IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Does Globalization asymmetrically impact on carbon emission in Bangladesh? Evidence from Nonlinear ARDL Approach

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Abstract: To check the asymmetric impact of globalization on carbon emission from 1973 to 2013 in Bangladesh is the main purpose of this article. Two unit root tests, the ADF test and the PP test, are used to find whether a variable is stationary or not. The NARDL method is appropriate to know the asymmetry and the co-integration among variables. By applying the Wald F test into the stepwise regression result, it is confirmed that there is no asymmetry among variables. So, the linear ARDL method is appropriate to use in this study. The short run and the long run results of the Linear ARDL model indicate that globalization and carbon emission are co-integrated and that globalization significantly increases carbon emission. The positive impact of PCGDP in the long run implies that LPCGDP is responsible for the increase in carbon emission in Bangladesh. The speed of adjustment is 136.62%. Therefore, policymakers should consider these findings to protect the environment.
Keywords: **Carbon emission, Globalization, Per capita GDP, ARDL, NARDL.**

I. Introduction

In recent years, developing countries have experienced increased growth in globalization. The world is more globalized and closer to the rest of the world than before because of the integration of trade and finance (Salahuddin et al., 2019). Three major effects of globalization like income effect, scale effect, and composition effect, is said to increase CO_2 (Antweiler et al., 2001). More carbon is emitted because of foreign trade and foreign investment which cover the income effect channel. Globalization also advocates the economics of scale by the accumulation of factors of production and integration of international markets and product diversifications (Salahuddin et al., 2019). Serious carbon emission as a result of scale effect and income effect is known as the composite effect. According to the KOF globalization index, Bangladesh is now more globalized comparing 1971(18.1) to 2017(51.3) in the index value. At the same time, carbon emission has increased more rapidly from 1973(0.067 metric tons per capita) to 2016(0.53 metric tons per capita).Many factors are responsible for the excessive carbon emission into the atmosphere. High economic growth, excessive energy use (renewable and non-renewable), electric power use, rapid urbanization process and trade openness are the key determinants ofCO_2 in the literature. Not only these factors, but globalization also the degraded environment by the pollution of air and water, ozone layer depletion from CFC gas, as a consequence, increase global warming for deforestation, and drastically change the climate, exhaustion of natural resources and deterioration of biodiversity cause the destruction of ecosystem (Kalayci, 2019). Besides, The EKC hypothesis (Grossman, & Krueger, 1995) explains the nexus between economic growth and quality of environment. At the initial level of growth, this relation is positive and after a certain point, it is negative. However, there exist two opposite theory named Pollution haven hypothesis introduced by Eskeland and Harrison, 2003 and the California effect hypothesis by Vogel, 1995 in the literature. These two hypotheses explain how globalization (trade) is responsible for and reduce carbon emission in developing countries.

The world is facing a potential threat, even the much afford and commitment of giant economy, of global warming and climate change. CO_2 emission is more responsible for global warming. Globalization and trade increase CO_2 drastically. But policymakers do not take into consideration these effects more seriously to a sustainable environment. Therefore, this study contributes to how globalization and trade impact carbon emission.

This analysis is completed by the following sub parts. The introduction is the very first chapter of the study. Then, a literature review is presented in part two. Part three covers methodology and data. Part four covers the analyses and discussion of empirical results and a conclusion and recommendation is added in the end of the study.

II. Literature Review

There is an interesting debate between the relationship of globalization and carbon emission. Some studies like Mehmood, & Tariq, (2020); Phong, L. H. (2019); Saint Akadiri, Lasisi, Uzuner, & Akadiri, (2019); Saint Akadiri et al, (2020); Khan, & Ullah, (2019); Shahbaz, Mahalik, Shahzad, & Hammoudeh, (2019); Salahuddin, Ali, Vink, & Gow,(2019); Shahbaz, Shahzad, & Mahalik, (2018); Haseeb, Xia, Baloch, & Abbas, (2018); Shahbaz, Mallick, Mahalik, & Loganathan, (2015) summarize that globalization is responsible for carbon emission.

Saint Akadiri et al. (2020) attempted to explain the cause of carbon emission. They added that the global environment is changing and a potential threat for humans despite commitments and awareness. They used different econometric techniques like ARDL and co-integration method by Bayer and Hanck, and Toda-Yamamoto causality approach to investigate the relationship between variables of interest. They concluded that globalization is responsible for environmental degradation. Khan, & Ullah, (2019) argued that human life and ecological system is hampered by global warming, climate change, and environmental degradation which are the results of excessive emission of CO2. They found that three types of globalization such as economic, political, and social globalization are responsible excessive CO2. They recommended that the reconstruction and reformation of the national environmental policy are essential to reduce emissions. Shahbaz et al. (2019) investigated the impact of globalization on CO2 using the cross-correlation approach on the ground of the EKC hypothesis. They found mixed results from high, middle, and low income countries. Globalization degrades only for 16 countries but enhances CO2 for the rest of the countries. They concluded that globalization degrades CO2 if the positive and negative cross-correlation between the present level of globalization with the past and future CO2 emission of countries. This interpretation is correct if EKC hypothesis is valid.

The impact of urbanization and globalization on CO2 for 44 Sub-saharan Africa(SSA) for 1984 t0 2006 was investigated by Salahuddin et al. (2019) and they found an insignificant effect of globalization on CO2. By using time series data of 1970-2014, Japan Shahbaz et al. (2018) explored the key determinants are globalization, economic growth and energy consumption are the key determinants of CO2. The ARDL method of threshold version is used and two shocks (positive and negative) of globalization increase CO2 where negative shock dominates positive shocks. They concluded that global warming and climate change affect at a micro and macro level more adversely if the policymakers do not take into consideration globalization as a policy variable for the sustainable environment. By applying Westerlund Co-integration test and Dumitrescu-Hurlin Granger Causality test for BRIC economics, Haseeb et al. (2018) investigated the EKC hypothesis. They found that globalization reduces CO2 insignificantly. And they concluded that globalization has a unidirectional relationship to CO2. Shahbaz et al. (2015) found that economic, social, and political globalization increase CO2 for India during 1970 t0 2012.

On the other hand, some studies like Suki, Sharif, Afshan, & Suki, (2020); Saud, Chen, & Haseeb, (2020); Amegavi, & Langnel, (2020); Zaidi, Zafar, Shahbaz, & Hou, (2019); Rafindadi, & Usman, (2019); Shahbaz, Khan, Ali, & Bhattacharya, (2017); Shahbaz, Solarin, & Ozturk, (2016); Baek, Cho, & Koo, (2009) mention that globalization reduces carbon emission.

Suki et al. (2020) investigated Malaysia for 1970-2018 applying QARDL and found that overall globalization and economic globalization reduce CO2. Saud et al. (2020) studied ecological footprint (EF) indicator for elected one-belt-one-road initiative countries for the time 1990-2014 and show that globalization hurts CO2. Amegavi, & Langnel, (2020) investigated Ghana from 1971 to 2016 using the ARDL method and found globalization decrease CO2. Zaidi et al. (2019) studied APEC countries for 1990-2016 under the EKC hypothesis and found that globalization reduces CO2. Baek et al. (2009) found that the consequence of increase in income and trade of globalization has a negative effect for developed countries and a positive effect for developing countries. Shahbaz et al. (2016) investigated EKC for 19 African countries for the time 1971-2012 and found that globalization reduces CO2 for 10 countries under study.

The purpose of this analysis is to explore the short-run and long-run asymmetric LGI effect on LCO2. In literature, for time series analysis, VAR, VECM, Pair-wise Granger causality, VECM Granger causality, and linear ARDL models are used to know the impact of LGI on CO2. But, no Nonlinear ARDL (NARDL) model is applied to find the asymmetric impact of LGI on CO2. Therefore, using NARDL feels the gap of the study.

III. Methods and Methodology

The purpose is to explore the asymmetric impact of LGI on LCO2. Time series annual data are taken for 1973 to 2016 from different sources such as, world development indicators, 2019 and KOF Globalization Index. CO2 is the carbon emission which is measured as a metric ton per capita, PCGDP is the per capita real GDP which is measured as constant 2010 US dollars, GI is the Globalization index. To express the data into percentage form, it is necessary to transform raw data into a natural log form. Therefore, the estimated coefficient is measured in elasticity form. Table: 1 is a short summary of the data. It includes the name of the variables, descriptions of each variable, their measurement units, and the sources of the data.

Table: 1 Data

Variables	Descriptions	Unit of measurement	Sources
LCO2	Emission of carbon dioxide gas	metric tons per capita	WDI
LPCGDP	Per capita real GDP	constant US$ of 2010	WDI
LGI	Globalization Index	KOF Index	KOF GI

In order to apply different time series model, the first task of a researcher is to check the unit root problem of a time series variables. If nonstationary series are used, it may result in spurious regression. Therefore, this study used Augmented Dickay Fuller (ADF) test and Phillips Perron (PP) test to know whether a variable has unit root problem or not. If the null hypothesis of unit root problem is rejected then it implies that there is no unit root problem, meaning the series is stationary.

The purpose of this analysis is to introduce the asymmetric impact of LGI on LCO2. To find this effect, Nonlinear Autoregressive Distributive Lag (NARDL) method is applied presented by Shin et al., 2014. This method can be applied by extending the ARDL method introduced by Pesaran et al., 2011. One of the pre-conditions in applying these methods is that the variables be I (0) and, or I (1), I (1) and, or I (0) mix but not I (2).

First, consider a regression model that shows the relationship LCO2 and LPCGDP and LGI. This relation is expressed by the following equation:

$$\Delta CO2_t = \alpha_0 + \alpha_1 LPCGDP_t + \alpha_2 GI_t + \upsilon_t \text{.................(1)}$$

Where, $\alpha_0, \alpha_1, and\, \alpha_2$, are the constant and the coefficients and υ_t is the residuals of the equation (1). In order to incorporate short-run and long run dynamics, it is necessary to build up a linear ARDL framework by the following equation:

$$\Delta LCO2_t = \delta_0 + \sum_{k=0}^{p} \delta_1 \Delta CO2_{t-k} + \sum_{k=0}^{p} \delta_2 LPCGDP_{t-k} + \sum_{k=0}^{p} \delta_3 LGI_{t-k}$$

$$+\beta_0 LCO2_{t-1} + \beta_1 LPCGDP_{t-1} + \beta_2 GI_{t-1} + \omega_t \text{..................(2)}$$

Where, Δ represents the first difference and k is the lagged value and the short-run coefficients are $\delta_1 \rightarrow \delta_3$ and the long-run coefficients are $\beta_0 \rightarrow \beta_2$ and ω_t is the residuals. The error correction form of the equation (2) is expressed by the following equation:

$$\Delta LCO2_t = \gamma_0 + \sum_{k=0}^{p} \gamma_1 \Delta CO2_{t-k} + \sum_{k=0}^{p} \gamma_2 LPCGDP_{t-k} + \sum_{k=0}^{p} \gamma_3 LGI_{t-k} + \lambda_0 ECT_{t-1} + \psi_t \text{.................(3)}$$

From equation (2), applying the bnound F test, the existence of cointegration can be checked. The hypothesis for the test is as follows:

$$H_0 = \beta_0 = \beta_1 = \beta_2 = 0, and\, H_1 = \beta_0 \neq \beta_1 \neq \beta_2 \neq 0.$$

From the linear ARDL, if the estimated F statistic value is greater than I(1) critical values introduced by Pesaran et al. (2001) then we can reject the null hypothesis, otherwise we do not reject. In equation (1), LGI is assumed linear effect on LCO2. Therefore, to apply NARDL Positive and negative shocks of LGI are introduced by the following equation:

$$LGI_t^+ = \sum_{j=1}^{t} LGI_j^+ = \sum_{j=1}^{t} \max(LGI_j^+, 0) \text{................................(4)}$$

$$LGI_t^- = \sum_{j=1}^{t} LGI_j^- = \sum_{j=1}^{t} \min(LGI_j^-, 0) \text{................................(5)}$$

To get the NARDL form, we introduce LGI_t^+ and LGI_t^- term into equation (2) as follows:

$$\Delta LCO2_t = \delta_0 + \sum_{k=0}^{p} \delta_1 \Delta CO2_{t-k} + \sum_{k=0}^{p} \delta_2 LPCGDP_{t-k} + \sum_{k=0}^{p} \delta_3 LGI_{t-k}^+ + \sum_{k=0}^{p} \delta_4 LGI_{t-k}^-$$

$$+\beta_0 LCO2_{t-1} + \beta_1 LPCGDP_{t-1} + \beta_2 LGI_{t-k}^+ + \beta_3 LGI_{t-k}^- + \vartheta_t \text{.................(6)}$$

The error correction form of the equation (6) is mention below:

$$\Delta LCO2_t = \gamma_0 + \sum_{k=0}^{p} \gamma_1 \Delta CO2_{t-k} + \sum_{k=0}^{p} \gamma_2 LPCGDP_{t-k} + \sum_{k=0}^{p} \gamma_3 LGI_{t-k}^+ + \sum_{k=0}^{p} \gamma_4 LGI_{t-k}^- + \lambda_0 ECT_{t-1} + \psi_t \text{.................(7)}$$

After estimating equation (6) and (7), a Wald test is used to check the short run and long run asymmetry incorporating the following restrictions: For, short-run: $\frac{\delta_{3+}}{\delta_1} = \frac{\delta_{4-}}{\delta_1}$ and long-run $\frac{\beta_{2+}}{\delta_1} = \frac{\beta_{3-}}{\delta_1}$.

If asymmetry is confirmed either short run or long run, then dynamic multipliers are calculated, otherwise, linear ARDL is more suitable than NARDL.

IV. RESULTS AND DISCUSSION

The first part of the findings and discussion is descriptive studies. Table 2 is the summary of different important value and test. CO2, GI, and TR data are normally distributed.

Table: 2 Descriptive studies

	CO2	PCGDP	GI
Mean	0.193894	497.8064	33.32674
Median	0.146247	439.2300	32.08146
Maximum	0.454664	907.2574	51.83924
Minimum	0.067336	328.0719	18.30952
Std. Dev.	0.113988	158.8818	10.37913
Skewness	0.889944	1.098678	0.326424
Kurtosis	2.691003	3.142569	1.946465
Jarque-Bera	5.575118	8.283198	2.624249
Probability	0.061571	0.015897	0.269247

Table 3 is the summary of ADF test and PP test. A unit root test is necessary to know the order of the integration of each variable. In unit root tests, intercept and trend are tested both in level and first difference form. Table 3(a) and 3(b) indicate that ADF test including the intercept term, all the variables are I (1) at first difference but ADF test including trend and PP test including intercept and trend either variables are stationary at a level or first difference. This indicates that variables are mixed order of integration, I (1) and I (0) or I (0) and I (1).

Table: 3(a) ADF and PP Results

	ADF(LEVEL)				**PP(LEVEL)**				
	Intercept		**Trend**			**Intercept**		**Trend**	
Variables	**T stats**	**P-value**	**T stats**	**P-value**	**Variables**	**T stats**	**P-value**	**T stats**	**P-value**
LCO2	1.228287	0.9977	-4.044587 **	**0.0149**	LCO2	1.426488	0.9988	-3.833279 **	**0.0249**
LPCGDP	3.811884	1.0000	0.495027	0.9989	LPCGDP	7.957668	1.0000	1.730527	1.0000
LGI	-0.831687	0.7990	-2.636227	0.2673	LGI	-0.887081	0.7821	-2.616907	0.2753
ADF (First difference)					**PP(First difference)**				
Variables	T stats	P-value	T stats	P-value	Variables	T stats	P-value	T stats	P-value
LCO2	-6.503997 *	0.0000	-6.669847 *	0.0000	LCO2	-12.44715 *	0.0000	-13.90171 *	0.0000
LPCGDP	-6.469582 *	0.0000	-13.31354 *	0.0000	LPCGDP	-6.752894 *	0.0000	-11.89501 *	0.0000
LGI	-7.387284 *	0.0000	-7.543760 *	0.0000	LGI	-7.387284 *	0.0000	-7.518698 *	0.0000
Significance level: *=1%, **=5%, ***=10%,									

Table: 3(b)

ADF					**PP**				
	Trend		**Intercept**			**Trend**		**Intercept**	
Variables	**Level**	**First difference**	**Level**	**First difference**	**Variables**	**Level**	**First difference**	**Level**	**First difference**
LCO2	I(1)	I(0)	I(0)	I(0)	LCO2	I(1)	I(0)	I(0)	I(0)
LPCGDP	I(1)	I(0)	I(1)	I(0)	LPCGDP	I(1)	I(0)	I(1)	I(0)
LGI	I(1)	I(0)	I(1)	I(0)	LGI	I(1)	I(0)	I(1)	I(0)
			I(1) and I(0)					**I(1) and I(0)**	

Table 4 indicates that optimum lag is 3 on the basis of AIC criteria where endogenous variables are D(LCO2) D(LPCGDP) D(LGI). AIC criteria select 3 optimal lag and ARDL takes (3, 3, 3) lag as fixed for the rest of the analysis.

Table 4 Lag Order Selection Criteria

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	233.4865	NA	7.80e-10	-12.45873	-12.32812*	-12.41268*
1	239.9248	11.48440	8.98e-10	-12.32026	-11.79780	-12.13607
2	250.6314	17.36207	8.28e-10	-12.41251	-11.49820	-12.09017
3	265.2373	21.31681*	6.28e-10*	**-12.71553***	-11.40938	-12.25505

Table 5 is the summary of nonlinear ARDL short run, long run and bound F test and asymmetry test result. In the short run, a 1% increase in LPCGDP causes a 0.82% decrease in LCO2. The increasing components of LGI increase LCO2 significantly. For a 1% increase in LGI, increase LCO2 by 0.50%. The decreasing components of LGI increase LCO2 but insignificantly. 0.19% LCO2 is increase by 1% decrease in LGI. This result indicates that the positive component of LGI responds more to LCO2 than that of the negative component. The speed of adjustment is 162.33%, meaning that the divergence from the long-run to short-run adjustment every year is 162.33% which is highly statistically significant.

The second portion of table 5 represents the long-run result. For a 1% increase in LPCGDP, 4.03% increases in LCO2. The positive components of LGI has a significant positive effect on LCO2, meaning that for a 1% increase in LGI, increase LCO2 by 0.62%. But the negative components of LGI decrease LCO2 by 1.69% and the effect is also significant.

The third part of table 5 represents the long run bound F test approach. The F statistics is 7.135731 which is greater than I (1) value at a 5% significance level. This result indicates that variables are co-integrated. Therefore, short-run and long-run asymmetry can be checked. Since the short-run asymmetry is not determined due to the inclusion of differenced positive and negative variable in to the stepwise regression. But the long-run asymmetry of Wald test indicates that there is no asymmetry of LGI variables on LCO2 in the long-run. Therefore, the linear ARDL model is more appropriate to apply to know the impact of LGI on LCO2.

Table: 5 Nonlinear ARDL results

Short-run result			
Variable	**Coefficient**	**t-statics**	**P-values**
D(LPCGDP)	-0.827146	-1.692425	0.1061
D(LGI_POS)	0.500713***	1.809218	0.0855
D(LGI_NEG)	-0.197640	-0.178582	0.8601
CointEq(-1)*	-1.623310*	-6.543270	0.0000
Long run result			
Variable	**Coefficient**	**t-statics**	**P-values**
LNPRGDP	0.437239*	3.692837	0.0014
LNGI_POS	0.625801	2.232328	0.0372
LNGI_NEG	1.691000**	2.514785	0.0206
@TREND	0.027961*	3.620718	0.0017
Bound F test result			
Test Statistic		**Value**	
F-statistic		7.135731	
Significance		**I(0)**	**I(1)**
10%		10%	2.97
5%		5%	3.38
Long run asymmetry test: Wald Test			
		Long-run Asymmetry	
Exogenous Variables		**F-stat**	**P-value**
LTR		0.859773	0.3605
Significance level: *=1%,**=5%,***=10%,			

Table 6 shows the model diagnostics test for heteroskedasticity, serial correlation, normality of the data and model specification test. The hypothesis is added in table 6 and shows no null hypothesis is rejected, meaning that there is no heteroskedasticity problem in the model, residual variances are serially uncorrelated, data is distributed normally and the model is correctly specified.

Table: 6 Model Diagnostics Test Result

Model Diagnostics	**Hypothesis**	**Statistic(s)**	**P-Value(s)**
Breusch-Pagan-Godfrey	H_0= There is heteroscedasticity	4.338647	0.5018
Breusch-Godfrey LM Test:	H_0= There is no serial correlation	0.125701	0.9391
Jarque Bera Test	H_0= Data is normally distributed	0.4908	0.7823
Ramsey RESET Test	H_0= The model is correctly specified	0.112500	0.7395

Figure 1 is the recursive test of CUSUM and CUSUM of the square. The CUSUM test indicates that the parameters are stable under the 5% significance level but the CUSUM of square test implies that the parameters are stable at 5% level of significance Therefore, the parameters are stable.

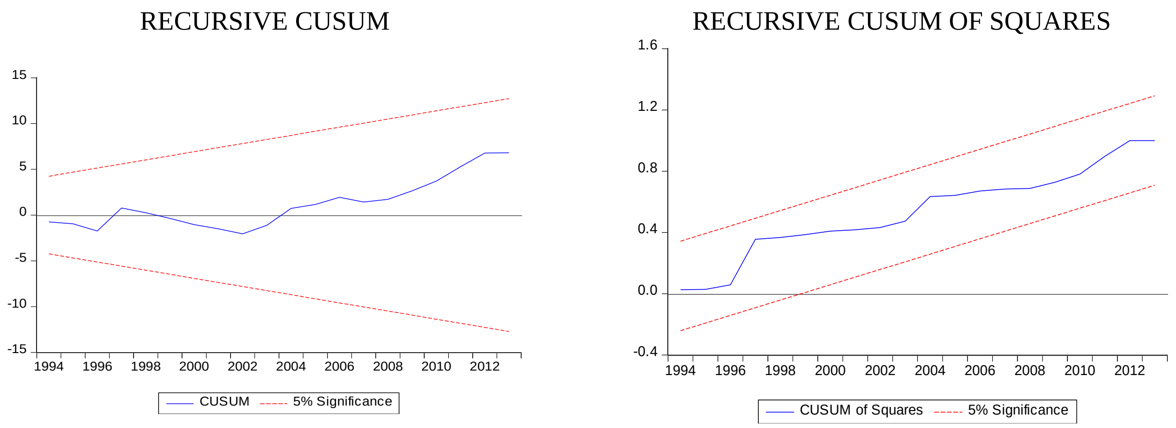

Figure 1: Stability test for NARDL

Table 6 represents the summary of linear ARDL results. In the short run, LPCGDP has a negative effect on LCO2. For a 1% increase in LGI causes a 0.47 % significant increase in LCO2, meaning that LFI is responsible for LCO2 in the short run. The deviation of long-run to short-run is 136.62% every year which is highly statistically significant. In the long-run, LPCGDP effects on LCO2 significantly positive. LGI significantly increase LCO2. For a 1% increase in LGI, increase a 0.50% increase in LCO2.

The value of long-run bound F test statistics is 7.100878 which is higher than the upper bound of I (1) at 5% level meaning that there is co-integration among the variables

Table 6: Linear ARDL result

Short-run result			
Variable	**Coefficient**	**t-statics**	**P-values**
D(LPCGDP)	-0.707662	-1.396495	0.1748
D(LGI)	0.475861**	2.053721	0.0506
CointEq(-1)*	-1.366211*	-5.640207	0.0000
Long run result			
Variable	**Coefficient**	**t-statics**	**P-values**
LNPRGDP	0.516067*	4.026469	0.0005
LNGI	0.507937**	2.172373	0.0395
@TREND	0.025475*	3.344788	0.0026
Bound F test			
Test Statistic		**Value**	
F-statistic		7.100878	
Significance		**I(0)**	**I(1)**
10%		3.38	4.02
5%		3.88	4.61
Significance level: *=1%,**=5%,***=10%,			

Table 7 is the results of the diagnostic test of the linear ARDL model. The heteroskedasticity test, Serial Correlation test, normality test, and model specification test indicate that there is no such problem because no null hypothesis is rejected.

Table: 7 Diagnostic tests result

Model Diagnostics		**Statistic(s)**	**P-Value(s)**
Breusch-Pagan-Godfrey	H_0= There is heteroscedasticity	13.6165	0.3259
Breusch-Godfrey Serial Correlation LM Test:	H_0= There is no serial correlation	0.9012	0.8095
Jarque Bera normality Test	H_0= Data is normally distributed	0.7468	0.6883
Ramsey RESET Test	H_0= The model is correctly specified	1.246321	0.2753

Figure 2 indicates the recursive CUSUM and CUSUM of square test. With 5% significance level, both tests indicate that the parameters are stable and there is no break.

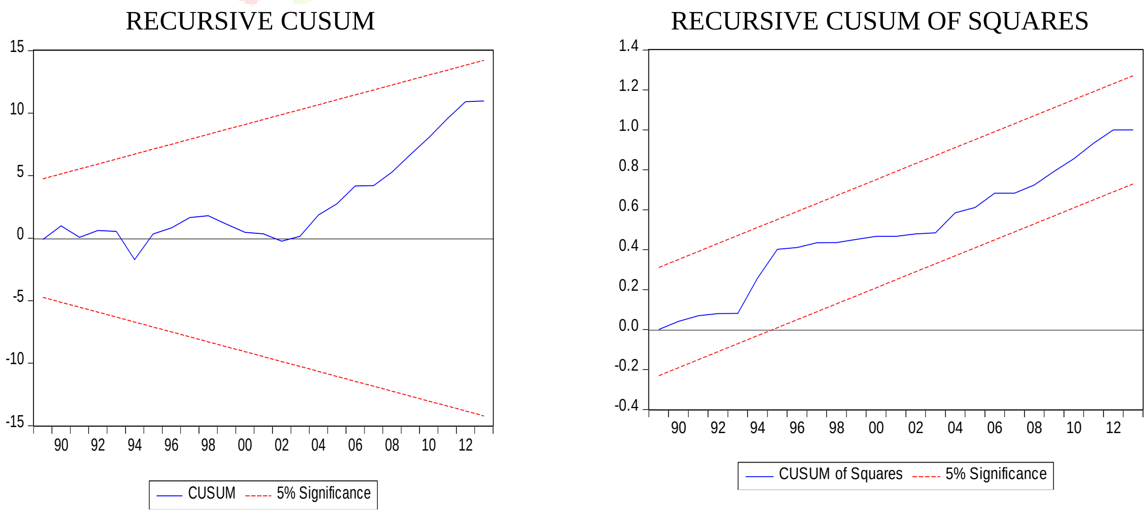

Figure 2: Stability test for ARDL

V. CONCLUSION

Globalization is the most influencing factors that is responsible for carbon emission in Bangladesh. The gradual increase in carbon emission degrades the environment. To capture this concept, this study, particularly investigates the asymmetric impact of globalization on CO2 by applying NARDL method. The study finds no asymmetry in the short run or long run and is recommended to apply the linear ARDL method. Globalization significantly increases CO2 both in the short-run and long-run Therefore, policymakers take into consider the globalization impact while taking the environmental policy.

This study has some limitations. The study should include more variables related to the asymmetric effect besides globalization. The short run the asymmetry is undermined due to the inclusion of the short-run shocked terms. Finally, the data set can be more up to date if we include 2014- 2020 data.

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