Trend of GDP per capita

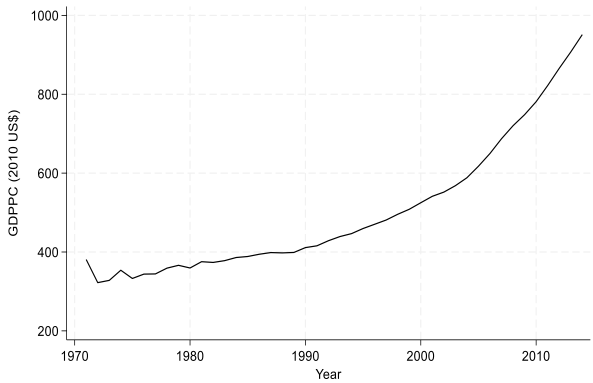
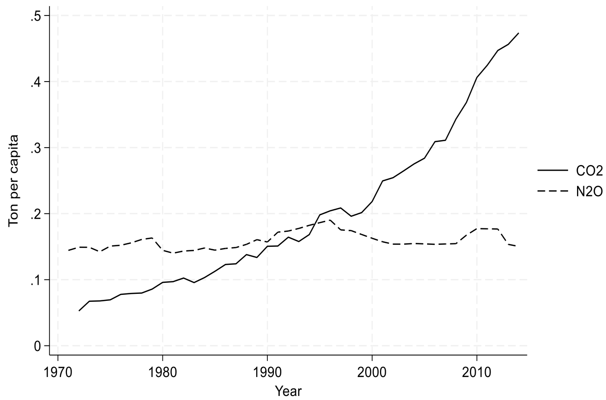


Figure 2: Trends of CO_2 and N_2O



Source: Constructed by the author based on data from World Development Indicators 2019, World Bank.

5. Methods and Materials

In this study, carbon dioxide (CO_2) emission per capita and nitrous oxide (N_2O) emissions per capita are used as the environmental indicators, and GDP per capita is used as the economic variable. CO_2 and N_2O emissions have been selected as environmental indicators considering their impact on the environment. Both of them have detrimental effects on human health and ecological health. Both types of emissions are responsible for increasing greenhouse gases, acid rain, and the problem of global warming. The impact of N_2O is more local, while the impact of CO_2 is global (Fodha and Zaghdoud, 2010). The long-run relationship between economic growth and environmental degradation, under the EKC hypothesis, can be expressed by a nonlinear quadratic function of the income. After reviewing the available literature related to this issue (Jalil and Mahmud, 2009; Fodha and Zaghdoud, 2010; Mrabe and Alsamara, 2012, and Sugiawan and Managi, 2016), the following factors, such as GDP per capita, trade openness, and energy consumption per capita can be considered as the determinants of environmental degradation. Most of the relevant economic and environmental varia bles are considered here based on the availability of data and the previous literature. The empirical equation for this study is represented in a quadratic form which is as follows (Mrabe and Alsamara, 2012):

$$ED_t = f(Y_t, Y_t^2, EC_t, TOP_t) \quad (1)$$

It is necessary to transform all variables to their logarithmic to obtain consistent empirical results. The log-linear form of Equation (1) is as follows:

$$lnED_t = \alpha + \beta_1 lnY_t + \beta_2 lnY_t^2 + \beta_3 lnEC_t + \beta_4 lnTOP_t + \varepsilon_t \quad (2)$$

Where $lnED_t$ is a natural log of the environmental degradation variable (it can be either CO_2 or N_2O), lnY_t, $lnEC_t$, and $lnTOP_t$ are a natural log of per capita real GDP, energy use per capita, and trade openness, respectively. ε_t is the error term with white noise properties, α is a scalar parameter, and β_1-β_4 are the parameter of interest, which indicate the long-run elasticity of Y_t, $Y^2{}_t$, EC_t, and TOP_t. Table A1 represents definitions of all variables and data sources of these variables in the Appendix. The relationship between environmental degradation and economic growth can take various forms depending on the signs of the estimated coefficient β_1 and β_2. If $\beta_1>0$ and $\beta_2<0$, an inverted U-shaped EKC is valid in the nonlinear function. If the opposite happens, It will be U-shaped, i.e., $\beta_1<0$ and $\beta_2>0$. The relationship will be monotonically increasing when $\beta_1>0$ and $\beta_2 = 0$. It is expected that $\beta_3>0$ since a higher level of energy consumption and economic activities cause higher emissions of CO_2 and N_2O. The effect of trade openness on environmental degradation is mixed depending on the stage of economic development. That's why the expected sign of β_4 may be negative for developed countries and vice versa for developing countries (Jalil and Mahmud, 2009). Since this study uses two different environmental indicators, CO_2 and N_2O, to test the validity of the EKC hypothesis, two separate equations can be constructed from Equation (2). Here, Equation (3) is constructed for CO_2 emissions and Equation (4) for N_2O emissions:

$$lnCO_{2t} = \alpha + \beta_1 lnY_t + \beta_2 lnY_t^2 + \beta_3 lnEC_t + \beta_4 lnTOP_t + \varepsilon_t \qquad (3)$$

$$lnN_2O_t = \beta + \alpha_1 lnY_t + \alpha_2 lnY_t^2 + \alpha_3 lnEC_t + \alpha_4 lnTOP_t + \varepsilon_t \qquad (4)$$

5.1 Data and Methods

To determine the long-run equilibrium relationship between economic growth and environmental degradation, the study uses the vector error correction model (VECM) depending on the Johansen (1991) cointegration test results. The sample period for investigation is 1971 to 2014. The number of sample observations is compatible with the cointegration technique. The empirical analysis of this study employs annual secondary data collected from World Development Indicators 2019 (World Bank, 2019b), Environmental Social and Governance Data-2019 (World Bank, 2019a), and Emission Database for Global Atmospheric Research-2016 (JRC, 2016). Most of the macroeconomic time series are nonstationary by their nature; they have unit roots. These series can be made stationary through differencing or detrending. The time series considered in this study are also likely to be nonstationary in their levels. Therefore, traditional empirical techniques such as the ordinary least squares (OLS) may not apply to such data since they may produce spurious regression. However, differencing the time series causes a problem in the long run analysis. One of the best techniques to get rid of this problem is the cointegration test, by which the existence of the long-run equilibrium relationship can be tested (Jalil and Mahmud, 2009). That's why the techniques of cointegration and vector error correction mechanisms are appropriate for handling non-stationary series (Gujarati, 2003: 805-820).

6. Empirical Findings

6.1 Descriptive Statistics of Variables

Table 1 shows the summary statistics of the variables that are included in the model. Before performing any econometric analysis, it is necessary to understand the characteristics of the variables. Generally, values for skewness zero (β_1=0) and kurtosis three (β_2=3) demonstrate that the variable is normally distributed. It is seen from Table 1 that the frequency distributions of all variables are not normal. The distribution is approximately symmetric if the skewness value lies between -0.5 and 0.5.

According to this, the distribution of variables is not symmetric. On the other hand, all variables fall under the extreme platykurtic distribution except *Y*.

Table 1: Descriptive statistics of variables

Variable	Obs.	Min	Max	Mean	SD	Variance	Skewness	Kurtosis
CO2	44	0.05	0.41	0.18	0.11	0.01	0.83	2.42
N2O	44	0.14	0.19	0.16	0.01	0.00	0.66	2.37
Y	44	322.33	951.31	501.47	171.13	29285.19	1.16	3.27
EC	44	86.77	229.25	137.25	39.74	1579.12	0.85	2.69
TOP	44	11.00	48.11	26.31	9.83	96.64	0.83	2.61

6.2 Unit Root Tests

Macroeconomic aggregates like asset prices, real GDP, exchange rates, etc. have nonstationary properties, and the main sources of this nonstationarity are the trend and structural break (Adejumo and Ikhide, 2019). The first step of any time series analysis is checking the nonstationarity of variables by operating unit root tests. There are several types of tests for diagnosing the nonstationarity of time series variables. The most popular and commonly used tests are the augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the Phillips-Perron (PP) test (Phillips and Perron, 1988). The ADF test is used in this study considering the Equation (5):

$$\Delta Y_t = \beta_1 + \beta_2 t + \Delta Y_{t-1} + u_t \quad (5)$$

where t is the trend variable in each case (Gujarati, 2003, p. 815). The ADF test has the null hypothesis that the series has a unit root. The Results of the ADF test and PP test are presented in Table 2. It is seen from Table 2 that all variables are nonstationary at their levels; that is, they contain a unit root. But in the case of the first difference of variables, null hypotheses are not accepted. Thus, it is evident from the unit root tests that all variables are stationary at their first differences; that is, they are integrated of order one, I(1). In the case of the ADF test, τ critical values -4.22, -3.53, and -3.19 at 1 percent, 5 percent, and 10 percent, respectively, have been reported. PP critical values are -4.21, -3.53, and -3.19 at 1 percent, 5 percent, and 10 percent, respectively.

Table 2: Results of unit-root tests

Variable	ADF		PP	
	Level	First Diff.	Level	First Diff.
CO_2	-2.89	-4.31***	-2.84	-6.75***
N_2O	-2.09	-3.49*	-1.89	-5.49***
Y	-0.76	-11.17***	-2.13	-15.55***
Y^2	-1.23	-10.05***	-1.66	-14.47***
EC	-0.32	-6.07***	-0.68	-8.72***
TOP	-3.00	-6.24***	-3.31	-8.38***

Note: *** indicates the significance of test statistic at the 1 percent level.

6.3 Cointegration Tests

Any regression between two nonstationary variables may produce a spurious regression. The regression will not be spurious if they are cointegrated. If the order of integration of different time series has been detected, it is easy to determine a relationship between them. Suppose all of the time series variables are integrated of order d, and a linear combination of these series is integrated of the order less than d. In that case, the set of variables is said to be cointegrated (Gujarati, 2003, pp. 805-822). Cointegration tests help detect long-run relationships among the variables if they have these relationships. Johansen (1991) test is the most popular among the available tests for cointegration. This test allows more than one cointegrating relationship.

Table 3: Johansen cointegration tests for CO_2 specification

Maximum Rank	Trace Statistic	5% Critical value	Max statistic	5% critical value
0	101.52	68.52	47.8707	33.46
1	53.65	47.21	24.9623	27.07
2	28.6836*	29.68	18.2029	20.97
3	10.48	15.41	7.3761	14.07
4	3.10	3.76	3.1046	3.76

Model: $CO_{2t} = f(Y_t, Y^2_t, EC_t, TOP_t)$

The Max-Eigen value and Trace test are the two main tests in the Johansen cointegration testing format. The decision can be made by any one of them. The null hypothesis for the Trace test is that the number of the cointegrating equation is $H_o: r = r^* < k$, and the alternative hypothesis that $H_a: r = k$. The null hypothesis for the Maximum Eigen Value test is similar to the Trace test, but the alternative hypothesis is $H_a: r = r^* +1$

(Johansen, 1991). All variables must be integrated of order one; I(1) to satisfy the condition for the Johansen test, and this condition has been met in this empirical study. The results of the Johansen cointegration tests for CO_2 and N_2O models have been reported separately in Table 3 and Table 4. Trace statistics show the existence of cointegrating relationships. According to these results, it is clear that a maximum of two cointegrating equations exists for the first model and the maximum one for the second model at the 5% level of significance. So, it is evident that there is a fixed long-run relationship between per capita emissions of two pollutants (CO_2 and N_2O) and economic variables (GDP per capita, energy consumption per capita, and trade openness). The next step is to model the long-run relationship between the variables in question, which a vector error correction model can represent.

Table 4: Johansen cointegration tests for N_2O specification

Maximum rank	Trace statistic	5% Critical value	Max statistic	5% critical value
0	87.3467	68.52	40.9836	33.46
1	46.3631*	47.21	24.1923	27.07
2	22.1709	29.68	13.9919	20.97
3	8.1789	15.41	5.6876	14.07
4	2.4913	3.76	2.4913	3.76

Model: $N_2O_t = f\,(Y_t, Y^2_t, EC_t, TOP_t)$

6.4 Interpretation of Vector Error Correction Model

The results of the VECM are presented in Table 5. According to the information in Table 5, an error correction term equation or cointegrating equation can be constructed for each pollutant emission in the long run model, which signifies the long-run relationship among the variables. Several diagnostic tests have been conducted for checking the presence of autocorrelation and the normality of residuals (See Table A3 and Table A4 in the Appendix). The Lagrange Multiplier (LM) test shows there is no serial correlation in the residuals of each model. The residuals of each model are Gaussian according to the multivariate normality test.

Two long-run cointegrating equations are shown in Table 6. For the CO_2 model, three coefficients (Y, Y^2, and TOP) are significant at 1% level, and all three have expected signs. The negative coefficient sign for EC is surprisingly opposite to the hypothesis of the study. In the case of N_2O specification, coefficients of Y, Y^2, and TOP are statistically significant at 1% level as well as they also have expected signs. Again the coefficient sign for EC is the opposite of the hypothesis, although it is not statistically significant.

Table 5: Vector error correction estimates

Beta	Coeff.	SE	Z	P>|Z|	Beta	Coeff.	SE	Z	P>|Z|
CO_2	1.00	.	.	.	***N_2O***	1.00	.	.	.
Y	-258.67	50.61	-5.11	0.00	***Y***	-25.90	6.69	-3.87	0.00
Y^2	19.63	3.93	4.99	0.00	***Y^2***	2.05	0.54	3.82	0.00
EC	18.63	10.79	1.73	0.08	***EC***	0.94	1.24	0.76	0.45
TOP	-4.99	1.47	-3.39	0.00	***TOP***	-0.90	0.23	-3.87	0.00
Cons.	769.60	.	.	.	**Cons.**	81.23	.	.	.

In the case of the CO_2 model, real GDP per capita and the squared value of real GDP per capita have a positive and negative impact on CO_2, respectively, i.e., β_1>0 and β_2<0. It implies an inverted U-shaped relationship between CO_2 per capita and real GDP per capita, i.e., the EKC hypothesis is valid for Bangladesh when using CO_2 as an environmental indicator. This particular finding is consistent with Sugiawan & Managi (2016), Kanjilal & Ghosh (2013), Hao et al. (2016), Tutulmaz (2015), and Islam & Shahbaz (2012). Husain (2016) also confirmed the inverted U-shaped relationship between income and environment indicator in the case of Bangladesh for CO_2 emissions. A similar conclusion can be made for the N_2O model. In this case, α_1>o and α_2<0. This result also confirms the validity of the EKC hypothesis for Bangladesh using N_2O as an environmental indicator. Most studies show that the EKC hypothesis is valid for anyone indicator, even if more than one environmental indicator is used (Fodha and Zaghdoud, 2010, Mrabet and Alsamara, 2017). This study examines the EKC hypothesis using two environmental indicators: carbon dioxide (CO_2) and nitrous oxide (N_2O). Surprisingly, the EKC hypothesis is valid for both environmental indicators in this study.

Table 6: Cointegrating equations

$$lnCO_{2t} = 258.67lnY_t - 19.63lnY_t^2 - 18.6lnEC_t + 4.99lnTOP_t$$
$$(5.11^{***}) \quad (-4.99^{***}) \quad (-1.73^{*}) \quad (3.39^{***})$$
$$lnN_2O_t = 25.90lnY_t - 2.05lnY_t^2 - 0.94lnEC_t + 0.90lnTOP_t$$
$$(3.87^{***}) \quad (-3.82^{***}) \quad (-0.76) \quad (3.87^{***})$$

Figures in the parentheses indicate t-statistics

6.5 Estimation of an Income Turning Point

It is imperative to estimate the income turning point of the inverted U-shaped environmental Kuznets curve if the existence of this curve is confirmed by empirical analysis. $\exp(\beta_1/|2\beta_2|)$ is the formula for estimating the income turning point of an inverted U-shaped EKC in a log-linear model (Sugiawan and Managi, 2016). In the case of the CO_2

model, the estimated turning point is exp(258.67/|2*19.63|) ≅ 727 US$ per capita, which lies within the sample period examined. And the estimated turning point for the N_2O model is exp(25.90/|2*2.05|) ≅ 554 US$ per capita, which also lies within the sample period of this study.

7. Conclusion

An empirical analysis is conducted under this study using the Johansen cointegration technique and VECM to check the long-run relationship between GDP per capita and per capita emissions of two pollutants (CO_2 and N_2O) for Bangladesh in the period of 1971 to 2014. The empirical results of the study demonstrate a significant long-run relationship between GDP per capita and per capita emissions of two pollutants. In both cases, empirical results confirm the existence of an inverted U-shaped relationship between GDP per capita and the indicator of environmental degradation, supporting the EKC hypothesis for Bangladesh. In the case of the CO_2 model, real GDP per capita and the squared value of real GDP per capita have a positive and negative impact on CO_2 emissions per capita, respectively. The threshold level of income at which CO_2 emissions started to fall is approximately equal to 727 US$ (constant 2010 US$) per capita. This level of per capita income was achieved in Bangladesh in 2009; for a level of per capita income equal to 727 US$, Bangladesh was able to decrease the emissions of CO_2. But after 2009, per capita income exceeded 727 US$, but the per capita CO_2 emissions did not decrease (Table A2 in Appendix). This turning point value for CO_2 emissions can be seen as unrealistically low. However, it can be easily shifted to higher values by widening the estimated curve using enlarged data set of a developing country (Tutulmaz, 2015). On the other hand, the income turning point for N_2O emissions is about 554 US$ (constant 2010 US) per capita. This per capita income level was achieved in Bangladesh in 2003. Since reaching this income level the per capita N_2O emissions in Bangladesh have started decreasing, consistent with the EKC hypothesis. Both the values lie within the sample period of the study.

Although the income turning point for CO_2 emissions in Bangladesh is 727 US$, the per capita CO_2 emissions have been rising at a fast rate over the last three decades. For this reason, this study suggests that Bangladesh should formulate sustainable economic policies to control environmental degradation. Particularly Bangladesh, like China, should have specific targets and strategies for reducing the per capita CO_2 emissions in its future five-year plans. Industry owners need to be encouraged to use green technologies with the necessary incentives to reduce CO_2 emissions in heavy industrial areas.

One of the limitations of the study is that it uses a relatively small sample size because data for many of the variables included in the analysis are not available after 2014. The small sample may not be compatible with the Johansen cointegration test, requiring a large sample. Therefore, future research can be extended by using quarterly data to larger the sample size. This will also be helpful to include a large number of control variables in the analysis.

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Appendix

Table A1: Definition of variables and sources of data

Variables	Definitions	Sources
ED: (either CO_2 or N_2O)	Natural log of carbon dioxide (CO_2) emissions per capita and nitrous oxide (N_2O) emissions per capita.	Emissions Database for Global Atmospheric Research 2016, and Environment Social and Governance Data 2019
Y_t	Natural log of GDP per capita (constant 2010 US$).	World Development Indicators 2019
Y^2_t	Natural log of squared of GDP per capita (constant 2010 US$).	World Development Indicators 2019

EC	Natural log of energy consumption (kg of oil equivalent per capita).	World Development Indicators 2019
TOP	Natural log of trade openness. Trade openness measured as the sum of exports and imports as a percentage of GDP.	World Development Indicators 2019

Table A2: Trends in CO_2 and N_2O emissions according to GDP per capita

Year	GDPPC (2010 US$)	Ton CO_2 per capita	Ton N_2O per capita
1971	380.9486	0.046668	0.144364
1972	322.3344	0.048063	0.149108
1973	328.0719	0.056287	0.148992
1974	353.7625	0.059156	0.142272
1975	332.8881	0.068966	0.150838
1976	343.9482	0.072272	0.152083
1977	344.4356	0.072087	0.155777
1978	359.0906	0.075413	0.160873
1979	366.2411	0.081726	0.163144
1980	359.4563	0.089576	0.144386
1981	375.4274	0.084881	0.140127
1982	373.5513	0.089743	0.143335
1983	378.0919	0.082234	0.144222
1984	386.0614	0.083508	0.147971
1985	388.6443	0.094899	0.144684
1986	394.3351	0.102586	0.147314
1987	398.5881	0.112542	0.148649
1988	397.7619	0.11544	0.153446
1989	398.8521	0.122374	0.160551
1990	411.1646	0.127123	0.157033
1991	415.7147	0.116094	0.17195
1992	428.661	0.128154	0.173636
1993	439.23	0.132086	0.177573
1994	446.6548	0.140488	0.182267
1995	459.6134	0.167934	0.186309
1996	470.2747	0.167684	0.190133
1997	481.1225	0.177946	0.175404
1998	495.6268	0.178771	0.174283
1999	508.3852	0.186279	0.168385
2000	524.9459	0.197502	0.162701
2001	541.2917	0.229346	0.157384
2002	551.903	0.236867	0.153805
2003	568.1392	0.244433	0.153814

2004	588.3273	0.247841	0.154716
2005	617.5427	0.267734	0.154183
2006	649.9299	0.279816	0.153499
2007	687.3231	0.300578	0.154045
2008	720.357	0.337216	0.154526
2009	748.2961	0.363917	0.167361
2010	781.1536	0.392606	0.177263
2011	822.1883	0.387577	0.176998
2012	865.7499	0.39027	0.176698
2013	907.2574	0.40274	0.153426
2014	951.3148	0.413429	0.150313

Table A3: Results of the Jarque-Bera test

Equation	chi^2	Df	Prob>chi^2	Equation	chi^2	Df	Prob>chi^2
CO_2	5.15	2	0.08	N_2O	3.60	2	0.17
Y	1.50	2	0.47	*Y*	8.07	2	0.02
Y^2	0.19	2	0.91	Y^2	1.58	2	0.45
EC	3.89	2	0.14	*EC*	0.08	2	0.96
TOP	2.03	2	0.36	*TOP*	0.47	2	0.79
All	12.75	10	0.24	*All*	13.81	10	0.18

Table A4: Results of the LM test

For C_2O Model				For N_2O Model			
Lag	chi^2	Df	Prob>chi^2	Lag	chi^2	Df	Prob>chi^2
1	25.95	25	0.41	1	30.02	25	0.22
2	23.58	25	0.54	2	28.63	25	0.28
3	22.84	25	0.59	3	34.39	25	0.10
4	21.87	25	0.64	4	39.19	25	0.04

H_0: no autocorrelation at lag order