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Exploring the Existence of the N-shaped Environmental Kuznets Curve in Bangladesh: An Autoregressive Distributed Lag Bounds Test Approach

Khaleda Akter, Md. Adnan Al Nahian, & Md. Roni Hossain

Abstract:
The study aims to explore the existence of the N-shaped Environmental Kuznets Curve (EKC) in Bangladesh. The policy implications for the inverted U-shaped and the N-shaped EKC are different, therefore, it is important to identify the real shape of the EKC for a country for adopting an appropriate policy for mitigating environmental pollution. Although many studies in the context of Bangladesh have explored the inverted U-shaped EKC, none of the study explores the N-shaped EKC. Against this backdrop, the present study has attempted to explore the N-shaped EKC in Bangladesh by using the Autoregressive Distributed Lag (ARDL) Bounds test approach. The study has found that the actual shape of the EKC in Bangladesh is N-shaped for both the short- and long-run. This implies that although higher economic growth mitigates the environmental pollution, but after a certain level of income, the pollution will rise again with the higher level of income per capita. Therefore, policymakers need to reconsider the existing growth promoting policy and adopt a new policy by considering the possibility of this N-shaped EKC.

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About Author (s)

Khaleda Akter (corresponding author), Lecturer, Department of Economics, Pabna University of Science and Technology, Pabna-6600, Bangladesh.
Email: khaleda.nur.econju@pust.ac.bd
Md. Adnan Al Nahian, Lecturer, Department of Economics, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh.
Md. Roni Hossain, Lecturer, Department of Economics, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh.

1. Introduction

Global warming has terrified the present world, as some adverse effects of it starts of visualize already. For instance, the sea level is rising, many coastal regions are in danger of drowned, unexpected drought, cyclone, and floods are occurring, ices of Antarctic are melting, etc. The carbon dioxide (CO2) gas emission is the dominant factor responsible for global warming (Rayhan & Islam, 2015). In 2015, the Paris Conference set a target of keeping the rise in global temperature enough below 2^0 Celsius. In order to achieve this target, at first it's important to identify the core determinants of CO2 emissions, so that alternative strategies can take into action to overcome the pollution situation.

A theoretical approach, named "Environmental Kuznets Curve" or EKC in short, was developed by Grossman & Krueger (1991) to explore the economic growth and pollution relationship in the light of the Kuznets curve of Simon Kuznets (Kuznets, 1955). Kuznets curve of Simon Kuznets predicted the inverted U-shaped relationship between inequality and economic growth of a country, while the theoretical setup of EKC asserted a similar relationship between pollution and economic growth. The EKC states that the level of pollution of a country increases at the initial level of economic development with low level of income per capita, but starts to fall eventually with higher level of economic development consistent with higher level of income per capita. So, the conventional EKC hypothesis was built on the assumption that its shape would be inverted U.

Some recent studies have examined the shape of EKC beyond the conventional inverted U-shape and found some new insights. For instance, some studies found the existence of N-shaped EKC instead of inverted U (e.g., Allard et al., 2018; Barış-Tüzemen et al., 2020; Koc & Bulus, 2020). The policy implications for the inverted U-shaped and the N-shaped EKC are different, therefore, it is important to identify the real shape of the EKC for a country for adopting an appropriate policy for mitigating environmental pollution. Although many studies in the context of Bangladesh have explored the inverted U-shaped EKC, none of the study explores the N-shaped EKC. Against this backdrop, the present study has attempted to explore the N-shaped EKC in Bangladesh.

This paper is divided into 5 sections. After introducing the issues in section 1, a brief review of literature is presented section in 2. Section 3 postulates the data and methodology, besides presenting the estimation model and econometric methodology. The analysis of the result and associated discussions are presented in section 4. Finally, section 5 concludes the paper with policy implications.

2. Literature Review

Over the last three decades, lots of research had been conducted to examine the authenticity of the inverted U-shaped EKC for various countries by using various sophisticated and rigorous econometric techniques, and a mixed of results have found. For instance, the study of Riti et al. (2017) in China from 1970 to 2015, Aslan et al. (2018) in the USA from 1966 to 2013, Haseeb et al. (2018) in the BRICS countries, Mosikari & Eita (2020) in the selected African countries from 2005 to 2019, Pata (2018) in Turkey, Rauf et al. (2018) in the "Belt and Road Initiative Economies", Rayhan & Islam (2018) in the five South-Asian countries, Akdiri et al. (2019) in 15 tourism prioritized countries, Kong & Khan (2019) in 14 developed and 15 developing countries, Dogan & Inglesi-Lotz (2020) in European countries, Murshed et al. (2020) in Bangladesh, and Villanthenkodath & Arakkal (2020) in New Zealand found the existence of inverted U-shaped EKC. While some other studies didn't find the existence of the inverted U-shape EKC, e.g., the EKC was found invalid by Gill et al. (2018) and Loganathan et al. (2020) for Malaysia, Destek et al. (2018) for EU countries, Moutinho et al. (2020) for OPEC countries, Pata & Caglar (2020) for China from 1980 to 2016, Erdogan et al. (2020) for 25 OECD countries from 1990 to 2014, and Nasir et al. (2021) for Australia from 1980 to 2014.

Therefore, the validity and shape of the EKC are highly dependent on the time frame, model specification, control variables, and econometric techniques applied. For example, Mehmood and Tariq (2020) analyzed the South Asia countries from 1972 to 2013 and revealed that an U-shape EKC exist in Afghanistan, Bangladesh, Nepal and Sri-Lanka while an inverted U-shape exit in Pakistan and Bhutan. But Murshed & Dao (2020) also studies the data of South Asia countries from 1972 to 2014 and revealed that an inverted U-shape EKC exist for Bangladesh and India, while for Pakistan the shape was U. So, in a general view, a totally opposite shape of the EKC was reported in two different studies but for the same region.

Besides, some recent studies have examined the shape of EKC beyond the conventional inverted U-shape and found some new insights (some studies have conducted by assuming the cubic shape of EKC and found the existence of N-shaped EKC instead of inverted U). For instance, the study of Bekhet & Othman (2018) examined the annual data of Malaysia from 1971 to 2015, and found the inverted N-shaped EKC. Similarly, the study of Barış-Tüzemen et al. (2020) also found inverted N-shaped EKC after analyzing the annual data of Turkey from 1980 to 2017. Besides, the study of Allard et al. (2018) found the validity of N-shaped EKC by analyzing the data of 74 countries from 1994 to 2012, and the study of Koc & Bulus (2020) also found the validity of N-shaped EKC for Korea from 1971 to 2017. The finding of these studies has uncovered that the real shape of EKC can be cubic, therefore, any analysis without checking the cubic shape can produce misleading results.

The N-shaped EKC implies that after coming the inverted U-shape the environmental pollution can increase further with higher level of economic growth. Therefore, it's important to identify the real shape of EKC for a country to adopt appropriate policy for mitigating pollution. If the shape becomes inverted U, then the policymakers can focus on accelerating current economic growth as higher economic growth will eliminate the degradation. But, if the shape of EKC becomes N-shaped, the policymakers have to think about the existing growth promoting policy since higher economic growth can further exacerbate the degradation. Against this backdrop, the present study has taken an attempt to explore the real shape of EKC in Bangladesh.

In the context of Bangladesh, all the studies have examined the shape of EKC by using the quadratic shape and found different results. For example, Islam et al. (2013) found the authenticity of inverted U-shaped EKC for Bangladesh from 1970 to 2010 by employing the ARDL model. Similarly, the study of Shahbaz et al. (2014) found the validity of inverted U-shaped EKC for Bangladesh from 1975 to 2010 by employing the ARDL model. Besides, the study of Rayhan et al. (2018) has found the authenticity of inverted U-shaped EKC for Bangladesh from 1973 to 2013 by employing the ARDL model. Recent studies of Murshed (2020) and Murshed et al. (2020) also examined the quadratic shape of EKC and found the inverted U-shape EKC for deforestation in Bangladesh. Contrary to these studies, the study of Rabbi et al. (2015) also examined the quadratic shape of EKC and reported a U-shaped EKC curve for Bangladesh from 1972 to 2012. Contradictory result was also reported on the study of Aziz & Chowdhury (2020). The study of Aziz & Chowdhury (2020) also examined the quadratic shape and found the monotonically increasing EKC curve for Bangladesh. It is a major gap in the existing literature, as none of the study in Bangladesh include the cubic shape in the EKC model which might produce misleading results. Therefore, the present study has aimed to meet up this research gap by exploring the cubic N-shape of EKC in the context of Bangladesh.

3. Methods and Materials

3.1 Estimation Model

The cubic specification of the EKC model implies the following function for estimation:

Environmental Pollution = f (economic growth, economic growth square, economic growth cube)… …(1)

But, estimating the function in equation (1) without considering some other relevant variables may constitute omitted variable bias problem, therefore, some other essential variables need to be included in the model besides economic growth.

One of the core variable in pollution research is energy consumption, omission of which may constitute omitted variable bias problem (Rayhan, 2020). Besides economic growth, energy consumption (from fossil fuels) deteriorate the environment by emitting various disastrous gases and particles in the air. Various studies have reported the detrimental impact of energy consumption on environmental pollution. For instance, the studies of Tachie et al. (2020), Moutinho et al. (2020), Mosikari & Eita (2020), and Usman et al. (2020) have reported the adverse effect of it.

Besides, globalization is another important variable that has some impacts on pollution. Globalization can improve the environmental quality, again it can impede the environmental quality too. For example, the study of Shahbaz et al. (2016) for China, and the study of Saud et al. (2020) for One Belt Road initiative countries have found that globalization has adverse impact of environment, while the study of Akadiri et al. (2019) for 15 tourism promoting countries, Khan & Ullah (2019) for Pakistan, and Salahuddin et al. (2019) for South Africa found that globalization improve the environmental quality. The advantage of the inclusion of globalization variable in the model is that it can capture the two other important variables named trade openness (which is export and import percentage of GDP) and foreign direct investment (FDI). Therefore, including the globalization index implies that trade openness and FDI are also included in the model. Similarly, financial sector development is another important variable that can influence the environmental quality. Therefore, to avoid the omitted variables bias problem the study also include energy consumption, globalization, and financial sector development variable in the model (1), which becomes now:

Environmental Pollution = f (economic growth, economic growth square, economic growth cube, energy consumption, globalization, financial sector development)… …(2)

The study used the carbon dioxide emissions (CO2) to represent the environmental pollution, real GDP per capita (PRGDP) to represent economic growth, energy consumption per capita (EC) to represent energy consumption, Globalization index (GI) to represent the degree of globalization, and domestic credit by financial institutions to represent financial development (FD). Therefore, the econometric model can be written as:

$$CO_2 = \beta_1 + \beta_2 PRGDP + \beta_3 PRGDP^2 + \beta_4 PRGDP^3 + \beta_5 EC + \beta_6 GI + \beta_7 FD + \in \cdots (3)$$

3.2 Sources and Nature of Data

Time series data of CO2 emissions per capita, real GDP per capita (constant dollar 2010), energy consumption per capita, and domestic credit provided by financial sector are collected from World Development Indicator (WDI) and data of globalization index is collected from KOF globalization index. Data were collected from 1974 to 2014. As energy consumption per capita data was available up to 2014, therefore, the study has included the data up to the years 2014 for analysis. Besides, the study has used the log transformation of the variables to estimate the elasticities. After log transformation, the equation (3) becomes as follows:

$$LNCO_2 = \beta_1 + \beta_2 LNPRGDP + \beta_3 LNPRGDP^2 + \beta_4 LNPRGDP^3 + \beta_5 LNEC + \beta_6 LNGI + \beta_7 LNFD + \in \cdots (4)$$

3.3 ARDL Bounds Test Procedure

The main advantage of the ARDL bounds test is the applicability of it for both the stationary and non-stationary time series. But, it is not applicable for the series where the integrated of order is more than one. Therefore, initially it is important to scrutinize the order of the time series before performing the bounds test. In this regard, the present study has employed the Phillips-Perron unit root test. After checking the unit root test, we can proceed the ARDL bounds test for checking the cointegration. The ARDL bounds test has required the estimation of the following equation:

$$\Delta LNCO2_t = \alpha_1 + \alpha_2 t + \beta_1 LNCO2_{t-1} + \beta_2 LNPRGDP_{t-1} + \beta_3 LNPRGDP^2_{t-1} + \beta_4 LNPRGDP^3_{t-1} + \beta_5 LNEC_{t-1} + \beta_6 LNGI_{t-1} + \beta_7 LNFD_{t-1} + \sum_{i=1}^{a} \gamma_{1i}\, \Delta LNCO2_{t-i} + \sum_{i=0}^{b} \gamma_{2i}\, \Delta LNPRGDP_{t-i} + \sum_{i=0}^{d} \gamma_{3i}\, \Delta LNPRGDP^2_{t-i} + \sum_{i=0}^{d} \gamma_{4i}\, \Delta LNPRGDP^3_{t-i} + \sum_{i=0}^{e} \gamma_{5i}\, LNEC_{t-i} + \sum_{i=0}^{f} \gamma_{6i}\, LNGI_{t-i} + \sum_{i=0}^{f} \gamma_{6i}\, LNFD_{t-i} + \omega_t \quad (5)$$

While, the null hypothesis for the bounds test is $H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$; against the alternative hypothesis $H_1: any\, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_{6,} \beta_7 \neq 0$. If the estimated value of the F statistic will exceed the upper bound value of the Pesaran et al. (2001) value set, then it can be concluded that the variables are cointegrated, otherwise not. If the variables are found to be cointegrated, then the long-run and short-run elasticities can be obtained by estimating the following error correction model:

$$\Delta LNCO2_t = \alpha_1 + \alpha_2 t + \sum_{i=1}^{a} \gamma_{1i}\, \Delta LNCO2_{t-i} + \sum_{i=0}^{b} \gamma_{2i}\, \Delta LNPRGDP_{t-i} + \sum_{i=0}^{d} \gamma_{3i}\, \Delta LNPRGDP^2_{t-i} + \sum_{i=0}^{d} \gamma_{4i}\, \Delta LNPRGDP^3_{t-i} + \sum_{i=0}^{e} \gamma_{5i}\, LNEC_{t-i} + \sum_{i=0}^{f} \gamma_{6i}\, LNGI_{t-i} + \sum_{i=0}^{f} \gamma_{6i}\, LNFD_{t-i} + \theta ECT_{t-1} + \vartheta_t \quad ......(6)$$

3.4 Diagnostic Tests

The study has also performed some essential diagnostic tests, which are required for the ARDL model. These tests are the test for serial correlation check, heteroskedasticity check, normal distribution check, and model correct specification check. Besides, structural stability of the estimated parameters are also checked.

4. Results and Discussions

The results of the Phillips-Perron (PP) unit root test are presented in Table-1. For the 'constant' specification, all the variables are non-stationary at their level form, but converted into stationary form after the first difference transformation. Therefore, for the 'constant' specification, all the variables are I(1) variables. For the 'constant & trend' specification, log of CO2 and FD are stationary at the level form, while remaining others are non-stationary. But, all these variables have converted into stationary after performing the first difference transformation. Therefore, for the 'constant & trend' specification, their exist an admixture of I(0) and I(1) series. However, none of the series is found to be I(2), therefore, there is no constraint to perform the ARDL bounds test.

Table 1. Results of Phillips-Perron Unit Root Test

		LNCO2	LNPRGDP	LNPRGDP2	LNGDP3	LNEC	LNFD	LNGI
Constant	t-Statistic	0.5479	7.7097	7.6489	8.6705	5.4013	0.0149	-1.4687
	Prob.	*0.9863*	*1.0000*	*1.0000*	*1.0000*	*1.0000*	*0.9544*	*0.5389*
		ns	ns	ns	ns	ns	ns	ns
Constant & Trend	t-Statistic	-3.7764	-0.2934	0.1747	0.9233	-0.7988	-3.6531	-2.0627
	Prob.	*0.0284*	*0.9882*	*0.9970*	*0.9998*	*0.9573*	*0.0377*	*0.5501*
		s	ns	ns	ns	ns	s	ns
		d(LNCO2)	**d(LNPRGDP)**	**d(LNPRGDP2)**	**d(LNGDP3)**	**d(LNEC)**	**d(LNFD)**	**d(LNGI)**
Constant	t-Statistic	-13.0571	-6.0940	-5.5256	-4.9405	-7.8820	-9.8583	-7.8788
	Prob.	*0.0000*	*0.0000*	*0.0000*	*0.0002*	*0.0000*	*0.0000*	*0.0000*
		s	s	s	s	s	s	s
Constant & Trend	t-Statistic	-13.3047	-9.2727	-8.5722	-7.9241	-13.8278	-9.6970	-8.2951
	Prob.	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
		s	s	s	s	s	s	s

(‘ns’ stands for non-stationary, and ‘s’ stands for stationary) (**Source: Software output)**

Table 2. Results of Bounds Test

Test Statistic	Value	k
F-statistic	6.688927	6
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.12	3.23
5%	2.45	3.61
2.5%	2.75	3.99
1%	3.15	4.43

(Source: Software output)

Table 3. Short-run Estimates of the ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNCO2(-1))	1.197425	0.158399	7.559560	0.0000
D(LNCO2(-2))	0.504512	0.099245	5.083496	0.0001
D(LAPRGDP)	1111.039083	475.389425	2.337114	0.0337
D(LAPRGDP(-1))	-595.905242	380.538045	-1.565954	0.1382
D(LNPRGDP2)	-175.714845	76.389616	-2.300245	0.0362
D(LNPRGDP2(-1))	95.023533	61.441431	1.546571	0.1428
D(LNGDP3)	9.236742	4.084385	2.261477	0.0390
D(LNGDP3(-1))	-5.025213	3.300173	-1.522712	0.1486
D(LNGDP3(-2))	-0.006154	0.005015	-1.227038	0.2387
D(LNEC)	2.122311	0.291370	7.283894	0.0000
D(LNEC(-1))	-1.771208	0.285486	-6.204179	0.0000
D(LNGI)	0.467389	0.164877	2.834780	0.0125
D(LNFD)	-0.127754	0.082791	-1.543091	0.1436
D(LNFD(-1))	-0.075155	0.064076	-1.172917	0.2591
D(LNFD(-2))	-0.348907	0.079453	-4.391354	0.0005
CointEq(-1)	-2.224214	0.222701	-9.987462	0.0000

(Source: Software output)

Before estimating the ARDL model, the study has performed the Vector Autoregressive (VAR) model to identify the optimal lag length and based on the Akaike information criteria lag 3 is selected for optimal lag to perform the ARDL model. The statistical software Eviews 9.0 evaluated total 12288 models with the optimal lag 3 for this study and among these models

ARDL (3, 2, 2, 3, 2, 1, 3) model is selected as the best model for analysis. The results of the bounds test for the selected model are presented in Table 2. The estimated F statistic (for k =6) has found about 6.6889, while the 1% critical upper bounds value is 4.43. As the estimated F statistic exceeds the 1% critical upper bounds value, therefore, it can be concluded that the variables are cointegrated at the one percent level of significance. As the variables are cointegrated, the error correction model can provide the short- and long-run estimates of the elasticities. Table 3 includes the results of the short-run estimates, while Table 4 presents the results of the long-run estimates.

Table 4. Long-run Estimates of the ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LAPRGDP	147.445031	29.859338	4.937987	0.0002
LNPRGDP2	-22.617310	4.927268	-4.590234	0.0004
LNGDP3	1.151376	0.270963	4.249193	0.0007
LNEC	1.871234	0.238384	7.849661	0.0000
LNGI	0.318468	0.085816	3.711068	0.0021
LNFD	0.143345	0.039363	3.641587	0.0024
C	-336.110622	60.541520	-5.551737	0.0001

(Source: Software output)

The short-run estimates have uncovered that the coefficient of the log PRGDP is statistically significant and positive, the coefficient of the square of the log RGDP is statistically significant and negative, and the coefficient of the cube of the log of PRGDP is statistically significant and positive. Therefore, the short-run results have justified the existence of the N-shaped EKC in Bangladesh. Similarly, the long-run estimates have confirmed that the coefficient of the log PRGDP is statistically significant and positive, the coefficients of the square of the log RGDP is statistically significant and negative, and the coefficients of the cube of the log of PRGDP is statistically significant and positive. Therefore, the long-run results also confirm the authenticity of the N-shaped EKC for Bangladesh.

The coefficient of the log of energy consumption per capita is significant and positive for both in the short- and long-run. But, the study has found that the long-run energy consumption elasticity is smaller than the short-run elasticities. This finding implies that in the long-run the emissions associated with energy consumption will decline. The will happen because of renewable energy transition. The study also finds that the coefficient of the log of globalization index is statistically significant and positive for both in the short- and long-run. This implies that globalization has a detrimental impact on the environment of Bangladesh. But, this impact will fall in the long-run compare to the short-run. Finally, the coefficient of the log of financial sector development is insignificant in the short-run, but significant and positive in the long-run. This implies that although in the short-run financial development has no impact on environmental pollution in Bangladesh, in the long-run it will significantly pollute the environment. Therefore, energy consumption, globalization, and financial development have long-run detrimental impact on the environment of Bangladesh. So, necessary mitigating policy should be adopted immediately to control the pollution.

The results of the associated diagnostic tests are summarized in table 5, from where it is observed that the estimated model is free from serial correlation and heteroskedascity problem, data are normally distributed, and the model is correctly specified. For checking the structural stability of the estimated parameters, Figure-1 and Figure-2 have illustrated the plot of CUSUM and plot of CUSUM square, respectively. In both plots, the parameters are within the confidence bounds that ensures the structural stability of the estimated parameters.

Table 5. Diagnostic Tests Results

Test	Statistic	p-value
ARCH Heteroskedasticity test	F (1, 35) = 0.9849	0.9849
Jarque-Bera Normality test	JB = 2.1912	0.3343
Breusch-Pagan LM test for serial correlation	F (3,12) = 0.9855	0.4323
Ramsey RESET test	F (1,14) = 1, 14	0.1479

(Source: Software output)

Figure 1. Plot of CUSUM

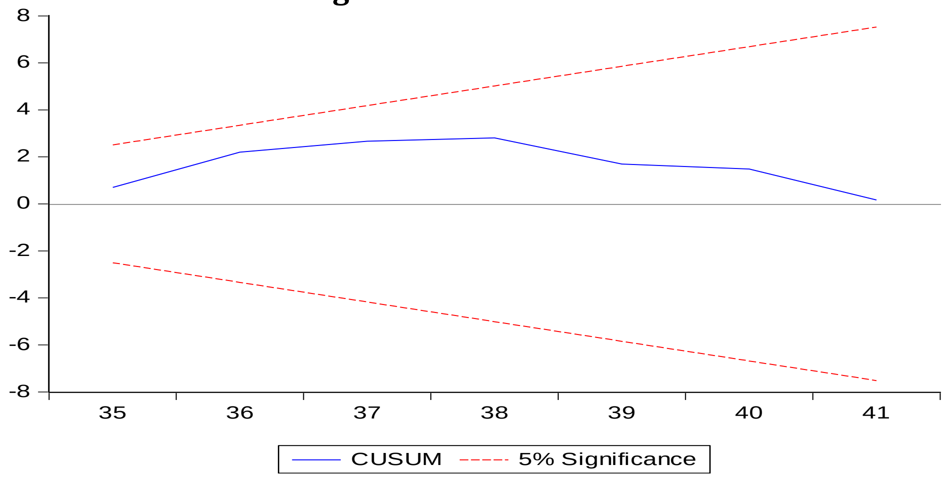
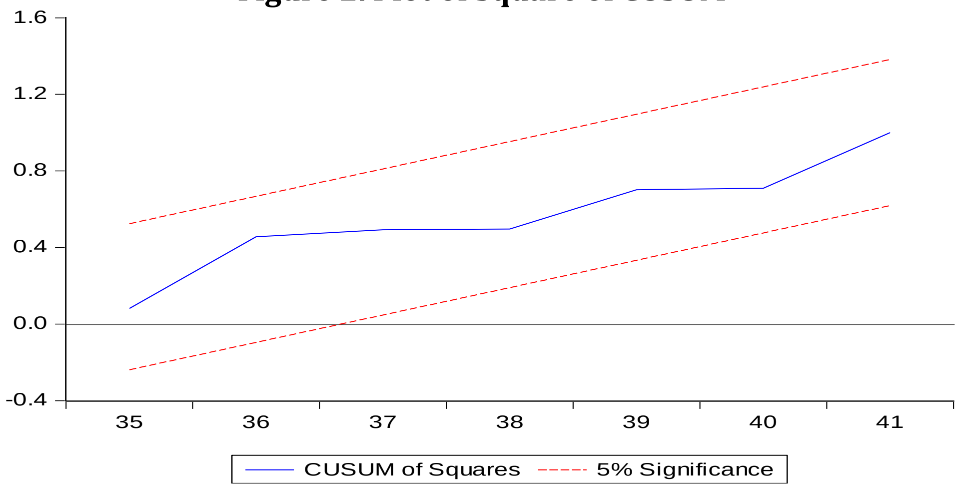


Figure 2. Plot of Square of CUSUM



5. Conclusions

The present study has explored the real shape of the Environmental Kuznets Curve for Bangladesh by using the cubic functional form. The estimated results have confirmed the authenticity of the N-shaped EKC for Bangladesh for both in the short- and long-run. The policymakers have to consider this findings seriously, as most of the previous studies related to Bangladesh had reported the inverted U-shaped EKC. This policy implication for this two different shapes are different. The existence of the inverted U-shape EKC implies that economic growth is the both cause and solutions of the pollution, therefore, higher economic growth will ensure the better environmental quality. So, there is nothing to be worried about controlling the current growth process. Contrary, the N-shaped EKC implies that although the higher economic growth can eliminate the environmental pollution, the pollution can increase further with the higher level of economic growth. Therefore, the policymakers have to adopt and in act appropriate policy to consider this possibility of increasing the pollution with higher economic growth. As N-shaped EKC is found in Bangladesh, the policymakers of Bangladesh should consider this issue at the time of mitigating pollution, otherwise, in the long-run environmental degradation will remain uncontrolled in Bangladesh and the population will face a serious deterioration in the overall health status.

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