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Understanding the Environmental Kuznets Curve Hypothesis: Empirical Evidence from Bangladesh

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Abstract: In the first quarter of the twenty-first century, the most substantial global concern is environmental contamination, and it has gained the prioritization of both the national and international community. Keeping in mind this crucial fact, this study conducted different statistical and econometrical methods to identify whether the gross national income of the country has a significant impact on electricity production from nonrenewable sources and different air pollutants like carbon dioxide, nitrous oxide, and methane emissions. Besides, the primary objective of this research was to analyze whether the environmental Kuznets curve hypothesis holds for the examined variables. After analyzing different statistical properties of the variables, this study came to the conclusion that the environmental Kuznets curve hypothesis holds for gross national income and carbon dioxide emission in Bangladesh in the short run as well as the long run. This study comes to this conclusion based on the findings of ordinary least square estimations; ARDL bound tests, short run causality analysis, the Error Correction Model, and other pre-diagnostic and post-diagnostic tests that have been employed in the structural model. Moreover, this study wants to demonstrate that the outline of gross national income and carbon dioxide emissions is in its initial stage of development and will increase up to the optimal peak. The compositional effect will then force the emission to decrease, and the environmental quality will be restored in the long run.

Keywords: Environmental Kuznets Curve Hypothesis, Carbon Dioxide Emission in Bangladesh, Gross National Income in Bangladesh, Auto Regressive Distributed Lag Model, Granger Causality, Error Correction Model

1. Introduction

The significances of economic expansion on the surrounding environment are indisputable in the standpoint of climate change and global warming. It is empirically appropriate that high-income states be acutely cognizant of environmental squalor [4]. On the other hand, as a magnitude of heightened industrialization, a low-income state like Bangladesh may see less environmental regulation. According to the pollution heaven hypothesis, as environmental directive turns out to be more rigorous, businesses would shift their investments to less delimited geographic areas [21]. Furthermore, emerging countries have a predisposition of prioritizing economic growth over environmental guidelines [25]. Bangladesh is ameliorating its economy at a steady pace, and the EKC along with pollution heaven paraphernalia are

both likely to be contemporaneous in the economy. The country's development is strengthening economic activity, and foreign direct investment (FDI) is swelling. In recent years, more development projects have been undertaken, and industrialized countries exponentially amplified their investment.

The Environmental Kuz-net Curve hypothesis states that, the emission in a developing or underdeveloped country will upsurge along with the per capita income in a certain point and steadily decrease when the level of income will grasp at a certain point. Consequently, Economic growth contributes to environmental improvement at high income levels. Besides, the hypothesis suggests that environmental degradation is an inverted U-shaped function of per capita income [26]. The descriptive analysis of Gross National Income, Electricity Production from non-renewable sources, CO_2 emission, Nitrous Oxide emission, Methane emission of Bangladesh shows an ascending inclination. It is possible to witness the environmental Kuz-net curve effect in the succeeding factors in Bangladesh. This study envisioned to scrutinize both hypothetical and evocative properties of the following factors to envisage the existence of EKC in the context of present economic circumstance of Bangladesh.

Numerous studies have been steered to inaugurate the theoretical framework of the environmental Kuznets curve hypothesis, from which some validated the U-shaped EKC curve while other studies designate a bell-shaped EKC curve in the context of economic growth and environmental pollution. Besides, other studies mostly investigated the theory of economic growth, although this study encompassed electricity production from non-renewable sources, gross national income, and un-investigated pollutants like methane emission and nitrous oxide emission in Bangladesh to establish a theoretical basis [12].

2. Literature Review

The rigorous econometric analysis fallouts, analyzed by [16] which accounted over several structural break concerns in the data, validate the environmental Kuz-net Curve hypothesis. Furthermore, the anticipated economic growth thresholds are higher than the current value, indicating that Bangladesh is still in the initiation stage, where the country is balancing environmental degradation with economic progress.

The autoregressive distributed lag-error correction modeling approach provided statistical support to the nonlinear inverted-U-shaped link between economic growth and deforestation practices in Bangladesh, according to a study directed by [15]. As a result, the findings support the deforestation-induced environmental Kuznets curve hypothesis in Bangladesh. However, both in the short and long runs, the vector error correction model and the Hacker and Hatemi-J Granger causality aerobics indicated the causal effects of economic expansion on deforestation predispositions. In an essence, the overall findings show an exchange between economic and environmental welfare throughout Bangladesh's early stages of economic expansion.

A Study have [1] investigated changes in Bangladesh's economic structure and inclinations in cutting-edge carbon dioxide (CO_2) emissions as a function of GDP per capita. The research also uses the environmental Kuznets curve hypothesis to evaluate the interaction between Bangladesh's economic development (GDP per capita) and CO_2 emissions. A faster structural transition from agriculture to non-agriculture is also observed. However, the study was unable to establish convincing evidence for the existence of the inverted U-shaped Environmental Kuznets Curve in the subsequent framework.

A study concluded that the prospect of dynamic causality between energy usage, power consumption, carbon emissions, and economic growth in Bangladesh [13]. Furthermore, the Johansen bi-variate cointegration model is used to evaluate cointegration associations. The study also investigates the robustness of the diagnosis outcome through autoregressive distributed lag approach. The findings of the study conclude that there is unidirectional causation between energy consumption and economic growth in both the short and long run, as well as a bidirectional long-run causality between electricity consumption and economic growth, but no causal link in the short run. For both situations, the high causality results show bi-directional causation. In the short run, a unidirectional causation occurs from energy use to CO_2 emission, whereas feedback causality exists in the long run. CO_2 Granger promotes economic growth in the short and long term.

Despite the fact that installed power generating capacity has been boosted to 10,709 MW, it is still insufficient to fulfill the country's demand. Furthermore, inadequate electricity generation stymies socio-economic and industrial growth. Bangladesh's present power generating problem may be solved by introducing renewable energy into the power generation process. The program might help the country achieve not just energy security, but also cut pollution and minimize the near-term depletion of nonrenewable energy supplies [18]. The study used the Augmented Dickey Fuller (ADF) test to examine stationarity qualities and discovered that variables are stationary at their level or at initial differences. The empirical data show that the variables have long run cointegration when using the Johansen co-integration technique.

Researcher have concluded that there is no causal association between economic growth and CO_2, implying that Bangladesh may achieve economic expansion without compromising environmental integrity [23]. Furthermore, energy consumption can result in CO_2 emissions as a common economic phenomenon. Besides, the research also showed that economic growth in Bangladesh is not energy-dependent; rather, economic growth is capable of ensuring energy consumption.

Over the previous decade, Bangladesh's gross domestic product and foreign direct investment have seen supreme increase. However, between 2000 and 2016, the country's yearly average greenhouse gas emissions increased by 3.3 percent. To investigate the objective of the study, researchers

used the Vector Error Correction Model and Granger Causality tests. The EKC theory appears to be beneficial to the country, according to the findings. At a significance level of 0.05, the causation test rules out short- and long-run causality from energy consumption per capita, GDP per capita, and FDI to GHGs [11].

A study utilizes data from the World Development Indicator to look at the variables that contributed to environmental degradation in terms of increasing carbon dioxide and nitrogen oxide emissions in Bangladesh and India between 1981 and 2011. Industrialization and greenhouse gas emissions have been cited as key contributors to the deterioration of air quality in Bangladesh and India, respectively. In both economies, population concentration in urban areas increases carbon emissions while economic globalization decreases nitrogen oxide emissions. The inverted U and N shaped Kuznets curve for India, which is robust to employing dynamic specification, is supported by the estimation findings of decreased from equation for CO_2 emission. Bangladesh's form is an inverted U; however, this isn't strong enough to be used in a dynamic model. Energy consumption has a significant impact in growing carbon emissions in India, but not in Bangladesh, according to a quadratic approach to the Kuznets curve [7].

The Environmental Kuznets Curve (EKC) theory was studied in research that focused on the country's resource stock in connection to the selection of environmental degradation indicators. Recognizing the EKC's importance in policymaking and development strategies, this study investigated the validity of the EKC hypothesis by looking at the relationship between economic growth, urbanization, energy consumption, trade openness, human capital, and ecological footprints in Bangladesh from 1972 to 2018. This is done by using autoregressive distributive lag bounds testing method, which takes into consideration the structural break in the time series. As a robustness check, the findings were also subjected to a completely modified OLS estimate. The empirical findings support the presence of the EKC in Bangladesh, both in the long and short term. The Vector Error Correction Granger causality test is used to investigate the causal relationship between the variables. Economic growth and urbanization both generate ecological footprints in the short and long term, according to the results of the causality test. Based on this finding, it can be concluded that Bangladesh's economic growth activities may be maintained and expanded at a low environmental cost through structural economic reform and good environmental management [17].

According to the environmental Kuznets curve (EKC) hypothesis, environmental deterioration and pollution rise during the early phases of economic expansion. However, after a country has reached a particular level of income, the tendency reverses, resulting in an inverted U-shaped curve. Bangladesh has had extraordinary economic development, which, along with other circumstances, has generated the threat of an impending environmental disaster. Utilizing data from 1971 to 2010, one such research empirically analyzes the EKC hypothesis for Bangladesh, using the Autoregressive distributed lag (ARDL) technique to cointegration for a long run relationship and Granger causality inside the vector error correction model for short run dynamics. The findings demonstrate that energy consumption is a key source of CO_2 emissions; trade openness reduces CO_2 emissions, while urbanization increases them. CO_2 emissions are caused by economic expansion, energy consumption, commerce, and urbanization, according to Granger [5].

Every country has a significant challenge in terms of energy planning. Understanding household energy choices has a significant impact on energy planning and policy. Socioeconomic variables play a key role in the choice system, determining energy consumption. Using the Energy Ladder and the environmental Kuznets curve (EKC) theory, the study intended to better understand the socio-economic factors that influence energy preferences in emerging nations. The findings reveal that biomass continues to play an important role in satisfying energy demand in many developing nations, and that family wealth is the most important factor in determining energy preferences. The macroeconomic situation, on the other hand, is the fundamental driving force. The study concludes that Bangladesh is still in the first half of the inverted U-shaped EKC for energy usage at the household level, and that the Energy Ladder is true in Bangladesh at the second stage of the EKC [24].

Despite the fact that many scholars have shown the empirical evidence and linkage between environmental deterioration and economic growth, this study is unique in methodological and contextual elements. The purpose of this research is to calculate the Environmental Kuznets Curve (EKC) hypothesis in Bangladesh. We computed EKC using the FMOLS (Fully Modified Ordinary Least Square) technique, Engle-Granger, and Phillips-Ouliaris co-integration tests for the long run and the Granger causality test for a short-run connection, using data from 1972 to 2013. According to the report, energy consumption rises in tandem with economic expansion, resulting in increased pollution. Furthermore, research demonstrates that non-renewable energy usage is Bangladesh's leading source of pollution. Bangladesh has an inverted U-shaped EKC, according to the study. The most important policy advice is to increase the use of renewable energy sources in order to minimize pollution and support economic growth [14].

3. Methodology

In order to analyze the linkage among Gross National Income (GNIBD), Electricity Production from Non-Renewable Sources (EPNRSBD), CO2 Emission (BDCO2E), Nitrous Oxide Emission (N2OEBD), and Methane Emission (CH4EBD) in Bangladesh, this study employed multivariate regression model specified as:

$$GNIBD = \gamma 0 + \gamma 1\ EPNRSBD + \gamma 2\ BDCO2E + \gamma 3\ N2OEBD + \gamma 4\ CH4EBD + \varepsilon \quad (1)$$

Where GNIBD represents Gross National Income in Bangladesh, EPNRSBD represents Electricity Production from Non-Renewable Sources, BDCO2E represents Carbon Dioxide Emission in Bangladesh, N2OEBD represents the Nitrous Oxide Emission in Bangladesh, CH4EBD represents Methane Emission in Bangladesh and εt represents the error term. By using natural logarithm to Eq 2, a log-linear model is expressed as follows:

$$\text{LnGNIBD} = \gamma 0 + \gamma 1\ \text{LnEPNRSBD} + \gamma 2\ \text{LnBDCO2E} + \gamma 3\ \text{LnN2OEBD} + \gamma 4\ \text{LnCH4EBD} + \varepsilon t \quad (2)$$

3.1. ARDL Model

3.1.1. Equation 3

$$\Delta \text{GNIBD}_t = \alpha_{01} + \beta_{11}\text{GNIBD}_{t\text{-}i} + \beta_{21}\text{EPNRSBD}_{t\text{-}i} + \beta_{31}\ \text{BDCO2E}_{t\text{-}i} + \beta_{41}\text{N2OEBD}_{t\text{-}i} + \text{CH4EBD}_{t\text{-}i} + \sum_{i=1}^{p} \alpha 1i\ \Delta \text{GNIBD}_{t\text{-}i} + \sum_{i=1}^{q} \alpha 2i\ \Delta \text{GNIBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 3i\ \Delta \text{EPNRSBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 4i\ \Delta \text{BDCO2E}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 5i\ \Delta \text{N2OEBDt}_{\text{-}1} + \sum_{i=1}^{q} \alpha 6i\ \Delta \text{CH4EBD}_{t\text{-}1} + e_{1t} \quad (3)$$

3.1.2. Equation 4

$$\Delta \text{EPNRSBD}_t = \alpha_{01} + \beta_{11}\text{EPNRSBD}_{t\text{-}i} + \beta_{21}\text{GNIBD}_{t\text{-}i} + \beta_{31}\ \text{BDCO2E}_{t\text{-}i} + \beta_{41}\ \text{N2OEBD}_{t\text{-}i} + \beta_{41}\ \text{CH4EBD}_{t\text{-}i} + \sum_{i=1}^{p} \alpha 1i\ \Delta \text{EPNRSBD}_{t\text{-}i} + \sum_{i=1}^{q} \alpha 2i\ \Delta \text{EPNRSBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 3i\ \Delta \text{GNIBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 4i\ \Delta \text{BDCO2E}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 5i\ \Delta \text{N2OEBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 6i\ \Delta \text{CH4EBD}_{t\text{-}1} + e_{1t} \quad (4)$$

3.1.3. Equation 5

$$\Delta \text{BDCO2E}_t = \alpha_{01} + \beta_{11}\ \text{BDCO2E}_{t\text{-}i} + \beta_{21}\text{EPNRSBD}_{t\text{-}i} + \beta_{31}\text{GNIBD}_{t\text{-}i} + \beta_{41}\ \text{N2OEBD}_{t\text{-}i} + \beta_{51}\text{CH4EBD}_{t\text{-}i} + \sum_{i=1}^{p} \alpha 1i\ \Delta \text{BDCO2E}_{t\text{-}i} + \sum_{i=1}^{q} \alpha 2i\ \Delta \text{BDCO2E}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 3i\ \Delta \text{EPNRSBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 4i\ \Delta \text{GNIBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 5i\ \Delta \text{N2OEBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 6i\ \Delta \text{CH4EBD}_{t\text{-}1} + e_{1t} \quad (5)$$

3.1.4. Equation 6

$$\Delta \text{N2OEBD}_t = \alpha_{01} + \beta_{11}\text{N2OEBD}_{t\text{-}i} + \beta_{21}\text{EPNRSBD}_{t\text{-}i} + \beta_{31}\text{GNIBD}_{t\text{-}i} + \beta_{41}\text{BDCO2E}_{t\text{-}i} + \beta_{51}\text{CH4EBD}_{t\text{-}i} + \sum_{i=1}^{p} \alpha 1i\ \Delta \text{N2OEBD}_{t\text{-}i} + \sum_{i=1}^{q} \alpha 2i\ \Delta \text{N2OEBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 3i\ \Delta \text{EPNRSBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 4i\ \Delta \text{GNIBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 5i\ \Delta \text{BDCO2E}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 6i\ \Delta \text{CH4EBD}_{t\text{-}1} + e_{1t} \quad (6)$$

3.1.5. Equation 7

$$\Delta \text{CH4EBD}_t = \alpha_{01} + \beta_{11}\text{CH4EBD}_{t\text{-}i} + \beta_{21}\text{EPNRSBD}_{t\text{-}i} + \beta_{31}\text{GNIBD}_{t\text{-}i} + \beta_{41}\text{BDCO2E}_{t\text{-}i} + \beta_{51}\text{N2OEBD}_{t\text{-}i} + \sum_{i=1}^{p} \alpha 1i\ \Delta \text{CH4EBD}_{t\text{-}i} + \sum_{i=1}^{q} \alpha 2i\ \Delta \text{CH4EBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 3i\ \Delta \text{EPNRSBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 4i\ \Delta \text{GNIBD}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 5i\ \Delta \text{BDCO2E}_{t\text{-}1} + \sum_{i=1}^{q} \alpha 6i\ \Delta \text{N2OEBD}_{t\text{-}1} + e_{1t} \quad (7)$$

3.2. Dependent Variable

The gross national income per capita of Bangladesh has primarily been used as a dependent variable in the initial structure of the model. The data for GNI has been collected from the world development indicators database from the period 1973 to 2015. The index is measured through the atlas method of GNI estimation, conducted and articulated by the World Bank. The definition of all the variables is illustrated in the appendix section of this paper.

3.3. Explanatory Variables

This study used data from world development indicators from the period of 1973 to 2015 for all the variables.

3.3.1. Epnrsbd

The electricity production prom nonrenewable sources of Bangladesh (EPNRSBD) are used as one of the independent variables in the structural model. The nonrenewable source states the inputs used to generate electricity including crude oil, natural gas, and coal as primary nonrenewable source.

3.3.2. Bdco2e

Carbon dioxide emission is measured in kilo tones. The carbon dioxide emission indicates the emission generated from burning fossil fuel, crude oil, solid fuel burning as well as gas flaring. The data from up to 1990 is sourced from Carbon Dioxide Information Center, Environmental Science Division, Oak Ridge National Laboratory, Tennessee, USA.

3.3.3. N2oebd

Nitrous oxide emission from agricultural biomass, industrial activity, and livestock management is used as independent variable in the structural model. The nitrous oxide emission is measured in thousand metric tons of CO_2 equivalent. The variables index is measured by Carbon Dioxide Information Center, Environmental Science Division, Oak Ridge National Laboratory, Tennessee, USA.

3.3.4. Ch4ebd

Along with other explanatory variables, methane emission generated from human activities, agricultural production and industrial production has been taken into consideration while estimation. This variable also calculated by the Carbon Dioxide Information Center, Environmental Science Division, Oak, Ridge National Laboratory, Tennessee, USA.

4. Result and Discussions

4.1. Unit Root Test

To establish a strong theoretical background for the

structural model, this study initially investigated the order of unit root for all of the variables. Therefore, this study conducted the ADF test [3] and the Phillips-Perron test [22] to analyze the stationary properties of the following variables. The result showed energy production from non-renewable sources in Bangladesh (EPNRSBD) was stationary at a level in trend and intercept. The probability value of EPNRSBD at I (0) with intercept is 0.5331, which is not significant at a 5% level. But when trend and intercept are both included in the equation, it becomes statistically significant with a calculated probability of 0.0944. Hence, the gross national income of Bangladesh is found non-stationary at I (0), but after the inclusion of trend and intercept, this variable is found to be stationary at I(1). This study found carbon dioxide emissions non-stationary at I (0) while stationary at I (1) when trends and intercept are included. Furthermore, when only the trend is included in the diagnostics tests, the nitrous oxide and methane emissions are stationary at I (0). Moreover, the results of unit root tests are represented in tables 2 and 3 respectively.

Table 1. *Augmented Dicky Fuller Tests.*

Variables	Level (Prob.) P		1st difference (Prob.)		Conclusion
	C	C & T	C	C & T	
EPNRSBD	0.5331	0.0944	0.0000	0.0001	I (0)
GNIBD	1.0000	1.0000	0.6269	0.1830	I (1)
BDCO2E	1.0000	1.0000	0.3814	0.0129	I (1)
N_2OBD	0.9751	0.0982	0.0000	0.0000	I (0)
CH_4BD	0.4735	0.8780	0.0000	0.0000	I (0)

Table 2. *Phillips-Perron Test.*

Variables	Level (Prob.) P		1st difference (Prob.)		Conclusion
	C	C & T	C	C & T	
EPNRSBD	0.6587	0.0944	0.0000	0.0000	I (0)
GNIBD	1.0000	1.0000	0.6193	0.2335	I (1)
BDCO2E	1.0000	1.0000	0.6313	0.0158	I (1)
N_2OEBD	0.9858	0.0971	0.0000	0.0000	I (0)
CH_4EBD	0.4918	0.8945	0.0000	0.0000	I (0)

4.2. ARDL Bounds Test for Co-integration

This study used the ARDL bound test to investigate the co-integrations among variables. The variables are stationary in different orders, conferring the unit root test, and therefore, the existing theory does not advocate running the Johanson co-integration test. Besides, empirical studies have shown that it is more rational to run an ARDL bound test for co-integration when variables are stationary at different orders [10]. The estimated value of GNIBD's F-statistics is 22.86, which is greater than the lower and upper bound values at a 95% level of significance. The result indicates a long-term relationship amongst the examined variables. Consequently, we can reject the null hypothesis of no co-integration. These findings provide a window to further investigate the nature of association among variables.

Table 3. *Results of the ARDL Bound Test.*

F-Statistic	90% Lower Bound	90% Upper Bound	95% Lower Bound	95% Upper Bound	Conclusion
22.86738	2.45	3.52	2.86	4.01	Cointegration

Table 4. *Results from ARDL and World Test (Short Run Causality).*

Dependent Variable	ARDL T Statistics	Prob*	World F Statistics	Prob*
GNIBD	GNIBD (-1) = Significant	0.0000	GNIBD (-1) = Significant	0.0000
	EPNRSBD (-1) = Significant	0.0356	EPNRSBD (-1) = Significant	0.0356
	BDCO2E = Significant	0.0001	BDCO2E = Significant	0.0001
	N2OEBD = Significant	0.0022	N2OEBD = Significant	0.0022
EPNRSBD	EPNRSBD (-1) = Significant	0.0025	EPNRSBD (-1) = Significant	0.0025
BDCO2E	BDCO2E (-1) = Significant	0.0000	BDCO2E (-1) = Significant	0.0000
	GNIBD = Significant	0.0025	GNIBD = Significant	0.0025
	N2OEBD = Significant	0.0004	N2OEBD = Significant	0.0004
	CH4EBD = Significant	0.0002	CH4EBD = Significant	0.0002
NO2EBD	N2OEBD (-1) = Significant	0.0000	N2OEBD (-1) = Significant	0.0000
	EPNRSBD (-1) = Significant	0.0306	EPNRSBD (-1) = Significant	0.0306
	BDCO2E = Significant	0.0468	BDCO2E = Significant	0.0468
CH4EBD	CH4EBD (-1) = Significant	0.0309	CH4EBD (-1) = Significant	0.0309
	BDCO2E = Significant	0.0000	BDCO2E = Significant	0.0000
	N2OEBD (-1) = Significant	0.0083	N2OEBD (-1) = Significant	0.0083

4.3. Short-Run Causality

This research induced ARLD and the World Test to analyze the nature of short-run causality among the examined variables. In addition, this study found a strong causal relationship between gross national income and carbon dioxide emissions in Bangladesh. The ARDL and World Test found out that there has been a bidirectional causal affiliation between GNIBD and BDCO2E in Bangladesh. At a 95% level of significance, the result was statistically significant. The results also indicate a unidirectional causality between GNIBD and the one-period lag of GNIBD. Along with that, electricity production from nonrenewable sources and nitrous oxide emissions has a unidirectional causal association with the gross national income of Bangladesh. Besides, the EPNRSBD exhibits a unidirectional causal effect on one period-lagged value of EPNRSBD. Consequently, carbon dioxide emission has a significant causal effect on nitrous oxide emission, methane emission, and one period-lag value of carbon dioxide emission. The test results identified bidirectional causality between BDCO2E and BDCO2 (-1), bidirectional causality between BDCO2E and N2OBD, and bidirectional causality between BDCO2E and CH4EBD. Furthermore, N2OEBD exhibits bidirectional causality on N2OEBD (-1) and a unidirectional causal effect on EPNRSBD (-1). Henceforward, the methane emission of Bangladesh has bidirectional causality with one period of the lagged value of its own. Above all, each of the variables is statistically significant at a 5% level. Later, the adjusted r squared point out that the explanatory variables describe the dependent variable GNIBD by 49%. Hence, the ARDL approach also indicates no severe autocorrelations among different variables of the structural model. Above and beyond, the f statistics of the ARDL approach are far more reliable compared to the previously examined OLS approach, with an approximate value of 8.182392.

4.4. Results of OLS Estimation

It is necessary to employed different statistical methods to appraise and compare the results of different outcomes of the structural model. Keeping in mind the fact, this study is intended to run the ordinary least squared method along with ARDL and ECM, The OLS estimation foretold that all environmental emission variables were statistically significant at a 95% confidence interval. This study built an ordinary least-squares approach after assuming gross national income as a function of energy production, carbon dioxide emission, nitrous oxide emission and methane emission. The regression results recognized positive associations between carbon dioxide emissions and the gross national income of Bangladesh. Above and beyond, it also indicated that a 1% increase in carbon dioxide emissions would increase gross national income by 0.01%. Hence, if the nitrous oxide emissions increased by 1%, it would cut off the gross national income of Bangladesh by approximately 0.017%. Despite that, if methane emissions increased by 1% in Bangladesh, it would probably decrease gross national income by 0.005%.

The explanatory variables of the model described the dependent variable by 98%, which clearly signposts the consistency of the selected econometric approach. Also, the OLS estimations indicate no severe autocorrelations amongst the examined variables with a probabilistic value of 0.784769. Consequently, it is empirically appropriate to conduct more sophisticated structural prototypes to analyze whether the outcomes differ when advanced methods are applied in the regression analysis. To do so, this study further engaged an auto-regressive distributed lag approach to cross-check regression output.

4.5. Interpretation of the Long-Run Relationship

This study found a long-run association between gross national income and carbon dioxide emissions in Bangladesh. The results of the ECM acknowledged carbon dioxide and the four-period lagged value of gross national income as statistically significant at a 5% level. Consequently, the results designate that a 1% increase in previous year carbon dioxide emissions can increase the current period gross national income by 0.01% in Bangladesh. Similarly, if the four-period lag value of gross national income increased by 1%, the current gross national income could increase by 0.30%, which is valid at a 5% level. Besides, it has been identified that if the previous year's carbon dioxide emissions increased by 1%, it could upsurge the contemporary period's CO_2 emissions by 0.56%. Hence, this study also found that the 4-year lagged value of gross national income has a significant effect on current period carbon dioxide emissions. The error correction estimation calculated that if GNIBD (-4) increased by 1%, it could potentially increase current period carbon dioxide emissions by 22.81% when the chances of error are 0.03%. Furthermore, the adjustment coefficient indicates that long-run convergence of GNIBD and BDCO2E equilibrium is possible but not statistically significant at any confidence level. Due to the significant property of the following variable, the following econometric model explains GNIBD by 38% when it is considered as a dependent variable.

Table 5. *Comparison of the Models.*

Model	R Squared	Adjusted R Squared	F-Statistic	DW Stat	S. E. of regression	Log likelihood
OLS	0.988084	0.986830	787.7662	0.784769	31.50326	-206.7106
ARDL	0.561115	0.492539	8.182392	1.256325	21.87416	-167.8961
ECM	0.468108	0.385000	5.632528	2.063755	1446.748	-327.1833

4.6. Empirical Framework of EKC with Respect of the Findings of This Study

The theoretical properties of EKC state that when one economy transforms from an industrial production base from an agrarian-based economy, income inequality increases as well as the surrounding environmental pollution [8] It is also stated that, according to increasing economic growth and gross national income of an economy, pollution initially started to increase up to a certain point, and after that point, pollution again tends downward. Therefore, the proposed environmental Kuznets curve is supposed to be inverted U-shaped. Besides, studies have expressed their evidence about the fact that increasing per capita income and economic growth may initially affect the environment adversely, but it will start to compensate after reaching a certain point in the economy [20]. Many studies have found that it is unavoidable during the early stages of development [6]. Besides, to support the theory, scholars also evaluated the functionality of technology in the industrial economy. Following the time, cleaner technology will be introduced in the production system, which will cut off pollution in a developed stage of that economy. Thus, the effect of the improved technology will then force the pollution to trend downward because of the scale effect and technology effect.

4.7. Present Trend of CO2EBD, N2OEBD and CH4EBD

This study is intended to identify the existence of the EKC hypothesis in the Bangladesh economy. The findings of this study identified short-run causal relationships among GNIBD, EPNRSBD, BDCO2E, N2EBD, and CH4EBD. Besides, the error correction model also identified a long-term relationship between gross national income and carbon dioxide emissions in Bangladesh. Different studies provide evidence that the economy of Bangladesh is in the initial stage of development with respect to the EKC hypothesis. But it is not clear at which initial stage the economy is running and at which point we can predict the scalar and technological effects that will start to push environmental pollution downward.

4.7.1. Present Trend of CO2EBD, N2OEBD and CH4EBD in Terms of EKC in Bangladesh

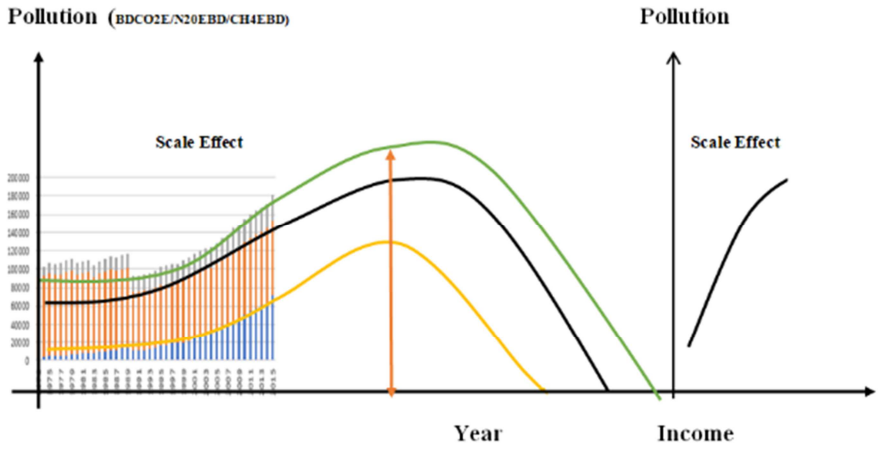

Figure 1. *Present Trends in Bangladesh.*

4.7.2. Figure (Trends of GNIBD in Terms of EKC in Bangladesh)

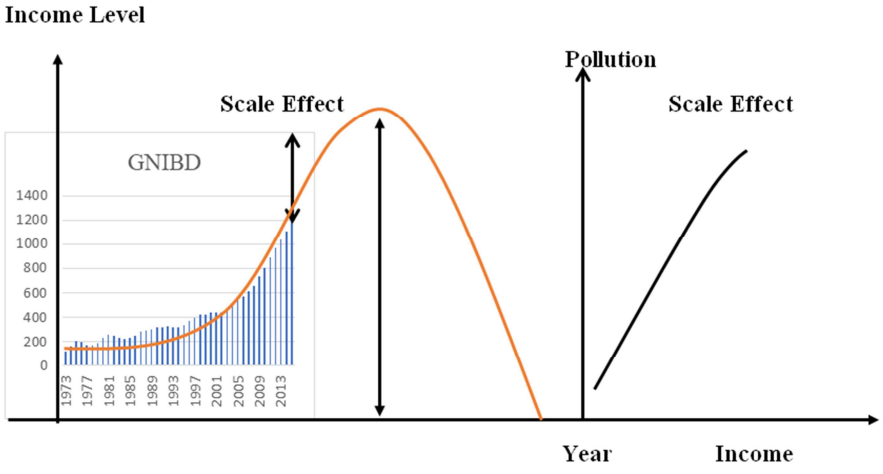

Figure 2. *Present Trends in Bangladesh.*

5. Conclusion

The objectives of this study were to evaluate the pattern of association among environmental pollution with respect to gross national income and energy production of Bangladesh. Also, this study intended to state the pattern and existence of EKC hypothesis in Bangladesh through empirical theory to compare the findings of this study with existing literature in this particular issue. This study found the existence of bell shaped EKC between carbon dioxide emission and gross national income while the analysis of the variable data from 1973 to 2015. This study could not find long run or short run association between energy production from non-renewable sources and carbon dioxide emission in Bangladesh while analyzing through ARDL and ECM approach. Most of the study has analyzed EKC hypothesis in terms of energy consumption, economic growth and carbon dioxide in Bangladesh. Besides, this study is exceptional from the perspective of variable selection to state EKC hypothesis. The structural model of this study used energy production instead of energy consumption, and used gross national income where most of the study used economic growth to analyze the EKC hypothesis. Subsequently, the findings of this study do not agree with the statement given by [2] which stated that the EKC hypothesis does not hold when greenhouse gas emission and income per capita considered in the analysis. This statement may partially hold when we consider nitrous oxide, methane and other emissions into account. Despite that as carbon dioxide emission is a major emission factor of GHG and as this study found that EKC hypothesis holds for carbon dioxide emission (CO2EBD), and gross national income (GNIBD) in Bangladesh therefore, this study express disagreement to the prior mentioned statement. Besides, this study used three different statistical approaches to analyze different properties of relationship of examined variables. The study objective of this research was to analyze the existence of EKC with respect to environmental pollution (BDCO2E, N2OEBD, CH4EBD) and economic growth (GNIBD) which eventually verified from the study verdicts. This study agrees with the assumption that the country is running in the initial stage of economic development [9]. Hence, this study also states that though energy consumption heavily predicts carbon dioxide in Bangladesh but this study could not find any significant association between electricity production and carbon dioxide emission. These findings suggest that Bangladesh is still running concisely in terms of electricity production and carbon dioxide emission from this particular sub sector. Also, the carbon di oxide and gross national income of Bangladesh following the EKC hypothesis and is at its primary stage which indicates in long run when the economy will be affected by compositional effect of income on carbon dioxide emission then it will eventually cut off carbon dioxide emission in Bangladesh [19]. Therefore, it is not yet a matter of concern for Bangladesh to imply strict restriction on electricity production in the economy as energy sufficiency is one of the major driving forces for economic development. Also, this study found other influential emission factors including nitrous oxide and methane has some significant association in short run but not statistically significant in long run. Therefore, this study propose that Bangladesh is way behind its emergency pick of emission and government and regulatory body should not immediately impose strict restriction on electricity production from non-renewable sources rather it is wise for them to gradually shift towards renewable electricity production.

Appendix

Abbreviation of the Statistical Models

Statistical Model	Abbreviation
ADF	Augmented Dicky Filler Test
EKC	Environmental Kuznets Curve Hypothesis
ECM	Error Correction Model
ARDL	Auto Regressive Distributed Lag Model
OLS	Ordinary Least Square Model

Abbreviation of the Variables

Short Form	Abbreviation
GNIBD	Gross National Income of Bangladesh
EPNRSBD	Electricity Production from Non-Renewable Resources in Bangladesh
CO2EBD	Carbon dioxide Emission from fossil fuel combustion in Bangladesh
N2OEBD	Nitrous Oxide Emission from biomass, industrial activity, and livestock management in Bangladesh
CH4EBD	Methane Emission from human activities, agricultural production, and industrial production in Bangladesh

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