Modeling Energy Consumption, CO2 Emissions and Economic Growth Nexus in Ethiopia: Evidence from ARDL Approach to Cointegration and Causality Analysis

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Abstract

Energy consumption is one of the important inputs to the production process. Energy consumption and energy supplied from fossil fuels in production process cause CO_2 emissions and environmental deterioration. Due to this fact achieving economic development and environmental sustainability simultaneously is one of the most significant development challenges for Africa today. Formulation of sound economic development and environmental sustainability policy needs knowing the relationship among energy use, economic growth and environmental quality. This study examines the relationship among economic growth, energy consumption, financial development, trade openness, urbanization, population and CO2 emissions over the period of 1970–2014 in case of Ethiopia. The PP, ADF, KPSS, Zivot-Andrews and Clemente, Montanes and Reyes unit root tests were used to test the stationarity of the variables under consideration. The ARDL cointegration technique for establishing the existence of a long-run relationship and Toda-Yamamoto approach to determine the direction of causality between the variables were used. The results show that cointegration exists among the variables. Energy consumption, population, trade openness and economic growth have statistically significant positive impact on CO_2 in the long-run while economic growth squared compacts CO2 emissions. This supports validity of the EKC hypothesis in Ethiopia. In the short-run urbanization and energy consumption intensify environmental degradation. Toda-Yamamoto granger causality results indicate the feedback relationship between energy consumption, CO2 emissions and urbanization. Financial development, population and urbanization cause economic growth while economic growth causes CO_2 emissions. Causality runs from energy consumption to financial development, urbanization and population which in turn cause economic growth. Form the result, CO2 emissions extenuation policy in Ethiopia should focus on environmentally friendly growth, enhancing consumption of clean energy, incorporating the impact of population growth, urbanization, trade and financial development.

Keywords: Growth, Energy, Financial development, Urbanization, CO2 emissions, Ethiopia

1. Introduction

Energy is considered as the basic input used in the production process and it is used as widely as capital and labour. Since energy consumption is so extensive among the industries, continuous energy supply is needed for maintaining and improving the current production level and standard of living in any countries, whether they are developing, emerging, developed or industrialized. As any shortfall in energy supply affects economic growth, energy consumption in the process of production is considered as a precondition of sustainable economic development. Environmental scientists argue that energy consumption is responsible for carbon dioxide (CO2) emission, which is one of the major causes of creating Green House Gas (GHG) in the atmosphere and resulting global warming and climate change. Global warming and climate change are evident from melting of snow and ice, raising the sea level, changing pattern of rainfall, raising temperature in air and ocean, worsening the agricultural productivity and wild life and reducing the productivity of labour force. Thus, the threat of global warming and climate change got more attention among the environmentalists in last few decades. Consequently, economists and environmentalists became more aware of the environmental consequences of economic growth, which shifted the attention from simple economic growth to the ecology (environment) friendly economic growth (Alam, Murad, Noman, & Ozturk, 2016).

The relationship between energy consumption and economic growth, energy consumption and environmental pollution as well as economic growth and environmental pollution, has been the subject of intense research in the energy-economic literature (Acaravci & Ozturk, 2010a). Nevertheless, the empirical evidence remains controversial and ambiguous to date. The existing literature reveals that empirical studies differ substantially in terms of methods of data analysis and are not conclusive to present policy recommendation that can be applied across countries. An assessment of the existing literature suggests that most studies focus either on the nexus of economic growth-energy consumption or economic growth-environmental pollutants where little effort has been made to test these two links under the same framework. Therefore, the aim of this study is an attempt to fill this gap.

Essentially there are three research strands in literature on the relationship between economic growth, energy consumption and environmental pollutants (Acaravci & Ozturk, 2010a;

Alkhathlan & Javid, 2013; Jafari, Ismail, Othman, & Mawar, 2015; Baek & Kim, 2011). The first strand focuses on the relationships between economic growth and environmental pollutants: Farhani , Shahbaz , Sbia , and Chaibi (2014), Akpan and Abang (2015), Dinda and Coondoo (2006), Odhiambo (2011), Paresh and Narayan (2010), Kim , Lee , and Nam (2010), Kim and Baek (2011), Ghosh (2010) and others. These studies are closely related to testing the validity of the so-called environmental Kuznets curve (EKC) hypothesis which postulates an inverted U-shaped relationship between the level of environmental degradation and income growth. This is to mean that environmental degradation increases with per capita income during the early stages of economic growth, and then declines with per capita income after arriving at a threshold (Acaravci & Ozturk, 2010a). First set of empirical EKC studies appeared independently in three seminal working papers (Dinda, 2004): Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993). The common point of these seminal works is the assertion that the environmental quality declines at the early stages of economic growth and subsequently improves at the later stages. Literature reviews by Lapinskienė and Peleckis (2017), Stern (2004) and Dinda (2004) assert that previous EKC studies have failed to provide clear and inclusive findings on the inverted U-shaped relationship between the environment and economic growth. Moreover, Stern (2004) and Narayan and Narayan (2010) noted that most of the EKC literatures are econometrically weak.

The second strand focuses on the energy–economic growth nexus: Apergis and Tang (2013), Apergis and Payne (2010), Apergis and Payne (2009a), Apergis and Payne (2009b), Chen , Chen and Chen (2012), Herrerias , Joyeux and Girardin (2013). According to this relationship energy consumption and economic growth may be jointly determined, because economic growth is closely related to energy consumption as higher economic development requires more energy consumption. However, Ozturk and Acaravci (2010b) argued that the empirical literature on the energy consumption-growth nexus have yielded mixed and often contradictory results due to the different data set, countries' specific characteristics and different econometric methodologies used.

The third strand of the literature combines the abovementioned lines of research in order to capture the intertemporal linkages in economic growth, energy use and pollution in the same framework (see Apergis and Payne (2010b), Apergis and Payne (2014), Bella , Massidda and

Mattana, 2014), Alkhathlan and Javid (2013), Yang and Zhao (2014), Saboori and Sulaiman (2013), Alam *et al.* (2016), Rafindadi (2016), Youssef, Hammoudeh, and Omri (2016) and others). However, these studies modeled carbon emissions as a function of income, income squared and/or income cubed in addition to other explanatory variables; thus, they suffered from problems of collinearity or multicollinearity (Alkhathlan & Javid, 2013).

In recent years, development efforts have increasingly focused on environmentally friendly growth rather than simple growth. In this respect, energy consumption and environmental degradation have gained a large amount of attention worldwide. Energy consumption plays the dual role of providing the foundation for economic activity and human well-being as well as acting as the driving force for environmental degradation. Energy is indispensable for economic activity because all production and consumption activities are directly related to energy consumption. Fossil fuels have become the main source of energy since the Industrial Revolution. The rapid use of fossil fuels for economic growth has led to a significant increase in the global emissions of several potentially harmful gases. These gases not only cause deterioration of the environment but also adversely affect human life. The ever-increasing amount of carbon dioxide (CO2) and other greenhouse gases in the atmosphere is considered to be one of the world's greatest environmental threats. Among the greenhouse gases, CO2 plays a powerful role in enhancing the greenhouse effect and is responsible for more than 60% of the greenhouse effect (Muhammad & Fatima, 2013)

Until recent years there are two parallel literatures regarding the link between economic growth and environmental pollution. The first set of literatures has concentrated on the economic growth-environmental pollutants nexus and has been closely concerned with testing the Environmental Kuznets Curve (EKC) hypothesis, the concept emerged in the early 1990s with Grossman and Krueger’s (1991) path breaking study of the potential impacts of NAFTA and the concept’s popularization through the 1992 World Bank Development Report (IBRD, 1992). The EKC hypothesis states that as income increases, emissions increase as well until some threshold level of income is reached after which emissions begin to decline (Lean & Smyth, 2009). The EKC hypothesis has stimulated considerable discussion within and between the economics and environmental communities, and debate continues about the validity of EKC. Since 1991 a number of studies on the validity of the EKC hypothesis have been carried out[1]. Important studies of ECK includes Han and Lee (2013), Kim and Baek (2011), Odhiambo (2011), Xu et al (2011), Piaggio and Padilla (2010), Lean et al (2010). All these studies have applied different

[1] See Stern (2004) and Lakshimi and Sahu (2012) for the detailed review of the EKC hypothesis.

theoretical and econometrical methodologies to arrive at certain conclusions. It is found that empirical researchers are far from agreement that the environmental Kuznets curve provides a good fit to the available data, even for conventional pollutants (Lakshmi & Sahu, 2012).

Although a number of studies have examined the relationship between carbon emissions and economic growth in developing countries, the majority of these studies have mainly concentrated on the relevance of the Environmental Kuznets Curve (EKC). Very few studies have gone the full distance to examine the nexus between CO2 emissions and economic growth. Even where such studies have been done, the focus has mainly been on Asia and Latin American countries. Studies on the causal relationship between carbon emissions and economic growth in sub-Saharan countries are very scant. In addition, the majority of the previous studies suffer from four major weaknesses; namely, 1) the use of a bivariate causality test, which may lead to the omission-of-variable bias; 2) the use of cross-sectional data, which does not satisfactorily address the country-specific effects; 3) the use of the maximum likelihood test based on Johansen (1988) and Johansen and Juselius (1990), which has been proven to be inappropriate when the sample size is too small (see Nerayan and Smyth, 2005); and 4) they employ unit root tests which fail to consider structural breaks. It is against this backdrop that the current study attempts to examine the inter-temporal causal relationship between CO2 emissions and economic growth, using the newly developed ARDL-Bounds testing approach. By incorporating energy consumption as an intermittent variable in a bivariate setting between CO2 emissions and economic growth, we develop a simple trivariate causality model between CO2 emissions, energy consumption and economic growth (Odhiambo, 2011).

The main objective of this paper is to analyze the significant determinants of CO_2 in Ethiopia using ARDL bounds test approach to cointegration and Toda-Yamamoto Granger causality technique. Analyzing the validity of the EKC hypothesis is the secondary objective of this paper. The rest of the paper is structured as follows. Section 2 presents model specification and data; Section 3 introduces estimation method; Section 4 deals with empirical results and discussions, and the last section presents conclusion and policy implications.

2. Model Specification and Data

The earliest EKCs were simple quadratic functions of the levels of income. But, economic activity cannot take place without using resources and, by the laws of thermodynamics, use of resources inevitably implies the production of waste. Due to this fact, Stern (2004) asserted that regressions that allow levels of pollution indicators to become zero or negative are inappropriate except in the case of deforestation where afforestation can occur and a logarithmic dependent variable should be used to impose this restriction. Another benefit of transforming variables into their natural logarithm considerably reduces or removes any heteroscedasticity problem (Hundie, 2014). Therefore, all the variables in the model are in logarithmic form.

Following Farhani, Chaibi, and Rault (2014), Shahbaz *et al.* (2013), Baek and Kim (2011), Ohlan (2015), Omri (2016), Rafindadi (2016), and Zambrano-Monserrate, Carvajal-Lara, and Urgiles-Sanchez (2016), this article employs an augmented standard EKC regression to analyze the long-run relationship and directon of causality among carbondioxide emmissions, energy consumption and economic growth with the intention of avoiding the omitted variable bias and collinearity problems. Abid (2017) and Omri (2016) argues that in addition to energy consumption and economc activity, environmental quality may be also affected by trade openness and financial development. whether the degree of trade opnenness improves or degrades envionmental quality depends on the level of economic development of a nation according to according to Baek and Kim (2011)[2] and Baek and Kim (2009). Bo (2011) asserts that free trade may improve environment quality through technical effect or it may, exacerbate environmental pollution with the expansion of economic scale. For instance, Feridun (2006) found that trade instensity has deterimental effect on environmental quality of Nigeria conrary to the finding of Zambrano-Monserrate, Carvaja, and Urgiles-Sanchez (2016) for Singapore and Shahbaz *et al*. (2013) for Indonesia.

[2] Baek and Kim (2011) finding supports *the gains-from-trade hypothesis* mostly for developed countries; with trade induced income growth, industrialized countries tend to be more willing and able to channel resources into environmental protection through the enforcement of environmental regulations and the investment on cleaner production technologies, thereby improving environmental quality. On the other hand, their result supports the *pollution haven hypothesis (PHH)* for developing countries which implies that trade liberalization deteriorates environmental quality.

Te fnancial development plays an important role to explain the CO2 emissions. On the one hand, it helps companies to implement advanced technologies that are more efcient and environment-friendly resulting in reducing CO2 emissions. Besides, the fnancial development of a country can attract foreign capital that improve the economic activity, which in turn influences the improvement of the environment through the implementation of projects that use this fnancing (Zambrano-Monserrate, Carvajal-Lara, & Urgiles-Sanchez, 2016). In line with this Shahbaz *et al*. (2013) contended that financial development decreases CO_2 emissions in Indonesia. Additionally, Katircioğlu and Taşpinar (2017) propose that financial development might moderate the effects of economic activity and energy consumption on CO2 emissions.

Population growth is the core factor in explaining CO2 emission dynamics (Alam, Murad, Noman, & Ozturk, 2016; Ohlan, 2015; Lin , Omoju , Nwakeze, Okonkwo, & Megbowon, 2016; Sohag, Mamun, Uddin, & Ahmed, 2017) which should be included in CO2 emissions function if the consistent and robust result is required. African countries like Ethiopia are currently in the process of rapid urbanisation. Empirical evidences (see Lin *et al*., 2016) show that urbanization influences CO_2 emission through the distance people travel and the mode of transportation. Accordingly, it is important to introduce urbanisation into the model in order to determine its impacts on CO_2 emission. Also, African countries depend largely on fossil fuel consumption, which promotes CO_2 emission. But the severity of the impact of energy consumption on the environment depends on the energy consumption structure (ES) of a country which denotes the share of clean or fossil energy in total energy consumption. Considering that Ethiopia is developing with substantial fossilfuel consumption, the variable ES is included in the model. ES is the share of fossil fuel consumption (petroleum,coal and gas) in total energy consumption. The square of GDP per capita is included to model the theoretical foundation of the EKC.

Therefore, the long-run relationship between energy consumption (ES), carbondioxide emmissions (CO_2), GDP (Y), square of GDP (Y^2), financial development (F), populaltion (P) and urbanization (UR) can be specified as below:

$$\ln \mathrm{C}_t = \alpha + \beta_1 \ln Y_t + \beta_2 \ln Y^2 + \beta_3 \ln \mathrm{E}S_t + \beta_4 \ln T_t + \beta_5 \ln F_t + \beta_6 \ln P_t + \beta_6 UR + \varepsilon_t \text{........................(1)}$$

The annual time series data from 1970 to 2014 on CO2 emissions measured in kt from the consumption of natural gas (million metric tons), CO2 emissions from the consumption of oil (million metric tons), natural gas consumption (billion cubic feet), per capita CO2 emissions from the consumption of energy (metric tons of CO2 per person), total oil consumption (thousand barrels per day) and total energy consumption per capita (million Btu per person) are obtained from the U.S. Energy Information Administration, 2012. Per capita GDP, CO2 emissions from electricity and heat production, (million metric tons) and electric power consumption (kilowatt hours per capita) data are obtained from the World Development Indicators (2016) online database.

3. Estimation Methods

3.1.Unit Root Test

Even though the Toda-Yamamoto (TY) and ARDL bounds test procedures are applicable irrespective of the order of integration of the series under consideration, unit root test still serves two important issues. It helps us to identify the maximum order of integration for the series which is used to augment VAR (p). Moreover, the unit root test is used to identify the series with I(2) and above in which the ARDL procedure is inappropriate. To this end three conventional unit root tests viz. Phillips and Perron (1988) (PP), Kwiatkowski, Phillips, Schmidt, and Shin (1992) (KPSS) and augmented Dickey Fuller (1979) (ADF) were employed. Katircioglu, Feridun and Kilinc (2014) and Jafari, Othman and Nor (2012) argued that PP and ADF unit root tests which were designed on the basis of the null hypothesis that a series is stationary have a low power of rejecting the null. It is suggested that KPSS unit root test eliminates a possible low power against stationary unit root that occurs in the ADF and PP (Katircioglu , Feridun , & Kilinc , 2014; Jafari , Othman, & Nor, 2012; Behera & Dash, 2017). Therefore, in order to obtain more robust results this study relied on the KPSS unit root test.

Baum (2001), however, argues that a well–known weakness of the conventional unit root tests with I (1) as a null hypothesis is its potential confusion of structural breaks in the series as evidence of non-stationarity because they may fail to reject the unit root hypothesis if the series have a structural break. Shahbaz, Hye, Tiwari, and Leitão (2013) also contend that these tests provide biased and spurious results due to not having information about structural break points occurred in the series.

To address this problem, Clemente, Montanes and Reyes (1998) proposed tests that would take into account for two structural breaks within the observed history of a time series, either additive outliers (the AO model, which captures a sudden change in a series) or innovational outliers (the IO model, allowing for a gradual shift in the mean of the series). The double–break additive outlier AO model as employed in Baum *et al*. (1999) involves the estimation of:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \tilde{y}_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where $DU_{mt} = 1$ for $t > T_{bm}$ and 0 otherwise, for m = 1, 2. T_{b1} and T_{b2} are the breakpoints, to be located by grid search. As stated in Baum, Barkoulas and Caglayan (1999), the residuals from this regression, $\tilde{y}_t$, are then the dependent variable in the equation to be estimated. They are regressed on their lagged values, a number of lagged differences and a set of dummy variables needed to make the distribution of the test statistic tractable:

$$\tilde{y}_t = \sum_{i=1}^{k} \omega_{1i} DT_{b1,t-i} + \sum_{i=1}^{k} \omega_{2i} DT_{b2,t-i} + \alpha \tilde{y}_{t-i} + \sum_{i=1}^{k} \theta_i \Delta \tilde{y}_{t-i} + e_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where $DT_{bm,t} = 1$ for $t = T_{bm} + 1$ and 0 otherwise, for m = 1, 2. This regression is then estimated over feasible pairs of T_{b1} and T_{b2}, searching for the minimal t–ratio for the hypothesis $\alpha = 1$; that is, the strongest rejection of the unit root null hypothesis[3]. The value of this minimal t–ratio is compared with critical values provided by Perron and Vogelsang (1992), as they do not follow the standard "Dickey–Fuller" distribution (Baum et al., 1999).

The comparable model for the innovational outlier (gradual change) model expresses the shocks to the series (the effects of δ_1, δ_2 above) as having the same effect on y_t as any other shocks, so that the dynamic effects of DT_b have the same ARMA representation as do other shocks to the model. This formulation, when transformed, generates the finite AR model to the model, leading to the formulation:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \varphi_1 DT_{b1,t} + \varphi_2 DT_{b2,t} + \alpha y_{t-i} + \sum_{i=1}^{k} \theta \Delta y_{t-i} + e_t \ldots\ldots\ldots(4)$$

Where again an estimate of α=1will tell us that the series has a unit root with structural break(s).

As stated by Baum, Barkoulas and Caglayan (1999), in each of these models, the breakpoints T_{b1}, T_{b2} and the appropriate lag order k are unknown. The breakpoints are to be found by a two–dimensional grid search for the maximal (most negative) t–statistic for the unit root hypothesis (α=1), while k is determined by a set of sequential F –tests. Baum, Barkoulas and Caglayan (1999) suggests that if the estimates of Clemente, Montanes and Reyes AO and IO model for two structural breaks show that there is no evidence of a second break in the series, the original Perron–Vogelsang techniques should be used to test for a unit root in the presence of one structural break. Therefore, for the sake of robustness, the conventional unit root testing techniques (ADF, PP and KPSS) and unit root tests that consider structural breaks (Clemente, Montanes and Reyes (1998) and Zivot and Andrews (1992)) were employed to test for the stationarity of the variables under consideration.

[3] In Clemente, Montanes and Reyes (1998) test, the null hypothesis is that the series has a unit root with structural break(s) against the alternative hypothesis that they are stationary with break(s).

3.2.Cointegration Test

In order to test the long-run cointegration among energy consumption, CO_2 emission and economic growth in Ethiopia, this study used Autoregressive Distributed Lag (ARDL) bounds test approach of Pesaran *et al.* (2001) due to its various advantages when compared to other cointegration techniques.[4] An ARDL representation of Equation (1) which involves an error-correction modeling format is given as follows:

$$\Delta C_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta C_{t-i} + \sum_{i=0}^{q_1} \eta_{1i} \Delta Y_{t-i} + \sum_{i=0}^{q_2} \gamma_{1i} \Delta \left(Y_{t-i}\right)^2 + \sum_{i=0}^{q_3} \theta_{1i} \Delta E_{t-i} + \sum_{i=0}^{q_4} \pi_{1i} \Delta T_{t-i} + \sum_{i=0}^{q_5} \phi_{1i} \Delta F_{t-i} + \sum_{i=0}^{q_6} \omega_{1i} \Delta P_{t-i}$$
$$+ \delta_1 \ln C_{t-1} + \delta_2 \ln Y_{t-1} + \delta_3 \ln \left(Y_{t-i}\right)^2_{t-1} + \delta_4 \ln E_{t-1} + \delta_5 \ln T_{t-1} + \delta_6 \ln F_{t-1} + \delta_7 \ln P_{t-1} + \varepsilon_{1t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The parameters δ_i , where i= 1, 2, 3, 4, 5, 6,7, are the corresponding long-run multipliers, while the parameters $\beta_i, \eta_i, \gamma_i, \theta_i, \pi_i, \phi_i, \omega_i$ are the short-run dynamic coefficients of the underlying ARDL model.

Basically, the ARDL bounds testing approach to cointegration involves two steps for estimating long-run relationship. The first step is to investigate the existence of long-run relationship among all variables in the equation. To this end, an appropriate lag length selection based on Schwartz Bayesian Criterion (SBC)[5] is conducted and Equation (5) is estimated using the OLS method. The bounds testing procedure is based on the joint F-statistic or Wald statistic that tested the null hypothesis of no cointegration, $H_0 : \delta_i = 0$ against the alternative of $H_1 : \delta_i \neq 0, i = 1,2,3,4,5,6,7$. This study applies the critical values of Narayan (2005) for the bounds F-test rather than Pesaran *et al.* (2001) since it is based on small samples ranging from 30 to 80 observations. Two sets of critical values that are reported in Narayan (2005) provide critical value bounds for all classifications of the regressors into purely I(1), purely I(0) or mutually cointegrated. If the calculated F-statistic lies above the upper level of the band, the null hypothesis is rejected, indicating cointegration. If the calculated F-statistic is below the upper critical value, we cannot reject the null hypothesis of no cointegration. Finally, if it lies between the bounds, a conclusive inference cannot be made without knowing the order of integration of the underlying regressors.

The second step is to estimate the following long-run and short-run models that are represented in Equations (6) and (7) if there is evidence of long-run relationships (cointegration) between these variables.

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[4] See Hundie (2014), Ghosh (2010), Sarboori and Sulaiman (2013) and Farhani *et al.* (2014) for more details.

[5] Pesaran and Shin (1995) argue that the Schwartz-Bayesian Criteria (SBC) is preferable to other model specification criteria because it often has more parsimonious specifications.

$$\ln C_t = \alpha_2 + \sum_{i=1}^{p} \beta_{2i} \ln C_{t-i} + \sum_{i=0}^{q_1} \eta_{1i} \ln Y_{t-i} + \sum_{i=0}^{q_2} \gamma_{1i} \ln \left(Y_{t-i}\right)^2 + \sum_{i=0}^{q_3} \theta_{1i} \ln Es_{t-i} + \sum_{i=0}^{q_4} \pi_{1i} \ln T_{t-i}$$

$$+ \sum_{i=0}^{q_5} \phi_{1i} \ln F_{t-i} + \sum_{i=0}^{q_6} \omega_{1i} \ln P_{t-i} + \sum_{i=0}^{q_7} \upsilon_{1i} UR_{t-i} + \varepsilon_{2t} \quad \text{......(6)}$$

$$\Delta C_t = \alpha_3 + \sum_{i=1}^{p} \beta_{3i} \Delta C_{t-i} + \sum_{i=0}^{q_1} \eta_{3i} \Delta Y_{t-i} + \sum_{i=0}^{q_2} \gamma_{3i} \Delta \left(Y_{t-i}\right)^2 + \sum_{i=0}^{q_3} \theta_{3i} \Delta E_{t-i} + \sum_{i=0}^{q_4} \pi_{3i} \Delta T_{t-i}$$

$$+ \sum_{i=0}^{q_5} \phi_{3i} \Delta F_{t-i} + \sum_{i=0}^{q_6} \omega_{1i} \Delta P_{t-i} + \sum_{i=0}^{q_7} \upsilon_{1i} \Delta UR_{t-i} + \psi ECT_{t-1} + \varepsilon_{3t} \quad \text{......(7)}$$

where ψ is the coefficient of error-correction term (ECT). ECT, defined as:

$$ECT_t = C_t - \alpha_2 - \sum_{i=1}^{p} \beta_{2i} C_{t-i} - \sum_{i=0}^{q_1} \eta_{1i} Y_{t-i} - \sum_{i=0}^{q_2} \gamma_{1i} \left(Y_{t-i}\right)^2 - \sum_{i=0}^{q_3} \theta_{1i} E_{t-i} - \sum_{i=0}^{q_4} \pi_{1i} T_{t-i}$$

$$- \sum_{i=0}^{q_5} \phi_{1i} F_{t-i} - \sum_{i=0}^{q_6} \omega_{1i} P_{t-i} - \sum_{i=0}^{q_7} \upsilon_{1i} UR_{t-i} \quad \text{......(8)}$$

ECT shows how quickly variables converge to equilibrium and it should have a statistically significant coefficient with a negative sign. (Acaravci & Ozturk, 2010a)

3.3.Granger-Causality Test

The ARDL bounds cointegration approach proves the existence or absence of a long-term relationship between the variables included in the model (Alkhathlan & Javid, 2013), but It does not indicate the direction of causality (Acaravci & Ozturk, 2010a). Thus, this article uses Granger non-causality procedure introduced by Toda and Yamamoto (1995) (hereafter TY) to examine the causal relationship between carbon dioxide emissions, energy consumption, output, trade openness, financial development and population growth in Ethiopia. The TY approach is preferred because it has many statistical advantages over other methods of testing Granger non-causality.

The basic idea is to artificially augment the correct VAR order, k, with d_{max} extra lags, where d_{max} is the maximum likely order of integration of the series in the system as follows. The TY representation of Equation (1) is given as follows:

$$\ln C_t = \beta_{10} + \sum_{i=1}^{p} \theta_{1i} \ln C_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \Omega_{1i} \ln C_{t-i} + \sum_{i=1}^{p} \delta_{1i} \ln E_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \phi_{1i} \ln E_{t-i} + \sum_{i=1}^{p} \gamma_{1i} \ln T_{t-i}$$
$$+ \sum_{i=p+1}^{p+d_{\max}} \psi_{1i} \ln T_{t-i} + \sum_{i=1}^{p} \mu_{1i} \ln F_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \eta_{1i} \ln F_{t-i} + \sum_{i=1}^{p} \vartheta_{1i} \ln P_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \omega_{1i} \ln P_{t-i}$$
$$+ \sum_{i=1}^{p} \varphi_{1i} \ln Y_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \mu_{1i} \ln Y_{t-i} + \sum_{i=1}^{p} \upsilon_{1i} \ln UR_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \nu_{1i} \ln UR_{t-i} + \varepsilon_{1t} \ldots\ldots (9)$$

$$\ln E_t = \beta_{20} + \sum_{i=1}^{p} \theta_{2i} \ln C_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \Omega_{2i} \ln C_{t-i} + \sum_{i=1}^{p} \delta_{2i} \ln E_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \phi_{2i} \ln E_{t-i} + \sum_{i=1}^{p} \gamma_{2i} \ln T_{t-i}$$
$$+ \sum_{i=p+1}^{p+d_{\max}} \psi_{2i} \ln T_{t-i} + \sum_{i=1}^{p} \mu_{2i} \ln F_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \eta_{2i} \ln F_{t-i} + \sum_{i=1}^{p} \vartheta_{2i} \ln P_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \omega_{2i} \ln P_{t-i}$$
$$+ \sum_{i=1}^{p} \varphi_{2i} \ln Y_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \mu_{2i} \ln Y_{t-i} + \sum_{i=1}^{p} \upsilon_{1i} \ln UR_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \nu_{1i} \ln UR_{t-i} + \varepsilon_{2t} \ldots\ldots (10)$$

$$\ln Y_t = \beta_{30} + \sum_{i=1}^{p} \theta_{3i} \ln C_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \Omega_{3i} \ln C_{t-i} + \sum_{i=1}^{p} \delta_{3i} \ln E_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \phi_{3i} \ln E_{t-i} + \sum_{i=1}^{p} \gamma_{3i} \ln T_{t-i}$$
$$+ \sum_{i=p+1}^{p+d_{\max}} \psi_{3i} \ln T_{t-i} + \sum_{i=1}^{p} \mu_{3i} \ln F_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \eta_{3i} \ln F_{t-i} + \sum_{i=1}^{p} \vartheta_{3i} \ln P_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \omega_{3i} \ln P_{t-i}$$
$$+ \sum_{i=1}^{p} \varphi_{3i} \ln Y_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \mu_{3i} \ln Y_{t-i} + \sum_{i=1}^{p} \upsilon_{1i} \ln UR_{t-i} + \sum_{i=p+1}^{p+d_{\max}} \nu_{1i} \ln UR_{t-i} + \varepsilon_{3t} \ldots\ldots (11)$$

We can write TY representation for the remaining variables in a similar fashion. The order p of the process is estimated by some consistent lag selection criteria. In the present study we have used SIC (preferably) and AIC and d_{max} is obtained from unit root test. Then, Granger causality is tested using the modified Wald (MWald) test which is theoretically very simple, as it involves estimation of an augmented VAR model in a straightforward way. For instance, from Equation (9) energy consumption (ES_t) Granger causes CO_2 emissions (C_t) if at least one of the δ_{1p}'s $\neq 0$.

4. Empirical Results and Discussions

4.1. Unit Root Test

Even though the Toda-Yamamoto (TY) and ARDL bounds test procedures are applicable irrespective of the order of integration of the series under consideration, unit root test still serves two important issues. It helps us to identify the maximum order of integration for the series which is used to augment VAR (p). Moreover, the unit root test is used to identify the series with I(2) and above in which the ARDL procedure is inappropriate. To this end three conventional unit root tests viz. Phillips and Perron (1988) (PP), Kwiatkowski, Phillips, Schmidt, and Shin (1992) (KPSS) and augmented Dickey Fuller (1979) (ADF) were employed. Katircioglu, Feridun and Kilinc (2014) and Jafari, Othman and Nor (2012) argued that PP and ADF unit root tests which were designed on the basis of the null hypothesis that a series is stationary have a low power of rejecting the null. It is suggested that KPSS unit root test eliminates a possible low power against stationary unit root that occurs in the ADF and PP (Katircioglu , Feridun , & Kilinc , 2014; Jafari , Othman, & Nor, 2012; Behera & Dash, 2017). Therefore, in order to obtain more robust results this study relied on the KPSS unit root test. The results are shown in Table 1 below. The result shows that most of the variables, in case of ADF, and all variables in case of PP and KPSS are non-stationary at level, but become stationary at their first difference at 5% significance level or less.

Table 1

Results of Conventional Unit Root Test

		ADF: t-Statistic	PP: Adj. t-Stat.	KPSS: LM-Stat.
Levels				
Intercept only	lnC	-4.088403**	-1.553601	0.506271(5)**
	lnES	-1.350324	-1.145716	0.689806(5)**
	lnT	-1.724615	-1.782051	0.599053(5)**
	lnF	-1.377113	-1.377113	0.501733 (5)**
	lnY	4.158995	5.364499	0.812004(5)***
	$\ln Y^2$	4.745510	6.643138	0.804810(5)***
	lnP	-4.579469**	-1.971074	0.180746(5)***
	lnUR	0.521673	-0.202579	0.862220(5)***
Intercept and trend	lnC	-4.477194**	-2.333245	0.183850(4)**
	lnES	-3.146223	-2.826115	0.188741(4)**
	lnT	-2.032029	-2.273933	0.599053(5)**
	lnF	-1.077342	-1.077342	0.156875(5)***
	lnY	0.847281	0.272262	0.218929(5)***
	$\ln Y^2$	1.234922	0.616090	0.218657(5)***
	lnP	-4.321182**	-1.989558	0.116834(5)***
	lnUR	-2.132119	-1.691429	0.147678(5)**
First Differences				
Intercept only	lnC	-4.850183***	-3.972950***	0.076415(3)

	lnES	-6.857512***	-7.396352***	0.216862(12)
	lnT	-6.241112***	-6.267085***	0.100138(6)
	lnF	-5.652532***	-5.660883***	0.160865(2)
	lnY	-10.15517***	-9.335105***	0.760101(3)
	$\ln Y^2$	-12.60877	-8.808092***	0.815341(3)
	lnP	-4.305795***	-2.049215	0.068504(3)
	lnUR	-1.637434	-2.926925	0.157059(5)
Intercept and trend	lnC	-5.058499***	-3.439057	0.055504(4)
	lnES	-6.874491***	-8.560948	0.190530(15)
	lnT	-6.193555***	-6.207440	0.095380(4)
	lnF	-5.665636***	-5.646782***	0.097060(3)
	lnY	-12.60877***	-12.60877	0.141915(13)
	$\ln Y^2$	-3.654045***	-12.38597**	0.139209(10)
	lnP	-2.234572	-2.016299	0.062434(3)
	lnUR	-1.532285	-2.842904	0.154517(5)

Note: *, ** and *** show rejection of the null hypothesis at 10, 5 and 1 per cent level of significance respectively. Figure in () for KPSS is bandwidth based on Bartlett kernel.

Table 2

Unit Root Tests with Structural Breaks

Clemente-Montanes-Reyes Unit-Root Test with Double Mean Shifts							**Zivot-Andrews Unit Root test allowing for a single break in intercept and/or trend**	
At Levels	**Innovative Outliers**			**Additive Outliers**			**t-statistic**	**Break Date**
	t-statistic	**TB1**	**TB2**	**t-statistic**	**TB1**	**TB2**		
lnC	-6.905(2)**	2002	2009	-1.815(8)	2002	2009	-6.136(2)***	2003
lnES	-4.702(0)	1984	1999	-4.822(1)	1990	2002	-4.090(0)	2001
lnT	-7.161(0)	1987	1990	-3.540(7)	1985	1993	-4.316(0)	1992
lnF	-6.679(10)	-	2009	-3.688(0)	1984	2008	-3.924(0)	2005
lnY	2.111(10)	1994	2002	-3.059(0)	1991	2005	-2.916(1)	1991
$\ln Y^2$	2.305(0)	1992	2002	-2.983(0)	1991	2005	-2.476(1)	1991
lnP	-4.579(8)	1973	1977	-6.630(1)**	1984	2000	-5.273(2)**	1992
lnUR	-5.692(2)**	1993	2002	-8.286(10)**	1984	1997	-3.975(1)	1990
At First Difference								
lnC	-5.681(5)**	1991	2006	0.235(6)	1990	2007	-3.441(0)	1979
lnES	-7.873(3)**	1983	1991	-7.650(1)**	1982	1990	-6.946(0)***	1994
lnT	-9.265(0)**	1990	1994	-4.331(2)	1989	1994	-8.704(0)***	1992
lnF	-12.766(2)**	2003	2009	-1.393(7)	2003	2008	-7.547(0)***	2001
lnY	-8.338(1)**	1992	2001	-8.165(1)**	1991	2003	-13.657(0)***	1983
$\ln Y^2$	-14.256(0)**	1992	2001	-8.168(1)**	1991	2003	-13.574(0)***	1983
lnP	-6.741(11)**	-	1985	-5.348(10)	1981	1987	-4.948 (2)***	1984
lnUR	-253.986(11)**	1983	1994	-1.273(8)	1986	1996	-8.915(1)***	1995

*Note: *, ** and *** show rejection of the null hypothesis at 10, 5 and 1 per cent level of significance respectively.*

Results of unit root test that consider structural breaks are given in Table 2 above[6]. Clemente, Montanes and Reyes unit root test result shows that lnC, lnP and lnUR are stationary at level, I(0), as well as at their first difference, I (1). But lnES, lnT,lnF, lnY and $\ln Y^2$ become stationary after first differences, i.e. they are I(1). This implies that lnC, lnP and lnUR are both I(0) and I(1) with remaining variables are I(1). This result corroborates with the evidences obtained by the conventional unit root tests given in Table 1 above.

The evidence on the unit root test above indicates that most of the variables are not stationary at the levels. This has both economic and statistical implications. The economic implication of non-stationarity is that shocks to the variables will have permanent effect. The statistical implication of non-stationarity is that there is likelihood of the ordinary least squares estimator producing spurious results, except in a special case where the series are cointegrated and the regressors are strictly exogenous. It is hard to meet the strict exogeneity requirement in most applied settings; hence we need an estimator that will treat both endogenous and nonstationarity problems in the regressors. This informed our choice of the ARDL approach for estimation, which does not impose strict exogeneity assumption and allows for both stationary and non-stationary regressors.

4.2. Cointegration Tests

The results of the cointegration test based on the ARDL bounds test approach are presented in Table 3.

Table 3

ARDL Bounds Test Result

	Models based on BIC	**F-Stat.**	**Result**
F_{lnC}(lnC|lnES,lnY,lnY2,lnF, lnT,lnP,lnUR)	(4, 4, 3, 4, 4, 4, 4, 4)	181.04***	Cointegration
F_{lnES}(lnES|lnC,lnY,lnY2,lnF, lnT,lnP,lnUR)	(4, 4, 3, 4, 4, 4, 4, 4)	71.90***	Cointegration

[6] Most of the beak dates determined by the tests coincide with the political and economic events of Ethiopia.

F_{lnY}(lnY|lnC,lnES,lnY2,lnF, lnT,lnP,lnUR)	(4, 4, 1, 4, 0, 4, 2, 4)	5.64***	Cointegration
F_{lnF}(lnF|lnC,lnES,lnY2,lnY, lnT,lnP,lnUR)	(4, 4, 4, 4, 3, 4, 4, 4)	45.61***	Cointegration
F_{lnT}(lnT|lnC,lnES,lnY2,lnY, lnF,lnP,lnUR)	(4, 4, 4, 4, 3, 4, 4, 4)	38.55***	Cointegration
F_{lnP}(lnP|lnC,lnES,lnY2,lnY, lnF,lnT,lnUR)	(4, 4, 4, 4, 3, 4, 4, 4)	44.56***	Cointegration
F_{lnUR}(lnUR|lnC,lnES,lnY2,lnY, lnF,lnT,lnP)	(4, 4, 4, 4, 4, 3, 4, 4)	102.75***	Cointegration

Table 3 above presents estimated ARDL models, F-statistic and optimal lag lengths. This study employs SBC for selecting appropriate lag order for ARDL model. Bounds F-test for cointegration reveals that there is a long-run relationship between CO_2 emissions, energy intensity (lnES), real GDP (lnY), real GDP squared (lnY^2), financial development (FINDEX), trade openness (lnT), population (lnP) and urbanization (lnUR) at 1% level of significance.

After investigating the long run relationship between the variables, the next step is to examine marginal impacts of economic growth, economic growth squared energy intensity, financial development, population, urbanization and trade openness on CO2 emissions. The results are reported in Table 4 showing that energy structure has positive and statistically significant impact on CO2 emissions. The coefficient of energy structure is the fourth largest (0.130386) among the statistically significant coefficients, indicating that a 1 per cent increase in the share of fossil fuel in the share of total energy consumption leads to about .13% increase in CO_2, keeping other factors constant. This implies that fossil fuel consumption is among the leading factor causing CO_2 in Ethiopia. This is due to the fact that majority of the rural as well as urban population in Ethiopia which account for 88% of total energy consumption depends on biomass fuels as the energy consumption as indicated in Ramakrishna (2015). Trade openness is the second largest contributor to CO_2 emissions with a coefficient of 0.195622 which implies that a 1% percent increment in trade openness leads to 0.2% increase in CO_2 emissions. This finding is in line with earlier findings by Al-Mulali, Ozturk and Solarin (2016), and Nahman and Antrobus (2005). This result supports the pollution haven hypothesis for Ethiopia because relatively low-income developing countries will be made dirtier with trade due to the fact that that pollution intensive manufacturing relocates from developed to developing countries where environmental regulations are assumed to be less strict. Under this situation, as developed countries create demand for tighter environment protection, trade liberalization leads to move more rapid growth of dirty industries from developed economies to developing world, thereby deteriorating environmental quality. Financial development and urbanization have no statistically significant impact on CO_2.

Table 4

Estimated Long Run Coefficients (dependent variable is lnC)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnES	0.130386	0.034582	3.770323	0.0327
lnY	0.976414	0.019382	50.377055	0.0000
lnY2	-0.044616	0.001589	-28.086026	0.0001
FINDEX	-0.031841	0.017412	-1.828656	0.1649
lnT	0.195622	0.050043	3.909071	0.0297
lnP	0.155104	0.018981	8.171453	0.0038
lnUR	-0.121495	0.062605	-1.940658	0.1476

Economic growth is the first largest contributor to CO_2 emissions in Ethiopia, with a coefficient of 0.976414 which is statistically significant at 1% level of significance. This indicates that a 1% increase in real GDP results in 0.98% increase in CO2 emissions. Contrary, a 1% rise in real GDP square reduces CO2 emissions by 0.045%. This result shows that there is evidence for the existence of EKC hypothesis in Ethiopia which corroborates with the findings of Onater-Isberk (2016), Halicioglu and Ketenci (2016) for Armenia, Estonia, Kyrgyzstan, Turkmenistan and Uzbekistan and Ben Youssef, Hammoudeh, and Omri (2016). However, it contradicts with result obtained by Lin *et al*. (2016) which argued that the EKC hypothesis does not holf for African countries while it conforms with result obtained by population has statistically significant positive impact on CO_2 in Ethiopia. This result corroborates the findings of earlier studies by Ohlan (2015) and Alam *et al.* (2016) for India. The justification is that more than 85% of the Ethiopian population which is growing at a very rapid rate, of about 3 percent annually depends on agriculuter for their livelihood. This resulted in land degradation main causes for increasing numbers of people to remain in poverty, suffer from shortage of food and deteriorating living conditions. Due to this fact the population has been clearing forests and vegetation to satisfy its increasing requirements of food and energy which results in environmental degradation, in addition to the pressure put on the environment from the growing industry.

After estimating the long-run coefficients, the next step is to find the error correction representation of (Equation 7) of the ARDL model. Table 5 provides the short-run results of ARDL approach to cointegration.The estimated coefficient of lagged error correction term, ECM(-1), is -0.103. It is statistically significant at 1% level of significance with correct sign which indicates that departure from the long-term CO_2 emissions path due to a certain shock is adjusted by 10.3% over the next year. And complete adjustment will take about 10 years. This is the alternative evidence for the existence of cointegration among the variables under consideration. In the short-run energy structure and urbanization are the only factors that are positively deriving CO_2 emissions. The EKC hypothesis is not confirmed in Ethiopia in the short-run because it is not a short-run phonomena.

Table 5

Estimated Short-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(lnF)	-0.003604	0.006078	-0.592988	0.5570
D(lnES)	0.081821	0.023808	3.436712	0.0015
D(lnP)	0.001369	0.026631	0.051413	0.9593
D(LNT)	0.023910	0.017434	1.371461	0.1790
D(lnUR)	2.056206	0.722202	2.847134	0.0073
D(LnY)	-0.643940	0.515147	-1.250013	0.2196
D($\ln Y^2$)	0.027408	0.021575	1.270395	0.2123
Constant	-0.025479	0.010708	-2.379439	0.0229
ECM(-1)	-0.102626	0.033519	-3.061711	0.0042

Note: Dependent variable is lnC

The existence of cointegration among the variables guarantees there must be at least a unidirectional causality (Ghosh, 2010) but it does not tell us the direction of causality. The knowledge of causal relationship is useful for articulating sound energy policies for sustainable economic growth and environment. Table 6 presents the empirical results derived applying

Toda-Yamamoto (Eq. 9-11) approach to causality. The results show that there is bidirectional causality between CO_2 emissions and energy consumption (fossil fuels). Energy consumption granger causes financial development, population and urbanization which in turn cause economic growth. Population causes financial development, economic growth and international trade and international trade in turn causes urbanization.

Table 6

Toda-Yamamoto Granger Causality Results

Dependent variables	**Sources of Causation**						
	lnC	lnES	lnF	lnT	lnP	lnUR	lnY
	χ^2 (2)	χ^2 (2)	χ^2 (2)	χ^2 (2)	χ^2 (2)	χ^2 (2)	χ^2 (2)
lnC	-	21.896***	0.150	0.703	3.803	4.984*	5.666*
lnES	4.833*	-	2.324	2.782	1.858	4.665*	4.553
lnF	1.940	5.944*	-	10.173***	6.830**	0.903	1.767
lnT	1.068	2.133	3.642	-	5.075*	0.192	4.380
lnP	0.544	7.878**	3.642	2.749	-	0.032	1.883
lnUR	0.940	17.916***	18.722***	8.910**	3.880	-	10.590***
lnY	0.142	0.831	12.128***	3.672	43.215***	10.590***	-

*Notes: *, **and *** indicate significance at 10 %, 5% and 1% respectively. This augmented VAR model was estimated using Zellner (1962) seemingly unrelated regression (SUR) model because the coefficient estimators obtained by the SUR are more efficient that those obtained by an equation-by-equation of least squares.*

5. Conclusion and Policy Implications

The main objective of this paper is to investigate the impact of population, energy consumption, economic growth, financial development, urbanization and trade openness on environmental quality (CO_2) in Ethiopia from 1970-2014. Unit root tests were conducted using conventional (ADF, PP and KPSS) and second generation (Zivot and Andrews, Clemente, Montanes and

Reyes) unit root test methods. The result reveals that some variables are I(0), others are I(I) while some of them are I(1)/I(0). For this reason ARDL approach to cointegration was applied to establish the long-run relationship the variables and to obtain the estimates for both long-run and short-run effects. Moreover, Toda-Yamamoto approach to Granger causality was employed to investigate the causal relationship between the series.

The results of the analysis show that economic growth and its square (measured by real GDP) are statistically significant positive and negative impact on CO_2 emissions respectively. This finding points the presence of the evidence for EKC hypothesis in Ethiopia which implies that economic growth negatively harms environmental quality at early stage of development and becomes panacea for environmental degradation at higher stages of economic development. Therefore, the EKC hypothesis is a worthy model for environmental and sustainable development policy in Ethiopia. Energy structure is also the key increasing factor which positively contributes to CO2 emissions in Ethiopia due to the high share of fossil fuel in total energy consumption and low penetration of clean energy in the country. Increase in population size exacerbates CO2 emissions due to the pressure that the populated human being puts on the environment. Urbanization and financial development do not affect CO_2 in the long-run. However, energy structure and urbanization are factors that determine the short-run dynamics of CO_2 emissions in Ethiopia.

fall into the category of developing countries, on the other hand, CO2 emissions are found to have a positive long-run relationship with openness, suggesting that air pollution tends to worsen with a higher degree of openness. This result generally supports the *pollution haven hypothesis (PHH)* for developing countries. Specifically, when confronted with international competition, developing countries have strong incentives to set environmental standards below their efficiency levels in order to attract foreign investment and multinational firms, particularly those engaged in highly polluting activities. Under this circumstance, as developed countries create demand for tighter environment protection, trade liberalization leads to move more rapid growth of dirty industries from developed economies to developing world, thereby deteriorating environmental quality.

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