TECHNOLOGICAL AND ECONOMIC DEVELOPMENT OF ECONOMY
ISSN 2029-4913 / eISSN 2029-4921

2016 Volume 22(1): 47–74
doi:10.3846/20294913.2014.989932

MULTIVARIATE GRANGER CAUSALITY BETWEEN CO_2 EMISSIONS, ENERGY INTENSITY AND ECONOMIC GROWTH IN PORTUGAL: EVIDENCE FROM COINTEGRATION AND CAUSALITY ANALYSIS

Muhammad SHAHBAZ[a], Farooq Ahmed JAM[b], Sadia BIBI[c], Nanthakumar LOGANATHAN[d]

[a]*Department of Management Sciences, COMSATS Institute of Information Technology, Lahore, Pakistan*
[b]*Institute of Graduate Studies, University of Malaya, Kuala Lumpur, Malaysia*
[c]*Department of Management Sciences, COMSATS Institute of Information Technology, Vehari, Pakistan*
[d]*Faculty of Economics and Management Sciences, Universiti Sultan Zainal Abidin, 21300 Kuala Terengganu, Terengganu, Malaysia*

Received 20 October 2012; accepted 01 June 2013

Abstract. The present study aims to investigate the relationship between economic growth, energy intensity and CO_2 emissions by incorporating financial development in CO_2 emissions function using Portuguese annual data over the period of 1971–2011. The unit root problem of variables is examined by applying Zivot-Andrews unit root test and the ARDL bounds testing approach is for long run relationship. The direction of causal relationship between the series is examined by the VECM Granger causality approach and robustness of causality analysis is tested by innovative accounting approach (IAA).

Our empirical evidence confirmed that the variables are cointegrated for long run relationship. The results exposed that economic growth and energy intensity increase CO_2 emissions, while financial development condenses it. The VECM Granger causality analysis showed the feedback effect between energy intensity and CO_2 emissions, while economic growth and financial development Granger cause CO_2 emissions. The study suggests that environment degradation can be controlled by using energy efficient technologies. Financial development can also play its role in improving the environmental quality by encouraging investment in energy efficient technology to enhance domestic production and save the environment from degradation.

Keywords: growth, energy, financial development, CO_2 emissions.

JEL Classification: O1, Q4, F65, Q5.

Corresponding author Muhammad Shahbaz
E-mail: *shahbazmohd@live.com*

Routledge
Taylor & Francis Group

Introduction

The analysis of the Portuguese energy system would enable us to suggest an appropriate energy and environmental policy to sustain economic growth as well as to improve the environmental quality for better living standards in the country. In these days, the Portugal's economy is under debate on the basis of two hot issues; its economy's growth for the last two decades and reduction in emissions of greenhouse gases following political agenda of Kyoto Protocol. So, adoption of energy and environmental policy in the Portuguese economy may affect the policy targets imposed by European Union. This entails that there is a tradeoff between efficient use of energy including environmental quality and sustained economic growth in long run. Since 1986, more concern has been paid on energy security, environmental protection and economic growth, after the inclusion of Portugal as a member in European Union. The surface area of the Portuguese economy is 92,000 square kilometers with a population of around 10.7 million. After access to European Union, Portugal has been diversifying itself by developing service-based economy, for instance; telecommunications, finance, transportation, and energy sectors. These services have enhanced international competitiveness which stimulates economic growth. Portugal was recognized as a rapid growing economy among the member countries of European Union after 1990s, although energy market in the country is relatively small and has a limited access to the domestic energy resources.

Due to limited availability of energy resources, per capita energy consumption is low in the Portugal as compared to other EU member countries, although energy consumption is growing higher than the growth of GDP per capita. But rising trend of primary and final energy intensities results in absolute energy intensity. Absolute energy intensity is upsetting the environmental situation, which seems to be unfavorable for Portugal compared to other EU member countries. The pattern of energy is based on oil products, although Portugal has not much of her own fossil energy resources but due to sustained economic growth, domestic energy resources such as, hydroelectric and biomasses are utilized to meet the rising demand of the country.

Following the terms of the EU allocation agreement, it is required to analyze whether Portugal can fulfill the targets set by the European Union by preventing the hike in greenhouse gases emissions up to 40 per cent, for the period of 2008–2012 or not. The principal cause of rise in CO_2 emissions is the rapid use of fossil fuel. Portugal contributed 74.6 per cent to total greenhouse gases emissions in 2000. Due to fossil fuel consumption in 1990–2000, only 43.6 per cent of CO_2 emissions were increased. This shows that target to reduce CO_2 emissions up to 40 per cent in 2008–2012 would not be fulfilled. During 1990s, fossil fuel consumption raised CO_2 emissions to 90–91 per cent and carbon emissions were increased to 44.5 per cent. This implies that it is difficult for the Portuguese economy to reduce present CO_2 emissions up to 40 per cent. That is why; rising trend of carbon emissions is the most important issue in the current political debate. The most important challenge for energy policy making authorities is to introduce new measures that can help in reducing energy emissions.

In case of Portugal, Narayan and Prasad (2008) and Chontanawat *et al.* (2008) reported the unidirectional causality running from energy consumption to economic growth. Shahbaz *et al.* (2011) exposed that energy consumption and economic growth are interdependent and same is confirmed by Fuinhas and Marques (2012) and later on Behemiria and Mansob (2012). Acaravci and Ozturk (2010) investigated the relationship between energy consumption, economic growth and CO_2 emissions for the EU including Portugal. They found that economic growth and CO_2 emissions Granger cause energy consumption. The unidirectional causality exists running from energy consumption and economic growth to CO_2 emissions. We find that results of above studies are vague and could not be helpful for policy makers in designing comprehensive economic, energy and environmental policy to sustain long run economic growth for the Portuguese economy. Moreover, the above studies ignored the role of role structural break stemming in series also affect energy consumption and economic growth as well as CO_2 emissions in an economy. We find the importance of financial development because it is also a determinant of economic growth and CO_2 emissions as well as energy consumption (Islam *et al.* 2013). We use energy intensity (capturing technological advancement) rather than energy consumption. Further, we augment the CO_2 emissions function by incorporating financial development and this is the main motivation for us to investigate the relationship between, energy intensity, economic growth, financial development and CO_2 emissions in case of Portugal.

This study contributes in existing literature by five ways applying: (i) Zivot and Andrews (1992) structural break unit root test; (ii) the ARDL bounds testing approach to cointegration for long run relationship between the variables; (iii) OLS and ECM for long run and short run impacts; (iv) the VECM Granger causality approach for causal relationship and (v) Innovative Accounting Approach (IAA) to test the robustness of causality analysis. Our empirical findings show that cointegration is found for long run relationship among the variables such as; economic growth, energy intensity, financial development and CO_2 emissions in case of Portugal. A rise in economic growth and energy intensity (financial development) increases (condenses) CO_2 emissions. The causality analysis reveals that bidirectional causal relationship is found between CO_2 emissions and energy intensity while economic growth and financial development Granger cause CO_2 emissions. These results may provide new avenues for policy makers to design a comprehensive energy, economic, financial and environmental plan to sustain economic growth as well as, to help Portuguese economy in attaining Kyoto Protocol targets.

1. Literature review

First strand of energy literature deals with wide range of mixed result studies about energy consumption and economic growth nexus. Now a days, energy-growth relation has been empirically investigated extensively since the pioneering study conducted by Kraft and Kraft (1978). The empirical findings of the existing energy literature are unambiguous due to the use of various econometrical approaches such as; correlation analysis, simple regressions, bivariate causality, unit root testing, multivariate cointegration, panel cointegration, vector error correction modeling (VECM) and innovative accounting approach to detect the direction of causality between economic growth and energy consumption (Chontanawat *et al.* 2008). These inconclusive empirical evidences could not help economic policy architects in articulating a comprehensive energy plan to sustain long run economic growth (Payne 2010;

Ozturk 2010). The appropriate knowledge about direction of causality between energy consumption and economic growth is very important regarding theoretical and policy point of view (Ghali, El-Sakka 2004).

In recent studies Payne (2010) and Ozturk (2010) reviewed the existing literature between energy consumption and economic growth nexus and provided four empirical competing hypotheses for said issue: (i) growth hypothesis i.e. energy consumption Granger causes economic growth implies that energy reduction policies should be discouraged and new sources of energy must be explored, (ii) if causality is found running from economic growth to energy consumption, then energy reduction policies would not have adverse effect on economic growth because economic growth of the country does not seem to be dependent on energy, (iii) feedback hypothesis implies the interdependence of energy consumption and economic growth. A rise in economic growth leads to increase in energy demand, which in return stimulates economic growth. In such a situation, energy conservation policies are detrimental for economic growth and (iv) no causality between energy consumption and economic growth infers neutrality hypothesis indicating that energy and growth are not interdependent. The adoption of conservation and exploration of energy policies will not have favorable effect on economic growth.

In case of Portugal, few studies investigated the relationship between energy consumption and economic growth. For instance; Narayan and Prasad (2008) investigated the direction of causality between both variables by applying bootstrapping causality approach[1]. Chontanawat *et al.* (2008) examined the causal relationship between energy consumption and economic growth by applying bivariate system using cross section data of 100 developed and developing countries including the Portugal. Their empirical exercise indicated that energy consumption Granger causes economic growth in case of Portugal. On same line, Shahbaz *et al.* (2011) re-examined the relationship between energy consumption, economic growth and employment and reported the feedback hypothesis between energy consumption and economic growth. This implies that new sources of energy should be explored to spur economic growth in Portuguese economy. Fuinhas and Marques (2012) examined relationship between energy use and economic growth in Portugal, Italy, Greece, Spain, and Turkey applying ARDL bounds testing and VECM Granger causality approach for long run and causal relationship between the variables. Their empirical findings confirmed that variables are cointegrated for long run relationship while feedback hypothesis is validated between energy consumption and economic growth. Later on; Behemiria and Mansob (2012) applied VECM and, Toda and Yamamoto (1995) Granger causality approaches to test the relationship between crude oil consumption and economic growth. They reported the bidirectional causality between both variables, which implies that energy conservation policies should be discouraged.

Second strand of existing literature on this topic provides empirical evidence on the relationship between economic growth and CO_2 emissions i.e. so called environmental Kuznets curve (EKC). The EKC hypothesis postulates that relationship between economic growth and CO_2 emissions is non-linear and inverted-U shaped. This implies that economic growth is

[1] Narayan and Prasad (2008) and Shahbaz *et al.* (2011) used electricity consumption as an indicator of energy consumption to examine the energy-growth nexus.

linked with an increase in CO_2 emissions initially and declines it, once economy matures[2]. Existing studies including Hettige *et al.* (1992); Cropper and Griffiths (1994); Selden and Song (1995); Grossman and Kueger (1995) & Martinez-Zarzoso and Bengochea-Morancho (2004) among others investigated the relationship between income and emissions and validated the existence of EKC. On contrary; Dinda and, Coonndoo (2006) used panel data and provided ambiguous results about economic growth and CO_2 emissions relationship. Recently, various studies validated the environmental Kuznets curve (EKC) using cross-sectional data. For instance; Lean and Smyth (2010) for ASEAN; Apergis and Payne (2009, 2010) for Central America and commonwealth of independent states; Pao and Tsai (2011a) for BRIC countries; Acaravci and Ozturk (2010) for Denmark and Italy; Pao and Tsai (2011b) for Russia; Iwata *et al.* (2011) for 28 countries & Wang (2013) for 138 developing and developed countries etc. But using time series data; Machado (2000); Mongelli *et al.* (2006); Ang (2007, 2008); Song *et al.* (2008); Jalil and Mahmud (2009); Shiyi (2009); Dhakal (2009); Halicioglu (2009); Ozturk and Acaravci (2010)[3]; Alam *et al.* (2011); Tiwari *et al.* (2013); Fodha and Zaghdoud (2010); Nasir and Rehman (2011); Shahbaz *et al.* (2012) and Shahbaz *et al.* (2013) also supported the empirical presence of environmental Kuznets curve (EKC) for Brazil, Italy, France, Malaysia, China, Turkey, India, Tunisia, Pakistan and Romania.

Third strand deals with country case studies, for example in case of United States, Soytas *et al.* (2007) investigated the dynamic relationship between CO_2 emissions, income and energy consumption. Their results showed that CO_2 emissions Granger causes income and energy consumption contributes to CO_2 emissions. A similar exercise was conducted by Ang (2007, 2008) for France and Malaysia. The results indicated that economic growth Granger causes energy consumption and carbon emissions in France and in Malaysia, the unidirectional causality is found running from economic growth to energy consumption. Chebbi (2010) collected the Tunisian data to investigate the causal relationship between energy consumption, income and CO_2 emissions. The empirical evidence indicated that energy consumption stimulates economic growth which Granger causes CO_2 emissions. In case of India; Gosh (2009) investigated the causal relationship between income and CO_2 emissions by incorporating investment and employment as additional determinants of CO_2 emissions but reported no causality between income and CO_2 emissions. Chang (2010) applied multivariate causality test to examine the causal relation between economic growth, energy consumption and CO_2 emissions using Chinese time series data. The findings of the study revealed that economic growth Granger causes energy consumption that leads to CO_2 emissions. Using Turkish data, Halicioglu (2009) also reported feedback hypothesis between economic growth and CO_2 emissions. In case of South Africa; Menyah and Wolde-Rufeal (2010) concluded that energy consumption Granger causes CO_2 emissions and in resulting economic growth is

2 At initial level of economic growth, a rise in income is linked with an increase in energy consumption that raises CO_2 emissions and hence environmental degradation. It implies that there is positive relationship between economic growth and CO_2 emissions at low level of income. After achieving certain of level of income, awareness about clean environment increases. This leads the government and people to increase their spending on environment protection and regulation. In such situation, environmental degradation and CO_2 emissions tend to decrease. This shows that how EKC is an inverted U-shaped i.e. an increase in income shifts the positive link between economic growth and CO_2 emissions to zero and then goes to negative relation between the both variables (Wang 2013).

3 Akbostanci *et al.* (2009) did not support their findings.

being Granger caused by CO_2 emissions. On contrary, Odhiambo (2011) reinvestigated the causality between energy consumption, economic growth and CO_2 emissions and unidirectional causality is found running from economic growth to CO_2 emissions. Similarly, Alam *et al.* (2011) examined the link between energy consumption, economic growth and energy pollutants in case of India. Their empirical evidence revealed the bidirectional causal relationship between energy consumption and CO_2 emissions while neutral hypothesis exists between CO_2 emissions and economic growth. In case of Bangladesh, Alam *et al.* (2012) detected the causal relationship between these variables and opined that variables are cointegrated for long run. These long run results are robust, confirmed by ARDL bounds testing. Their VECM causality analysis reported the presence of the feedback hypothesis between energy consumption and CO_2 emissions, while the unidirectional causality is found running from CO_2 emissions to economic growth. In case of Greece, Hatzigeorgiou *et al.* (2011) applied the VECM Granger causality test to investigate the causality between energy intensity, income and CO_2 emissions by applying Johansen multivariate cointegration approach. Their results concluded the existence of long run relationship between the series. The VECM Granger causality analysis reported that unidirectional causality is found running from economic growth to energy intensity and CO_2 emissions, while the feedback hypothesis exists between energy intensity and CO_2 emissions.

In fourth strand of economic literature, Tamazian *et al.* (2009) paid their attention to test the affect of other potential determinants of CO_2 emissions such as economic, institutional, financial variables. In their pioneering effort, Tamazian *et al.* (2009) investigated the impact of economic development as well as financial development on CO_2 emissions in case of Brazil, Russia, India, China, Untied States and Japan and later on Tamazian and Rao (2010) examined the role of institutions on CO_2 emissions. Their empirical evidence reported that economic development, trade openness, financial development and institutions play their role to control environment from degradation while supporting the presence of EKC hypothesis. Additionally, Claessens and Feijen (2007) explored the role of governance in reducing CO_2 emissions and reported that with the help of more advanced governance; enterprises can lower growth of CO_2 emissions. So, financial development may stimulate the performance of firms due to the adoption of energy efficient technologies which reduce carbon emissions. In case of China; Yuxiang and Chen (2010) argued that financial sector polices enables the firms to utilize advanced technology which emits less CO_2 emissions and enhances domestic production. They also claimed that financial development promotes capitalization and financial regulations that favor environmental quality. Later on; Jalil and Feridun (2010) tested the impact of economic growth, energy consumption and financial development on carbon emissions in case of China. They disclosed that energy consumption, economic growth and trade openness are harmful for environmental quality. On contrary, financial development and foreign direct investment save environment from degradation. Recently Zhang (2011) reinvestigated the finance-environment nexus and concluded that financial development increases CO_2 emissions due to inefficient allocation of financial resources to enterprises. In case of Sub Saharan African countries, Al-mulali and Sab (2012) examined the dynamic relationship between energy consumption, income, financial development, and CO_2 emissions by incorporating investment and employment as potential determinants of domestic production. Their empirical exercise reported that energy consumption spurs economic growth. A rise in economic growth and energy consumption adds to the demand of financial services and hence financial development that increases the improvements in environmental quality by controlling CO_2 emissions through the implementation of well-organized and transparent financial policies.

The existing review of literature failed to provide any study in case of Portugal which discusses the causality between energy intensity, economic growth, financial development, and CO_2 emissions. Hatzigeorgiou *et al.* (2011) empirically investigated the said issue for Greek economy but did not pay their attention to include financial development as a potential determinant of CO_2 emissions. Financial development may affect CO_2 emissions by stimulating economic activity and encouraging the enterprises to use advanced technology for the enhancement of domestic production that saves the environment from degradation. The exact direction of causality between economic growth and CO_2 emissions has major policy implications to expedite economic growth by controlling carbon emissions in case of Portugal. The causality running from carbon emissions to economic growth implies that we have to sacrifice economic growth to lower energy pollutants. An efficient energy policy must be implemented which may not have detrimental impact on economic growth if economic growth Granger causes carbon emissions. So, CO_2 emissions can be reduced without fall in economic growth. The policy regarding environment may be adopted to improve the environmental quality if there is no causal relationship between income and CO_2 emissions then environmental policy does not have adverse impact on economic growth. But reductions in CO_2 emissions may have negative effect on economic growth if the feedback hypothesis exists between both the variables. The present study is an effort to fill the gap in energy literature regarding the case study of Portugal.

2. Modelling framework and data collection

Existing energy economics literature provides various empirical studies investigating the dynamic relationship between economic growth, energy consumption and CO_2 emissions. For instance, Ang (2007, 2008) for France and Malaysia; Soytas *et al.* (2007) for United States; Zhang and Cheng (2009); Chang (2010) and Wang *et al.* (2011) for China; Halicioglu (2009) and Ozturk and Acaravci (2010) for Turkey; Pao and Tsai (2011a) for Brazil and Alam *et al.* (2011, 2012) for India and Bangladesh examined causal relationship between the series. Some studies included other potential determinants of CO_2 emissions such as capital by Xepapadeas (2005) and latter on by Menyah and Wolde-Rufael (2010); fossil fuels consumption by Lotfalipour *et al.* (2010); coal consumption by Baloch *et al.* (2012); electricity consumption by Lean and Smyth (2010); openness and urbanisation by Hossain (2011); foreign direct investment by Pao and Tsai (2011a); energy intensity by Roca and AlcaHntara (2001) and latter on by Hatzigeorgiou *et al.* (2011).

Tamazian *et al.* (2009) and Tamazian and Rao (2010) added financial development as potential determinant of CO_2 emissions. Latter on; Yuxiang and Chen (2010); Jalil and Feridun (2010) and Zhang (2011) investigated the empirical relationship between financial development and energy pollutants. Sound and developed financial markets stimulate capitalization by attracting local and foreign investors to accelerate economic growth (Frankel, Romer 1999). Financial development allocates financial resources to firms to utilize environment-friendly technology (Frankel, Rose 2002) which uses energy efficiently (Sadorsky 2010, 2011) and emits less carbon emissions (Tamazian *et al.* 2009; Tamazian, Rao 2010; Leitão 2013). However, financial development harms environment by increasing CO_2 emissions via the growth of industrial sector for dirty products. Following above discussion, we investigate the relationship between economic growth, energy intensity, financial development and CO_2 emissions. The general form of our empirical model can be written in the following way:

$$C_t = f(E_t, Y_t, F_t). \tag{1}$$

Now we transform all the series into logarithms to attain direct elasticities. The empirical equation is modelled as follows:

$$\ln C_t = \alpha_0 + \alpha_E \ln E_t + \alpha_Y \ln Y_t + \alpha_F \ln F_t + \mu_i, \tag{2}$$

where C_t is CO_2 emissions (measured in kt) per capita, E_t is energy intensity per capita, F_t is financial development proxied by real domestic credit to private sector per capita and Y_t is real GDP per capita used as a proxy of economic growth. Finally, μ_i is error term assumed to be normally distributed with zero mean and constant variance. We presume that a rise in energy intensity will increase carbon emissions and $\alpha_E > 0$. $\alpha_Y > 0$, an increase in economic growth is linked with high CO_2 emissions otherwise $\alpha_Y < 0$. Sound financial sector may act as conduits by enabling firms in adopting advanced cleaner and environment friendly techniques (Talukdar, Meisner 2001) to save environment from degradation and $\alpha_F < 0$ otherwise $\alpha_F > 0$ if the focus of financial sector is to boost industrial sector.

The data on real GDP per capita, energy intensity per capita, domestic credit to private sector as share of GDP and CO_2 emissions (measured in kt) per capita has been collected from world development indicators (World Development Indicators 2012). We use CPI (consumer price index) and population series to convert domestic credit to private sector into real terms and then into per capita. The data sample of the present study is 1971–2011.

3. Estimation strategy

Numerous unit root tests are available in applied economics to test the stationarity properties of the variables. These unit tests are ADF by Dickey and Fuller (1979); P-P by Phillips and Perron (1988); KPSS by Kwiatkowski *et al.* (1992); DF-GLS by Elliott *et al.* (1996) and Ng-Perron by Ng and Perron (2001). These tests provide biased and spurious results due to not having information about structural break points occurred in series. In doing so; Zivot and Andrews (1992) developed three models to test the stationarity properties of the variables in the presence of structural break point in the series: (i) this model allows a one-time change in variables at level form, (ii) this model permits a one-time change in the slope of the trend component i.e. function and (iii) model has one-time change both in intercept and trend function of the variables to be used for empirical purpose. Zivot and Andrews (1992) followed three models to check the hypothesis of one-time structural break in the series as follows:

$$\Delta x_t = a + ax_{t-1} + bt + cDU_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t; \tag{3}$$

$$\Delta x_t = b + bx_{t-1} + ct + bDT_t + \sum_{j=1}^{k} b_j \Delta x_{t-j} + \mu_t; \tag{4}$$

$$\Delta x_t = c + cx_{t-1} + ct + dDU_t + dDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t, \tag{5}$$

where dummy variable is indicated by DU_t showing mean shift occurred at each point with time break while trend shift variables are shown by DT_t [4]. So,

$$DU_t = \begin{cases} 1 \ldots if\ t > TB \\ 0 \ldots if\ t < TB \end{cases} \text{ and } DU_t = \begin{cases} t - TB \ldots if\ t > TB \\ 0 \ldots if\ t < TB \end{cases}.$$

The null hypothesis of unit root break date is $c = 0$ which indicates that series is not stationary with a drift not having information about structural break point while $c < 0$ hypothesis implies that the variable is found to be trend-stationary with one unknown time break. Zivot and Andrews unit root test fixes all points as potential for possible time break and provides estimation through regression analysis for all possible break points successively. Then, this unit root test selects that time break which decreases one-sided t-statistic to test $c = 0$ $\hat{c}(=c-1)=1$. Zivot and Andrews intimates that in the presence of end points, asymptotic distribution of the statistics is diverged to infinity point. It is necessary to choose a region where end points of sample period are excluded. Further, we followed the Zivot and Andrews suggested "trimming regions" i.e. (0.15T, 0.85T).

After testing the stationarity properties of the series, we apply the ARDL bounds testing approach developed by Pesaran *et al.* (2001) to investigate cointegration for long run relationship between economic growth, energy intensity, financial development and carbon emissions for the case of Portuguese economy. Various cointegration approaches have been applied to test the presence of cointegration between the variables in numerous studies. These approaches are Engle and Granger (1987); Johansen and Juselius (1990) and Phillips and Hansen (1990) require that all the series should be integrated at unique order of integration. The ARDL bounds testing approach is more appropriate as compared to other traditional cointegration approaches. For example, it seems flexible regarding the stationarity properties of the variables. This approach is more suitable once variables are found to be stationary at I(1) or I(0) or I(1)/I(0). The ARDL bounds testing approach provides efficient and consistent empirical evidence for small sample data (Narayan, Smyth 2005) as in case of Portugal. This approach

[4] We used model-5 for empirical estimations following Sen (2003).

investigates short run as well as long run parameter instantaneously. The unrestricted error correction model (UECM) version of ARDL model is expressed as follows:

$$\Delta\ln C_t = \beta_1 + \beta_T T + \beta_C \ln C_{t-1} + \beta_E \ln E_{t-1} + \beta_Y \ln Y_{t-1} + \beta_F \ln F_{t-1} + \sum_{i=1}^{p}\beta_i \Delta\ln C_{t-i} +$$
$$\sum_{j=0}^{q} B_j \Delta\ln E_{t-j} + \sum_{k=0}^{r}\beta_k \Delta\ln Y_{t-k} + \sum_{l=0}^{s}\beta_l \Delta\ln Y_{t-l} + \mu_t; \quad (6)$$

$$\Delta\ln E_t = \phi_1 + \phi_T T + \phi_C \ln C_{t-1} + \phi_E \ln E_{t-1} + \phi_Y \ln Y_{t-1} + \phi_F \ln F_{t-1} + \sum_{i=1}^{p}\phi_i \Delta\ln E_{t-i} +$$
$$\sum_{i=0}^{q}\phi_j \Delta\ln C_{t-j} + \sum_{k=0}^{r}\phi_k \Delta\ln Y_{t-k} + \sum_{l=0}^{s}\phi_l \Delta\ln F_{t-l} + \mu_t; \quad (7)$$

$$\Delta\ln Y_t = \varphi_1 + \varphi_T T + \varphi_C \ln C_{t-1} + \varphi_E \ln E_{t-1} + \varphi_Y \ln Y_{t-1} + \varphi_F \ln F_{t-1} + \sum_{i=1}^{p}\varphi_i \Delta\ln Y_{t-i} +$$
$$\sum_{i=0}^{q}\varphi_j \Delta\ln C_{t-j} + \sum_{k=0}^{r}\varphi_k \Delta\ln E_{t-k} + \sum_{l=0}^{s}\varphi_l \Delta\ln F_{t-l} + \mu_t; \quad (8)$$

$$\Delta\ln F_t = \theta_1 + \theta_T T + \theta_C \ln C_{t-1} + \theta_E \ln E_{t-1} + \theta_Y \ln Y_{t-1} + \theta_F \ln F_{t-1} + \sum_{i=1}^{p}\theta_i \Delta\ln F_{t-i} +$$
$$\sum_{j=0}^{q}\theta_j \Delta\ln C_{t-j} + \sum_{k=0}^{r}\theta_k \Delta\ln E_{t-k} + \sum_{l=0}^{s}\theta_l \Delta\ln Y_{t-l} + \mu_t. \quad (9)$$

The difference operator is shown by Δ and μ_t is for residual terms. The appropriate lag length of the first differenced regression is chosen on the basis of minimum value of akaike information criteria (AIC). The F-statistic is much sensitive with lag order selection. The inappropriate lag length selection may provide misleading results. Pesaran *et al.* (2001) developed an F-test to determine the joint significance of the coefficients of lagged level of the variables. For example, the hypothesis of no cointegration between the variables in equation-2 is $H_0 : \beta_C = \beta_E = \beta_Y = \beta_F = 0$, $H_0 : \phi_C = \phi_E = \phi_Y = \phi_F = 0$, $H_0 : \varphi_C = \varphi_E = \varphi_Y = \varphi_F = 0$, $H_0 : \theta_C = \theta_E = \theta_Y = \theta_F = 0$ while hypothesis of cointegration is $H_a : \beta_C \neq \beta_E \neq \beta_Y \neq \beta_F \neq 0$, $H_a : \phi_C \neq \phi_E \neq \phi_Y \neq \phi_F \neq 0$, $H_a : \varphi_C \neq \varphi_E \neq \varphi_Y \neq \varphi_F \neq 0$, $H_a : \theta_C \neq \theta_E \neq \theta_Y \neq \theta_F \neq 0$. Pesaran *et al.* (2001) generated two asymptotic critical values i.e. upper critical bound (UCB) and lower critical bound (LCB), are used to take decisions whether cointegration exists or not between the series. The lower critical bound is used to test cointegration if all the series are integrated at I(0) otherwise we use upper critical bound (UCB). Our computed F-statistics are $F_C(C/E,Y,F)$, $F_E(E/C,Y,F)$, $F_Y(Y/C,E,F)$ and $F_F(F/C,E,Y)$ for equations (6) to (9) respectively. The long run relationship between the variables exists if our calculated F-statistic is greater than upper critical bound (UCB). There is no cointegration between the series, if our calculated F-statistic does not exceed lower critical bound (LCB). Our decision regarding cointegration is inconclusive if calculated F-statistic falls between LCB and UCB. In such an environment, error correction method is an easy and suitable way to investigate cointegration between the variables. We have used critical bounds generated by Narayan (2005) to test cointegration rather than Pesaran *et al.* (2001) and Turner (2006).

The direction of causality between economic growth, energy intensity, financial development, and CO_2 emissions is investigated by applying the VECM Granger causality approach after confirming the presence of cointegration between the variables. On the same lines; Granger (1969) argued that vector error correction method (VECM) is more appropriate to examine the causality between the series if the variables are integrated at I(1). The VECM is restricted form of unrestricted VAR (vector autoregressive) and restriction is levied on the presence of long run relationship between the series. The system of error correction model (ECM) uses all the series endogenously. This system allows the predicted variable to explain itself both by its own lags and lags of forcing variables as-well-as error correction term and by residual term. The VECM equations are modeled as follows:

$$\Delta \ln C_t = \alpha_{01} + \sum_{i=1}^{l} \alpha_{11} \Delta \ln C_{t-i} + \sum_{j=0}^{m} \alpha_{22} \Delta \ln Y_{t-j} + \sum_{k=0}^{n} \alpha_{33} \Delta \ln E_{t-k} + \sum_{r=0}^{o} \alpha_{44} \Delta \ln F_{r-t} + \eta_1 ECT_{t-1} + \mu_{1i}; \quad (10)$$

$$\Delta \ln E = \beta_{11} + \sum_{i=1}^{l} \beta_{11} \Delta \ln E_{t-i} + \sum_{j=0}^{m} \beta_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \beta_{33} \Delta \ln Y_{t-k} + \sum_{r=0}^{o} \beta_{44} \Delta \ln F_{t-r} + \eta_2 ECT_{t-1} + \mu_{2i}; \quad (11)$$

$$\Delta \ln Y_t = \varphi_{01} + \sum_{i=1}^{l} \varphi_{11} \Delta \ln Y_{t-i} + \sum_{j=0}^{m} \varphi_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \varphi_{33} \Delta \ln E_{t-k} + \sum_{r=0}^{o} \varphi_{44} \Delta \ln F_{t-r} + \eta_3 ECT_{t-1} + \mu_{3i}; \quad (12)$$

$$\Delta \ln F_t = \rho_{11} + \sum_{i=1}^{l} \rho_{11} \Delta \ln F_{t-i} + \sum_{j=0}^{m} \rho_{22} \Delta \ln C_{t-j} + \sum_{k=0}^{n} \rho_{33} \Delta \ln Y_{t-k} + \sum_{r=0}^{o} \rho_{44} \Delta \ln EF_{t-r} + \eta_4 ECT_{t-1} + \mu_{4i}, \quad (13)$$

where u_{it}, are random terms and supposed to be normally distributed with zero means and constant variances. The established long run relation between the series is further confirmed by the statistical significance of lagged error term i.e. ECT_{t-1}. The estimates of ECT_{t-1} also shows the speeds of convergence from short run towards long run equilibrium path. The vector error correction method (VECM) is appropriate to examine causality between the variables once series are found to be cointegrated and then causality must be found at least from one direction. The VECM also distinguishes causality relationships between short-and-long runs. The VECM is also used to detect the causality in long run, short run and joint i.e. short-and-long runs respectively.

The t-statistic of estimate of lagged error term i.e. ECT_{t-1} with negative sign is used to test long run casual relation and the joint χ^2 statistical significance of the estimates of first difference lagged independent variables is used to investigate short run causality. Economic growth Granger causes carbon emissions if $\alpha_{22,i} \neq 0 \forall_i$ is found statistically significant. On contrary, if $\beta_{22,i} \neq 0 \forall_i$ is statistically significant then causality runs from CO_2 emissions to economic growth. The rest of causality hypotheses can be inferred similarly. The joint causality i.e. long-and-short runs is investigated by using Wald or F-test on the joint significance of estimates of lagged terms of independent variables and error correction term. The presence of short-and-long run causality relation between the variables is known as measure of strong Granger causality (Shahbaz *et al.* 2011).

4. Results and their discussions

Table 1 shows the results of descriptive statistics and pair-wise correlations between the series. The results exposed that all the variables have normal distributions while error term is having zero mean as well as finite variance confirmed by the statistic of Jarque-Bera. The pair-wise correlation analysis reveals that energy intensity, economic growth and financial development are positively correlated with CO_2 emissions. A negative correlation exists between economic growth and energy intensity and same is true for financial development and energy intensity. A positive correlation is found between financial development and economic growth. This correlation analysis provides no evidence of multi-colinearity between the variables.

Table 1. Descriptive statistics and correlation matrix

Variables	$\ln C_t$	$\ln E_t$	$\ln Y_t$	$\ln F_t$
Mean	1.3681	–1.7968	9.1084	8.9002
Median	1.5284	–1.7540	9.1813	8.5677
Maximum	1.8624	–1.6064	9.4684	10.100
Minimum	0.6399	–2.0866	8.5851	8.0686
Std. Dev.	0.3803	0.1449	0.2876	0.6550
Skewness	–0.2968	–0.3967	–0.1689	0.6647
Kurtosis	1.5765	1.8798	1.5363	1.8012
Jarque-Bera	3.9646	3.1407	3.7606	5.3411
Probability	0.1377	0.2079	0.1525	0.0692
$\ln C_t$	1.0000			
$\ln E_t$	0.4486	1.0000		
$\ln Y_t$	0.5060	–0.2639	1.0000	
$\ln F_t$	0.1068	–0.0346	0.1820	1.0000

We apply the ARDL bound testing approach to examine the long run relationship between economic growth, energy intensity, financial development and CO_2 emissions in case of Portugal. The advantage of bounds testing is that it is flexible regarding the order of integration of the series. This requires the variables to be integrated at I(0) or I(1) or I(0)/I(1). The computation of the ARDL F-statistic becomes useless if none of the variables is stationary at I(2) or beyond that order of integration. In doing so, we have applied Zivot, Andrews structural break trended unit root test to ensure that all the variables are integrated at I(0) or I(1) or I(0)/I(1)[5]. This test accommodates the information about single unknown structural break stemming in the series. The results of Zivot and Andrews (1992) structural break trended unit root test are reported in Table 2. Our empirical evidence discloses that all the series show unit root problem at their level but found to be integrated at I(1). This entails that the

[5] Various unit root tests are available in economics literature to examine the stationarity properties of the series. These unit root tests are ADF (Dickey, Fuller 1979); DF-GLS (Elliot *et al.* 1996); Ng-Perron (Ng, Perron 2001) etc. These tests may provide biased and inconsistent empirical evidence regarding stationarity properties of the variables. The main reason is that ADF, DF-GLS and Ng-Perron do not seem to have information about structural breaks occurring in the time series data (Baum 2004).

series are stationary at their first differenced form. So, unique level of the variables leads us to examine the existence of long run relationship between economic growth, energy intensity, financial development and CO_2 emissions by applying the ARDL bounds testing approach to cointegration over the period of 1971–2011.

Table 2. Zivot-Andrews structural break trended unit root test

Variable	At Level		At 1st Difference	
	T-statistic	Time Break	T-statistic	Time Break
$\ln C_t$	−3.522 (2)	2001	−8.107 (0)*	1991
$\ln E_t$	−3.462 (2)	2002	−8.824 (1)*	1996
$\ln Y_t$	−3.551 (3)	1990	−3.871(1)***	2000
$\ln F_t$	−3.729 (3)	2002	−6.817 (1)*	1990

Note: * and *** represent significant at 1%, and 10% level of significance. Lag order is shown in parenthesis.

Before applying the ARDL bounds testing, there is a pre-requisite to choose appropriate lag order of the variables to compute suitable the ARDL F-statistic and to test whether cointegration exists between the variables or not. The computation of F-test is very much sensitive with the selection of lag length (Ouattara 2004). We chose lag length 2 following minimum value of akaike information criterion (AIC) as shown in Table 3. The AIC criterion has superior power properties as compared to SBC and provides effective and reliable results which help in capturing the dynamic relationship between the series (Lütkepohl 2006)[6].

Table 3. The results of ARDL cointegration test

Bounds testing to cointegration			Diagnostic tests			
Estimated models	Optimal lag length	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$F_C(C/E,F,Y)$	2, 2, 2, 2	10.667*	0.3285	[1]: 0.7889	[1]: 0.9365	[1]: 0.2083; [2]: 0.7884
$F_E(E/C,F,Y)$	2, 2, 2, 1	14.158*	0.6448	[1]: 3.9821	[1]: 0.3746	[1]: 1.7145; [2]: 1.3143
$F_F(F/C,E,Y)$	2, 2, 2, 1	0.217	0.4757	[1]: 0.1547	[1]: 1.5110	[1]: 4.5934; [2]: 4.1174
$F_Y(Y/C,E,Y)$	2, 2, 2, 2	2.705	0.2622	[1]: 0.9978	[1]: 2.9656	[1]: 0.0173; [2]: 0.0086
Significant level	Critical values (T = 40)					
	Lower bounds $I(0)$	Upper bounds $I(1)$				
1 per cent level	7.527	8.803				
5 per cent level	5.387	6.437				
10 per cent level	4.447	5.420				

Note: *represents significant at 1 per cent at level.

6 The results of lag order of the variables are available from authors upon request.

The next step is to apply F-test investigating cointegration for long run between the variables. Table 3 reports the results of the ARDL bounds testing approach to cointegration. The results showed that our calculated F-statistics are greater than upper critical bound at 1 per cent level, once we used CO_2 emissions and energy intensity are treated as predicted variables. It leads us to reject the null hypothesis of no cointegration. This indicates that there are two cointegrating vectors. This confirms that the variables are cointegrated for long run relationship between economic growth, energy intensity, financial development and CO_2 emissions in case of Portugal.

After investigating long run relationship between the variables, next step is to examine marginal impacts of economic growth, energy intensity and financial development on CO_2 emissions. The results are reported in Table 4 indicate that energy intensity has positive and statistically significant impact on CO_2 emissions. This shows that an increase in energy intensity contributes to energy pollutants significantly. The results inferred that a 1 per cent rise in energy intensity is linked with a 0.9559 per cent increase in CO_2 emissions, all else same. The impact of financial development is negative and it is statistically significant at 1 per cent level of significance. It implies that a 0.0784 per cent decline in CO_2 emissions is linked with a 1 per cent increase in financial development. This exposes that financial sector development contributes in condensing CO_2 emissions by directing banks to provide loans to firms for those investment projects which are environment friendly. The relationship between economic growth and CO_2 emissions is positive and it is significant at 1 per cent level. Keeping other things same, a 1 per cent increase in economic growth raises CO_2 emissions by 1.007 per cent. Our empirical exercise indicates that economic growth is a major contributor to CO_2 emissions after energy intensity in case of Portugal. Furthermore, our results confirmed the presence of inverted U-shaped relationship between financial development and CO_2 emissions. The impact of linear and nonlinear terms of financial development is positive and negative on CO_2 emissions and it is statistically significant at 5 per cent and 1 per cent levels respectively. This entails that initially CO_2 emissions are positively linked with financial development and financial development starts to decline it once financial sector matures. It is suggested that financial sector should provide loans (subsidies) for energy efficient technologies and allocate funds to energy system for exploring new sources of energy such as renewables.

The short run results illustrated that energy intensity and economic growth have positive impact on carbon emissions and it is statistically significant at 1 per cent level of significance. It is found that energy intensity is major contributor to carbon emissions in short run. Financial sector development is negatively related with CO_2 emissions but insignificant. Surprisingly, financial sector development with lagged period also increases carbon emissions. The statistically significant estimate of lagged error term i.e. ECM_{t-1} with negative sign corroborates our established long run relationship between economic growth, energy intensity, financial development and carbon emissions. The empirical evidence reported in Table 4 pointed out that coefficient of ECM_{t-1} is –0.9916 which is statistically significant at 1 per cent level of significance. This concludes that changes in CO_2 emissions are corrected by 99.16 per cent every year in long run[7]. It suggests that full convergence process will take more than a year to reach the stable path of equilibrium. This implies that adjustment process is very fast and significant for Portuguese economy in any shock to CO_2 emissions equation in the case of Portugal.

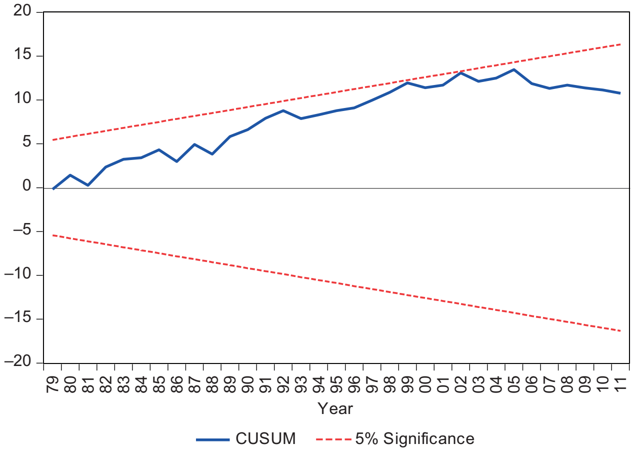
[7] The statistically significance of lagged error term i.e. ECM_{t-1} is a further proof of the existence of stable long run relationship between the series (Banerjee *et al.* 1998).

Table 4. Long-and-short runs analysis

Dependent variable = $\ln C_t$				
Long run analysis				
Variables	Coefficient	T-Statistic	Coefficient	T-Statistic
Constant	–5.3958*	–5.0277	–13.8480*	–4.4327
$\ln E_t$	0.9559*	6.1073	0.7555*	6.1057
$\ln F_t$	–0.0784*	–2.7983	1.6100**	2.6310
$\ln F_t^2$	…	…	–0.0917*	–2.7576
$\ln Y_t$	1.0078*	9.4075	1.0483*	13.2041
Short run analysis				
Variables	Coefficient	Std. Error	T-Statistic	Prob. values
Constant	–0.0023	0.0090	–0.2601	0.7966
$\ln E_t$	0.8823*	0.1391	6.3404	0.0000
$\ln F_t$	–0.0399	0.0621	–0.6423	0.5257
$\ln F_{t-1}$	0.1389***	0.0783	1.7735	0.0866
$\ln Y_t$	0.8774*	0.2034	4.3138	0.0002
$\ln ECM_{t-1}$	–0.9916*	0.2183	–4.5412	0.0001
R^2	0.7890			
F-statistic	21.6962*			
D. Watson	1.8870			
Short Run Diagnostic Tests				
Test	F-statistic	Prob. value		
$\chi^2 NORMAL$	0.3332	0.8464		
$\chi^2 SERIAL$	0.1976	0.8218		
$\chi^2 ARCH$	2.3768	0.1101		
$\chi^2 WHITE$	0.5167	0.8614		
$\chi^2 REMSAY$	0.8386	0.3676		

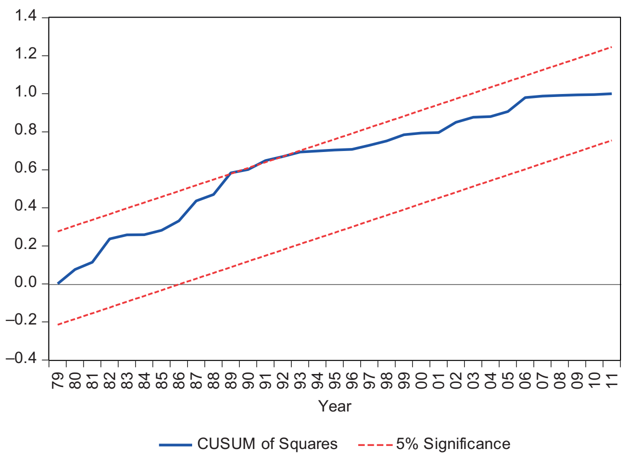
Note: *, ** and *** show significant at 1, 5 and 10 per cent levels of significance respectively.

The plots of both CUSUM and CUSUMsq are shown by Figures 1 and 2 at 5 per cent level of significance. Results indicated that plots of both tests are within critical bounds at 5 per cent level of significance. The empirical evidence for diagnostic tests is detailed in Table 4. The results suggest that short run model seems to pass all tests successfully such as test of normality, serial correlation, autoregressive conditional heteroskedasticity, white heteroskedasticity and specification of short run model. This indicated that there is no problem of non-normality of error term, no serial correlation between the variables as well as no evidence is found for autoregressive conditional heteroskedasticity. The variables are homoscedastic and functional form of short run model is well organized. The stability and sensitivity analysis favors that the parameters of long run and short run empirical evidence is consistent and stable for policy purpose regarding carbon emissions in case of Portugal.



Note: The straight lines represent critical bounds at 5% significance level

Fig. 1. Plot of cumulative sum of recursive residuals



Note: The straight lines represent critical bounds at 5% significance level

Fig. 2. Plot of cumulative sum of squares of recursive residuals

The presence of cointegration for long run economic growth, energy intensity, financial development, and carbon emissions leads us to implement the VECM Granger causality approach to analyze the direction of causal relationship between the series. The appropriate knowledge about the direction of causality between the variables helps policy making authorities in articulating inclusive energy, economic, financial and environmental policy to sustain economic growth and improve the environmental quality in long run. Granger (1969) suggested that in the presence of cointegration, once variables are found to be stationary at unique order then the VECM Granger causality framework is an appropriate approach to detect the long-and-short runs causal relationship between economic growth, energy intensity, financial development and carbon emissions. Table 5 reports the results of Granger causality test.

Table 5. The VECM Granger Causality Analysis

Dependent variable	Direction of Causality								
	Short Run				Long Run	Joint Long-and-Short Run Causality			
	$\Delta\ln C_{t-1}$	$\Delta\ln E_{t-1}$	$\Delta\ln F_{t-1}$	$\Delta\ln Y_{t-1}$	ECT_{t-1}	$\Delta\ln C_{t-1}$, ECT_{t-1}	$\Delta\ln E_{t-1}$, ECT_{t-1}	$\Delta\ln F_{t-1}$, ECT_{t-1}	$\Delta\ln Y_{t-1}$, ECT_{t-1}
$\Delta\ln C_t$	…	24.5188* [0.0000]	0.6861 [0.5811]	27.8183* [0.0000]	−0.5729** [−2.4283]	…	20.2686* [0.0000]	2.8869*** [0.0532]	46.8625* [0.0000]
$\Delta\ln E_t$	28.6458* [0.0000]	…	0.9136 [0.4123]	4.7349** [0.0166]	−0.7317* [−2.8783]	20.6499* [0.0000]	…	2.9131*** [0.0512]	14.6628* [0.0000]
$\Delta\ln F_t$	0.0467 [0.9544]	0.0175 [0.9825]	…	0.5131 [0.6038]	…	…	…	…	…
$\Delta\ln Y_t$	15.4471* [0.0000]	12.4398* [0.0001]	0.3213 [0.7277]	…	…	…	…	…	…

Note: *, ** and *** show significance at 1, 5 and 10 per cent levels respectively.

In long span of time, empirical evidence indicated that the bidirectional causal relationship is found between energy intensity and CO_2 emissions. This implies that efficient use of modern technology declines energy intensity that results in lowering CO_2 emissions during production process and vise versa. This finding is with the line of existing energy literature such as Papadopoulos and Haralambopoulos (2006) and later on with Hatzigeorgiou *et al.* (2011) in case of Greece. This empirical evidence implies that in current setup it is difficult for Portuguese economy to find decoupling carbon emissions. There is a need of overhauling energy structure to encourage energy efficient technologies by considering a number of policy reforms. The unidirectional causality is found running from economic growth to energy intensity also suggests adopting energy efficient technology which helps in enhancing domestic production but with less CO_2 emissions. Economic growth Granger causes CO_2 emissions. This shows that Portugal is growing at cost of environment. This implies the exploration of environment friendly sources of energy for example wind, solar and other renewable energy sources as well as implementation of energy efficient technology to boost domestic production and hence economic growth.

This exposes that a rise in economic activity raises more demand for energy and in result increases CO_2 emissions. Our empirical evidence is contradictory with findings of Hatzigeorgiou *et al.* (2011) who reported bidirectional causal relationship between economic growth and energy intensity. Finally, unidirectional causality is also found from financial development to energy intensity. This supports the view argued by Shahbaz and Lean (2012) that sound financial sector enables the firms to adopt advance and energy efficient technology during production process. Although, they reported that bidirectional causality exists between financial development and energy consumption in case of Tunisia. Finally, the unidirectional causality is found running from financial development to carbon emissions. This supports the argument that financial sector development lowers CO_2 emissions by encouraging the firms to adopt advanced technology which emits less carbon emissions during production. These results are consistent with energy literature such as Talukdar and Meisner (2001).

In short span of time, causality analysis exposed that economic growth and energy intensity are interdependent. The bidirectional causality is found between energy intensity and CO_2 emissions. The feedback hypothesis also exists between economic growth and CO_2 emissions. The joint long-and-short runs causality analysis also supports the empirical findings for long run as well as short run. The neutral effect exists between financial development and energy intensity and same is true for financial development and carbon emissions. Economic growth and financial development are independent.

It is argued in economic literature that the Granger causality approaches such as the VECM Granger causality test has some limitations. The causality test cannot capture the relative strength of causal relation between the variables beyond the selected time period. This weakens the reliability of causality results by the VECM Granger causality approach. To solve this issue, we applied innovative accounting approach (IAA) i.e. variance decomposition method and impulse response function. We have implemented the generalized forecast error variance decomposition method using vector autoregressive (VAR) system to test the strength of causal relationship between economic growth, energy intensity, financial development and CO_2 emissions in case of Portugal. The variance decomposition approach indicates the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variable over different time-horizons beyond the selected time period. It is pointed by Pesaran and Shin (1999) that the generalized forecast error variance decomposition method shows proportional contribution in one variable due to innovative shocks stemming in other variables. The main advantage of this approach is that like orthogonalized forecast error variance decomposition approach; it is insensitive with ordering of the variables because ordering of the variables is uniquely determined by VAR system. Further, the generalized forecast error variance decomposition approach estimates the simultaneous shock affects. Engle and Granger (1987) and Ibrahim (2005) argued that with VAR framework, variance decomposition approach produces better results as compared to other traditional approaches.

The results of variance decomposition approach are described in Table 6. The empirical evidence indicates that a 10.65 per cent portion of CO_2 emissions is contributed by its own innovative shocks and one standard deviation shock in financial development explains energy pollutants by 59.96 per cent. This implies that financial development plays vital role to improve the environmental quality by directing financial resources to projects where firms utilize advanced technology to enhance domestic production with less CO_2 emissions.

The contribution of economic growth to CO_2 emissions is 23.09 per cent. This contribution in CO_2 emissions due to economic growth first rises, goes to peak point, and then starts to fall. This confirms the existence of inverted-U relationship between economic growth and CO_2 emissions in case of Portugal. A very little portion of CO_2 emissions is explained by innovative shocks stemming in energy intensity i.e. 6.28 per cent. A 12.91 per cent portion of energy intensity is explained by one standard deviation shock in CO_2 emissions and 16.62 per cent portion is contributed to energy intensity by its own innovative shocks. A standard deviation shock stemming in financial development and economic growth attribute to energy intensity by 58.27 per cent and 12.18 per cent respectively. A 37.50 per cent contribution exists in financial development by shocks stemming in economic growth. CO_2 emissions and energy

Table 6. Variance decomposition approach

Variance decomposition of $\ln C_t$					
Period	S.E.	$\ln C_t$	$\ln E_t$	$\ln F_t$	$\ln Y_t$
1	0.0522	100.0000	0.0000	0.0000	0.0000
2	0.0638	76.6092	2.1222	0.6995	20.5690
3	0.0748	63.4918	2.8381	2.5768	31.0931
4	0.0886	47.0122	6.6878	7.13683	39.1630
5	0.1021	36.3854	8.7809	15.3446	39.4889
6	0.1152	28.9803	9.6342	23.5514	37.8339
7	0.1274	24.0528	9.4032	30.9497	35.5941
8	0.1386	20.5698	8.9114	36.8973	33.6213
9	0.1490	18.0081	8.4077	41.7433	31.8407
10	0.1587	16.0382	7.9792	45.7951	30.1874
11	0.1678	14.4817	7.6004	49.3234	28.5943
12	0.1763	13.2282	7.2468	52.4534	27.0715
13	0.1842	12.2058	6.9068	55.2478	25.6393
14	0.1916	11.3622	6.5834	57.7409	24.3133
15	0.1984	10.6582	6.2809	59.9652	23.0955
Variance decomposition of $\ln E_t$					
Period	S.E.	$\ln C_t$	$\ln E_t$	$\ln F_t$	$\ln Y_t$
1	0.0397	41.3522	58.6477	0.0000	0.0000
2	0.0427	40.9854	57.2635	1.6685	0.0825
3	0.0453	42.2503	51.0118	5.9790	0.7586
4	0.0483	39.5151	45.0318	9.1273	6.3256
5	0.0521	35.1489	39.2479	13.3500	12.2530
6	0.0567	30.1423	35.0699	19.1538	15.6338
7	0.0614	25.8761	31.5370	26.2586	16.3281
8	0.0660	22.5906	28.2826	33.1124	16.0142
9	0.0702	20.1345	25.4707	38.9132	15.4814
10	0.0739	18.2557	23.1955	43.5723	14.9764
11	0.0774	16.7622	21.3710	47.3929	14.4737
12	0.0806	15.5348	19.8806	50.6536	13.9309
13	0.0836	14.5082	18.6277	53.5168	13.3471
14	0.0864	13.6447	17.5533	56.0483	12.7535
15	0.0889	12.9165	16.6260	58.2762	12.1811
Variance decomposition of $\ln F_t$					
Period	S.E.	$\ln C_t$	$\ln E_t$	$\ln F_t$	$\ln Y_t$
1	0.0770	0.0408	0.0000	99.9591	0.0000
2	0.1255	0.6199	0.3527	97.2746	1.7527
3	0.1649	0.5499	0.2049	93.6071	5.6380
4	0.1946	0.4757	0.5709	89.5279	9.4252
5	0.2166	0.4086	1.5751	85.3679	12.6483
6	0.2327	0.3697	2.6028	81.6620	15.3653
7	0.2450	0.3514	3.3926	78.3072	17.9486
8	0.2553	0.3510	3.9892	75.0770	20.5826
9	0.2645	0.3642	4.5265	71.8050	23.3040
10	0.2729	0.3876	5.0845	68.4894	26.0383
11	0.2808	0.4184	5.6766	65.2112	28.6936

Continued Table 6

Variance decomposition of $\ln C_t$					
Variance decomposition of $\ln F_t$					
Period	S.E.	$\ln C_t$	$\ln E_t$	$\ln F_t$	$\ln Y_t$
12	0.2882	0.4553	6.2742	62.0685	31.2018
13	0.2953	0.4978	6.8441	59.1347	33.5232
14	0.3023	0.5449	7.3671	56.4568	35.6310
15	0.3092	0.5954	7.8368	54.0673	37.5004
Variance decomposition of $\ln Y_t$					
Period	S.E.	$\ln C_t$	$\ln E_t$	$\ln F_t$	$\ln Y_t$
1	0.0244	8.7243	18.4880	0.2776	72.5100
2	0.0394	5.0323	7.1570	1.3121	86.4983
3	0.0521	3.5118	10.4445	0.7509	85.2926
4	0.0620	2.7139	16.0544	1.9805	79.2510
5	0.0694	2.3590	18.1751	5.2498	74.2160
6	0.0755	2.2222	17.9333	9.0049	70.8394
7	0.0811	2.1861	17.0002	12.3479	68.4656
8	0.0866	2.1698	16.1278	15.2859	66.4163
9	0.0921	2.1412	15.4834	18.1446	64.2307
10	0.0974	2.0993	14.9746	21.1300	61.7959
11	0.1027	2.0539	14.4755	24.2461	59.2243
12	0.1078	2.0108	13.9415	27.3862	56.6613
13	0.1127	1.9712	13.3897	30.4480	54.1909
14	0.1174	1.9336	12.8481	33.3804	51.8377
15	0.1219	1.8966	12.3319	36.1716	49.5997

intensity explain financial development minimally and one standard innovative shock stems in financial development explains itself by 54.06 per cent. The contribution of CO_2 emissions, energy intensity and financial development to economic growth 1.89 per cent, 12.33 per cent and 36.17 per cent respectively and rest is explained by its own standard innovative shocks. The existing empirical evidence confirms the feedback hypothesis between financial development and economic growth.

The impulse response function is alternate of variance decomposition approach and shows the reaction in one variable due to shocks stemming in other variables. The Figure 3 indicated the positive response in carbon emissions due to standard shocks stemming in economic growth and energy intensity while CO_2 emissions is negatively responded by financial development. This means that financial sector development contributes in condensing carbon emissions. The contribution of carbon emissions and economic growth is positive to energy intensity while financial development declines energy intensity due to adoption of energy-efficient technologies. The response of financial development is positive due to innovative shocks stemming in energy intensity and economic growth. A standard shock occurs in energy intensity stimulates economic growth while financial sector development declines it. This shows that financial development does not contribute to economic growth. This confirms that current financial crisis in the Europe has decayed economic activity in case of Portugal.

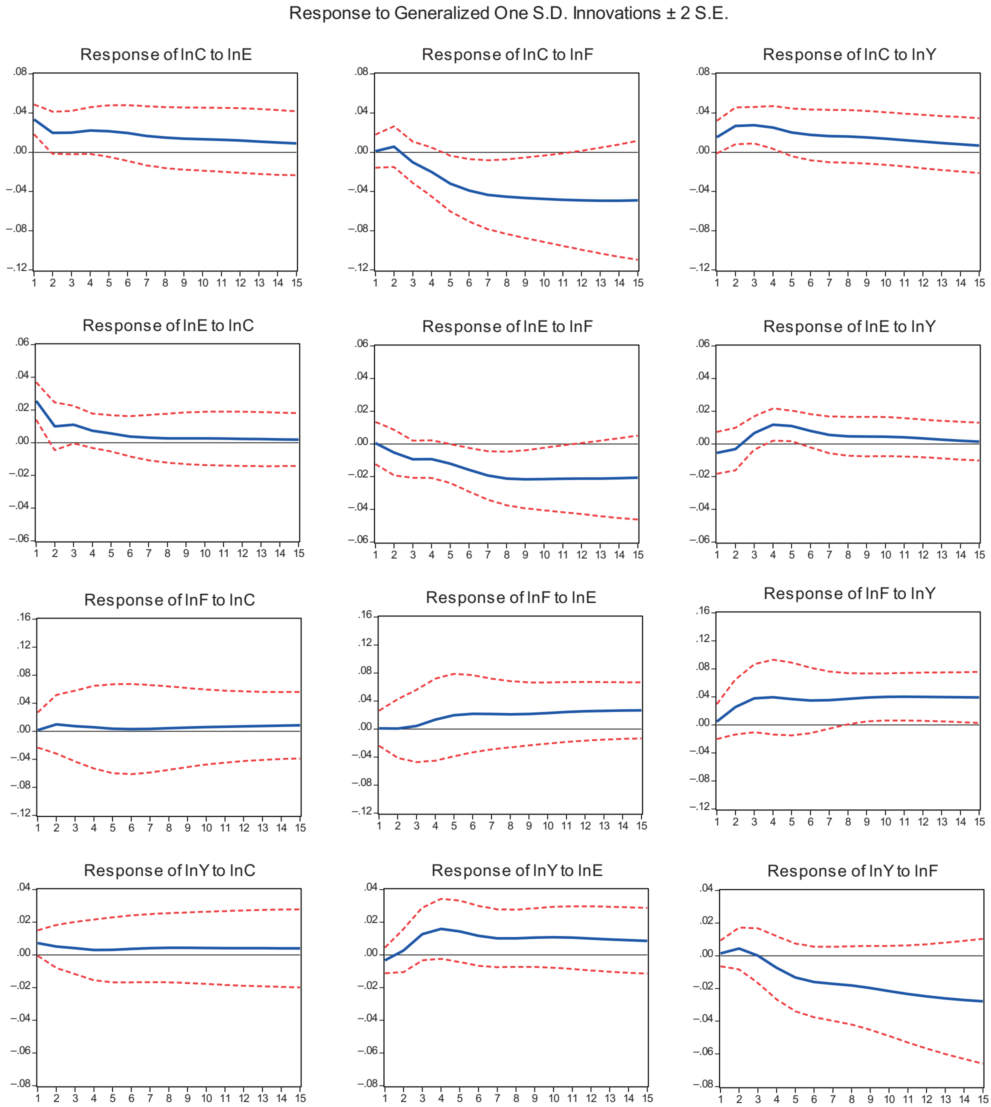


Fig. 3. Impulse response function

Conclusions and future directions

This study investigated the dynamic relationship between economic growth, energy intensity, financial development, and CO_2 emissions in case of Portuguese economy over the period of 1971–2011. For this purpose, we applied the ARDL bounds testing approach to cointegration to examine the cointegration among the variables for long run, the VECM Granger causality to test the direction of causal relationship between the variables and robustness of causality analysis was tested by applying innovative accounting approach (IAA).

Our results indicated that the variables are cointegrated for long run relationship. The empirical evidence showed that energy intensity increases carbon emissions and economic growth is a major contributor to CO_2 emissions. Financial sector development condenses carbon emissions and inverted-U shape relationship is confirmed between financial sector development and carbon emissions. This validates the contribution of financial sector to improve the quality of environment. The causality analysis exposed the bidirectional causality between energy intensity and carbon emissions. The unidirectional causal relation is found running from economic growth and financial development to CO_2 emissions. This suggests that carbon emissions can be reduced at the cost of economic growth or energy efficient technologies should be encouraged to enhance domestic production with the help of financial sector. Economic growth and financial development Granger causes energy intensity which suggests that adoption of energy conservation would not adversely affect economic growth. Again, financial sector must fix its focus on the allocation of funds to those firms which adopt environment friendly technologies and encourage the firms to use more energy efficient technology for production purpose and hence to save environment from degradation.

The rising trend of carbon emissions in current momentum is a debatable issue in case of Portugal. To overcome this controversial issue, there is a need of comprehensive economic, financial and energy policy reforms to sustain economic growth by developing domestic financial sector. This present study has some limitations about other potential determinants of CO_2 emissions. Future research may be conducted by investigating the relationship between renewable energy consumption, nonrenewable energy consumption, economic growth and carbon emissions following (Tiwari 2011a, b). Other variables may also be included in model as potential determinants of carbon emissions such as urbanisation (Hossain 2011); trade openness (Hossain 2011); intra-industry trade (Leitão 2011); foreign direct investment (Pao, Tsai 2011a); exchange rate / terms of trade (Jalil, Feridun 2010); interest rate (Karanfil 2009); population or population density (Himayatullah *et al.* 2009) and industrialization (Zhang 2011) to examine relationship between economic growth, energy intensity and CO_2 emissions in case of Portugal.

Acknowledgements

The authors would like to thank the two anonymous referees for their constructive comments and suggestions. In addition, the author would also like to acknowledge Prof. Edmundas K. Zavadskas (Editor) of the Technological and Economic Development of Economy for their contribution to this research. All remaining flaws are the responsibility of the author and the usual disclaimer applies.

Reference

Acaravci, A.; Ozturk, I. 2010. On the relationship between energy consumption, CO2 emissions and economic growth in Europe, *Energy* 35(12): 5412–5420. http://dx.doi.org/10.1016/j.energy.2010.07.009

Akbostanci, E.; Türüt-AsIk, S.; Ipek, T. G. 2009. The relationship between income and environment in Turkey: is there an environmental Kuznets curve?, *Energy Policy* 37(3): 861–867. http://dx.doi.org/10.1016/j.enpol.2008.09.088

Alam, M. J.; Begum, I. A.; Buysse, J.; Huylenbroeck, G. V. 2012. Energy consumption, carbon emissions and economic growth nexus in Bangladesh: cointegration and dynamic causality analysis, *Energy Policy* 45(6): 217–225. http://dx.doi.org/10.1016/j.enpol.2012.02.022

Alam, M. J.; Begum, I. A.; Buysse, J.; Rahman, S.; Huylenbroeck, G. V. 2011. Dynamic modeling of causal relationship between energy consumption, CO2 emissions and economic growth in India, *Renewable and Sustainable Energy Reviews* 15(6): 3243–3251. http://dx.doi.org/10.1016/j.rser.2011.04.029

Al-mulali, U.; Sab, C. N. B. C. 2012. The impact of energy consumption and CO2 emission on the economic growth and financial development in the Sub Saharan African countries, *Energy* 39(1): 180–186. http://dx.doi.org/10.1016/j.energy.2012.01.032

Ang, J. B. 2007. CO2 emissions, energy consumption, and output in France, *Energy Policy* 35(10): 4772–4778. http://dx.doi.org/10.1016/j.enpol.2007.03.032

Ang, J. B. 2008. Economic development, pollutant emissions and energy consumption in Malaysia, *Journal of Policy Modeling* 30(2): 271–278. http://dx.doi.org/10.1016/j.jpolmod.2007.04.010

Apergis, N.; Payne, J. E. 2009. CO2 emissions, energy usage, and output in Central America, *Energy Policy* 37(8): 3282–3286. http://dx.doi.org/10.1016/j.enpol.2009.03.048

Apergis, N.; Payne, J. E. 2010.The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states, *Energy Policy* 38(1): 650–655. http://dx.doi.org/10.1016/j.enpol.2009.08.029

Baloch, H.; Rafiq, S.; Salim, R. 2012. Coal consumption, CO2 emission and economic growth in China: empirical evidence and policy responses, *Energy Economics* 43(2): 518–528. http://dx.doi.org/10.1016/j.eneco.2011.07.014

Banerjee, A.; Dolado, J. J.; Mestre, R. 1998. Error-correction mechanism tests for cointegration in a single-equation framework, *Journal of Time Series Analysis* 19(3): 267–283. http://dx.doi.org/10.1111/1467-9892.00091

Baum, C. F. 2004. A review of Stata 8.1 and its time series capabilities, *International Journal of Forecasting* 20(1): 151–161. http://dx.doi.org/10.1016/j.ijforecast.2003.11.007

Behemiria, N. B.; Mansob, J. R. P. 2012. *Does Portuguese economy support crude oil conservation hypothesis*? University of Beira Interior, Covilha, Portugal.

Chang, C.-C. 2010. A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China, *Applied Energy* 87(11): 3533–3537. http://dx.doi.org/10.1016/j.apenergy.2010.05.004

Chebbi, H. E. 2010. Long and short–run linkages between economic growth, energy consumption and CO_2 emissions in Tunisia, *Middle East Development Journal* 2(1): 139–158. http://dx.doi.org/10.1142/S1793812010000186

Chontanawat, J.; Hunt, L. C.; Pierse, R. 2008. Does energy consumption cause economic growth? Evidence from a systematic study of over 100 countries, *Journal of Policy Modeling* 30(2): 209–220. http://dx.doi.org/10.1016/j.jpolmod.2006.10.003

Claessens, S.; Feijen, E. 2007. *Financial sector development and the millennium development goals*, World Bank Working Paper 89, The World Bank.

Cropper, M.; Griffiths, C. 1994. The interaction of population growth and environmental quality, *American Economic Review* 84(2): 250–254.

Dhakal, S. 2009. Urban energy use and carbon emissions from cities in China and policy implications, *Energy Policy* 37(11): 4208–4219. http://dx.doi.org/10.1016/j.enpol.2009.05.020

Dickey, D.; Fuller, W. A. 1979. Distribution of the estimates for autoregressive time series with unit root, *Journal of the American Statistical Association* 74(4): 427–431.

Dinda, S.; Coondoo, D. 2006. Income and emission: a panel data-based cointegration analysis, *Ecological Economics* 57(2): 167–181. http://dx.doi.org/10.1016/j.ecolecon.2005.03.028

Elliott, G.; Rothenberg, T. J.; Stock, J. H. 1996. Efficient tests for an autoregressive unit root, *Econometrica* 64(4): 813–836. http://dx.doi.org/10.2307/2171846

Engle, R. F.; Granger, C. W. J. 1987. Cointegration and error correction representation: estimation and testing, *Econometrica* 55(2): 251–276. http://dx.doi.org/10.2307/1913236

Fodha, M.; Zaghdoud, O. 2010. Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve, *Energy Policy* 38(2): 1150–1156. http://dx.doi.org/10.1016/j.enpol.2009.11.002

Frankel, J.; Romer, D. 1999. Does trade cause growth?, *American Economic Review* 89(3): 379–399. http://dx.doi.org/10.1257/aer.89.3.379

Frankel, J.; Rose, A. 2002. An estimate of the effect of common currencies on trade and income, *Quarterly Journal of Economics* 117(2): 437–466. http://dx.doi.org/10.1162/003355302753650292

Fuinhas, J. A.; Marques, A. C. 2012. Energy consumption and economic growth nexus in Portugal, Italy, Greece, Spain and Turkey: an ARDL bounds test approach (1965–2009), *Energy Economics* 43(2): 511–517. http://dx.doi.org/10.1016/j.eneco.2011.10.003

Ghali, K. H.; El-Sakka, M. I. T. 2004. Energy use and output growth in Canada: a multivariate cointegration analysis, *Energy Economics* 26(2): 225–238. http://dx.doi.org/10.1016/S0140-9883(03)00056-2

Gosh, S. 2009. Import demand of crude oil and economic growth: evidence form India, *Energy Policy* 37(2): 699–702. http://dx.doi.org/10.1016/j.enpol.2008.10.021

Granger, C. W. J. 1969. Investigating causal relations by econometric models and cross-spectral methods, *Econometrica* 37(3): 424–438. http://dx.doi.org/10.2307/1912791

Grossman, G.; Krueger, A. 1995. Economic environment and the economic growth, *Quarterly Journal of Economics* 110(2): 353–377. http://dx.doi.org/10.2307/2118443

Halicioglu, F. 2009. An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey, *Energy Policy* 37(3): 1156–1164. http://dx.doi.org/10.1016/j.enpol.2008.11.012

Hatzigeorgiou, E.; Polatidis, H.; Haralambopoulos, D. 2011. CO2 emissions, GDP and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977–2007, *Applied Energy* 88(4): 1377–1385. http://dx.doi.org/10.1016/j.apenergy.2010.10.008

Hettige, H.; Lucas, R. E. B.; Wheeler, D. 1992. The toxic intensity of industrial production: global patterns, trends, and trade policy, *American Economic Review* 82(2): 478–481.

Himayatullah, K.; Inamullah, E.; Shams, K. 2009. Population, environment and poverty in Pakistan: linkages and empirical evidence, *Environmental and Development Sustainability* 11(2): 375–392. http://dx.doi.org/10.1007/s10668-007-9119-y

Hossain, S. M. 2011. Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanisation of newly industrialized countries, *Energy Policy* 39(11): 6991–6999. http://dx.doi.org/10.1016/j.enpol.2011.07.042

Ibrahim, M. H. 2005. Sectoral effects of monetary policy: evidence from Malaysia, *Asian Economic Journal* 19(1): 83–102. http://dx.doi.org/10.1111/j.1467-8381.2005.00205.x

Islam, F.; Shahbaz, M.; Ahmed, A. U.; Alam, M. M. 2013. Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis, *Economic Modelling* 30: 435–441. http://dx.doi.org/10.1016/j.econmod.2012.09.033

Iwata, H.; Okada, K.; Samreth, S. 2011. A note on the environmental Kuznets curve for CO2: a pooled mean group approach, *Applied Energy* 88(5): 1986–1996. http://dx.doi.org/10.1016/j.apenergy.2010.11.005

Jalil, A.; Feridun, M. 2010. The impact of growth, energy and financial development on the environment in China: a cointegration analysis, *Energy Economics* 33(2): 284–291. http://dx.doi.org/10.1016/j.eneco.2010.10.003

Jalil, A.; Mahmud, S. 2009. Environment Kuznets curve for CO2 emissions: a cointegration analysis for China, *Energy Policy* 37(12): 5167–5172. http://dx.doi.org/10.1016/j.enpol.2009.07.044

Johansen, S.; Juselius, K. 1990. Maximum likelihood estimation and inference on cointegration with applications to the demand for money, *Oxford Bulletin of Economics and Statistics* 52(2): 169–210. http://dx.doi.org/10.1111/j.1468-0084.1990.mp52002003.x

Karanfil, F. 2009. How many times again will we examine the energy–income nexus using a limited range of traditional econometric tools?, *Energy Policy* 36(4): 3019-3025. http://dx.doi.org/10.1016/j.enpol.2008.11.029

Kraft, J.; Kraft, A. 1978. On the relationship between energy and GNP, *Journal of Energy and Development* 3(2): 401–403.

Kwiatkowski, D.; Phillips, P.; Schmidt, P.; Shin, Y. 1992. Testing the null hypothesis of stationary against the alternative of a unit root: how sure are we that economic time series have a unit root?, *Journal of Econometrics* 54(1–3): 159–178. http://dx.doi.org/10.1016/0304-4076(92)90104-Y

Lean, H. H.; Smyth, R. 2010. CO2 emissions, electricity consumption and output in ASEAN, *Applied Energy* 87(6): 1858–1864. http://dx.doi.org/10.1016/j.apenergy.2010.02.003

Leitão, N. C. 2011. Environmental change and agriculture: the role of international trade, *African Journal of Agricultural Research* 6(17): 4065–406.

Leitão, N. C. 2013. The environmental Kuznets curve and globalization: the empirical evidence for Portugal, Spain, Greece and Ireland, *Energy Economics Letters* 1(1): 15–23.

Lotfalipour, M. R.; Falahi, M. A.; Ashena, M. 2010. Economic growth, CO2 emissions, and fossil fuels consumption in Iran, *Energy* 35(10): 5115–5120. http://dx.doi.org/10.1016/j.energy.2010.08.004

Lütkepohl, H. 2006. Structural vector autoregressive analysis for cointegrated variables, *AStA Advances in Statistical Analysis* 90(1): 75–88. http://dx.doi.org/10.1007/3-540-32693-6_6

Machado, G. V. 2000. Energy use, CO2 emissions and foreign trade: an IO approach applied to the Brazilian case, in *Thirteenth International Conference on Input–Output Techniques*, 21–25 August 2000, Macerata, Italy.

Martinez-Zarzoso, I.; Bengochea-Morancho, A. 2004. Pooled mean group estimation of an environmental Kuznets curve for CO2, *Economics Letters* 82(1): 121–126. http://dx.doi.org/10.1016/j.econlet.2003.07.008

Menyah, K.; Wolde-Rufeal, Y. 2010. Energy consumption, pollutants emissions and economic growth in South Africa, *Energy Consumption* 32(6): 1374–1382. http://dx.doi.org/10.1016/j.eneco.2010.08.002

Mongelli, I.; Tassielli, G.; Notarnicola, B. 2006. Global warming agreements, international trade and energy/carbon embodiments: an input-output approach to the Italian case, *Energy Policy* 34(1): 88–100. http://dx.doi.org/10.1016/j.enpol.2004.06.004

Narayan, P. K. 2005. The saving and investment nexus for China: evidence from co-integration tests, *Applied Economics* 37(17): 1979–1990. http://dx.doi.org/10.1080/00036840500278103

Narayan, P. K.; Prasad, A. 2008. Electricity consumption-real GDP causality nexus: evidence from a bootstrapped causality test for 30 OECD countries, *Energy Policy* 36(2): 910–918. http://dx.doi.org/10.1016/j.enpol.2007.10.017

Narayan, P. K.; Smyth, R. 2005. Electricity consumption, employment and real income in Australia: Evidence from multivariate granger causality Tests, *Energy Policy* 33(9): 1109–1116. http://dx.doi.org/10.1016/j.enpol.2003.11.010

Nasir, M.; Rehman, F.-U. 2011. Environmental Kuznets curve for carbon emissions in Pakistan: An empirical investigation, *Energy Policy* 39(3): 1857–1864. http://dx.doi.org/10.1016/j.enpol.2011.01.025

Ng, S.; Perron, P. 2001. Lag selection and the construction of unit root tests with good size and power, *Econometrica* 69(6): 1519–1554. http://dx.doi.org/10.1111/1468-0262.00256

Odhiambo, M. N. 2011. Economic growth and carbon emissions in South Africa: an empirical investigation, *International Business & Economics Research Journal* 10(7): 75–84.

Ouattara, B. 2004. *Foreign aid and fiscal policy in Senegal*. Unpublished manuscript, University of Manchester, Manchester, UK.

Ozturk, I.; Acaravci, A. 2010. CO2 emissions, energy consumption and economic growth in Turkey, *Renewable and Sustainable Energy Reviews* 14(9): 3220–3225. http://dx.doi.org/10.1016/j.rser.2010.07.005

Ozturk, I. 2010. A literature survey on energy-growth nexus, *Energy Policy* 38(1): 340–349. http://dx.doi.org/10.1016/j.enpol.2009.09.024

Pao, H. T.; Tsai, C. M. 2011a. Modelling and forecasting the CO2 emissions, energy consumption and economic growth in Brazil, *Energy* 36(5): 2450–2458. http://dx.doi.org/10.1016/j.energy.2011.01.032

Pao, H.-T.; Tsai, C.-M. 2011b. Multivariate Granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries, *Energy* 36(1): 685–693. http://dx.doi.org/10.1016/j.energy.2010.09.041

Papadopoulos, E.; Haralambopoulos, D. A. 2006. Carbon emissions: responses to energy intensity, energy conversion and energy prices. Cointegration analysis for Greece, in *19th Int. Conf. on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems,* 12–14 July 2006, Crete, Greece. ECOS, American Society for Mechanical Engineers (ASME).

Payne, J. 2010. A survey of the electricity consumption-growth literature, *Applied Energy* 87(3): 3723–3731. http://dx.doi.org/10.1016/j.apenergy.2009.06.034

Pesaran, M. H.; Shin, Y. 1999. An autoregressive distributed-led modeling approach to cointegration analysis, in S. Strom (Ed.). *Econometrics and economic theory in the 20th century. The Ragnar Frisch Centennial Symposium.* Cambridge: Cambridge University Press. http://dx.doi.org/10.1017/CCOL521633230.011

Pesaran, M. H.; Shin, Y.; Smith, R. J. 2001. Bounds testing approaches to the analysis of level relationships, *Journal of Applied Econometrics* 16(3): 289–326. http://dx.doi.org/10.1002/jae.616

Phillips, P. C. B.; Hansen, B. E. 1990. Statistical inference in instrumental variables regression with I(1) processes, *Review of Economic Studies* 57(1): 99–125. http://dx.doi.org/10.2307/2297545

Phillips, P. C. B.; Perron, P. 1988. Testing for a unit root in time series regression, *Biometrika* 75(2): 335–346. http://dx.doi.org/10.1093/biomet/75.2.335

Roca, J.; AlcaHntara, V. 2001. Energy intensity, CO2 emissions and the environmental Kuznets curve: the Spanish case, *Energy Policy* 29(7): 553–556. http://dx.doi.org/10.1016/S0301-4215(00)00154-3

Sadorsky, P. 2010. The impact of financial development on energy consumption in emerging economies, *Energy Policy* 38(5): 2528–2535. http://dx.doi.org/10.1016/j.enpol.2009.12.048

Sadorsky, P. 2011. Financial development and energy consumption in Central and Eastern European frontier economies, *Energy Policy* 39(2): 999–1006. http://dx.doi.org/10.1016/j.enpol.2010.11.034

Selden, T. M.; Song, D. 1995. Neoclassical growth, the J curve for abatement and the inverted U for pollution, *Journal of Environmental Economics and Management* 29(2): 162–168. http://dx.doi.org/10.1006/jeem.1995.1038

Sen, A. 2003. On unit root tests when the alternative is a trend break stationary process, *Journal of Business and Economic Statistics* 21(1): 174–184. http://dx.doi.org/10.1198/073500102288618874

Shahbaz, M.; Lean, H. H. 2012. Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia, *Energy Policy* 40(7): 473–479. http://dx.doi.org/10.1016/j.enpol.2011.10.050

Shahbaz, M.; Lean, H. H.; Shabbir, M. S. 2012. Environmental Kuznets curve hypothesis in Pakistan: Cointegration and Granger causality, *Renewable and Sustainable Energy Reviews* 16(5): 2947–2953. http://dx.doi.org/10.1016/j.rser.2012.02.015

Shahbaz, M.; Mutascu, M., Azim, P. 2013. Environmental Kuznets curve in Romania and the role of energy consumption, *Renewable and Sustainable Energy Reviews* 18(2): 165–173. http://dx.doi.org/10.1016/j.rser.2012.10.012

Shahbaz, M.; Tang, C. F.; Shabbir, M. S. 2011. Electricity consumption and economic growth nexus in Portugal using cointegration and causality approaches, *Energy Policy* 39(6): 3529–3536. http://dx.doi.org/10.1016/j.enpol.2011.03.052

Shiyi, C. 2009. Energy consumption, CO2 emission and sustainable development in Chinese industry, *Economic Research Journal* 4: 1–5.

Song, T.; Zheng, T.; Tong, L. 2008. An empirical test of the environmental Kuznets curve in China: a panel cointegration approach, *China Economic Review* 19(3): 381–392. http://dx.doi.org/10.1016/j.chieco.2007.10.001

Soytas, U.; Sari, U.; Ewing, B. T. 2007. Energy consumption, income and carbon emissions in the United States, *Ecological Economics* 62(3–4): 482–489. http://dx.doi.org/10.1016/j.ecolecon.2006.07.009

Talukdar, D.; Meisner, C. M. 2001. Does the private sector help or hurt the environment? Evidence from carbon dioxide pollution in developing countries, *World Development* 29(5): 827–840. http://dx.doi.org/10.1016/S0305-750X(01)00008-0

Tamazian, A.; Piñeiro, J.; Vadlamannati, K. C. 2009. Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries?, *Energy Policy* 37(1): 246–253. http://dx.doi.org/10.1016/j.enpol.2008.08.025

Tamazian, A.; Rao, B. B. 2010. Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies, *Energy Economics* 32(1): 137–145. http://dx.doi.org/10.1016/j.eneco.2009.04.004

Tiwari, A. K. 2011a. A structural VAR analysis of renewable energy consumption, real GDP and CO2 emissions: evidence from India, *Economic Bulletin* 31(2): 1793–1806.

Tiwari, A. K. 2011b. Comparative performance of renewable and nonrenewable energy source on economic growth and CO2 emissions of Europe and Eurasian countries: A PVAR approach, *Economic Bulletin* 31(3): 2356–2372.

Tiwari, A. K.; Shahbaz, M.; Hye, M. Q. A. 2013. The environmental Kuznets curve and the role of coal consumption in India: cointegration and causality analysis in an open economy, *Renewable and Sustainable Energy Reviews* 18(3): 519–527. http://dx.doi.org/10.1016/j.rser.2012.10.031

Toda, H. Y.; Yamamoto, T. 1995. Statistical inferences in vector autoregressions with possibly integrated processes, *Journal of Econometrics* 66(1): 225–250. http://dx.doi.org/10.1016/0304-4076(94)01616-8

Turner, P. 2006. Response surfaces for an F-test for cointegration, *Applied Economics Letters* 13(8): 479–482. http://dx.doi.org/10.1080/13504850500401726

Wang, K.-M. 2013. The relationship between carbon dioxide emissions and economic growth: quintile panel-type analysis, *Quality & Quantity* 47(3): 1337–1366. http://dx.doi.org/10.1007/s11135-011-9594-y

Wang, S. S.; Zhou, D. Q.; Zhou, P.; Wang, Q. W. 2011. CO2 emissions, energy consumption and economic growth in China: a panel data analysis, *Energy Policy* 39(9): 4870–4875. http://dx.doi.org/10.1016/j.enpol.2011.06.032

World Development Indicators. 2012. The World Bank 1818 H Street, NW USA, Washington, DC 20433. (CD-ROM).

Xepapadeas, A. 2005. Regulation and evolution of compliance in common pool resources, *Scandinavian Journal of Economics* 107(3): 583–599. http://dx.doi.org/10.1111/j.1467-9442.2005.00424.x

Yuxiang, K.; Chen, Z. 2010. Financial development and environmental performance: evidence from China, *Environment and Development Economics* 16(1): 93–111. http://dx.doi.org/10.1017/S1355770X10000422

Zhang, X. P.; Cheng, X. M. 2009. Energy consumption, carbon emissions, and economic growth in China, *Ecological Economics* 68(10): 2706–2712. http://dx.doi.org/10.1016/j.ecolecon.2009.05.011

Zhang, Y.-J. 2011. The impact of financial development on carbon emissions: an empirical analysis in China, *Energy Policy* 39(4): 2197–2203. http://dx.doi.org/10.1016/j.enpol.2011.02.026

Zivot, E.; Andrews, D. 1992. Further evidence of great crash, the oil price shock and unit root hypothesis, *Journal of Business and Economic Statistics* 10(3): 251–270.

Muhammd SHAHBAZ. Assistant Professor at the Department of Management Sciences, COMSATS Institute of Information Technology, Lahore Campus, Pakistan. Author and co-author of more than 200 scientific articles. Research interests: Development Economics, Energy Economics and Environmental Economics.

Farooq Ahmed JAM. Affiliated with Institute of Graduate Studies, University of Malaya, Kuala Lumpur Malaysia. He has published more 10 journal articles in various journals. Research interests: Development Economics.

Sadia BIBI. Lecturer at the Department of Management Sciences, COMSATS Institute of Information Technology, Vehari Campus, Pakistan. She is author and co-author of 2 journal articles and 2 conference papers. Research Interest: Development Economics, Applied Economics.

Nanthakumar LOGANATHAN. Assistant Professor at the Faculty of Economics and Management Sciences, Universiti Sultan ZainalAbidin, 21300 Kuala Terengganu, Terengganu, Malaysia. He is author and co-author of more than 30 scientific articles. Research interest: Development Economics, Resource Economics, Tourism Economics.