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Asymmetric impact of trade on carbon emission in Bangladesh: Evidence from nonlinear ARDL

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Abstract:*To investigate the existence of Environmental Kuznets curve (EKC) hypothesis for 1973-2014 in Bangladesh incorporating the asymmetric impact of trade and symmetric impact of per capita GDP and square of per capita GDP on carbon emission, is the purpose of this analysis. ADFtest is performed to know the orders of integrations of data and the Nonlinear ARDL (NARDL)method is applied to check the asymmetric impact of trade on carbon emission. Both NARDL and ARDL methods are used to find the short run and long run relationship. The Wald test result shows that there is a long-run asymmetry between trade and carbon emission. The statistical results confirm,in the short run, that trade is significantly responsible to increase carbon emission. The short run and the long run NARDL and ARDL results indicate the statistically significant positive impact of per capita GDP and statistically significant negative impact of per capita GDP square on carbon emission. These findings confirm the validity of EKC in Bangladesh. Policymakers should take these findings into consideration while taking policy regarding trade and environmental quality.*
Key words:*Carbon emission, Trade, Per capita GDP,Nonlinear ARDL, EKC.*

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I. Introduction

The analysis to know about the effect of economic growth onthe quality of environmenthas crucial importance for the economists, environmentalists, policymakers, and general people. The world faces hazardous problems on the matter of global warming. In the existing literature, Carbon dioxide emissions, sulfur dioxide emissions, Greenhouse gas emissions, deforestation, municipal -waste etc. are considered as the good indicatorsof environmental quality loss, while Economic growth, Trade, energy use, electricity use, urbanization process and population density are the key responsible factors for the environmental degradation. The main reason for increasing carbon emission is the additional Energy use (Alamet al.2016).This connection between quality of environment and economic growth are known as EKC. The EKC hypothesis has been dominating the literature since1980s (Mahmood et all.,2019).

Most studies on EKC reported the inverted U shape EKC exists along with only a few different shapes for different countries (Shahbazet all, 2015). Carbon emission increases when economic growth is initial level and it gradually decreases when economic growth is high level on the basis of EKC. Therefore, there is no unique policy recommendation that can be prescribed across the countries. This paper has immense contribution to check the EKC hypothesis for Bangladesh.

Trade directly influences economic growth and it is also anessential determinant, in literature, of CO2 (Grossman & Krueger, 1996, 1991). Besides the existence of EKC, Trade significantly influences on environment. This influence comes from either imported goods and services or exported goods and services or both. The rationale behind choosing trade as an important variable in the analysis is that trade has asymmetric impact on CO2.Therefore, policy regarding trade (increasing or decreasing) influence the policy recommendation of environmental pollution. The CO2 emission is 0.48 metric tons per capita which is very low in comparison of Trade which 44.51 percent of GDP in Bangladesh in 2014. Policy regarding trade can protect environment. Therefore, Trade along with growth and environmental quality are focusing concern about the public policy makers.

This analysis is divided into five chapters. Chapter one covers introduction. A literature review is presented in chapter two. Chapter three covers methodology and data. Chapter four covers the analyses and discussionof empirical result and finally, Chapter five includes conclusion.

II. Literature review

There is an interesting debate among the economists about the environmental quality and economic prosperity. Most of the studies reported that environmental quality can degraded due to increase economic growth and some other factors like trade, energy consumption, urbanization, population density etc. The

impactof economic growth on environmental degradation is known as EKC and its general shape is inverted U. One important thing for EKC is that it takes different shape in different countries, meaning that the existence of EKC hypothesis is much more changeable for different countries. That is why policy makers cannot provide a unique treatment for pollution.

The studies like Al-Mulali, Ozturk, & Lean, (2015);Apergis&Ozturk, (2015);Lau, Choong, &Eng, (2014);Shahbaz, Khraief, Uddin, &Ozturk, (2014);Jayanthakumaran, Verma, & Liu, (2012);Farhani, Chaibi, &Rault, (2014);Kasman, &Duman, (2015);Pao, & Tsai, (2010);Saboori, Sulaiman, &Mohd, (2012); Kohler (2013);Shafiei&Salim, (2014);Atici (2009) reported the existence of EKC in different countries. For these studies, economic growth has positive and square of economic growth has inverse effect on CO2.

At the same time, there are only a few studies reported the nonexistence of EKC. There are many catagories of EKC depending on the target variables. CO2 has been used as the most common indicator of environmental degradation. Some previous studies like Pata&Aydin, (2020); Leal & Marques,(2020);Murshed& Dao, (2020);Murshed, Nurmakhanova, Elheddad, & Ahmed, (2020);Dogan, &Inglesi-Lotz, (2020); Awodumi, &Adewuyi, (2020);Usman, Iorember, &Olanipekun, (2019);Işık, Ongan, &Özdemir, (2019); Zhang, Chen, Wu, Shuai, &Shen, (2019);Shahbaz, Balsalobre-Lorente, &Sinha,(2019);Pata, (2018); Dong, Sun, & Dong,(2018);Riti, Song, Shu, &Kamah, (2017); Zoundi, (2017);Saboori, Sapri, & bin Baba, (2014);Chandran, & Tang, (2013); Kohler, (2013);Shahbaz, Lean, &Shabbir, (2012);Pao, & Tsai,(2011); Narayan, & Narayan, (2010) focus Carbon emission is the most important indicator of environmental degradation.

Some studies have emphasized on finding the connection of economic growth onCO2 and found that trade is the major cause of CO2for scale effect and it is also helpful to reduce emission for technique effects. According to Grossman & Krueger (1996, 1991) the EKC hypothesis tells us that more income at the early stage of growth is the cause for higher emission and reduces emission at the next stage of growth. The asymmetry between economic growth and CO2 exists for trade. Some other empirical studies like Haug&Ucal, (2019);Muhammad ,Long, Salman, &Dauda, (2020); Essandoh, Islam, &Kakinaka, (2020);Wasti&Zaidi, (2020);Koshta, Bashir, &Samad, (2020);Koc&Bulus, (2020);Koc&Bulus, (2020); Van Chien, (2020);Rana, & Sharma, (2019); Chen, Wang, &Zhong, (2019);Zafar, Mirza, Zaidi, &Hou, (2019); Huang, Chen, Zhu, Huang, &Tian, (2019); Chen, Wang, &Zhong, (2019);Isik, Ongan, &Ozdemir, (2019);Ozatac, Gokmenoglu, &Taspinar, (2017);Jafari, Othman, & Nor, (2012);Jayanthakumaran, Verma, & Liu, (2012); Kohler, (2013);Shahbaz, Lean, &Shabbir, (2012); Halicioglu, (2009) include as a determinant of CO2 emissions. These findings suggeststhat trade influence positively,negatively and no effect on the all investigated emission.

Most of the studies like Hakimi, &Hamdi,(2016); Chang, (2015);Shahbaz, Khraief, Uddin, &Ozturk, (2014); Kozul-Wright, &Fortunato, (2012);Chebbi, Olarreaga, &Zitouna, (2011);Managi, Hibiki, & Tsurumi, (2009);Halicioglu,(2009);repoted that trade is responsible for carbon emission. On the other hand studies like ,Mahmood, &Alkhateeb, (2017);Shahbaz, Nasreen, Ahmed, &Hammoudeh, (2017); Ahmed, Shahbaz, &Kyophilavong, (2016); Al-Mulali, Ozturk, & Lean, (2015)reported that trade is good for environment. andMahmood, Furqan, Alkhateeb, &Fawaz, (2019) reported no significant relationship.

Many time series studies use convention estimation technique like Johansen co-integration test, VAR and VECM Granger Causality and Granger Pair-wise causality test and ARDL method butonly Yasin (2020), Iorember, Usman, &Jelilov, (2019) are used Nonlinear ARDL test between CO2 and trade.

Objective and Research Gap

Thepurpose of this analysis is to check the relevance of EKC for Bangladesh both in short run and long run incorporating asymmetric trade effect. In literature, for time series analysis, VAR, VECM, Pair-wise Granger causality, VECM Granger causality, and Symmetric or linear ARDL models are used to know the impact of Trade on CO2. But, only a few studies have conducted considering the asymmetric impact of trade on CO2. In Bangladesh, no Nonlinear ARDL(NARDL)model is applied in order to find the asymmetric impact of trade on CO2. Therefore .using NARDL feels the gap of the study.

III. Empirical modeling and econometric methodology

Data

The study analyzes the asymmetric impact of trade on Carbon emission and check the existence of EKC in Bangladesh during 1973-2014 data. Carbon emission is set as dependent variable and Trade, GDP per capita, square of GDP per capita are the independent variables. Last two variables are introduced to know the shape of EKC in Bangladesh.CO2, a proxy of environmental loss, is measured in metric tons per capita, PCGDP, the proxy of economic growth, is taken constant 2010 US$ and TR is measured as the percentage of GDP. Data are transformed in to natural log, so that the unit is expressed as percentage form. The source of data isWorld Development Indicators,2019.

Econometric methods

This analysisis represented by using an unconventional method to consider the nonlineareffect of trade on carbon emissions, since conventional methods of co-integration do not implement the nonlinear effect (Katrakilidis, and Trachanas,2012).

In the ARDLmethod, co-integration among variables represents the long run relationship while ECM shows the short run to long run adjustment among variables with linear effect. But, the asymmetric aspect was overlooked in the analysis.In the linear ARDLmethod, the relationship among variables is symmetric. Therefore, linear ARDL model is modified to introducenon-linear effect and named Nonlinear ARDL model (Shin, Yu, and Greenwood-Nimmo2014).The Nonlinear ARDL model has an advantage over other models that it allows I(0) and I(1), or I(1) and I(0), meaning that the model permit to use mixed integration order for the Co-integration. ARDL model is extended by the following equation:

$$CO2_t = \gamma_0 + \gamma_1 LPCGDP_t + \gamma_2 LPCGDP_t^2 + \gamma_3^+ LTR_t^+ + \gamma_4^- LTR_t^- + \varepsilon_t ...(1)$$

Where, $\gamma = (\gamma_1, \gamma_2, \gamma_3^+, \gamma_4^-)$ shows the long run coefficient. As LTR_t^+ shows the positive partial sum decomposition and LTR_t^- shows the negative partial sum decomposition in LTR :

$$LTR_t^+ = \sum_{j=1}^{t} LTR_j^+ = \sum_{j=1}^{t} \max(LTR_j, 0)$$
$$LTR_t^- = \sum_{j=1}^{t} LTR_j^- = \sum_{j=1}^{t} \min(LTR_j, 0) ...(2)$$

From equation (1), Nonlinear ARDL model (Shin, Yu, and Greenwood-Nimmo2014) is expressed using following equation:

$$\Delta LCO2_t = \phi_0 + \phi_1 CO2_{t-i} + \phi_2 LPCGDP_{t-1} + \phi_3 LPCGDP_{t-1}^2 + \phi_4^+ LTR_{t-1}^+ + \phi_5^- LTR_{t-1}^-$$
$$+ \sum_{i=1}^{p} \Omega_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \Omega_2 \Delta LPCGDP_{t-i} + \sum_{i=1}^{r} \Omega_3 \Delta LPCGDP2_{t-i} + \sum_{i=1}^{m} \Omega_4^+ LRT_t^+ + \sum_{i=1}^{m} \Omega_5^- LRT_t^- + \Psi_t ...(3)$$

Where, p, q, r and m present the orders of lags. In order to estimate equation (1) without the problem of hidden Co-integration the following restriction on the coefficient of the equation (1) are required as:

$$\gamma_3^+ = \phi_4^+ / \phi_1 \text{ and } \gamma_4^- = \phi_5^- / \phi_1$$

And $\sum_{i=1}^{m} \Omega_4^+$ calculate thepositive effectand $\sum_{i=1}^{m} \Omega_4^-$ calculate the negative effect in the short run of LTR on LCO2, respectively.From equation (3), the error correction model is expressed by following equation:

$$\Delta LCO2_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \beta_2 \Delta LPCGDP_{t-i} + \sum_{i=1}^{r} \beta_3 \Delta LPCGDP2_{t-i} + \sum_{i=1}^{m} \beta_4^+ LRT_t^+ + \sum_{i=1}^{m} \beta_5^- LRT_t^- + \lambda_i ECT_{t-1} + \xi \nu_t ...(4)$$

Here, $\beta_0, \beta_1, \beta_2, and \beta_3$, show thecoefficients in short-run, while $\beta_4^+ and \beta_5^-$ show the adjustment of symmetry in the short runand λ_i is the ECM.To find the long run asymmetry, Wald test is used. The hypothesis is mention below:

$$H_0 : \phi_0 = \phi_1 = \phi_2 = \phi_3 = \phi_4^+ = \phi_5^- = 0$$

$$H_1 : \phi_0 \neq \phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4^+ \neq \phi_5^- \neq 0$$

Dynamic multiplier effect is checked in the presence of longrun asymmetry between LTR and LCO2.As one percent change in $LTR_{t-i}^+ and LTR_{t-i}^-$ presented as:

$$M_b^+ = \frac{\sum_{j=1}^{b} \Delta LCO2_{t+j}}{\Delta LTR_t^+} and M_b^- = \frac{\sum_{j=1}^{b} \Delta LCO2_{t+j}}{\Delta LTR_t^-} where, b \to \infty, M_b^+ \to \gamma_3^+ and M_b^- \to \gamma_4^- ...(5)$$

IV.Empirical findings and discussion

Descriptive statistics is the first part of this paper. Table-1includesshort summary of each variable. It includes mean, median, maximum and minimum, standard deviations, skewness, Kurtosis and Jarque-Bera test and its probability value.

Table: 1 Descriptive studies

	CO2	PCGDP	PCGDP2	TR
Mean	0.200642	508.6042	287499.9	26.69886
Median	0.151269	442.9424	196211.8	23.24941
Maximum	0.477336	951.3148	904999.9	48.11092
Minimum	0.067336	328.0719	107631.2	10.99563
Std. Dev.	0.120785	171.8274	209030.9	9.896058
Skewness	0.878699	1.109956	1.501382	0.760280
Kurtosis	2.620869	3.145655	4.278547	2.510366
Jarque-Bera	5.656323	8.661143	18.63973	4.465726
Probability	0.059121	0.013160	0.000090	0.107221

The ADF tests are performed to knowwhether a variable is stationary or not. The results ofTable-2shows that LCO2, LPCGDP, LPCGDP2 are I(1) in nature and LTR is I(0) in nature. Therefore, data of the variables are mixed order of integration, meaning that they are I(1) and I(0). Since, no variables take I(2), and all the variables are I(1) and I(0), then nonlinear ARDL model is appropriate to apply for finding the co-integration using bound F test approach .

Table: 2ADF Test: Unit root test

Level Form Constant, Linear Trend				**First difference Form** Constant, Linear Trend			
	t Statistic	**P value**	**Order(s) of Integration**		**t Statistic**	**P value**	**Order(s) of Integration**
LCO2	-2.902936	0.1722	I(1)	**LCO2**	-5.526307	0.0003	I(0)
LPCGDP	1.155973	0.9999	I(1)	**LPCGDP**	-13.42384	0.0000	I(0)
LPCGDP2	1.748069	1.0000	I(1)	**LPCGDP2**	-12.56896	0.0000	I(0)
LTR	-3.603087	0.0419	I(0)	**LTR**			

Table-3showstheresultsof non-linear ARDL method in theshort run. In the short run, Positiveshock of LTR has increasing and statistically significant impact on LCO2; while negative shock of LTR has increasing and significant effect on LCO2, in of Bangladesh. In the short run 1% positive increase of trade, increase LCO2 29% while 1% decrease in LTR, increase CO2 19%. So, positive shock dominates negative shock in short run. Further, results confirmed significant positive impact of LNPCGDP and significant negative impactof LNPCGDP2 on LCO2, implying the existence the inverted U shaped EKC for Bangladesh. Error correction term for asymmetry ARDL show that 67.65% disequilibrium is corrected every year towards long-run equilibrium path.

Table 3. Nonlinear ARDL short-run results

Variable	**Coefficient**	**t-statics**	**P-values**
D(LPCGDP)	23.57156 ***	5.052315	0.0000
D(LNPCGDP2)	-4.674568***	-5.201759	0.0000
D(LTR_POS)	0.291699***	6.566462	0.0000
D(LTR_NEG)	-0.187422**	-2.471493	0.0194
CointEq(-1)*	-0.676516***	-7.645844	0.0000

(*=10%),(**=5%), (***=1%)level of significance

Table-4 is the summery of long run NARDL results. The increasingshock of LTR has increasing and significant impact on LCO2 while the decreasing shock of LTR has increasing and significant impact on LCO2 in the long run. In the long run, 1% positive increase of trade, increase LCO2 22% while 1% decrease in LTR, increase CO2 26%. So, negative shock dominatespositive shock in the long runrun. Moreover, LPCGDP significantly positive impact and LNPCGDP2 has significantly negative impact on LCO2, which implies the existence of long run EKC in Bangladesh.

Table 4.NARDL Long-run result

Variable	**Coefficient**	**t-statics**	**P-values**
LPCGDP	10.11776***	4.196640	0.0002
LNPCGDP2	-1.563650**	-3.702777	0.0009
LTR_POS	0.218501*	1.862640	0.0723
LTR_NEG	-0.257259**	-2.653557	0.0126
C	-16.84714***	-4.950641	0.0000

(*=10%),(**=5%), (***=1%)level of significance

Table-5 showsthe results of long run bound F testing approach. In order to know the co-integration, bound F test is applied. Since, the value of F-stats is 8.35 confirmed the existence of co-integration relationship amongst LCO2, LPCGDP, LPCGDP2 and LTR since F stats is greater than I(1) at 1% level of significance.

Table 5 NARDL bound Ftest

Test Statistic		**Value**
F-statistic		8.35
Significance	**I(0)**	**I(1)**
10%	2.2	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Table-6 show the result of Wald test which express the guide line about the asymmetry. The long-run results for asymmetry suggest thatthere is asymmetry in the long-run butin the short run the result is undetermined.However, the effect of negative component is higher than that of positive component. The result ensures that the presence of long run asymmetry between LCO2 and LNTR exists which give the guide line to use the nonlinear ARDL model.

Table 6. Long run asymmetry test: Wald Test

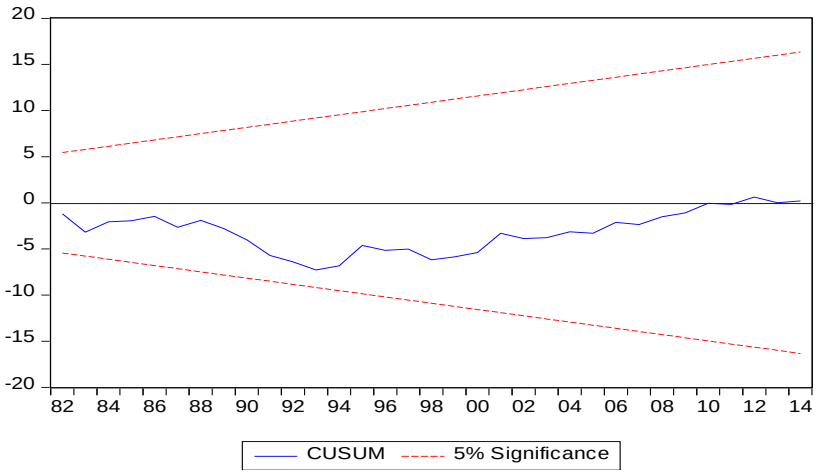
	Long-run Asymmetry	
Exogenous Variables	F-stat	P-value
LTR	8.381623	0.0067

Table-7 shows the result of diagnostic tests. Results of the diagnostic tests reveal that there exists no serial correlation, no heteroscedasticity anddata is normally distributed in the model.

Table 7. Diagnostic tests results.

Model Diagnostics	**Statistic(s)**	**P-Value(s)**
Heteroskedasticity Test: Breusch-Pagan-Godfrey	3.587661	0.9364
Breusch-Godfrey Serial Correlation LM Test:	1.503133	0.2202
JarqueBeranormality Test	0.287145	0.866258
Ramsey RESET Test	0.077082	0.7833

Figure-1 shows the graph of recursive CUSUM and CUSUM square and thses tests indicate the stability of parameters at 5% level of significance.



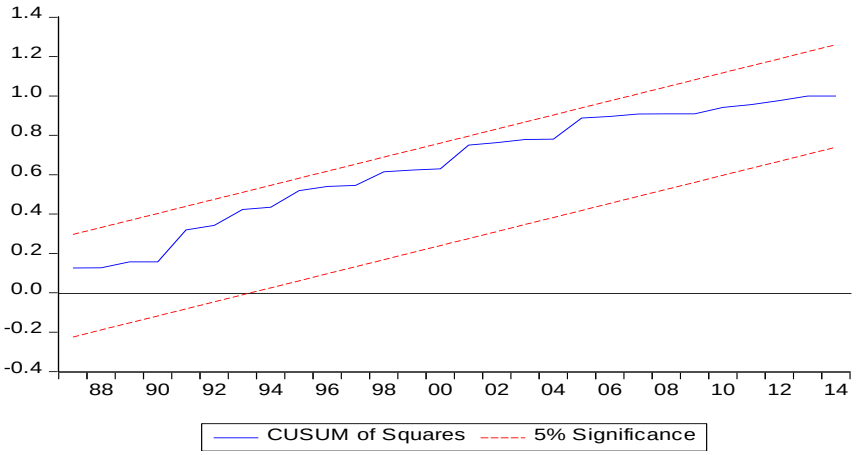


Figure 1.CUSUM and CUSUM of Squares for NARDL.

Figure-2 is the graphical representation of dynamic multipliers of LTR. The deep black solid line presents the positive shock and deep black dashed line represent the negative shock of LTR. The red dashed line represents the asymmetry with 5% area.The figure indicates that, in the short run, LCO2 respond more to negative shocks than positive shocks from LTR.

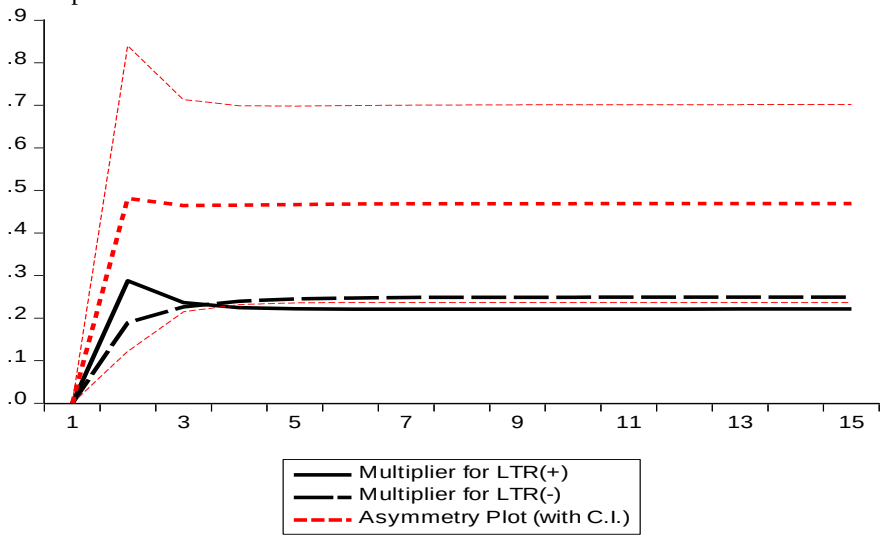


Figure 2. Dynamic Multipliers Graph.

Table 8. Optimum lag length selection Criteria:

Lag	LogL	LR	FPE	AIC	**SC**	HQ
0	287.0253	NA	5.84e-12	-14.51412	**-14.34349**	-14.45290
1	545.5006	450.6749	2.34e-17	-26.94875	**-26.09564***	-26.64266*
2	565.8927	31.37250*	1.92e-17*	-27.17398*	**-25.63839**	-26.62303
3	578.5904	16.93025	2.44e-17	-27.00463	**-24.78655**	-26.20881

ARDL model select SC criteria and choose lag 1 as fixed, therefore (1, 1,1,1,1) lags order is selected for the study.

Table-9 shows the results of short run linear ARDLmodel. The result suggests that thereexists a positive and significant relationship between LCO2 and trade. This indicates that in the short-run trade in Bangladesh increase carbon emission.Theresultssuggest that 1% increase oftrade,12.24% increase in carbon emission. LPCGDP has positive and significant effect and LPCGDP2 has a negative and significant impact on LCO2. ECMindicates that 44.08% disequilibrium iscorrected every yeartowards long-run equilibrium path.

Table 9 LinearARDL short-run results

Variable	**Coefficient**	**t-statics**	**P-values**
D(LPCGDP)	29.66060***	5.460496	0.0000
D(LNPCGDP2)	-5.746021***	-5.46717	0.0000
D(LTR)	0.122451***	3.348760	0.0020

CointEq(-1)*	-0.440817***	-7.311518	0.0000

(*=10%),(**=5%), (***=1%)level of significance

Table-10 shows the results of long-run symmetric ARDL.It suggests that there is positive and statistically insignificant relationship exists between LTR and LCO2. Moreover, LPCGDPpositivelyaffect andLPCGDP2 negative and significant impact onLCO2.

Table 10 Linear ARDL long-run results

Variable	Coefficient	t-statics	P-values
LPCGDP	16.68262***	6.014817	0.0000
LNPCGDP2	-2.604141***	-4.914304	0.0000
LTR	0.001818	0.014112	0.9888
C	-26.65214***	-7.368312	0.0000

(*=10%),(**=5%), (***=1%)level of significance

Table-11 shows the result of linear bound test.Since, the value of F-stats obtained is 9.54 is higher than I(1) test at 1% level ,so there is the long-run relationship among the variables.

Table 11. Linear ARDL bound F test

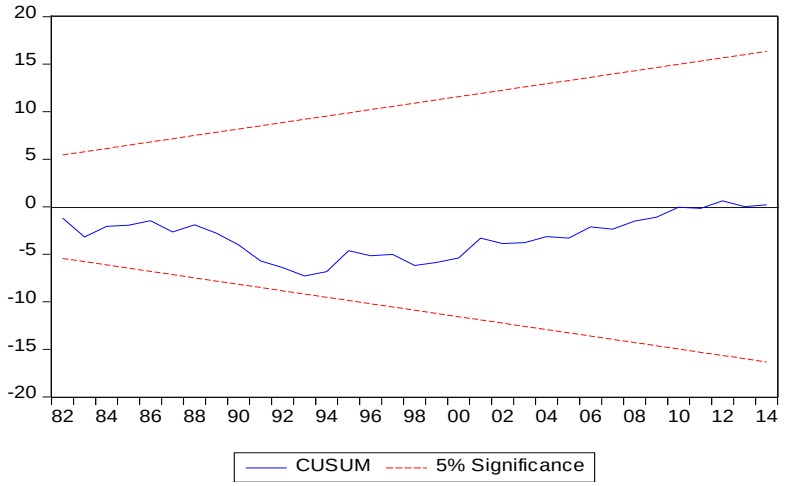
Test Statistic		Value
F-statistic		9.54
Significance	**I(0)**	**I(1)**
10%	2.37	3.2
5%	2.79	3.67
2.5%	3.15	4.08
1%	3.65	4.66

Table-12Diagnostic tests result indicates that there is noheteroscedasticity, serial correlation, and the data is normally distributed.

Table-12 Diagnostic tests result

Model Diagnostics	Statistic(s)	P-Value(s)
Heteroskedasticity Test: Breusch-Pagan-Godfrey	3.459352	0.8395
Breusch-Godfrey Serial Correlation LM Test:	1.692851	0.1932
JarqueBera normality Test	0.514	00.773
Ramsey RESET Test	2.908032	0.0978

Figure-2 shows the result of CUSUM and CUSUM of squares. The result shows that parameters are stable at 5% level of significance.



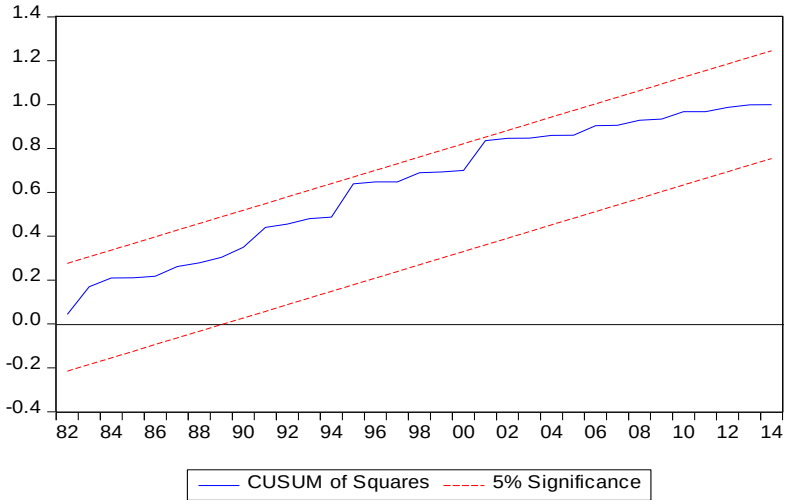


Figure 3.CUSUM and CUSUM of Squares for linear ARDL.

V.Conclusion

Many Economist and Environmentalists focus economic growth is the key determinant s of CO2 but no study has been conducted regarding the asymmetric impact of trade on CO2 in Bangladesh. Therefore the positive and negative trade effect, using NARDL approach, remain unknown. The major contribution of this article is to check the asymmetric effects of trade on CO2 under the EKC hypothesis for Bangladesh during the time 1973-2014.The study reported that the EKC hypothesis exists in the short run and long run both linear ARDL and Nonlinear ARDL in the case of Bangladesh. Because LPCGDP is positively and LPCGDP2 is negatively related to LCO2 in the short run and long run. However, both the effects are highly statistically significant. The symmetric and asymmetric ARDL method suggests that trade has a positive statistically significant effect on carbon emission. The long run asymmetry suggests that NARDL is appropriate instead of linear ARDL model. ECM for NARDL is 67.65 which is higher than the ECMof ARDLmodel.

The major draw backs of the study are that the model does not consider all the other variables and their asymmetric effect of trade is considered. The asymmetric effect of other variables should include in to the model. Another limitation is that it is not possible to find the short run asymmetry forthe lack of the neg_LTRshort run variable in suitable format on Eviews 9. Finally, data set is not updated enough. We have used data from 1973 to 2014, because time series data of carbon emission is not available after 2015.

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