



Modelling Energy Consumption, Carbon Dioxide Emissions and Economic Growth Nexus in Ethiopia: Evidence from Cointegration and Causality Analysis

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ABSTRACT

Policy makers need to know the relationship among energy use, economic growth and environmental quality in order to formulate rigorous policy for economic growth and environmental sustainability. This study analyzes the nexus among energy consumption, affluence, financial development, trade openness, urbanization, population and CO₂ emissions in Ethiopia using data from 1970–2014. The ARDL cointegration results show that cointegration exists among the variables. Energy consumption, population, trade openness and economic growth have positive impact on CO₂ in the long-run while economic growth squared reduces CO₂ emissions which confirms that the EKC hypothesis holds in Ethiopia. In the short-run urbanization and energy consumption intensify environmental degradation. Toda-Yamamoto granger causality results indicate the bi-directional causality between energy consumption and CO₂ emissions, CO₂ emissions and urbanization. Financial development, population and urbanization cause economic growth while economic growth causes CO₂ emissions. Causality runs from energy consumption to financial development, urbanization and population which in turn cause economic growth. From the result, CO₂ emissions extenuation policy in Ethiopia should focus on environmentally friendly growth, enhancing consumption of cleaner energy, incorporating the impact of population, urbanization, trade and financial development.

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Introduction

Energy which is used as widely as capital and labour is regarded as the basic input for the production process. Continuous energy supply is compulsory for sustaining and improving the current production level and standard of living since energy consumption is so extensive among the industries. Energy consumption is, therefore, considered as a prerequisite of sustainable economic development in the process of production. Energy consumption fuels economic growth, but also inevitably emits CO₂ (Alam et al., 2016; Zhou and Liu, 2016), 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 affect pattern of rainfall, worsen the agricultural productivity and reduce the productivity of labour force. Accordingly, 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 et al., 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 issue of intense research in the energy-economics literature (Acaravci and Ozturk, 2010a). Nevertheless, the empirical evidence remains controversial and unclear. 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 (Ozturk et al., 2010). Most of the existing 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 relations under the same model (Acaravci and Ozturk, 2010b).

Three research aspects in literature exist on the relationship between economic growth, energy consumption and environmental pollutants (Acaravci and Ozturk, 2010a; Alkathlan and Javid, 2013; Jafari et al., 2015; Baek and Kim, 2011). The first aspect, which is

considered as one of the most significant empirical relationships tested in the economic literature, focuses on the relationships between economic growth and environmental pollutants: Farhani et al. (2014b), Akpan and Abang (2015), Dinda and Coondoo (2006), Odhiambo (2011), Naraya and Narayan (2010), Kim et al. (2010), Kim and Baek (2011), Ghosh (2010) and others. The main aim of these studies are testing the validity of the environmental Kuznets curve (EKC) hypothesis which claims 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 and Ozturk, 2010a; Saidi and Hammami, 2015). The first empirical evidences on EKC hypothesis appeared in three independent seminal working papers (Dinda, 2004): Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993). 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) mentioned that most of the EKC literatures are based on weak econometric modelling.

The second aspect of literature emphasizes on the energy-economic growth nexus: Apergis and Tang (2013), Apergis and Payne (2010a), Apergis and Payne (2009b), Apergis and Payne (2009c), Chen et al. (2012), Herrerias et al. (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 part of the literature combines the abovementioned lines of research in order to capture the linkages in economic growth, energy use and pollution in the same framework: Apergis and Payne (2010c), Apergis and Payne (2014), Bella et al. (2014), Alkhathlan and Javid (2013), Yang and Zhao (2014), Saboori and Sulaiman (2013), Alam et al. (2016), Rafindadi (2016), Youssef et al. (2016). However, these studies modelled 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 and Javid, 2013).

Although a number of studies have examined the relationship between CO₂ emissions, economic growth and energy consumption 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, economic growth and energy consumption. Even where such studies have been done, the focus has not mainly been on Sub-Sahara African countries. Studies on the causal relationship

between carbon emissions, economic growth and energy consumption in sub-Saharan countries are very scant and the existing ones are not conclusive. In addition, the majority of the previous studies suffer from three major weaknesses; firstly, the use of a bivariate causality test, which may lead to the omission-of-variable bias; secondly, the use of cross-sectional data, which does not satisfactorily address the country-specific effects; as the third, 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 (Narayan and Smyth, 2005) and they employ unit root tests which fail to consider structural breaks.

It is against this backdrop that the current study attempts to examine the causal relationship and cointegration between CO₂ emissions, energy consumption and economic growth, using the newly developed TY and ARDL-Bounds testing approach. By incorporating energy consumption, population, urbanization, financial development and trade openness as control variables in a tri-variate setting between CO₂ emissions, energy consumption and economic growth, this study develops a simple multivariate causality model between CO₂ emissions, energy consumption and economic growth. The main objective of this paper is to analyse the significant determinants of CO₂ in Ethiopia using ARDL bounds test approach to cointegration and causal relationship among variables under consideration using Toda-Yamamoto Granger causality technique. In addition, the model specifications and estimation methods have been introduced. According to the obtained results, policy recommendations are made.

Material and Method

Model Specification and Data

Unlike the recent EKC models, the earliest ones were formulated as simple quadratic functions of the levels of income. But, resources are used in an economic activity and, by the laws of thermodynamics; consumption of resources unavoidably leads to the production of waste. Due to this fact, it is asserted that regressions output that yields zero or negative levels of pollution indicators are incorrect except in the rare case and a logarithmic dependent variable should be used to enforce this restriction (Stern, 2004). Moreover, transforming variables into their natural logarithm considerably reduces or removes any heteroscedasticity problem (Hundie, 2014). Therefore, all the variables in the model of this study are in logarithmic form.

Following Farhani et al. (2014a), Shahbaz et al. (2013), Baek and Kim (2011), Ohlan (2015), Rafindadi (2016), and Zambrano-Monserrate et al. (2016), this article employs an augmented standard EKC regression to analyse the long-run relationship and direction of causality among carbon dioxide emissions, energy consumption and economic growth with the intention of avoiding the omitted variable bias and collinearity problems. Abid (2017) argued that in addition to energy consumption and economic activity, environmental quality may be also affected by trade openness and financial development. Whether the degree of trade openness improves or degrades environmental quality depends on the level of economic development of a nation according to Baek and Kim (2011) and Baek, et al.

(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 et al. (2006) found that trade intensity has detrimental effect on environmental quality of Nigeria contrary to the finding of Zambrano-Monserrate et al. (2016) for Singapore, and Shahbaz et al. (2013) for Indonesia.

Financial development plays an important role to explain the CO₂ emissions through helping companies to implement advanced technologies that are more efficient and environment-friendly resulting in reducing CO₂ emissions. Besides, the financial development can attract foreign capital that improves the economic activity, which in turn influences the improvement of the environment through the implementation of projects that use this financing (Zambrano et al., 2016). In line with this, Shahbaz et al. (2013) contended that financial development decreases CO₂ 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 et al., 2016; Ohlan, 2015; Lin et al., 2016; Sohag et al., 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 show that urbanization degrades CO₂ 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 CO₂ emission. Also, African countries depend largely on fossil fuel consumption, which increases CO₂ 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 (Lin et al., 2016). Considering that Ethiopia is developing with substantial fossil fuel consumption, the variable ES which is the share of fossil fuel consumption (petroleum, coal and gas) in total energy consumption is included in the model. The square of GDP per capita is included to model the theoretical basis of the EKC. Therefore, the long-run relationship between energy consumption (ES), carbon dioxide emissions (CO₂), GDP (Y), square of GDP (Y²), financial development (F), population (P) and urbanization (UR) can be specified as EQ (1).

The annual time series data from 1970 to 2014 on CO₂ emissions measured in kilo ton (kt), energy consumption measured as proportion of fossil fuel (petroleum, coal and gas) in total energy consumption, population size, urbanization measured as percentage of the population living in urban centres, trade openness measured as ratio of export and import to real GDP, financial development index developed from financial development indicators (broad money to GDP and total reserve to GDP) using principal component analysis and real GDP. The data are obtained from the World Development Indicators (2016) online database and Ethiopian Economics Association (EEA) database.

Estimation Methods

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 identify the maximum order of integration for the series which is used to augment VAR (p). Moreover, the unit root test helps to identify the series with I(2) and above in which the ARDL procedure is inappropriate. To this end, three conventional unit root tests namely Phillips and Perron (1988) (PP), Kwiatkowski et al. (1992) (KPSS) and Augmented Dickey Fuller (1979) (ADF) were employed. Katircioglu et al. (2014) and Jafari et al. (2012) argued that PP and ADF unit root tests 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 et al., 2014; Jafari et al., 2012; Behera and 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 et al. (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 et al. (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) or innovational outliers (the IO model). The double-break additive outlier AO model as employed in Baum et al. (1999) involves the estimation EQ (2).

Where $DU_{mt} = 1$ for $t > T_{bm}$ and 0 otherwise, for $m = 1, 2$. T_{b1} and T_{b2} are the breakpoints. As stated in Baum et al. (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 EQ (3).

Where $DT_{bm,t} = 1$ for $t = T_{bm} + 1$ and 0 otherwise, for $m = 1, 2$. The value of minimal t-ratio obtained from regression of Equation (3) 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 below) 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 of EQ (4).

Where again an estimate of $\alpha = 1$ will tell us that the series has a unit root with structural break(s). 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, et al., (1998), CMR hereafter and Zivot and Andrews (1992), ZA hereafter) were employed to test for the stationarity of the variables under consideration.

$$\ln C_t = \alpha + \beta_1 \ln Y_t + \beta_2 \ln Y^2 + \beta_3 \ln E S_t + \beta_4 \ln T_t + \beta_5 \ln F_t + \beta_6 \ln P_t + \beta_6 UR + \varepsilon_t \tag{EQ (1)}$$

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

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

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

In order to test the long-run cointegration among energy consumption, CO₂ 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. An ARDL representation of Equation (1) which involves an error-correction modeling format is given as EQ (5).

The parameters δ_i , where $i = 1,2,3,4,5,6,7$, are the corresponding long-run multipliers, while the parameters $\beta_i, \eta_i, \gamma_i, \theta_i, \pi_i, \phi_i, \varpi_i$ are the short-run dynamic coefficients of the underlying ARDL model. The first step in the ARDL bounds testing approach to cointegration 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) 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 $H_0: \delta_i \neq 0, i = 1,2,3,4,5,6,7$. 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.

Where Ψ is the coefficient of error-correction term (ECT) as defined in EQ (8).

ECT shows how quickly variables converge to equilibrium and it should have a statistically significant coefficient with a negative sign (Acaravci and Ozturk, 2010a). The ARDL bounds cointegration approach proves the existence or absence of a long-term relationship between the variables included in the model (Alkhatlan and Javid, 2013), but it does not indicate the direction of causality (Acaravci and 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 EQ (9).

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 CO₂ emissions (C_t) if at least one of the δ_{1p} 's $\neq 0$.

Results and Discussions

Unit Root Test

Unit root test helps to identify the maximum order of integration for the series which is used to augment VAR (p). Moreover, it is used to identify the series that surpassed the order of integration I (1) under which the application of the ARDL approach 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 et al. (2014), Jafari et al. (2012) and Farhani and Ozturk (2015) argued that PP and ADF unit root tests have a low power of rejecting the null hypothesis. It is suggested that the KPSS unit root test outshines the ADF and the PP in removing a possible low power against stationary unit root that occurs in them Katircioglu et al. (2014), Jafari et al. (2012), Behera and Dash (2017). Therefore, this study relied on the KPSS unit root test where contradictory results arise from these conventional unit root tests. The results shown in Table 1 below indicates 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. This firmly proves that the conventional cointegration and granger causality testing techniques cannot be applied in this study.

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

EQ (5)

$$\ln C_t = \alpha_2 + \sum_{i=1}^p \beta_{2i} \ln C_{t-i} + \sum_{i=0}^{q_1} \eta_{1i} \ln Y_{t-i} + \sum_{i=0}^{q_2} \gamma_{1i} \ln (Y_{t-i})^2 + \sum_{i=0}^{q_3} \theta_{1i} \ln E_{t-i} + \sum_{i=0}^{q_4} \pi_{1i} \ln T_{t-i} + \sum_{i=0}^{q_5} \phi_{1i} \ln F_{t-i} + \sum_{i=0}^{q_6} \omega_{1i} \ln P_{t-i} + \sum_{i=0}^{q_7} \nu_{1i} \ln UR_{t-i} + \varepsilon_{2t}$$

EQ (6)

$$\Delta C_t = \alpha_3 + \sum_{i=1}^p \beta_{3i} \Delta C_{t-i} + \sum_{i=0}^{q_1} \eta_{3i} \Delta Y_{t-i} + \sum_{i=0}^{q_2} \gamma_{3i} \Delta (Y_{t-i})^2 + \sum_{i=0}^{q_3} \theta_{3i} \Delta E_{t-i} + \sum_{i=0}^{q_4} \pi_{3i} \Delta T_{t-i} + \sum_{i=0}^{q_5} \phi_{3i} \Delta F_{t-i} + \sum_{i=0}^{q_6} \omega_{1i} \Delta P_{t-i} + \sum_{i=0}^{q_7} \nu_{1i} \Delta UR_{t-i} + \psi ECT_{t-1} + \varepsilon_{3t}$$

EQ (7)

$$ECT_t = C_t - \alpha_2 - \sum_{i=1}^p \beta_{2i} C_{t-i} - \sum_{i=0}^{q_1} \eta_{1i} Y_{t-i} - \sum_{i=0}^{q_2} \gamma_{1i} (Y_{t-i})^2 - \sum_{i=0}^{q_3} \theta_{1i} E_{t-i} - \sum_{i=0}^{q_4} \pi_{1i} T_{t-i} - \sum_{i=0}^{q_5} \phi_{1i} F_{t-i} - \sum_{i=0}^{q_6} \omega_{1i} P_{t-i} - \sum_{i=0}^{q_7} \nu_{1i} UR_{t-i}$$

EQ (8)

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

EQ (9)

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

EQ (10)

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

EQ (11)

Results of unit root test that consider structural breaks are given in Table 2 above. CMR unit root test result confirms 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 lnY² 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) while the remaining variables are I(1). This result corroborates with the evidences obtained by the conventional unit root tests given in Table 1. Moreover, the ZA unit root test result reveals that all the variables are integrated of order one, I(1), except lnC.

Cointegration Tests

Selection of appropriate lag length is a crucial step in estimating the ARDL model. To do so, this study

employed the SBC criteria as Pesaran and Shin (1995) recommended that this criterion results in more parsimonious specifications. The results of the cointegration test based on the ARDL bounds test approach are presented in Table 3.

Table 3 above presents estimated ARDL models, F-statistic and optimal lag lengths selected by the SBC. Bounds F-test for cointegration reveals that there is a long-run relationship between CO₂ emissions, energy intensity (lnES), real GDP (lnY), real GDP squared (lnY²), financial development (FINDEX), trade openness (lnT), population (lnP) and urbanization (lnUR) at 1% level of significance since the calculated F-statistic is greater than the upper bound critical value. Moreover, the null hypothesis of no long-run relationship is rejected when each variable is considered as a dependent variable.

Table 1 Results of conventional unit root test

Specification	Variables	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)***
	lnY 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)***
	lnY 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)
	lnY 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)
	lnY 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 brackets 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
lnY 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
lnY 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.

Table 3 ARDL Bounds test result

Specification	Models based on BIC	F-Stat.	Result
$F_{\ln C}(\ln C \ln ES, \ln Y, \ln Y2, \ln F, \ln T, \ln P, \ln UR)$	(4, 4, 3, 4, 4, 4, 4)	181.04***	Cointegration
$F_{\ln ES}(\ln ES \ln C, \ln Y, \ln Y2, \ln F, \ln T, \ln P, \ln UR)$	(4, 4, 3, 4, 4, 4, 4)	71.90***	Cointegration
$F_{\ln Y}(\ln Y \ln C, \ln ES, \ln Y2, \ln F, \ln T, \ln P, \ln UR)$	(4, 4, 1, 4, 0, 4, 2, 4)	5.64***	Cointegration
$F_{\ln F}(\ln F \ln C, \ln ES, \ln Y2, \ln Y, \ln T, \ln P, \ln UR)$	(4, 4, 4, 4, 3, 4, 4, 4)	45.61***	Cointegration
$F_{\ln T}(\ln T \ln C, \ln ES, \ln Y2, \ln Y, \ln F, \ln P, \ln UR)$	(4, 4, 4, 4, 3, 4, 4, 4)	38.55***	Cointegration
$F_{\ln P}(\ln P \ln C, \ln ES, \ln Y2, \ln Y, \ln F, \ln T, \ln UR)$	(4, 4, 4, 4, 3, 4, 4, 4)	44.56***	Cointegration
$F_{\ln UR}(\ln UR \ln C, \ln ES, \ln Y2, \ln Y, \ln F, \ln T, \ln P)$	(4, 4, 4, 4, 4, 3, 4, 4)	102.75***	Cointegration

*** indicates significance at 1% level

The next step, after investigating the long run relationship between the variables, is to examine impacts of economic growth, economic growth squared, energy consumption, 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 CO₂, keeping other factors constant. This implies that fossil fuel consumption is among the leading factor causing CO₂ 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 CO₂ emissions with a coefficient of 0.195622 which implies that a 1% percent increment in trade openness leads to 0.2% increase in CO₂ emissions. This finding is in line with earlier findings by Al-Mulali et al. (2016), Baek and Kim (2011) and Nahman and Antrobus (2005) which argued that trade openness has an adverse effect on the environment for the developing countries because relatively low-income developing countries will be made dirtier with trade due to the fact 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 openness 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 CO₂. This result is in line with Kais and Sami (2016).

Economic growth is the first largest contributor to CO₂ 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 et al. (2016). However, it contradicts with

result obtained by Lin et al. (2016) which argued that the EKC hypothesis does not hold for African countries while it conforms with result obtained by population has statistically significant positive impact on CO₂ 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 agriculture 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 CO₂ 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 CO₂ emissions. The EKC hypothesis is not confirmed in Ethiopia in the short-run because it is not a short-run phenomena.

Granger Causality

The presence of cointegration among the variables guarantees the existence of at least a unidirectional causality (Ghosh, 2010) but it does not tell us the direction of causality. When the variables under consideration are mixture of I(0) and I(1) or above, the TY procedure is the most appropriate method to test for the granger causality (Chindo et al., 2014). In order to apply the TY method, the optimal lag length of VAR suggested by all lag length criteria (LR, FPE, AIC, BIC and HQ) is 2 and since the maximum order of integration is 1 ($d = 1$), augmented VAR (3) model was estimated using the Seemingly Unrelated Regression (SUR) framework. Table 6 presents the empirical results obtained from TY (Eq. 9-11) approach to granger causality.

Table 4 Estimated long run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Probability
lnES	0.130	0.034582	3.770323	0.0327
lnY	0.976	0.019382	50.377055	0.0000
lnY2	-0.045	0.001589	-28.086026	0.0001
FINDEX	-0.032	0.017412	-1.828656	0.1649
lnT	0.196	0.050043	3.909071	0.0297
lnP	0.155	0.018981	8.171453	0.0038
lnUR	-0.121	0.062605	-1.940658	0.1476

Note: Dependent variable is lnC

Table 5 Estimated short-run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Probability
D(lnF)	-0.004	0.006078	-0.592988	0.5570
D(lnES)	0.081	0.023808	3.436712	0.0015
D(lnP)	0.001	0.026631	0.051413	0.9593
D(lnT)	0.024	0.017434	1.371461	0.1790
D(lnUR)	2.056	0.722202	2.847134	0.0073
D(LnY)	-0.644	0.515147	-1.250013	0.2196
D(lnY ²)	0.027	0.021575	1.270395	0.2123
Constant	-0.025	0.010708	-2.379439	0.0229
ECM(-1)	-0.103	0.033519	-3.061711	0.0042

Note: Dependent variable is lnC

Table 6 Toda-Yamamoto Granger causality results

Dependent variables	Sources of Causation						
	lnC	lnES	lnF	lnT	lnP	lnUR	lnY
	$\chi^2(2)$	$\chi^2(2)$	$\chi^2(2)$	$\chi^2(2)$	$\chi^2(2)$	$\chi^2(2)$	$\chi^2(2)$
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.

The results shown in Table 6 above can be summarized as below:

There is two-way causal relationship between CO₂ emissions and energy consumption (fossil fuels as share of total energy consumption). This means that energy consumption granger causes CO₂ emissions and there is feedback from CO₂ emissions as well. The presence of bidirectional causal relationship between energy consumption and CO₂ emissions recommends that any fluctuations in energy consumption may change the environmental quality and any effort that may reduce CO₂ emissions will affect energy consumption. Moreover, bi-directional causality exists between energy consumption and urbanization. Urban areas are where economic activities and industrializations are concentrated which granger cause energy consumption.

There is no direct causal relationship between energy consumption and economic growth. Energy consumption granger causes financial development, population and urbanization and they in turn cause economic growth. Moreover, economic growth granger causes CO₂ emissions. However, energy consumption affects economic growth through financial development,

urbanization and population while economic growth and energy consumption are related through CO₂ emissions. Population size causes financial development, economic growth and trade openness and trade openness in turn causes urbanization.

Conclusion

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 (CO₂) and causal relationship between them in Ethiopia from 1970-2014. Unit root tests were conducted using conventional (ADF, PP and KPSS) and second generation (ZA and CMR) unit root test methods. The result reveals that some variables are I(0), others are I(1) while some of them are I(1)/I(0). For this reason, ARDL approach to cointegration was applied to establish the long-run relationship among 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 CO₂ 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 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 CO₂ in the long-run. However, energy structure and urbanization are factors that determine the short-run dynamics of CO₂ emissions in Ethiopia. CO₂ emissions are found to have a positive long-run relationship with trade openness. The TY granger causality results show that energy consumption causes financial development, urbanization and population which in turn cause CO₂ emissions. Economic growth causes CO₂ emissions and CO₂ emissions granger causes energy consumption with feedback effect.

Based on the above findings the main policy implication that can be forwarded is summarized as follows. First, economic growth leads to more carbon dioxide emissions at lower stage of development. This implies that Ethiopia should focus on formulating environmentally friendly growth strategies and policies. Second, the degree to which economic growth affects environmental quality depends on quality and efficiency of energy used. Since energy consumption contributes to economic growth through financial development, population and urbanization, the effort of designing sustainable and environmentally favourable policy should take these variables into account. Moreover, the country should shift from fossil fuel consumption to renewable and cleaner energy sources. Third, Ethiopia should give due attention to having standard trade policies and restrictions to reduce import of environmentally pollutant products and investments.

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