Economic Determinants of Greenhouse Gas Emissions in Ethiopia: Bounds Testing Approach

Walaa mahrous[3]

Abstract

This paper aims at investigating the main economic determinants that contribute to greenhouse gases emissions in Ethiopia. By applying the bounds testing approach, the long and short-run impacts of economic growth, trade openness, and industry on air pollution in Ethiopia are estimated. The data set used in the estimation process covers the period (1981-2013). The study also attempts to find out whether the Environmental Kuznets Curve (EKC) hypothesis applies to the Ethiopian economy or not. Results indicate that both trade liberalization and industry, when they interact together, have adverse impacts on the environment in Ethiopia. Furthermore, there are still no evidences to support the existence of EKC in Ethiopia.

Key words: Bounds testing approach, EKC hypothesis, Ethiopia, Greenhouse gas emissions, Economic growth, Foreign Trade, Industry.

JEL Classification Q53 _ Q54

[3] Lecturer of Economics, Department of Economics and Political Science, Institute of African Research and Studies, Cairo University, Cairo, Egypt, E-mail: Walaa.mahrous@cu.edu.eg

1. Introduction

Concentration of greenhouse gases (carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons) in the air had been constant before the industrial revolution. And since that time, the level of the greenhouse gases in the atmosphere has increased significantly; due to the tremendous increase in world's population and the huge expansion in the industrial sector around the world. Consequently, this phenomenon has caused severe global climate change that threatens all aspects of human's life (Intergovernmental Panel on Climate Change (IPCC) 1990).

African countries generally, and the Nile Basin countries particularly, have very limited contribution to the world climate change. However, they are considered to be the most vulnerable countries to the adverse impacts of this phenomenon (IPCC 2007). For example, Ethiopia suffers air pollution, soil erosion, land degradation, deforestation, forest degradation, water scarcity, biodiversity loss, and other types of pollution. Consequently, these problems have increased the vulnerability of many Ethiopian people to food and water insecurity. Also, they represent major challenges to the Ethiopian government while achieving high economic growth rates and sustainable development (UNDP 2011).

Since the late 1970s, the relationship between various economic activities and environmental pollution has gone through deep theoretical and empirical investigation. As a result, in the early 1990s, the Environmental Kuznets Curve (EKC) hypothesis emerged. This hypothesis assumes that the relationship between the environmental degradation and income per capita takes an inverted "U" shaped. It justifies this assumption by the fact that early stages of economic growth in any country often witnesses severe exploitation of natural resources as well as huge increase in pollution level. However, after reaching a certain level of per capita income, this relationship reverses and high levels of economic growth leads to environmental improvement (Stern et al 1996).

Thus, in order to alleviate the environmental degradation and its adverse impacts in Ethiopia, it is necessary to study the relationship between different economic activities and air pollution there. In this way, policy makers can put strategies for stimulating economic growth and development without causing more damage to their environment. So, by applying the bounds testing approach, this paper estimates an extended EKC function for Ethiopia over the period (1981-2013). Through this function, the long and short-run impacts of GDP growth rate, foreign trade, and industrial sector on CO_2 emissions are measured[4]. Furthermore, to what extent the EKC hypothesis is relevant to the Ethiopian economy is being tested.

The remainder of this paper is organized as follows. Section 2 reviews the literature on the main economic determinants of air pollution. Section 3 illustrates the link between environmental degradation and some main socio-economic variables in Ethiopia. Section 4 demonstrates the methodology and data sources while section 5 presents the diagnostic tests used. Section 6 reports the empirical results. Finally, section 7 provides the conclusion.

[4] We concentrate on CO_2 emissions as they have been responsible for over half the greenhouse effect (despoiling environment and climate change) in the past, and are likely to remain so in the future (IPCC 1990).

2. Literature Review

Many empirical studies have started to test the existence of the EKC in both developed and developing countries. Furthermore, some studies extended the EKC function to include additional explanatory variables; such as political freedom, output structure, population, and/or trade. Different estimation approaches have been used and results reasonably vary (Stern 1998). Therefore, as a matter of organization, these studies are reviewed by putting them in two groups according to their results.

Concerning the first group of studies, they proved that EKC hypothesis holds for their case studies. For example, Shahbaz et al (2012) investigated the relationship between CO_2 emissions, energy consumption, economic growth and trade openness in Pakistan over the period (1971–2009). The results supported the existence of EKC hypothesis. Also, energy consumption was found to increase CO_2 emissions both in the short and long runs while trade openness was found to reduce CO_2 emissions in the long run. In addition, Arouri et al (2014) tried to test the EKC hypothesis in Thailand over the period of (1971-2010). It also examined the long-run relationship between economic growth, energy consumption, trade openness, urbanization and energy emissions. Results revealed that energy consumption and trade openness added to energy emissions while urbanization lowered it. They also validated the EKC hypothesis.

Likewise, Opoku *et al* (2014) tested the EKC hypothesis and measured the impact of trade openness on CO_2 emissions in Ghana for the period (1970-2010). Estimation results proved the inverted "U" relationship between real GDP per capita squared and CO_2 emissions. Also, they showed a positive relationship between the liberalization of trade and greenhouse gases. This was explained by the flow of a very large number of multinational corporations to Ghana after initiating market reform programs in 1980s, and their involvement in the extractive and manufacturing activities that harm the environment. Furthermore, Keho (2015) examined the long-run determinants of CO_2 emissions in Cote d'Ivoire from 1970 till 2010. The effects of per capita income, the share of industrial sector in GDP, and trade openness on CO_2 were estimated. The results gave support to the existence of the EKC. They also showed that trade openness and industrialization work together in worsening environmental quality in Cote d'Ivoire; as the country industrializes, trade openness adds more to the level of CO_2 emissions.

While for the second group, they rejected the validity of EKC hypothesis for their case studies. For instance, Choi et al (2010) estimated the environmental consequences of economic growth and international trade in each of China, Korea, and Japan, over the period (1971-2006). Economic growth and openness of trade didn't show homogenous environmental impacts across the three countries. For example, China showed an N-shaped for the EKC while Japan revealed a U-shaped curve. This might suggest that economic growth is not the only way to improve the quality of the environment. In Bangladesh, Alam (2014) examined the relationship between trends of CO_2 emissions and changes in economic structure during the period (1972-2010). Also, it estimated the relationship between GDP per capita and CO_2 emissions based on the EKC hypothesis. Results didn't support the existence of an inverted "U" shape relationship between GDP per capita and CO_2 emissions. In addition, findings showed that Bangladesh witnessed huge economic structural change during the period of the study, as it turned from the dominance of the agriculture sector towards the dominance of the services sector, and that contributed to an uprising trend in CO_2 emissions there.

Furthermore, Alam (2015) analyzed the impact of trade openness on CO_2 emissions in selected five high income countries; Australia, Canada, Japan, Norway, United Kingdom and selected five low income countries; Benin, Liberia, Nepal, Sudan and Zimbabwe, for the period (1960-2011). It also examined relationship between GDP per capita and CO_2 emissions (EKC hypothesis) in these countries. The findings suggested that free trade didn't help at reducing CO_2 emissions in case of high income countries. Besides, CO_2 emissions were found to increase with high GDP per capita. Hence, EKC in both high and low income countries didn't hold.

Finally, for the case of Ethiopia, some studies have investigated the relationship between environmental pollution and some macroeconomic variables there. For example, Tariku (2015) analyzed the impact of trade liberalization on CO_2 emissions in Ethiopia, over the period (1970-2010). The trade effect was decomposed into 3 sub-types: scale, composition, and intensity effect. The results indicated that while air pollution was negatively related with trade intensity and composition effect, it was positively related with the scale effect. Also, Wolde (2015) studied the relationship between air pollution and economic growth to test the existence of the EKC hypothesis, using data from 1969 to 2011. The findings proved the inverted "U" shaped relationship between CO_2 emissions and real GDP per capita.

3. Environmental Degradation and Socio-Economic Variables in Ethiopia

Ethiopia is one of the first countries in the Nile Basin region to formulate strategies for low carbon development that maintain the essential socio-economic conditions and ecosystem functions (NBI 2013). Also, the Ethiopian government aims at reaching middle income country status by 2025 with no net increase in carbon emissions. However, the country witnesses severe environmental problems that represent a challenge for achieving green economic growth and sustainable development. Hence, these environmental issues, their links to the Ethiopian economy, and their implications for economic growth need deep investigation (UNDP 2011).

The Ethiopian economy is based primarily on agriculture[5]. Besides, there is a strong link between the industrial and agricultural sectors in Ethiopia (African Development Bank/OECD/UNDP 2016). Hence the environmental problems that face the agriculture, mainly soil erosion and land degradation, also have implications for industry. Recent research has shown that population and livestock growth in regions of limited resources, unsustainable farming techniques, the Ethiopian land tenure system, and the persistence of poverty, have resulted in land degradation. Moreover, soil erosion and land degradation can lead to food scarcity, loss of income, resource conflicts and further environmental degradation (Gashaw et al 2014).

With respect to the industry sector, it includes both heavy and light industries. Heavy industries (such as oil, gas, and cement production) contribute to the depletion of natural resource, emissions of greenhouse gases, and contaminants of soil and water. Also, light industries (e.g. leather industry) still involve the use of particular substances that result in environmental damage. In addition, the transport sector is associated with several environmental issues. For example, modes of transport that use fossil fuels contribute to climate change and local air pollution. Similarly, building roads, railways, and airports leads to land clearance, soil erosion, land degradation, ecological change, and biodiversity loss (Ethiopian Panel on Climate Change 2015).

Furthermore, urban and peri-urban areas have added to the environmental problems in Ethiopia through land-use change. Urban areas are also center for industrial and transport activities that are sources of air and water pollution. Likewise, peri-urban areas are full of houses made from flammable materials (such as wood) that contribute to unhealthy and unsafe working environments for many (poor) people in Ethiopia (Roychowdhury et al 2016).

[5] Its share of real GDP and labour force is about 39 % and 73 % respectively. Also, it provides local industries with about 70 % of the required raw materials.

4 Methodology and Data

4.1 ARDL Approach

According to Halicioglu (2008), the EKC equation for Turkish economy is estimated by adopting economic growth, energy consumption, and trade openness, as determinants of CO_2 emissions. All these variables are included in a single multivariate framework. The same equation is used in our paper with some changes in the explanatory variables; energy consumption is replaced with the industrial sector share in GDP due to some statistical issues[6]. Thus, the following log quadratic EKC equation is used to examine the relationship between pollution emissions, economic growth, trade liberalization, and industry sector in Ethiopia:

$$CO_{2t} = \theta_0 + \theta_1 GDP_t + \theta_2 GDP_t^{\,2} + \theta_3 TR_t + \theta_4 Ind_t + \theta_5 TR_t * Ind_t + \mu_t \qquad (1)$$

where CO_{2t} is per capita carbon dioxide emissions (as a proxy for the level of pollution emissions), GDP_t is the per capita real GDP in constant 2010 US dollars, $GDP_t^{\,2}$ is included to test for the EKC hypothesis, TR_t is trade openness measured as ratio of merchandise exports and imports to GDP, Ind_t is the share of the industrial sector in GDP, $TR_t * Ind_t$ is an interaction term to test whether the environmental impact of trade depends on the share of the industrial sector in the economy, and μ_t is the regression error term. All these variables are converted into natural logarithms to facilitate estimation procedure. Also, annual data for these variables from 1981 till 2013 are obtained from the World Development Indicators Database provided by the World Bank (World Bank 2017). The descriptive statistics, mean value, standard deviation and coefficient of variation of different variables are given in Table (1) in Appendix.

The autoregressive distributed lag (ARDL) – also known as bounds testing approach – is one of the most popular econometric procedures that has been extensively used in investigating the environmental pollution functions. This is a single cointegration approach developed by Pesaran et al in 2001 and has some econometric advantages if compared to other single cointegration procedures (Pesaran et al 2001)[7]. First, it gives unbiased estimates of the long-run coefficients even if there is an endogeneity problem among the regressors. Second, it can estimate the long and short-run parameters simultaneously. Third, it can test for the existence of a long-run relationship between the variables in levels irrespective of whether they are *I* (0), *I* (1), or a combination of both. Fourth, in small samples, it gives estimates with properties more superior to that of Gregory and Hansen cointegration procedures (Narayan 2005). Thus, the ARDL representation of equation (1) can be put as follows:

$$\begin{aligned}\Delta CO_{2t} = \alpha_0 &+ \alpha_1 CO_{2t-1} + \alpha_2 GDP_{t-1} + \alpha_3 GDP_{t-1}^2 + \alpha_4 TR_{t-1} + \alpha_5 Ind_{t-1} + \alpha_6 TR_{t-1} * Ind_{t-1} \\ &\sum_{i=1}^{m}\alpha_{7i}\Delta CO_{2t-i} + \sum_{i=0}^{m}\alpha_{8i}\Delta GDP_{t-i} + \sum_{i=0}^{m}\alpha_{9i}\Delta GDP_{t-i}^2 + \sum_{i=0}^{m}\alpha_{10i}\Delta TR_{t-i} + \sum_{i=0}^{m}\alpha_{11i}\Delta Ind_{t-i} + \varepsilon_t \qquad (2)\end{aligned}$$

[6] When we examined the energy consumption variable for unit root, it turned to be I (2). Thus, we tried to search for another variable that has the same implications but with good statistical properties. As a result, we chose the industrial sector share in GDP and tested for its integration order which turned to be I (1).

[7] There are several examples of univariate cointegration approaches including Engle and Granger (1987) and the fully modified OLS procedures of Phillips and Hansen (1990). There are also many examples of multivariate cointegration procedures of Johansen (1988), Johansen and Juselius (1990), and Johansen's (1996) full information maximum likelihood technique.

4.2 Estimation Procedure

Firstly, to estimate equation (2) by the Pesaran et al (2001) procedure, we should examine each variable series included in equation (1) for its order of integration. This has been done by the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The results reported in Table (2) in Appendix indicate that, at the 5% level of significance, all the series appear to contain a unit root in their levels but stationary in their first differences (i.e. they are I (1)). This provides a good rationale for carrying out the bounds testing approach.

Secondly, equation (2) is estimated by a specialized estimator that has been included in recent versions of EViews (EViews 9) for handling ARDL models. Fortunately, this estimator offers built-in lag-length selection methods, critical values for the bounds test, as well as other post-estimation tests. Based upon the estimation results of equation (2) - as displayed in Table (3) in Appendix – the ARDL bounds test is carried out. As it shows from Table (1), the F-statistic (3.485185) is bigger than the critical value of the upper bound at 5% significance level (3.38). Thus, we reject the null hypothesis of $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = 0$ (i.e. no cointegration among the relevant variables) and conclude that there exists a long-run relationship between CO_2 and its determinants.

Table (1): ARDL Bounds Test

Sample: 1984-2013
Included observations: 30
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	3.485185	5
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound
10%	2.08	3
5%	2.39	3.38
2.5%	2.7	3.73
1%	3.06	4.15

5. Diagnostic Tests

Concerning the goodness of fit of the model specification, R-squared and adjusted R-squared, are 0.95 and 0.93 respectively. The robustness of the model has been validated by several diagnostic tests. For example, Breusch-Godfrey serial correlation LM test, in Table (4) in Appendix, indicates that there is no serial correlation between the estimated model errors (F-statistic = 0.133 and P = 0.875). Besides, CUSUM and CUSUMQ tests ascertain the stability of the estimated coefficients because the plot of each statistic falls inside the critical bands of the 5% confidence interval of parameter stability (See Figures 1&2). Also, Jarque-Bera normality test assures the normality of errors (Refer to Figure 3). Furthermore, Breusch-Pagan-Godfrey heteroskedasticity test, in Table (5) in Appendix, shows that the residuals don't suffer from heteroskedasticity (Obs*R^2 = 8.63, P= 0.65). Given the above results, we can conclude that the outcomes reported are serially uncorrelated, normally distributed, and homoskedastic. Hence, the results reported are valid for reliable interpretations.

Figure (1): Results of CUSUM Test

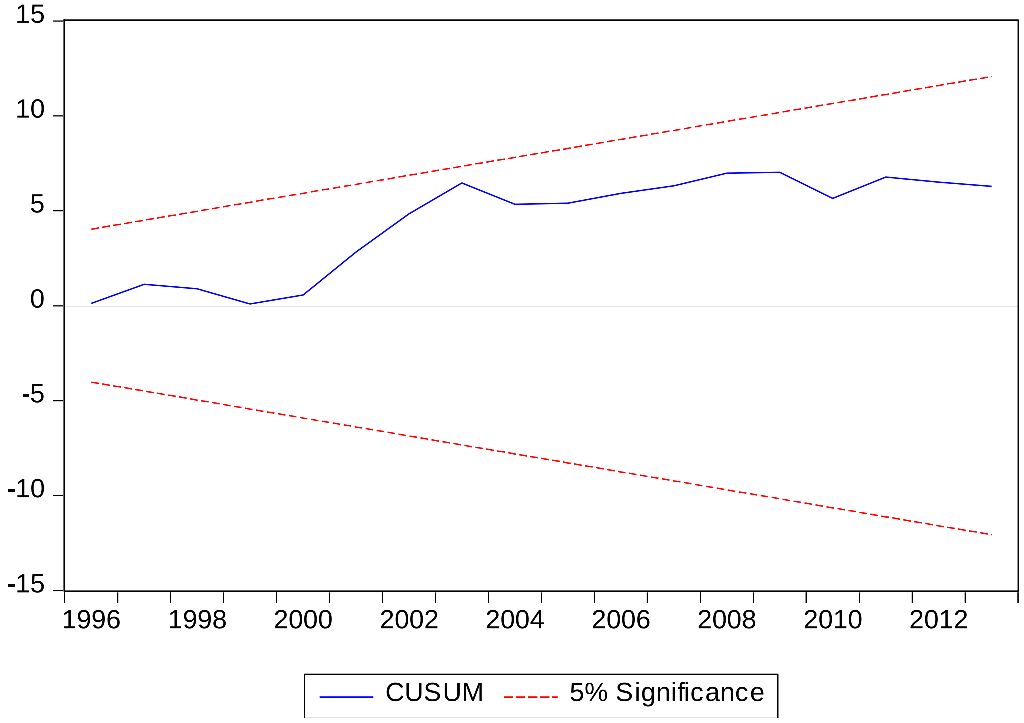


Figure (2): Results of CUSUMSQ Test

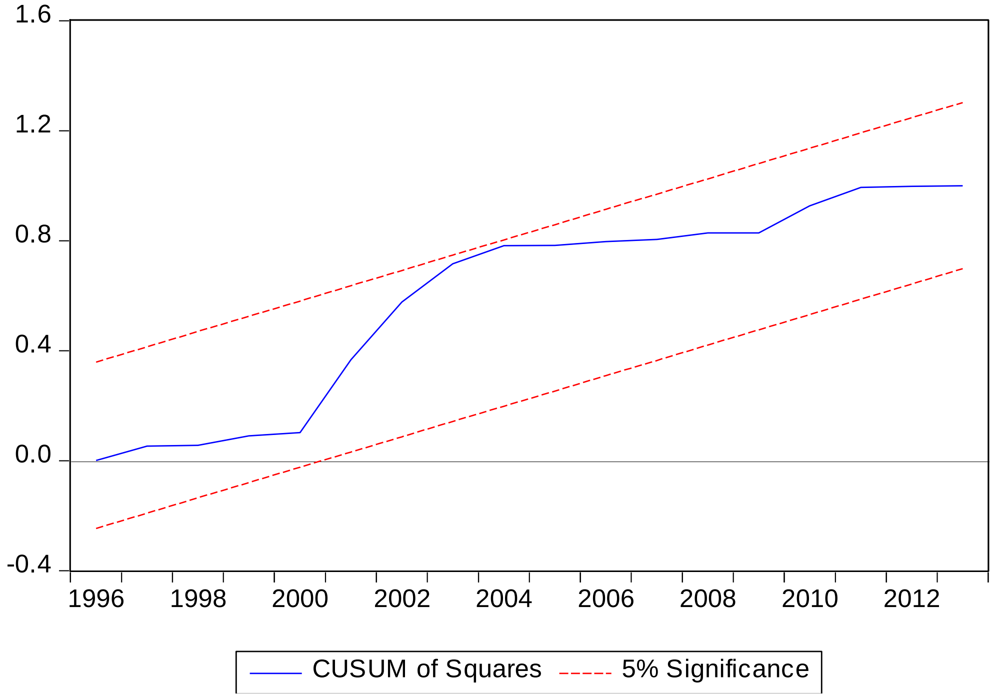
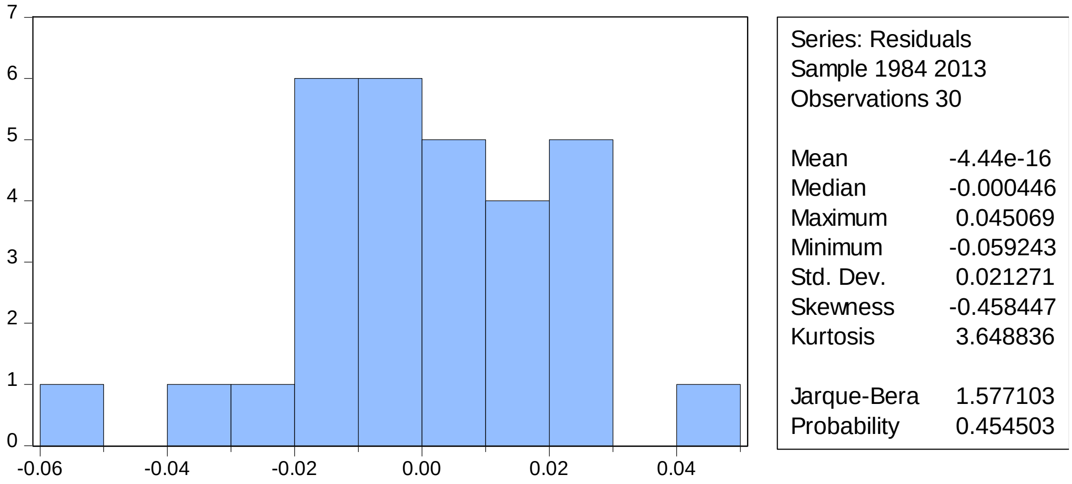


Figure (3): Results of Normality Test



6. Empirical Results

To capture the long and short-run relationships among the variables of our model, ARDL cointegrating form has been estimated. Results of the long-run estimated coefficients are shown in table (2). It is found that the long-run impact of real GDP per capita on CO_2 emissions is negative and insignificant while the squared real GDP per capita coefficient is positive and significant. The unexpected signs of these two variables indicate that there is still no evidence in favor of the EKC hypothesis in the Ethiopian economy.

Concerning the estimated long-run coefficients for trade openness, industrial sector share in GDP, and their interaction effect, they are found to be significant at 10% level. Each of foreign trade and the share of industry in GDP has a negative relationship with CO_2 emissions while their interaction term has a positive relationship with these emissions. So, there is a non-linear relationship between per capita CO_2 emissions and each of foreign trade and the share of industry in GDP.

This implies that these two variables are interdependent in their impact on air pollution in Ethiopia. That is to say, increasing trade openness in Ethiopia won't be harmful unless the industrial sector has exceeded a certain threshold that may threaten the surrounding environment. The reverse also holds for the industrial sector share in GDP; it won't increase CO_2 emissions unless international trade has encouraged the migration of polluting industries to the Ethiopian economy. Thus, both trade openness and industrialization are complementing each other at worsening the environmental quality in Ethiopia. This result accords with the findings of Tariku (2015) for Ethiopia and Opoku et al (2014) for Ghana. It can also be justified by the pollution haven hypothesis.

Table (2): Estimated Long-Run Coefficients

Variable	Coefficient	Standard Error	t-Statistic	Probability
GDP	-12.519231	7.410357	-1.689423	0.1084
GDP^2	2.803790	1.526857	1.836314	0.0829*
TR	-2.618655	0.606206	-4.319742	0.0004*
IND	-1.512617	0.784966	-1.926985	0.0699*
TR*IND	2.118259	0.558836	3.790486	0.0013*
C	14.784130	8.687276	1.701814	0.1060

* indicates significance at the 10% level.

Concerning the estimated short-run effects of our variables, they are displayed in table (3). It is found that there is no relationship between each of real GDP per capita, squared real GDP per capita and CO_2 emissions in the short-run. Also, the same interpretation for the estimated long-run effects of foreign trade, industrial sector, and their interaction term goes for their short-term impacts.

Also, the error correction mechanism (ECM) has been estimated to capture the speed of the adjustment of the model variables in the short-run in case any deviation from the long-run equilibrium occurs. When ECM (-1) is negative and significant, this means that the model variables are error-correcting (adjusting) themselves till they reach their steady-state values (Enns et al 2014). In our case, the estimated coefficient of ECM is negative and statistically significant at 5%. This confirms the existence of a stable long-run relationship between the regressors (GDP, GDP^2, TR, Ind, TR*Ind) and the dependent variable CO_2 emissions. As it shows from table (3), ECM (-1) value is -0.553. This suggests that when CO_2 emissions and the other regressors are above or below their equilibrium level, they adjust by almost 55.3% within the first year. The estimated ECM (-1) equation can be represented as follows:

$$\begin{aligned} ECM(-1) = CO_2 - (&-12.5192*GDP + 2.8038*GDP^2 - 2.6187*TR \\ &- 1.5126*IND + 2.1183*TR*LIND + 14.7841) \end{aligned}$$

Table (3): Estimated Short-Run Coefficients

Variable	Coefficient	Standard Error	t-Statistic	Probability
D(GDP)	-5.568569	4.553249	-1.222988	0.2371
D(GDP(-1))	-0.288791	0.181424	-1.591801	0.1288
D(GDP(-2))	0.686786	0.179435	3.827497	0.0012*
D(GDP^2)	1.517034	0.967261	1.568382	0.1342
D(TR)	-0.897154	0.326210	-2.750230	0.0132*
D(IND)	-0.743757	0.455951	-1.631222	0.1202
D(TR*IND)	0.758022	0.347919	2.178733	0.0429*
ECM(-1)	-0.553619	0.101896	-5.433171	0.0000*

* indicates significance at the 5% level.

7. Conclusion

Despite their limited contribution to the global greenhouse gases emissions, many African countries face severe environmental degradation that has raised many economic and social problems. Currently, these countries are developing and implementing environmental policies to maintain their ecosystem functions and socio-economic conditions.

Ethiopia is considered to be one of the first Nile Basin countries that aim at increasing economic growth rates in a pro-environmental way. Thus, this study investigates the long and short-run impacts of real GDP growth rate, trade liberalization, and industrial sector on environmental degradation in Ethiopia. This is done by using the ARDL method to estimate an extended EKC function from 1981 till 2013. Concerning the economic growth impact on air pollution, empirical findings give no evidence on the existence of EKC hypothesis in Ethiopia. Also, results show that the trade-pollution relationship depends greatly on the size of the industrial sector. Thus, openness to international trade increases CO_2 emissions by promoting the migration of industries that harm the environment.

Therefore, it is highly recommended for the Ethiopian government to apply economic policies that promote pro-environmental industries and restrict those that pollute the environment. Also, the government should follow trade policies that contribute to the sustainability and improvement of livelihoods in developing countries. Such policies are widely supported and provided by International Centre for Trade and Sustainable Development, International Trade Centre, and World Trade Organization.

Appendix

Table (1): Descriptive Statistics

	CO_2	GDP	GDP^2	Trade	Industry	Trade*Industry
Mean	-1.222874	2.356279	5.562614	1.324231	1.029576	1.375310
Median	-1.225292	2.319940	5.382121	1.326096	1.034921	1.440641
Maximum	-0.948991	2.626188	6.896865	1.611752	1.142395	1.790187
Minimum	-1.398793	2.214224	4.902786	0.691032	0.799236	0.609097
Standard Deviation	0.106375	0.104378	0.504977	0.222384	0.080429	0.301498
Skewness	0.419687	1.208729	1.277281	-0.622697	-0.770011	-0.526488
Kurtosis	2.856251	3.540621	3.696047	3.078116	3.495697	2.663240
Jarque-Bera	0.997167	8.437519	9.639123	2.141027	3.598902	1.680479
Probability	0.607391	0.014717	0.008070	0.342833	0.165390	0.431607
Sum	-40.35485	77.75720	183.5663	43.69963	33.97601	45.38522
Sum Square Deviation	0.362100	0.348632	8.160071	1.582547	0.207002	2.908828
Observations	33	33	33	33	33	33

Table (2): Unit Root Tests

Series	Level		1st Difference	
	ADF	PP	ADF	PP
CO_2	-0.063526	-0.063526	-6.667820*	-6.667820*
GDP	1.524431	-3.926180	1.380304*	-3.850176*
GDP^2	1.775108	-3.789478	1.608538*	-3.706544*
Trade	-1.238907	-7.182043	-1.096113*	-7.348100*
Industry	-2.001658	-1.953414	-4.635426*	-4.635426*
Trade*Industry	-1.096653	-1.130690	-5.197033*	-5.200274*

* The null hypothesis of a unit root is rejected by the Mackinnon critical values at 5%.

Table (3): ARDL Model Estimation Results

Dependent Variable: CO_2
Method: ARDL
Sample (adjusted): 1984 2013
Included observations: 30 after adjustments
Maximum dependent lags: 3 (Automatic selection)
Model selection method: Schwarz criterion (SIC)
Dynamic regressors (3 lags, automatic): GDP GDP^2 TR IND TR*IND
Fixed regressors: C
Number of models evaluated: 3072
Selected Model: ARDL(1, 3, 0, 1, 0, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
CO_2(-1)	0.456406	0.138081	3.305349	0.0039
GDP	-5.603537	3.496687	-1.602527	0.1264
GDP(-1)	-1.498868	0.326374	-4.592480	0.0002
GDP(-2)	0.972099	0.310442	3.131337	0.0058
GDP(-3)	-0.675073	0.251131	-2.688130	0.0150
GDP^2	1.524123	0.743905	2.048814	0.0553
TR	-0.950634	0.433704	-2.191897	0.0418
TR(-1)	-0.472852	0.171736	-2.753360	0.0131
IND	-0.822250	0.531904	-1.545861	0.1395
TR*IND	0.816793	0.437915	1.865183	0.0785
TR*IND(-1)	0.334680	0.130777	2.559177	0.0197
C	8.036565	4.282075	1.876792	0.0769
R-squared	0.958290	Mean dependent variable		-1.211760
Adjusted R-squared	0.932801	S.D. dependent variable		0.104151
S.E. of regression	0.026999	Akaike info criterion		-4.096861
Sum squared residuals	0.013121	Schwarz criterion		-3.536382
Log likelihood	73.45292	Hannan-Quinn criterion		-3.917559
F-statistic	37.59575	Durbin-Watson stat		2.045144
Probability (F-statistic)	0.000000			

* Note: p-values and any subsequent tests do not account for model selection.

Table (4): Breusch-Godfrey Serial Correlation LM Test

F-statistic	0.133970	Probability F(2,16)	0.8756
Observations*R-squared	0.494111	Probability Chi-Square(2)	0.7811

Test Equation:
Dependent Variable: RESID
Method: ARDL
Sample: 1984 2013
Included observations: 30
Pre-sample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LCO2(-1)	0.044773	0.171132	0.261625	0.7969
LGDP	0.334031	3.791771	0.088094	0.9309
LGDP(-1)	0.020904	0.352457	0.059309	0.9534
LGDP(-2)	0.010817	0.334518	0.032336	0.9746
LGDP(-3)	0.002158	0.266780	0.008089	0.9936
LGDP2	-0.081077	0.808741	-0.100251	0.9214
LTR	0.013142	0.457056	0.028753	0.9774
LTR(-1)	0.029522	0.190143	0.155263	0.8786
LIND	0.048059	0.567227	0.084726	0.9335
LTR_LIND	-0.010050	0.461180	-0.021792	0.9829
LTR_LIND(-1)	-0.030185	0.151082	-0.199792	0.8442
C	-0.411373	4.627412	-0.088899	0.9303
RESID(-1)	-0.112454	0.306133	-0.367336	0.7182
RESID(-2)	-0.124495	0.280137	-0.444408	0.6627

R-squared	0.016470	Mean dependent variable	-4.44E-16
Adjusted R-squared	-0.782647	S.D. dependent variable	0.021271
S.E. of regression	0.028400	Akaike info criterion	-3.980136
Sum squared residuals	0.012905	Schwarz criterion	-3.326243
Log likelihood	73.70203	Hannan-Quinn criterion	-3.770950
F-statistic	0.020611	Durbin-Watson statistic	1.964269
Probability (F-statistic)	1.000000		

Table (5): Heteroskedasticity Test (Breusch-Pagan-Godfrey)

F-statistic	0.661855	Prob. F(11,18)	0.7551
Observations*R-squared	8.639581	Prob. Chi-Square(11)	0.6551
Scaled explained SS	4.119269	Prob. Chi-Square(11)	0.9663

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1984 2013
Included observations: 30

Variable	Coefficient	Standard Error	t-Statistic	Probability
C	-0.044401	0.122984	-0.361031	0.7223
CO2(-1)	0.002067	0.003966	0.521265	0.6085
GDP	0.019715	0.100427	0.196307	0.8466
GDP(-1)	0.003059	0.009374	0.326297	0.7480
GDP(-2)	0.003332	0.008916	0.373720	0.7130
GDP(-3)	0.007182	0.007213	0.995721	0.3326
GDP^2	-0.007102	0.021365	-0.332410	0.7434
TR	0.001941	0.012456	0.155786	0.8779
TR(-1)	0.004573	0.004932	0.927231	0.3661
IND	0.005341	0.015277	0.349599	0.7307
TR*LIND	-0.000572	0.012577	-0.045441	0.9643
TR*IND(-1)	-0.003400	0.003756	-0.905223	0.3773
R-squared	0.287986	Mean dependent variable		0.000437
Adjusted R-squared	-0.147134	S.D. dependent variable		0.000724
S.E. of regression	0.000775	Akaike info criterion		-11.19714
Sum squared residuals	1.08E-05	Schwarz criterion		-10.63666
Log likelihood	179.9571	Hannan-Quinn criterion		-11.01784
F-statistic	0.661855	Durbin-Watson stat		2.335118
Probability (F-statistic)	0.755149			

References

African Development Bank/OECD/UNDP (2016) *African Economic Outlook 2016: Sustainable Cities and Structural Transformation*. OECD Publishing, Paris.

Alam J (2014) On the Relationship between Economic Growth and CO_2 Emissions: The Bangladesh Experience. *Journal of Economics and Finance* 5 (6): 36-41

Alam J (2015) Effects of Free Trade on CO2 Emissions: The Case of High and Low Income Countries. *World Journal of Social Sciences* 5(3): 143 – 156

Arouri M, Muhammad Shahbaz, Rattapon Onchang, Faridul Islam and Frédéric Teulon (2014) Environmental Kuznets Curve in Thailand: Cointegration and Causality Analysis. *IPAG working paper* 2014-204

Choi E, Almas Heshmati and Yongsung Cho (2010) An Empirical Study of the Relationships between CO_2 Emissions, Economic Growth and Openness. *IZA Discussion Paper* 5304,

Enns P K, Takaaki Masaki and Nathan J. Kelly (2014) Time Series Analysis and Spurious Regression: An Error Correction. Cornell University

Ethiopian Panel on Climate Change (2015) Industry, Transport and Infrastructure. The Ethiopian Academy of Sciences, Addis Abbaba.

Gashaw T, Amare Bantider and Hagos G/Silassie et al (2014) Land Degradation in Ethiopia: Causes, Impacts and Rehabilitation Techniques. *Journal of Environment and Earth Science* 4(9): 98-104.

Halicioglu F (2008): An Econometric Study of CO_2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey. *MPRA Paper 11457*, November 2008.

IPCC (1990) Climate Change-The IPCC Scientific Assessment. Report Prepared for Intergovernmental Panel on Climate Change by Working Group 1.

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Keho Y (2015) An Econometric Study of the Long-Run Determinants of CO2 Emissions in Cote d'Ivoire. *Journal of Finance and Economics* 3(2): 11-21

Narayan P K (2005) The Saving and Investment Nexus for China: Evidence from Cointegration Tests. *Applied Economics* 37(17): 1979- 1990

NBI (2013) NBI Climate Change Strategy. NBI, Entebbe.

Opoku E, Amoako S, Amankwa I (2014) Trade Openness, Economic Growth and the Environment: The Case of Ghana. *International Journal of Economics, Commerce and Management* 2(8): 1-13

Pesaran M H, Shin Y, Smith R J (2001) Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics* 16(3): 289-326

Roychowdhury A et al (2016): Urban Air Quality Management in Ethiopia: A Guidance Framework. Centre for Science and Environment, New Delhi, 2016.

Shahbaz M, Hooi Hooi L, Muhammad Shahbaz S (2012) Environmental Kuznets Curve hypothesis in Pakistan: Cointegration and Granger causality. *Renewable and Sustainable Energy Reviews* 16: 2947– 2953

Stern D I et al (1996) Economic Growth and Environmental Degradation: The Environmental Kuznets Curve and Sustainable Development. *World Development* 24 (7): 1151-l160

Stern D I (1998) Progress on the Environmental Kuznets Curve. *Environment and Development Economics* 3(2): 173–196

Tariku L (2015) The Impact of Trade Liberalization on Air Pollution: In Case of Ethiopia. *New Media and Mass Communication* (40): 42-55

UNDP (2011) Ethiopia's Climate-Resilient Green Economy- Green Economy Strategy. UNDP, New York

Wolde E T (2015) Economic Growth and Environmental Degradation in Ethiopia: An Environmental Kuznets Curve Analysis Approach. *Journal of Economics and International Finance* 7(4): 72-79

World Bank (2017) *World Development Indicators.*