Acheampong, Alex. "Economic growth, CO_2 emissions and energy consumption: what causes what and where?" Published in *Energy Economics*, Vol. 74, p. 677-692, (2018).

Available from: http://dx.doi.org/10.1016/j.eneco.2018.07.022

Economic Growth, CO_2 Emissions and Energy Consumption: What Causes What and Where?

Alex O. Acheampong[1]

Newcastle Business School, University of Newcastle, Australia

ABSTRACT

This paper applies panel vector autoregression (PVAR) along with a system-generalized method of moment (System-GMM) to examine the dynamic causal relationship between economic growth, carbon emissions and energy consumption for 116 countries over the period 1990-2014. Using multivariate model, the empirical results from this study have established key relationships which have important policy implications. First, at the global and regional levels, economic growth does not causal energy consumption. Second, with the exception of the global and Caribbean-Latin America, economic growth has no causal impact on carbon emissions, however, economic growth has a negative impact on carbon emissions at the global level and the Caribbean-Latin America. Third, carbon emissions positively cause economic growth. Fourth, energy consumption positively causes economic growth in sub-Saharan Africa while it negatively causes economic growth at the global, Middle East and North Africa (MENA), Asia-Pacific and Caribbean-Latin America. Fifth, energy consumption positively causes carbon emissions in MENA but causes carbon emissions negatively in sub-Saharan Africa and Caribbean-Latin America. Lastly, with the exception of MENA and the global sample, carbon emissions do not cause energy consumption. The impulse response function shows evidence of Environmental Kuznets curve at the global scale and sub-Saharan Africa. The policy implications of this paper are discussed.

Keywords: CO_2; Economic growth; Energy; Global; Regions; system-GMM PVAR

[1] Corresponding Author: The University of Newcastle, Newcastle Business School, 409 Hunter Street, Newcastle, NSW 2300, Australia or by via email at alexopokuacheampong@gmail.com/alex.acheampong@uon.edu.au

1. Introduction

This paper aims to employ an integrative framework approach to examine the relationship between economic growth, energy consumption and carbon emissions at the global and regional levels. Climate change has been the most challenging environmental issue in our time and has attracted the attention of international organizations, policymakers and researchers. According to the Kaya identity, the total carbon emissions resulting in global warming is influenced by economic growth, the intensity of energy consumption, population growth and intensity of carbon emissions (Kaya & Yokoburi, 1997). On the other hand, researchers and policymakers have attributed the high-intensity of carbon emissions to energy consumption due to rapid economic growth and an increased use of fossil fuel (Ahmad et al., 2017; Andreoni & Galmarini, 2016; Sohag, Begum, Abdullah, & Jaafar, 2015).

It is estimated that the overall cost associated with climate change due to carbon emissions is equivalent to about 5 percent reduction in GDP each year, now and forever and even 20 per cent if immediate action is not taken (Stern, 2007). Therefore, to mitigate carbon emissions, the demand for energy needs to be reduced (Martinho, 2016). Contrarily, it is also argued that there are macroeconomic costs of mitigating carbon emissions (Amano, 1993; Fan, Zhang, & Zhu, 2010; Hourcade & Robinson, 1996). Thus, an attempt to reduce energy consumption in other to mitigate carbon emissions will put negative pressure on economic growth since energy is a key input in the production function (Ahmad et al., 2017; Al-mulali & Binti Che Sab, 2012; Asafu-Adjaye, 2000; Mahadevan & Asafu-Adjaye, 2007; Omri, 2013; Omri, Nguyen, & Rault, 2014; Sadorsky, 2011, 2012). These counter arguments make economic, environmental and energy conservation policies at odds with one another.

Thus, these conflicting arguments have resulted in two major strands of empirical works. The first strand of the empirical research has been examining the environment-economic growth nexus which aims to tests the validity of the Environmental Kuznets curve (EKC). The EKC argues that the quality of the environment will initially deteriorate as income increases and eventually improve as income increases in the long-run (Grossman & Krueger, 1995). Thus, an increase in economic growth will initially increase carbon emissions and eventually falls as economic growth increases. Extensive empirical studies exist on the pollution-economic growth nexus with inconsistent findings (see Ahmad et al., 2017; Al-Mulali, Ozturk, & Solarin, 2016; Alam, Murad, Noman, & Ozturk, 2016; Anastacio, 2017; Apergis & Ozturk, 2015; Awad & Abugamos, 2017; Ben Jebli, Ben

Youssef, & Ozturk, 2016; Dinda, 2004; Dogan & Ozturk, 2017; Huang, Hwang, & Yang, Jardón, Kuik, & Tol, 2017; 2008; Keho, 2017; Narayan & Narayan, 2010; Ozcan, 2013; Özokcu & Özdemir, 2017; Saboori, Sulaiman, & Mohd, 2012; Stern, 2004; Stern & Common, 2001).

On the other hand, the second strand of the empirical studies has been investigating the relationship between energy consumption and economic growth. These studies were pioneered by Kraft and Kraft (1978) in their seminal work. Earlier versions of these studies which were conducted in bivariate models could have resulted in an omitted variable bias resulting in inconsistent estimates (see Akarca & Long, 1980; Yu & Hwang, 1984). However, recent studies have been using multivariate models and advanced time series estimation approaches but their findings have been conflicting (see Apergis & Payne, 2010; Asafu-Adjaye, 2000; Cong, Aidong, & Chongqi, 2011; Dagher & Yacoubian, 2012; Dergiades, Martinopoulos, & Tsoulfidis, 2013; Huang et al., 2008; Kandemir Kocaaslan, 2013; Lee, 2006; Lee & Chang, 2007; Mahadevan et al., 2007; Mutascu, 2016; Narayan & Smyth, 2008; Oh & Lee, 2004; Ozturk, 2010; Zhang-wei & Xun-gang, 2012; Zhang, 2011; Zhixin & Xin, 2011).

Some scholars have argued that these two strands of works must be studied together since the causal relationship between economic growth, energy consumption and carbon emissions have important policy implications (Soytas & Sari, 2009). On the other hand, energy consumption has a direct impact on carbon emissions (Ang, 2007) and, therefore, understanding the relationships between these variables in tandem will help solve any conflicting impact of economic, environmental and energy conservation policies on one another. Put differently, Ang (2007) argues that economic growth, energy consumption and carbon emissions are inter-related and, therefore, their relationship must be examined using an integrated framework to avoid misspecification.

However, with the extensively published literature on economic growth and environment relationship and a separate even more extensive literature looking at the relationship between economic growth and energy consumption, very few empirical works bring these two separate streams of literature together to examine the causal relationships. In addition, there are only a limited number of studies which have examined the Granger causality link between economic growth and environmental degradation (Soytas, Sari, & Ewing, 2007). This study, therefore, aims to fill in these gaps by providing a new empirical evidence on the causal linkages between economic growth, energy consumption and carbon emissions using the multivariate framework which controls for trade openness since trade has an important effect on these variables (see Antweiler, Copeland, & Taylor, 2001; Cole, 2006; Ghani, 2012; Ren, Yuan, Ma, & Chen, 2014; Sadorsky, 2011, 2012; Shahbaz, Nasreen, Ling, & Sbia, 2014).

This study is unique from any other empirical studies that have examined the relationships between economic growth, energy consumption and carbon emissions and contributes to the literature in three main ways. First, this study is the first to utilize the recently developed panel vector autoregression (PVAR)[2] to examine the causal relationship between energy consumption, CO_2 emissions, and economic growth. This advanced econometric approach is efficient and its estimates are robust as it uses system-generalized method of moment (system-GMM) estimator to estimate the relationships and test the Granger causality simultaneously between the variables. This advanced econometric approach helps solve the issue of endogeneity and, therefore, makes the results consistent and robust. The variance decomposition and the impulse response functions are sensitive to variable ordering; this enables the study to forecast how a shock in economic growth will affect energy consumption and carbon emissions in both short-run and long-run.

To the best of the author's knowledge, this is the first study to have used a larger sample size of 116 countries to examine the causal relationships between energy consumption, CO_2 emissions, and economic growth. Finally, this study further disaggregate this global sample into regional samples to examine the causal relationship between these variables and make sound policy recommendations.

The rest of the paper is organized as follows. Section 2 presents the review of the literature, followed by section 3 which gives an overview of the methodology and data. Section 4 presents the main empirical results and discussions, followed by conclusions and policy analysis in section 5.

[2] See the methodology for the more discussions on the system-GMM PVAR.

2. Literature review

Examining the causal relationship between economic growth, energy consumption and carbon emissions using an integrated approach could have important policy implications and help solve misspecification problems. However, there is an extensive literature looking at the relationship between energy consumption and economic growth and a separate even more extensive literature looking at the relationship between economic growth and carbon emissions. Some scholars have argued these two strands of studies are inter-related and must be studied together to overcome the inherent weakness of each strand of studies.

For instance, it is argued against the EKC studies that an increasing income does not always improve the environment as pollutant emissions – carbon emissions- are monotonically increasing with income (Farhani & Ozturk, 2015; Fodha & Zaghdoud, 2010; Holtz-Eakin & Selden, 1995). Adewuyi and Awodumi (2017) also argue that studies examining the relationship between energy consumption and economic growth without considering carbon emissions do not contribute much to the literature. In addition, given that energy consumption also has a direct impact on the level of environmental pollution (carbon emissions), examining these two strands of studies using an integrated framework is necessary. Thus, economic growth, energy consumption and carbon emissions are inter-related and, therefore, their relationship must be examined using an integrated framework to avoid misspecification (Ang, 2007, p. 4773). However, few empirical works have addressed the weakness of these studies using an integrative framework to analyse the relationship between economic growth, carbon emissions and energy consumption (see Ang, 2007; Soytas et al., 2009; Soytas et al., 2007), however, the results are inconclusive because of the difference in methodology, data and countries involved in the analysis.

For instance, Ang (2007) examined the dynamic causal relationships between pollutant emissions, energy consumption and output for France over the period 1960-2000 using cointegration and vector error-correction modelling techniques and found that economic growth exerts a causal influence on the growth of energy use and growth of pollution in the long-run. The study also found a uni-directional causality which runs from energy use to output growth in the short run. Following the work of Ang (2007), Jahangir Alam, Ara Begum, Buysse, and Van Huylenbroeck (2012) also investigated the dynamic causality between energy consumption, electricity consumption, carbon emissions and economic growth in Bangladesh using Johansen cointegration, VECM and ARDL techniques. The study found a uni-directional causality which runs from energy consumption to economic growth both in the short and long-run while a bi-directional long-run causality exists between electricity consumption and economic growth but no causal relationship exists in short-run. A uni-directional causality was also found to run from energy consumption to CO_2 emissions for the short-run but feedback causality exists in the long-run. CO_2 Granger causes economic growth both in the short and in the long-run. In the same way, Mirza and Kanwal (2017) also employed Johansen cointegration, ARDL and VECM techniques to investigate the dynamic causality between economic growth, energy consumption and CO_2 emissions for Pakistan over the period 1971-2009 and found the presence of bi-directional causalities between energy consumption, economic growth and the CO_2 emissions.

Soytas et al. (2007) also investigated the causal relationship between income, energy consumption, and carbon emissions in the U.S by including labour and gross fixed capital formation in the model and found that income does not Granger cause carbon emissions in the US in the long-run, but energy use does. Soytas et al. (2009) further extended their study to Turkey and discovered that carbon emissions Granger cause energy consumption, but the reverse is not true. In the same way, Zhang and Cheng (2009) explored the causality between economic growth, energy consumption, and carbon emissions in China over the period 1960-2007 and found a uni-directional Granger causality which runs from GDP to energy consumption, and a uni-directional Granger causality which runs from energy consumption to carbon emissions in the long-run. Evidence shows that neither carbon emissions nor energy consumption leads economic growth.

Using ARDL bound testing, Halicioglu (2009) analysed the dynamic causal relationship between carbon emissions, energy consumption, income, and foreign trade in the case of Turkey for the period 1960–2005. The study found that energy consumption, income, squared income and foreign trade Granger-cause CO_2 emissions and the direction of causality runs interactively through the error-correction term from energy consumption, income, squared income and foreign trade to the CO_2 emissions. Another long-run Granger causality was found to run interactively through the error-correction terms from energy consumption, CO_2 emissions, squared income and foreign trade to the income. In the case of short-run causality tests, a bi-directional Granger causality exists between CO_2 emissions and commercial energy consumption. This result contradicts the empirical findings of Soytas et al. (2009) who found a uni-directional causality from carbon emissions to energy consumption in Turkey. In the same way, Menyah and Wolde-Rufael (2010) employed ARDL bound test to examine the long-run and the causal relationship between economic growth, pollutant emissions and energy consumption for South Africa for the period 1965–2006 and found a significant positive relationship between pollutant emissions and economic growth. Further, applying a modified version of the Granger causality test, the study also found a uni-directional causality which runs from pollutant emissions to economic growth; from energy consumption to economic growth and from energy consumption to CO_2 emissions all without a feedback.

Additionally, Al-mulali et al. (2013) employed Canonical Cointegration Regression (CCR) to investigate the causal relationship between energy consumption, carbon dioxide emission, and economic growth in the Latin American and Caribbean countries over the period 1980-2008 and found that 60 percent of the countries have a positive bi-directional long-run relationship between energy consumption, carbon dioxide emissions and economic growth while the remaining 40 percent of the countries have mixed results.

Arouri, Ben Youssef, M'Henni, and Rault (2012) also employed bootstrap panel unit root tests and cointegration techniques to investigate the relationship between carbon dioxide emissions, energy consumption, and real GDP for 12 the Middle East and North African Countries (MENA) over the period 1981–2005 and found that energy consumption has a positive significant impact on CO_2 emissions in the long-run. Furthermore, real GDP exhibits a quadratic relationship with CO_2 emissions for the region as a whole. Although the estimated long-run coefficients of income and its square satisfy the EKC hypothesis in most of the studied countries, the turning points are very low in some cases and very high in other cases, hence providing poor evidence in support of the EKC hypothesis. The authors concluded that CO_2 emission reductions per capita have been achieved in the MENA region, even while the region exhibited economic growth over the period 1981–2005.

Omri (2013) also examined the nexus between CO_2 emissions, energy consumption and economic growth using simultaneous-equations models with panel data of 14 MENA countries over the period 1990–2011 and found a bi-directional causal relationship between energy consumption and economic growth. The study also found a uni-directional causality from energy consumption to CO_2 emissions without any feedback effects and a bi-directional causal relationship between economic growth and CO_2 emissions for the region as a whole. In the same way, Salahuddin and Gow (2014) also examined the relationship between economic growth, energy consumption and carbon dioxide emissions in GCC (Gulf Cooperation Council countries) countries and found a positive and significant association between energy consumption and CO_2 emissions and between economic growth and energy consumption both in the short- and the long-run. No significant relationship was found between economic growth and CO_2 emissions. Energy consumption and CO_2 emissions Granger cause each other while uni-directional causal link running from economic growth to energy consumption also exist.

3. Methodology and data

In this study, panel vector autoregression (PVAR) methodology was adopted. The PVAR combines the traditional VAR approach, which treats all the variables in the system as endogenous, with the panel data approach, which allows for unobserved individual heterogeneity (Love & Zicchino, 2006, p. 193)[3]. The empirical model for energy consumption (logencpc), economic growth (logrdpg), carbon dioxide emissions (logco$_2$gdp) and the control variable trade openness (logtra) is given in equation (1). Following Andrews and Lu (2001)[4], the optimal lag for the model selection was based on the first-order PVAR. Therefore, the first order panel VAR is specified as given below:

$$Z_{it} = \mu_i + \Phi(I)Z_{it-1} + v_i + \theta_t + \varepsilon_{it} \quad (1)$$

Where $i = 1, 2, 3 \ldots\ldots N$ and $t = 1, 2, 3 \ldots\ldots T$, Z_{it} is energy consumption ($logencpc_{it}$), economic growth ($logrgdp_{it}$), carbon emissions ($logco2gdp_{it}$) and trade openness ($logtra_{it}$) as the control variable. $\Phi(I)$ is the lag operator of the endogenous covariates, v is an individual specific effect, θ is fixed time effect and ε is the stochastic error term.

Given the implications of trade on energy consumption, economic growth and carbon emissions (see Ahmed et al., 2017; Antweiler et al., 2001; Arouri et al., 2012; Ertugrul, Cetin, Seker, & Dogan, 2016; Ghani, 2012; Giles & Williams, 2000; Kasman & Duman, 2015; Kyophilavong, Shahbaz, Anwar, & Masood, 2015; Lean & Smyth, 2010a, 2010b; Nasreen & Anwar, 2014; Ren et al., 2014; Sadorsky, 2011; 2012), the incorporation of trade openness in the model will provide more information that affect these variables and also prevent variable omission bias.

Estimating equation (1) using Ordinary least squares (OLS) would lead to inconsistent results because of the country-specific fixed and time effect. Therefore, to estimate equation (1), first difference approach is needed to remove the country-specific effect.

$$\Delta Z_{it} = \Delta\mu_i + \Phi(I)\Delta Z_{it-1} + \Delta v_i + \Delta\theta_t + \Delta\varepsilon_{it} \quad (2)$$

[3] (Love & Zicchino, 2006) were the earlier scholars to have used panel VAR in Stata in their studies and made these programs available to other researchers (see Abrigo & Love, 2015).

[4] The (Andrews & Lu, 2001) optimal model selection criteria resembles the widely likelihood-based selection criteria BIC, HQIC, and AIC. The GMM selection criteria are based on the *J* statistic for testing over-identifying restrictions.

Where Δ is the difference operator. Estimating equation (2) using OLS would still lead to inconsistent and bias results since the unobserved panel fixed effect[5] is correlated with the lag of the independent variable (Arellano & Bond, 1991). To obtain consistent and efficient estimates under this condition, Arellano et al. (1991) developed a generalized method of moment (GMM) which uses the lag of the dependent variable as an instrument to overcome the problem of where $(\Delta Z_{it-1}\ \Delta\varepsilon_{it}) \neq 0$. However, when the autoregressive parameter is moderately large and the number of time series observations is moderately small, the widely used linear generalised method of moments (GMM) estimator obtained after first differencing has been found to have large finite sample bias and poor precision in simulation studies (cited in Blundell & Bond, 1998, p. 115). To overcome this weakness of the first difference GMM[6], Blundell et al. (1998) developed the system-generalized method of moment (System-GMM) which uses the lagged differences of the dependent variable as instruments for equations in levels and also includes the lagged levels of the dependent variable as instruments for equations in first differences. Therefore, the PVAR was estimated using the robust system-GMM estimator and test the Granger causality between energy consumption, CO_2 emission, and economic growth. Unlike the traditional VAR, the system-GMM PVAR increases the estimation sample and makes the results more consistent and robust.

The impulse response functions (IRF) describe the reaction of one variable to the shock in another variable within a system while holding all shocks equal to zero (Love et al., 2006). In the model, I assumed that the panel error-term is identical and normally distributed. However, in practice this assumption could fail as the concrete variance-covariance of the errors are unlikely to be diagonal (Čeh Časni, Dumičić, & Tica, 2016; Love et al., 2006). Thus, it is necessary to decompose the residual in a way that they become orthogonalized in order to isolate shocks to one of the VAR errors. Variables in VAR should have recursively causal ordering[7] based on their degree of exogeneity (Sims, 1980). Thus, variables that come earlier in the ordering affect the following variables contemporaneously, as well as with a lag,

---

[5] Since the fixed effects are correlated with the regressors due to lags of the dependent variables, the mean-differencing procedure commonly used to eliminate fixed effects would create biased coefficients. To avoid this problem, the forward mean-differencing, also referred to as the 'Helmert procedure' was used (Arellano et al., 1995).

[6] This uses the "Helmert procedure" which uses forward mean differencing to eliminate the only the forward mean and preserves the orthogonality between the transformed variables and lagged regression (Love et al., 2006)

[7] This process is known as the Cholesky decomposition of variance-covariance matrix of residual and ensures orthogonalization of shocks

while the variables that come later affect the previous variables only with a lag (Love et al., 2006).

In this paper, I specify with the assumption that a current shock to economic growth has a contemporaneous effect on energy consumption CO_2 emissions while energy consumption and CO_2 emissions have an effect on economic growth only with their lags. This is plausible because current environmental pollution and energy consumption would not affect current economic growth but they will affect future economic growth. Thus, current economic growth is affected by previous environmental pollution and energy consumption. Economic growth was ordered first, followed by energy consumption, carbon emissions and trade openness. The confidence intervals are needed to analyze the Impulse Response Functions (IRF); following (Love et al., 2006) approach, the standard errors of the impulse-response functions were calculated and Monte Carlo simulations were used to generate confidence intervals. The 10 years period forecast error variance decompositions were also estimated.

The data for the study is over the period 1990-2014 for a total of 116 countries[8]. Energy consumption was proxied using kg of oil equivalent per capita. The GDP per capita growth was used to represent economic growth while carbon dioxide emissions were proxied using carbon emission (kg) per 2010 US dollars as a percent of GDP. Trade openness was represented using (Export + Import) as percent GDP. These data were sourced from the World Bank Development Indicators (2016).

[8] See the appendix for the countries used in this study

4. Empirical results and discussions

This section reports the empirical results from the system-generalised method of moment PVAR, forecast error variance decomposition and the impulse response functions analysis.

4. 1 System-GMM PVAR causality results

Panel A of Table 1 presents the causal relationship between economic growth, carbon emissions and energy consumption at the global level. The result shows that economic growth does not cause energy consumption. This indicates that an increase in global economic growth would not cause energy consumption and this is inconsistent with the findings of (Huang et al., 2008; Saidi & Hammami, 2015) who find that economic growth causes demand for energy. Also, economic growth causes carbon emissions and the relationship is negative. Thus, carbon emissions will decrease by 0.005 percent when economic growth increases by 1 percent. The negative impact of economic growth on carbon emissions emphasis that increases in global income will take care of the environment. This result is consistent with the empirical findings of Aşıcı (2013) and Tamazian, Chousa and Vadlamannati (2009) who found that economic growth decreases environmental degradation.

Also, energy consumption causes economic growth and the relationship is negative. This implies that 1 percent increase in energy consumption will decrease economic growth by 1.754 percent. The negative effect of energy consumption on the global income reflects the possibility of inefficient and excessive energy consumption at the global level. This empirical evidence supports the findings of Menyah et al. (2010) who find that energy consumption negatively causes economic growth. Additionally, energy consumption does not cause carbon emissions. This result could be due to the rapid expansion in the use of renewable energy in the major energy demanding countries.

From Panel A of Table 1, carbon emissions positively cause economic growth. This suggests that global economic growth will increase by 1.631 percent when carbon emissions increase by 1 percent. This confirms previous studies which have shown that a reduction in carbon emissions would decrease global economic growth (see Amano, 1993; Fan et al., 2010; Hourcade et al., 1996). This result is also consistent with the empirical findings of

Menyah et al. (2010) who discovered that carbon emissions increase economic growth. Also, carbon emissions cause energy consumption and the relationship is negative. Thus, 1 percent increase in carbon emissions will decrease energy consumption by 0.070 percent. The negative causal impact of carbon emissions on energy consumption contradicts the empirical findings of Apergis et al. (2015) who found a positive impact of carbon emissions on energy consumption. Trade openness causes economic growth and the relationship is positive while it negatively causes energy consumption and carbon emissions. This implies that 1 percent increase in trade openness will decrease energy consumption and carbon emission by 0.039 percent and 0.048 percent respectively.

Panel B of Table 1 shows the causal relationship between economic growth, carbon emissions and energy consumption for Asia-Pacific. The result shows that economic growth does not cause energy consumption. Thus, economic growth does not affect the demand for energy in the Asia-Pacific region and this result is inconsistent with findings of Lu (2017) and Nasreen et al. (2014) who found that economic growth causes energy consumption in Asia. Additionally, economic growth does not carbon emissions. Thus, changes in economic growth have no causal effect on carbon emissions and this result supports the findings of Soytas et al. (2007) and contradicts the findings of Lu (2017) who found that economic growth causes carbon emissions in Asia. The non-causal negative effect of economic growth on carbon emissions works through energy consumption. As shown in the result, economic growth does not cause energy consumption and energy consumption does not cause carbon emissions since the Asia-Pacific region has made substantial investments in renewable energy as result of an increase in the region's economic growth (see Lu, 2017).

From Panel B, energy consumption causes economic growth and the relationship is negative. This suggests that a percentage increase in energy consumption will decline economic growth by 4.361 percent. The negative impact of energy consumption on economic growth could be due to inefficiency and excessive use of energy. The causal effect of energy consumption on economic growth is consistent with the findings of Lu (2017) and Nasreen et al. (2014) who found that energy consumption causes economic growth in Asia. The results also show that energy consumption does not cause carbon emissions. This result could be due to the rapid expansion in the use of renewable energy and the shift of the region's economy towards the service-oriented economy. This evidence contradicts the findings of Lu (2017) who found that energy consumption causes carbon emissions in Asia.

Also, carbon emissions cause economic growth and the relationship is positive. This implies that economic growth will increase by 1.396 percent when carbon emissions increase by 1 percent. This is inconsistent with the findings of Lu (2017) who found that carbon emissions do not cause economic growth in Asia. Additionally, carbon emissions do not cause energy consumption and this contradicts the findings of Ahmed et al. (2017), Lu (2017) and Soytas et al. (2009). Trade openness causes economic growth and energy consumption and the relationship is negative. This indicates that 1 percent increase in trade openness will decrease economic growth in Asia-Pacific by 0.310 percent, however, energy consumption will decrease by 0.014 percent when trade openness increases by 1 percent. Trade openness does not cause carbon emissions.

In the Caribbean and Latin America, as shown in Panel A of Table 2, economic growth does not cause energy consumption. Thus, economic growth has no causal effect on energy consumption in Latin America and the Caribbean. This result collaborates the empirical findings of Apergis et al. (2010) who found that economic growth has no causal effect on energy consumption in South America. Also, economic growth causes carbon emissions and the relationship is negative. This means that a percentage increase in the economic growth will decrease carbon emissions by 0.010 percent. This supports the empirical findings of Aşıcı, (2013) and Tamazian et al. (2009) who found that economic growth improves the quality of the environment- thus reducing carbon emissions.

Energy consumption causes economic growth and the relationship is negative. This suggests that a percentage increase in energy consumption will decrease economic growth by 4.876 percent. The negative impact of energy consumption on the Caribbean and Latin America's economic growth is expected because as a developing region, energy consumption has been inefficient due to the abundance and production of fossil fuel (see Apergis et al., 2015). This result is consistent with the findings of (Al-mulali et al., 2013; Apergis et al., 2010). Furthermore, energy consumption causes carbon emissions and the relationship is negative. Thus, 1 percent increase in energy consumption will reduce carbon emissions by 0.357 percent. This negative impact could be an explained by the decline in the intensity of energy consumption caused by the relative hike in the recent energy price and the region commitment to adopt clean energy production source (renewable energy).

Panel A of Table 2 also shows that carbon emissions cause economic growth and the relationship is positive. This suggests that 1 percent increase in carbon emission will increase economic growth by 4.196 percent. This result supports the empirical evidence of Al-mulali et al. (2013) and Apergis et al. (2015) who found that carbon emissions increase economic growth in the Caribbean and Latin America. Also, carbon emissions do not cause energy consumption. This contradicts the findings of Apergis et al. (2015) Saidi et al. (2015) who found that carbon emissions have a significant impact on energy consumption in the Caribbean and Latin America. Trade openness does not cause economic growth, energy consumption and carbon emissions.

Panel B of Table 2 shows the causality between economic growth, carbon emissions and energy consumption in the Middle East and North Africa (MENA) region. The empirical results show that economic growth does not cause energy consumption. This suggests that economic growth does not affect energy demand and this result is inconsistent with the findings of Omri (2013) and Ozcan (2013) who found that economic growth causes energy consumption in MENA. The result also shows that economic growth has no causal effect on carbon emissions and this result is consistent with the findings of Salahuddin et al. (2014) who found that economic growth has no effect on carbon emissions in the Gulf Cooperation Council (GCC) countries but contradicts the findings of Salahuddin et al. (2018).

Panel B of Table 2 shows that energy consumption causes economic growth and the relationship is negative. Thus, economic growth will decrease by 1.469 percent when energy consumption increases by 1 percent. Like the Caribbean and Latin America, the negative impact of energy consumption on economic growth could be caused by the excessive and inefficient energy consumption. This evidence is inconsistent with the empirical evidence found by Omri (2013). Additionally, energy consumption causes carbon emissions and the relationship is positive. This implies that 1 percent increase in energy consumption will increase carbon emissions by 0.395 percent. This could be due to the region dependence and excessive exploitation of fossil fuel to boost their economy resulting in carbon emissions. This result supports the empirical findings of Arouri et al. (2012) and Salahuddin et al. (2014) who found that energy consumption increases carbon emissions in the MENA countries.

Carbon emissions cause economic growth and the relationship is positive. This indicates that 1 percent increase in carbon emission will increase economic growth by 2.181 percent. This is consistent with the findings of Menyah et al. (2010) who found that carbon emissions increase economic growth. Also, carbon emissions cause energy consumption and the relationship is negative. This implies that 1 percent increase in carbon emission will decrease energy consumption by 0.474 percent. The causal effect of carbon emissions on energy consumption is consistent with the empirical findings of (Ahmed, Rehman, & Ozturk, 2017; Soytas et al., 2009). Trade openness causes economic growth and the relationship is positive. This indicates that economic growth will increase by 0.147 percent when trade openness increases by 1 percent. Trade openness causes energy consumption and carbon emissions and the relationships are negative. This implies that a percentage increase in trade openness will decrease energy consumption and carbon emissions by 0.065 and 0.038 percent respectively.

The causality results in Table 3 show the dynamic relationship between economic growth, energy consumption and carbon emissions in sub-Saharan Africa. The results show that economic growth does not cause carbon emissions. This implies that changes in economic growth do not pollute the environment. This evidence is consistent with the findings of Soytas et al. (2007) but contradicts Menyah et al. (2010) who found that carbon emissions increase economic growth in South Africa. The empirical results also suggest that economic growth has no causal effect on energy consumption in Africa and this supports the findings of Odhiambo (2009).

Energy consumption causes economic growth and the relationship is positive. Thus, 1 percent increase in energy consumption will increase economic growth by 3.547 percent. This result is consistent with the empirical evidence found by Menyah et al. (2010), Odhiambo, (2009), Ouedraogo (2013), Wandji (2013) and Wolde-Rufael (2009) and contradicts the neo-classical economics claims that energy does not matter in the production function. Also, energy consumption causes carbon emissions and the relationship is negative. This implies that 1 percent increase in energy consumption will reduce carbon emissions by 0.262 percent. The negative effect of energy consumption on carbon emissions in Africa could be attributed to two major factors. First, the decline in the intensity of energy consumption caused by the increase in energy prices and the relatively less energy consumption in Africa (see Karekezi, 2002).

As shown in Table 3, carbon emissions do not cause economic growth and energy consumption. Trade openness causes economic growth and carbon emissions. However, trade openness causes economic growth positively while it causes carbon emissions negatively. This suggests that an increase in trade openness will reduce carbon emission while it will increase economic growth in sub-Saharan African. Trade openness does not cause energy consumption.

Table 1: Estimated Causality Results from the Dynamic Panel SYS-GMM

Panel A: GLOBAL				
Independent variables	Dependent variables			
	dlogrgdpg	dlogencpc	dlogco$_2$gdp	dlogtra
dlogrgdpg$_{t-1}$		-0.001	-0.005*	0.005
		(0.00)	(0.00)	(0.00)
dlogencpc $_{t-1}$	-1.754***		0.068	-0.280***
	(0.62)		(0.06)	(0.08)
dlogco$_2$gdp $_{t-1}$	1.631***	-0.070**		0.181**
	(0.57)	(0.03)		(0.07)
dlogtra $_{t-1}$	0.211***	-0.039***	-0.048***	
	(0.07)	(0.00)	(0.02)	
Panel B: ASIA-PACIFIC				
	dlogArgdpg	dlogAencpc	dlogAco$_2$gdg	dlogAtra
dlogAgdpg$_{t-1}$		0.002	-0.001	0.023***
		(0.00)	(0.00)	(0.01)
dlogAencpc $_{t-1}$	-4.361***		-0.103	-0.550***
	(1.32)		(0.10)	(0.18)
dlogAco$_2$gdp $_{t-1}$	1.396***	0.031		0.575***
	(0.50)	(0.03)		(0.14)
dlogAtra $_{t-1}$	-0.310*	-0.014***	-0.011	

(0.19)	(0.00)	(0.02)	

Heteroskedasticity robust standard errors in parenthesis. * p < 0.1, ** p <0.05, *** p < 0.01

Table 2: Estimated Causality Results from the Dynamic Panel SYS-GMM

Panel A: CARIBBEAN-LATIN AMERICA				
	Dependent variables			
Independent variables	dlogLrgdpg	dlogLencpc	dlogLco_2gdp	dlogLtra
dlogLrgdpg$_{t-1}$		0.002	-0.0101**	0.009*
		(0.00)	(0.00)	(0.00)
dlogLencpc $_{t-1}$	-4.876***		-0.357**	0.139
	(1.59)		(0.16)	(0.14)
dlogLco_2gdp $_{t-1}$	4.196***	-0.065		-0.217***
	(1.20)	(0.05)		(0.08)
dlogLtra $_{t-1}$	-0.356	0.009	-0.037	
	(0.65)	(0.04)	(0.07)	
Panel B: Middle East North Africa (MENA)				
	dlogMrgdpg	dlogMencpc	dlogMco_2gdp	dlogMtra
dlogMrgdpg$_{t-1}$		-0.003	0.003	0.024***
		(0.00)	(0.00)	(0.01)
dlogMencpc $_{t-1}$	-1.469**		0.395***	-1.190***
	(0.66)		(0.03)	(0.12)
dlogMco_2gdp $_{t-1}$	2.181***	-0.474***		1.300***
	(0.74)	(0.06)		(0.16)
dlogMtra $_{t-1}$	0.147***	-0.065***	-0.038***	

	(0.05)	(0.00)	(0.00)

Heteroskedasticity robust standard errors in parenthesis. * p < 0.1, ** p <0.05, *** p < 0.01

Table 3: Estimated Causality Results from the Dynamic Panel SYS-GMM

	SUB-SAHARAN AFRICA			
	Dependent variables			
Independent variables	dlogSrgdpg	dlogSencpc	dlogSco$_2$gdp	dlogStra
dlogSrgdpg$_{t-1}$		0.001	-0.001	-0.003
		(0.00)	(0.01)	(0.01)
dlogSencpc $_{t-1}$	3.547**		-0.740***	-0.400***
	(1.78)		(0.28)	(0.13)
dlogSco$_2$gdp $_{t-1}$	0.573	0.013		0.194***
	(0.50)	(0.04)		(0.07)
dlogStra $_{t-1}$	1.510***	-0.047	-0.220***	
	(0.55)	(0.03)	(0.07)	

Heteroskedasticity robust standard errors in parenthesis. * p < 0.1, ** p <0.05, *** p < 0.01

4.2. Forecast error variance decomposition

This section presents the forecast error variance decomposition[9] for the global level and each region. At the global level, a shock to economic growth accounts for 0.001 percent of the variance in energy consumption while it accounts for 0.009 percent of the variation in carbon emissions for 10-years period ahead. In the Asia-Pacific, economic growth accounts for 0.033 percent of the variance in energy consumption while it accounts for 0.005 percent of the variation in carbon emissions at the 10-years horizon.

[9] See the appendix for the variance decomposition tables

Economic growth accounts for 0.031 percent variation in energy consumption and 0.015 percent in carbon emissions in MENA countries over the 10-year period ahead. In the Caribbean and Latin America, economic growth accounts for 0.006 percent variation in energy consumption while it accounts for 0.016 percent variation in carbon emissions. In sub-Saharan Africa, a shock to economic growth accounts for 0.016 percent variation in energy consumption while it accounts for 0.039 percent of the total variation in carbon emissions. These results suggest that a positive shock to economic growth has an insignificant or minor impact on carbon emissions and energy consumption in both short run and long run. These results are evident and consistent with the causality tests, as economic growth does not cause carbon emissions and energy consumption.

4.3 Impulse Response Analysis

The section presents the impulse response functions and the 95 per cent confidence interval band that was generated based on 200 Monte Carlo simulations.

The orthogonalization of the VAR residuals helps to isolate the response of energy consumption and carbon emission to a shock on economic growth. Figure 1 reports the global Impulse Response Function (IRF) of carbon emissions and energy consumption to a shock in global economic growth. Figure 1 shows that a positive shock to global economic growth initially decreases energy consumption and later increases marginally and stabilizes in the long-run. A positive shock to global economic growth initially increases and later decreases and stabilizes carbon emissions and stabilizes in the long-run. This shows evidence of Environmental Kuznets curve (EKC).

Figure 2 shows that a positive innovation to economic growth in Asia-Pacific decreases energy consumption and stabilizes in the long-run. A positive shock to economic growth in Asia-Pacific initially decreases carbon emissions and stabilizes in the long-run.

In figure 3, a positive shock to economic growth in the Caribbean- Latin America countries decreases energy consumption and the impact is shortlived. A positive shock to economic growth initially decreases carbon emissions and eventually increases carbon emissions and stabilizes in the long-run. This is an evidence against the existence of Environmental Kuznets Curve (EKC) in the Caribbean- Latin America should there be a positive innovation in economic growth.

Figure 4 shows that one standard deviation shock to economic growth in MENA region initially decreases energy consumption and stabilizes in the long run. A positive shock in economic growth in the MENA region has a cubic effect on carbon emissions. This shows an evidence against the existence of EKC in the MENA region.

Figure 4 shows that a positive shock to economic growth in sub-Saharan Africa initially increases energy consumption and but later decreases and stabilizes in the long run. Also, a positive shock to economic growth in sub-Saharan Africa initially increases carbon emissions and later decreases and stabilizes in the long run. This shows an evidence of EKC in sub-Saharan Africa.

The stability graphs show that PVAR satisfies the stability conditions. The VAR model is stable if all the companion matrix are strictly less one (Abrigo & Love, 2015; Hamilton, 1994; Lutkepohl, 2005). Thus, the VAR model is stable[10] if all the eigenvalues lie in the unit circle. From the roots of the companion matrix, the global and regional eigenvalues lie in the unit circle which suggests that the PVAR models[11] are stable and the results are good for forecasting and policy recommendations.

[10] Stability implies that the panel VAR is invertible and has an infinite-order vector moving-average representations, providing known interpretation to estimated IRF and forecast error variance decompositions (see Abrigo et al., 2015)

[11] See the appendix for the stability graphs

Figure 1: Global Impulse response functions

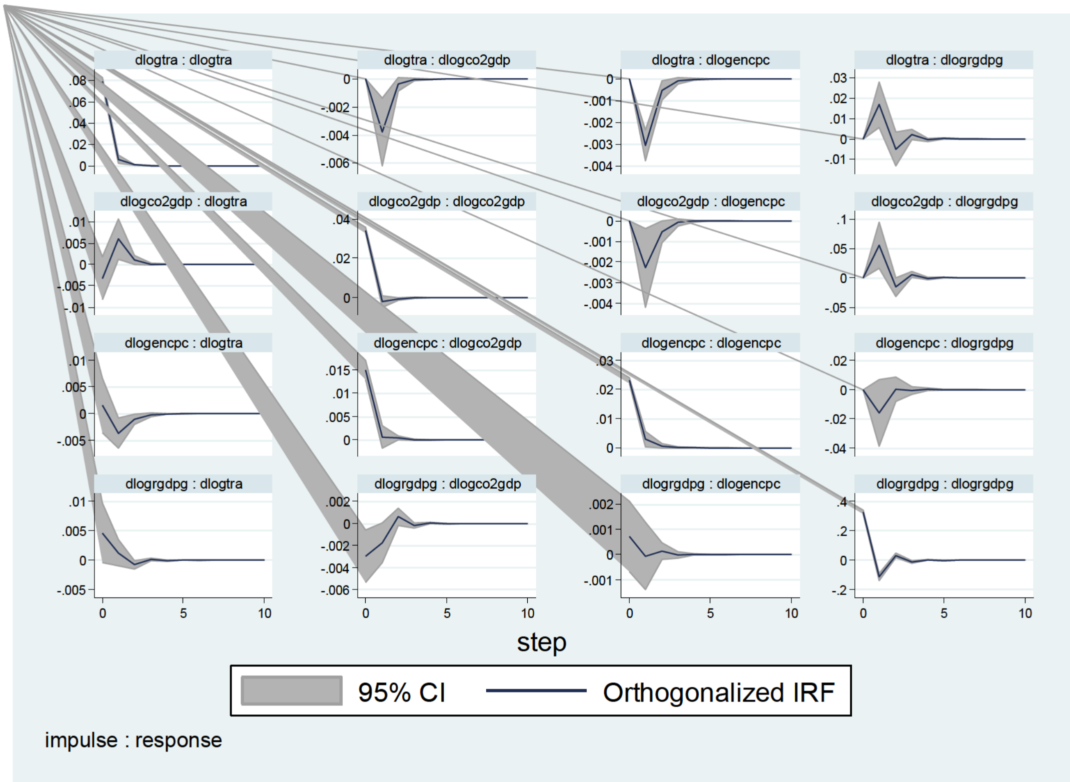


Figure 2: Asia-Pacific impulse response functions

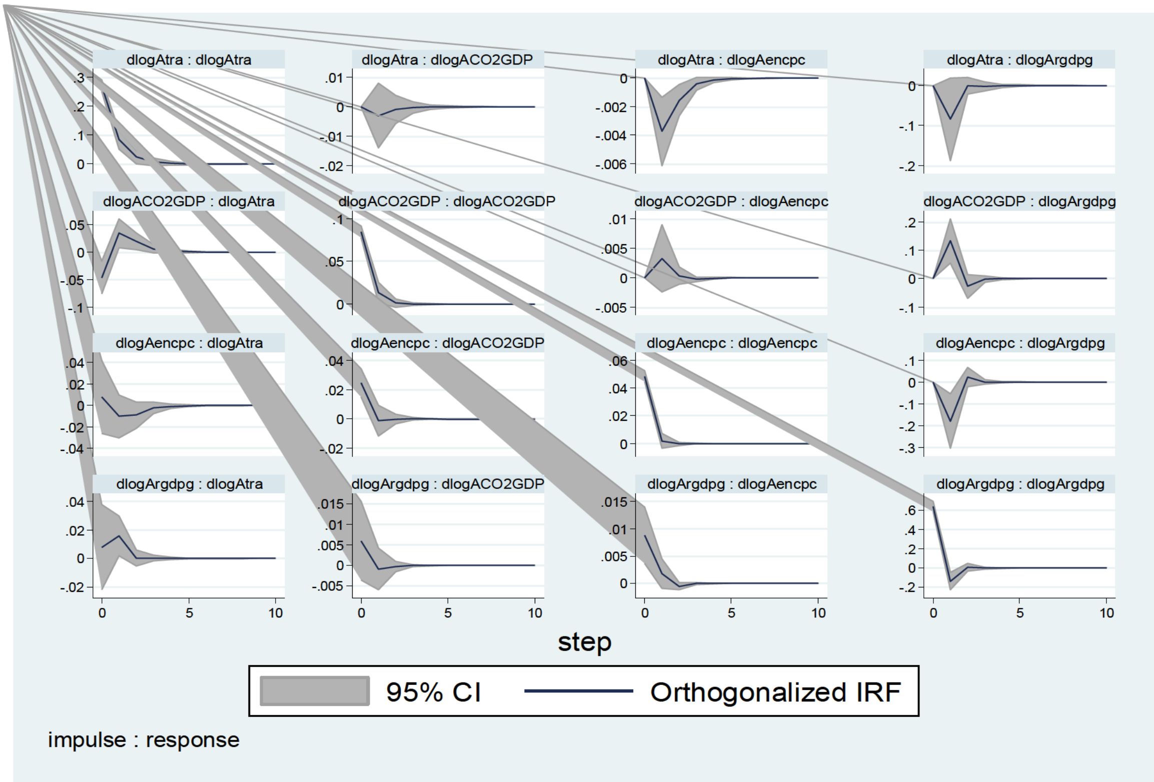


Figure 3: Caribbean-Latin America impulse response functions

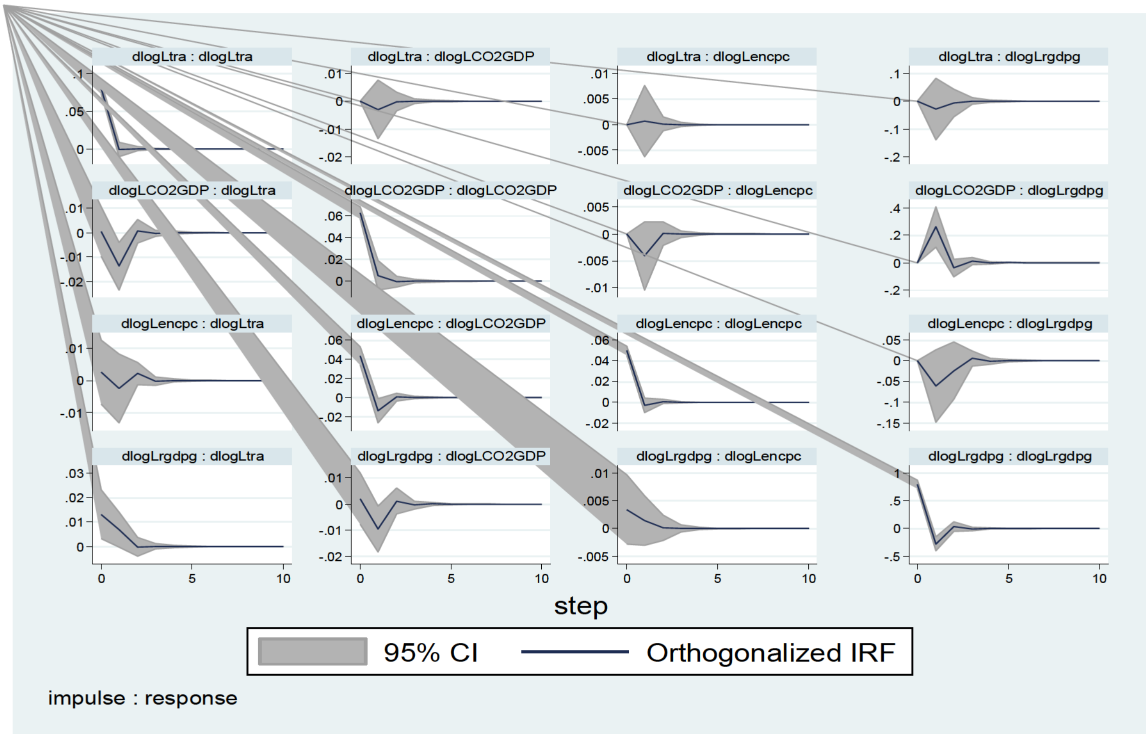


Figure 4: MENA impulse response functions

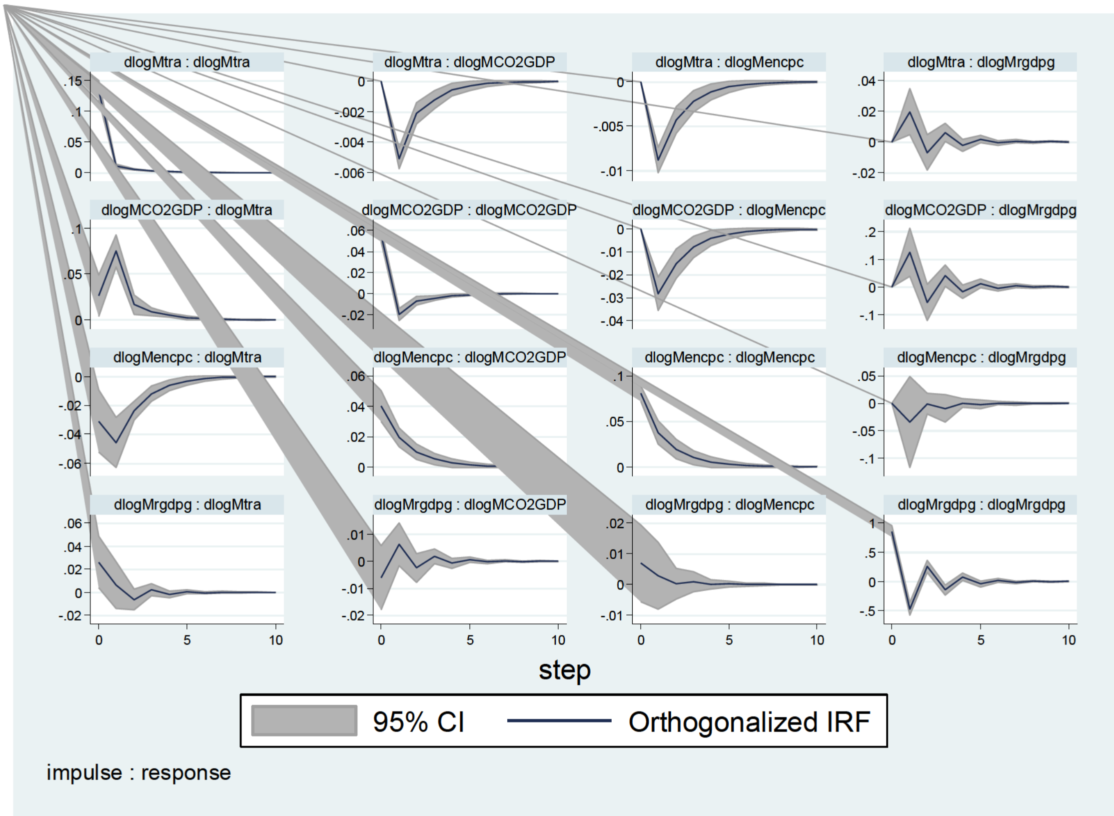
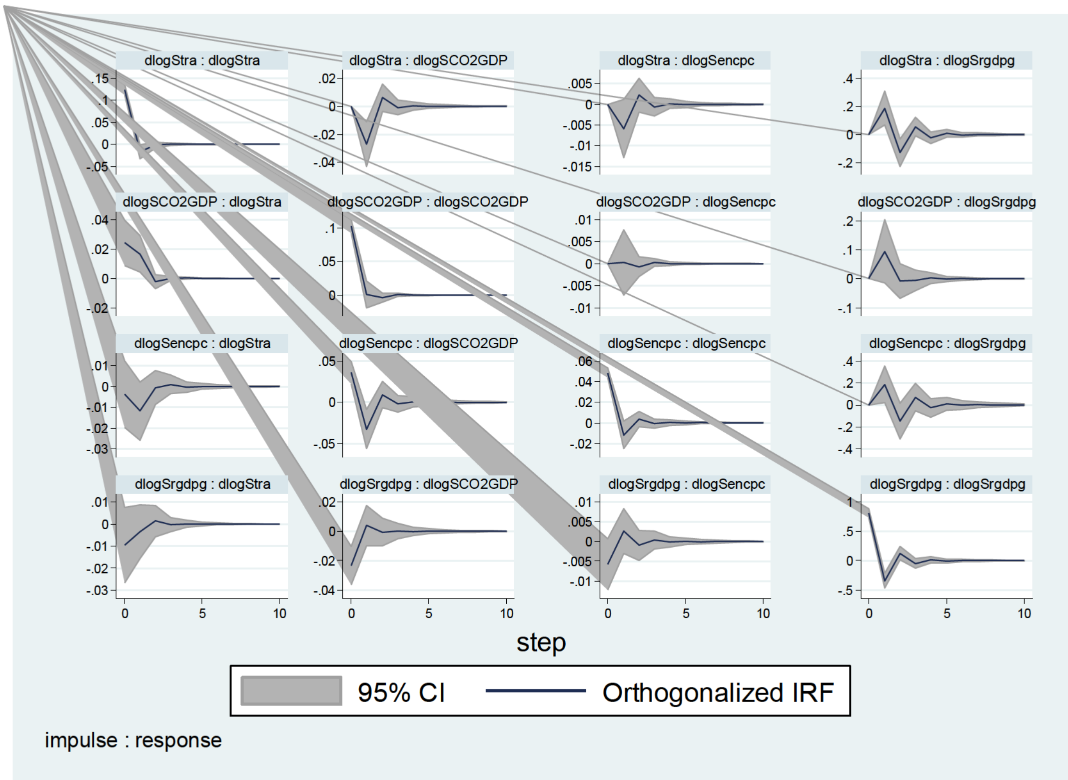


Figure 5: Sub-Saharan Africa impulse response functions



4.4 Robustness Check

This section uses the panel Granger causality test to determine the robustness of the causality results obtained by the system-generalised method of moment (system-GMM) PVAR as presented in Tables 1-3. The direction of causality established between economic growth, energy consumption and carbon emissions using the panel Granger causality (Table 4-5) is consistent with the direction of causality presented in Table 1-3.

As shown in Table 4 and 5, energy consumption uni-directionally causes economic growth at the global and regional level without feedback relationship. There is also a feedback causal relationship between economic growth and carbon emissions at the global level and Caribbean-Latin America while carbon emissions uni-directionally cause economic growth in the Asia-Pacific and MENA countries. However, there is no causal relationship between economic growth and carbon emissions in sub-Saharan Africa. Also, energy consumption uni-directionally causes carbon emissions in sub-Saharan Africa and Caribbean-Latin America while there is uni-directional causality which runs from carbon emissions to energy consumption at the global level. Additionally, there is a bi-directional causal relationship between energy consumption and carbon emissions in MENA countries while there is no causal relationship between energy consumption and carbon emissions in the Asia-Pacific region.

Table 4: Panel Granger causality results

Global				
Independent variables	Dependent variables			
	dlogrgdpg	dlogencpc	dlogco$_2$gdp	dlogtra
dloggdpg$_{t-1}$		0.116 (0.733)	3.249* (0.071)	2.101 (0.147)
dlogencpc $_{t-1}$	8.014*** (0.005)		1.391 (0.238)	12.863***(0.000)
dlogco$_2$gdp $_{t-1}$	8.244*** (0.004)	5.825** (0.016)		6.261** (0.012)
dlogtra $_{t-1}$	8.111*** (0.004	74.525*** (0.000)	9.821*** (0.002)	
Asia-Pacific				
	dlogArgdpg	dlogAencpc	dlogAco$_2$gdp	dlogAtra
dlogArgdpg$_{t-1}$		1.083 (0.298)	0.103 (0.748)	10.314*** (0.001)
dlogAencpc $_{t-1}$	10.906*** (0.001)		0.979 (0.322)	9.015*** (0.003)
dlogAco$_2$gdp $_{t-1}$	7.729*** (0.005)	0.835 (0.361)		16.337*** (0.000)
dlogAtra $_{t-1}$	2.721* (0.99)	9.545*** (0.002)	0.310 (0.578)	
Caribbean-Latin America				
	dlogLrgdpg	dlogLencpc	dlogLco$_2$gdp	dlogLtra
dlogLgdpg$_{t-1}$		0.510 (0.475)	4.235** (0.40)	3.647* (0.056)
dlogLencpc $_{t-1}$	9.439*** (0.002)		4.961** (0.026)	1.002 (0.317)
dlogLco$_2$gdp $_{t-1}$	12.263*** (0.000)	1.709 (0.191)		6.953*** (0.008)
dlogLtra $_{t-1}$	0.299 (0.585)	0.039 (0.844)	0.284 (0.594)	

Probability values are in paranthesis. * p < 0.1, ** p <0.05, *** p < 0.01

Table 5: Panel Granger causality results

MENA				
Independent variables	Dependent variables			
	dlogMrgdpg	dlogMencpc	dlogMco$_2$gdp	dloMgtra
dlogMrgdpg$_{t-1}$		0.596 (0.440)	0.460 (0.498)	7.868*** (0.005)
dlogMencpc $_{t-1}$	4.938** (0.026)		136.002*** (0.000)	104.038*** (0.000)
dlogMco$_2$gdp $_{t-1}$	8.714*** (0.003)	65.468*** (0.000)		69.230*** (0.000)
dlogMtra $_{t-1}$	8.401*** (0.004)	259.569*** (0.000)	711.376*** (0.000)	
Sub-Saharan Africa				
	dlogSrgdpg	dlogSencpc	dlogSco$_2$gdp	dlogStra
dlogSrgdpg$_{t-1}$		0.163 (0.686)	0.019 (0.890)	0.175 (0.676)
dlogSencpc $_{t-1}$	3.968** (0.046)		6.777*** (0.009)	9.289*** (0.002)
dlogSco$_2$gdp $_{t-1}$	1.305 (0.253)	0.122 (0.727)		8.830*** (0.003)
dlogStra $_{t-1}$	7.630*** (0.006)	2.470 (0.116)	9.608*** (0.002)	

Probability values are in paranthesis. * p < 0.1, ** p <0.05, *** p < 0.01

5. Conclusions and policy implications

Extensive published literature exists on economic growth and environment relationship and a separate even more extensive literature looking at the relationship between economic growth and energy consumption. Since economic growth, carbon emissions and energy consumption are inter-related, combining these two streams of literature using an integrated framework prevent variable omission bias or misspecification problem and helps to make sound policy recommendations. This study, for the first time, utilized system-GMM PVAR to examines the dynamic causal relationship between economic growth, carbon emissions and energy consumption while controlling for trade openness for panel data of 116 countries over the period 1990-2014. The policy implications of this study are discussed as follows:

The empirical results reveal that at the global level, there is uni-directional causality which runs from energy consumption to economic growth, however, energy consumption negatively causes economic growth. This suggests that energy conservation policies will increase economic growth at the global level. A bi-directional causality exists between carbon emissions and economic growth. However, economic growth negatively causes carbon emissions while carbon emissions positively cause economic growth. This implies that environmental and energy conservation policies, which aim at reducing carbon emissions, will hurt global economic growth, however, structural policies, which also aim at increasing global economic growth, will improve the quality of the environment. Carbon emissions uni-directionally cause energy consumption and the relationship is negative. This implies that environmental and energy conservation policies, which aims at reducing carbon emissions, will increase energy consumption. This negative impact of carbon emissions on energy consumption works through economic growth although economic growth has an insignificant negative effect on energy consumption. Thus, reducing carbon emissions will cause a decline in economic growth which will reduce the efficiency in energy consumption.

In the Asia-Pacific region, economic growth also does not cause energy consumption and carbon emissions. This suggests that structural policies which seek that increase economic growth in the Asia-Pacific region will not have any impact on energy consumption as well as degrading the environment. Carbon emissions uni-directionally cause economic growth and the direction is positive. This implies that carbon emissions reduction policies will retard economic growth in Asia-Pacific region. It is evident that there is no causal relationship between carbon emissions and energy consumption. This suggests that energy conservation policies will not have any impact on carbon emissions while carbon emissions policies will also not have any impact on energy consumption. Energy consumption uni-directionally causes economic growth and the direction of causality is negative. This suggests that energy conservation policies will increase economic growth rate in Asia-Pacific. Thus, while energy conservation policies will not have any impact on carbon emissions reduction, investing in green energy technologies will accelerate economic growth rate.

In the Caribbean region and Latin America, economic growth does not cause energy consumption. This implies that structural policies in the Caribbean and Latin America which seek to increase economic growth rate will not affect energy consumption. There is feedback causality between economic growth and carbon emissions. However, economic growth negatively causes carbon emissions. This shows that allowing the economy to growth will take care of environmental pollution- thus reducing carbon emissions. On the other hand, carbon emission causes economic growth positively. This suggests that environmental policies which aim to reduce carbon emissions will retard the Caribbean and Latin America's economic growth rate. There exist negative uni-directional causality which runs from energy consumption to economic growth. This shows that policies that aimed at reducing energy consumption and investing in renewable energy will increase the economic growth rate. Energy consumption uni-directionally causes carbon emissions and the direction of causality is negative. This shows that energy consumption reduction strategies will increase carbon emissions.

In the MENA region, economic growth does not cause energy consumption and carbon emissions. Carbon emissions uni-directionally cause economic growth and the relationship is positive. This implies that environmental and energy conservation policies which aim at reducing carbon emissions will decrease economic growth in the MENA region. Additionally, there is feedback causal relationship between carbon emissions and energy consumption. Energy consumption positively causes carbon emissions. Thus, energy conservation policies will decrease carbon emissions, however, environmental policies, which aim at reducing carbon emissions, will increase energy consumption. Uni-directional causality runs from energy consumption to economic growth and the relationship is negative. Thus, energy conservation policies will accelerate economic growth in this region.

In sub-Saharan Africa, no causal relationship exists between carbon emissions and economic growth. Energy consumption uni-directionally causes economic growth and the relationship is positive without feedback response. This suggests that energy conservation policies will hurt economic growth in sub-Saharan Africa. Additionally, energy consumption uni-directionally causes carbon emissions and the causal direction is negative. This suggests that energy conservation policies will accelerate carbon emissions.

In addition, trade openness negatively causes energy consumption and carbon emissions at the global level, Asia-Pacific, MENA and Sub-Saharan Africa. Thus, trade liberalization policies will enable the transfer of technologies which will help in energy and environmental conservations. In addition, trade liberalization policies will increase economic growth at the global level, sub-Saharan Africa and MENA but will decrease economic growth in the Asia-Pacific region. The negative impact of trade openness in Asia-Pacific economic shows that trade liberalisation policies could make the Asia-Pacific region to specialize in sectors with a dynamic comparative disadvantage in terms of potential productivity growth or where technological innovations or learning by doing are largely exhausted (see Lucas, 1988; Redding, 1999; Young, 1991). Additionally, trade liberalisation policies will have an insignificant causal effect on energy consumption, economic growth and carbon emissions in the Caribbean and Latin America.

Finally, the forecast error variance decomposition shows that a shock in economic growth does not significantly cause many variations in energy consumption and carbon emissions in the long run at the global and the regional levels. However, the behaviour of energy consumption and carbon emissions in response to a shock in economic growth varies at the global and regional levels. The impulse response functions reveal the existence of the Environmental Kuznets curve (EKC) at the global level and sub-Saharan Africa. The results are stable as all the eigenvalues lie in the circle and hence good for forecasting and policy recommendations.

This study has demonstrated that there are macroeconomic costs associated with environmental and energy conservation policies which seek to reduce carbon emissions. From the findings, I recommend that since economic growth has no causal impact on energy consumption and to some extent ensures environmental sustainability (reducing carbon emissions), structural policies should pursue at both the global and regional levels to achieve robust economic growth. Also as carbon emissions cause economic growth positively, global and regional policies that target reduction in carbon emissions will constrain future economic growth. Additionally, energy conservation policies will increase economic growth, however, energy and environmental conservation policies should be implemented with care without causing close-form relationships which will cause a decline in global and regionals economic growth.

Despite the efficiency of the results obtained using the panel estimation technique (Sadorsky, 2012), the limitation of this study is that its conclusions and policy recommendations apply at the global and regional levels but may probably not apply for individual countries. Therefore, further studies should examine the causal relationship between energy consumption, economic growth and carbon emissions using time series data.

Appendix

Table A.1: Global variance decomposition

Forecast horizon	Impulse variable			
	dlogrgdpg	dlogencpc	dlogCO2gdp	dlogtra
dlogrgdpg				
0	0	0	0	0
1	1	0	0	0
2	.9711812	.0020046	.024571	.0022433
3	.9693466	.001982	.0262554	.0024159
4	.9691212	.0019839	.0264471	.0024478
5	.9691036	.0019838	.0264628	.0024498
6	.9691017	.0019838	.0264645	.0024501
7	.9691015	.0019838	.0264646	.0024501
8	.9691015	.0019838	.0264646	.0024501
9	.9691015	.0019838	.0264646	.0024501
10	.9691015	.0019838	.0264646	.0024501
dlogencpc				
0	0	0	0	0
1	.0009504	.9990496	0	0
2	.000918	.9729654	.0092588	.0168578
3	.0009491	.9719734	.0097696	.017308
4	.0009494	.9719483	.0097809	.0173214
5	.0009495	.9719467	.0097817	.017322
6	.0009495	.9719467	.0097817	.0173221
7	.0009495	.9719467	.0097817	.0173221
8	.0009495	.9719467	.0097817	.0173221
9	.0009495	.9719467	.0097817	.0173221
10	.0009495	.9719467	.0097817	.0173221
dlogco2gdp				
0	0	0	0	0
1	.0062325	.1594854	.8342821	0
2	.0082702	.1574467	.8242393	.010044
3	.0085394	.157449	.823879	.0101325
4	.0085597	.1574484	.8238593	.0101326
5	.0085618	.157448	.8238573	.0101329
6	.008562	.157448	.8238572	.0101329
7	.008562	.157448	.8238572	.0101329
8	.008562	.157448	.8238572	.0101329
9	.008562	.157448	.8238572	.0101329
10	.008562	.157448	.8238572	.0101329
dlogtra				
0	0	0	0	0
1	.003463	.0003808	.0016623	.9944938
2	.0036721	.0024429	.0072099	.986675
3	.0037631	.0026184	.007377	.9862415
4	.0037688	.0026233	.0073771	.9862308
5	.0037695	.0026235	.0073777	.9862294
6	.0037695	.0026235	.0073777	.9862293
7	.0037695	.0026235	.0073777	.9862293
8	.0037695	.0026235	.0073777	.9862293
9	.0037695	.0026235	.0073777	.9862293
10	.0037695	.0026235	.0073777	.9862293

Table A. 2: Asia-Pacific variance decomposition

Forecast	Impulse variable

horizon	dlogArgdpg	dlogAencpc	dlogACO2GDP	dlogAtra
dlogArgdpg				
0	0	0	0	0
1	1	0	0	0
2	.8816108	.0669251	.036768	.0146961
3	.879366	.0677705	.0382064	.014657
4	.8793539	.0677698	.0382106	.0146657
5	.8793526	.0677697	.0382109	.0146667
6	.8793525	.0677697	.038211	.0146668
7	.8793525	.0677697	.038211	.0146668
8	.8793525	.0677697	.038211	.0146668
9	.8793525	.0677697	.038211	.0146668
10	.8793525	.0677697	.038211	.0146668
dlogAencpc				
0	0	0	0	0
1	.0318953	.9681047	0	0
2	.0327943	.9571207	.0043814	.0057037
3	.0328657	.9560401	.004425	.0066691
4	.032862	.9559438	.0044588	.0067354
5	.0328617	.9559336	.0044624	.0067424
6	.0328616	.9559324	.0044628	.0067431
7	.0328616	.9559323	.0044629	.0067432
8	.0328616	.9559323	.0044629	.0067432
9	.0328616	.9559323	.0044629	.0067432
10	.0328616	.9559323	.0044629	.0067432
dlogACO2GDP				
0	0	0	0	0
1	.0046167	.0772453	.918138	0
2	.0045983	.0755222	.9187379	.0011414
3	.0046099	.0754991	.9186451	.0012459
4	.0046098	.0754995	.9186367	.0012541
5	.0046098	.0754994	.9186357	.001255
6	.0046098	.0754994	.9186355	.0012551
7	.0046098	.0754994	.9186355	.0012551
8	.0046098	.0754994	.9186355	.0012551
9	.0046098	.0754994	.9186355	.0012551
10	.0046098	.0754994	.9186355	.0012551
dlogAtra				
0	0	0	0	0
1	.0008587	.0008517	.0287177	.9695719
2	.0037039	.0019461	.039732	.9546181
3	.0036584	.0028575	.0438117	.9496724
4	.0036556	.0029074	.0441849	.9492521
5	.0036553	.0029127	.0442254	.9492066
6	.0036553	.0029132	.0442295	.9492019
7	.0036553	.0029133	.04423	.9492015
8	.0036553	.0029133	.04423	.9492014
9	.0036553	.0029133	.04423	.9492014
10	.0036553	.0029133	.04423	.9492014

Table A. 3: Caribbean-Latin America variance decomposition

Forecast	Impulse variable

horizon	dlogLrgdpg	dlogLencpc	dlogLCO2GDP	dlogLtra
dlogLrgdpg				
0	0	0	0	0
1	1	0	0	0
2	.9066132	.0047153	.0876344	.0010371
3	.9044003	.0054394	.0890759	.0010845
4	.9042318	.0054755	.0892082	.0010844
5	.9042246	.0054791	.0892118	.0010844
6	.9042243	.0054792	.089212	.0010844
7	.9042243	.0054793	.089212	.0010844
8	.9042243	.0054793	.089212	.0010844
9	.9042243	.0054793	.089212	.0010844
10	.9042243	.0054793	.089212	.0010844
dlogLencpc				
0	0	0	0	0
1	.0048442	.9951558	0	0
2	.0056675	.9874304	.0067023	.0001998
3	.0056784	.9874136	.0067007	.0002072
4	.0056784	.9874126	.0067017	.0002072
5	.0056784	.9874126	.0067017	.0002072
6	.0056784	.9874126	.0067017	.0002072
7	.0056784	.9874126	.0067017	.0002072
8	.0056784	.9874126	.0067017	.0002072
9	.0056784	.9874126	.0067017	.0002072
10	.0056784	.9874126	.0067017	.0002072
dlogLCO2GDP				
0	0	0	0	0
1	.0007407	.3242404	.6750188	0
2	.0158143	.339033	.6437197	.001433
3	.016026	.3389821	.6435525	.0014394
4	.016046	.3389693	.6435452	.0014394
5	.0160464	.3389691	.643545	.0014394
6	.0160465	.3389691	.643545	.0014394
7	.0160465	.3389691	.643545	.0014394
8	.0160465	.3389691	.643545	.0014394
9	.0160465	.3389691	.643545	.0014394
10	.0160465	.3389691	.643545	.0014394
dlogLtra				
0	0	0	0	0
1	.0258603	.0010536	.0000398	.9730462
2	.0319329	.0019579	.0270049	.9391043
3	.0319109	.002622	.0270389	.9384282
4	.0319122	.0026292	.0270501	.9384086
5	.0319122	.0026296	.0270501	.9384081
6	.0319122	.0026296	.0270501	.9384081
7	.0319122	.0026296	.0270501	.9384081
8	.0319122	.0026296	.0270501	.9384081
9	.0319122	.0026296	.0270501	.9384081
10	.0319122	.0026296	.0270501	.9384081

Table A. 4: MENA variance decomposition

Forecast	Impulse	variable

horizon	dlogMrgdpg	dlogMencpc	dlogMCO2GDP	dlogMtra
dlogMrgdpg				
0	0	0	0	0
1	1	0	0	0
2	.9822517	.0012354	.0161215	.0003914
3	.9803079	.0011539	.0181271	.0004111
4	.9791479	.001217	.0191975	.0004377
5	.978983	.0012097	.0193677	.0004396
6	.9788842	.0012144	.0194595	.0004418
7	.9788685	.0012137	.0194757	.000442
8	.9788599	.0012141	.0194838	.0004422
9	.9788583	.001214	.0194854	.0004422
10	.9788575	.001214	.0194861	.0004423
dlogMencpc				
0	0	0	0	0
1	.0074536	.9925464	0	0
2	.0065107	.8936161	.0911113	.008762
3	.0060902	.8744109	.1093497	.0101491
4	.0060645	.869594	.1138495	.010492
5	.0060379	.8684364	.1149472	.0105787
6	.0060368	.8681061	.115255	.010602
7	.006035	.8680264	.1153306	.010608
8	.006035	.8680034	.1153521	.0106096
9	.0060349	.8679978	.1153573	.01061
10	.0060349	.8679961	.1153589	.0106101
dlogMCO2GDP				
0	0	0	0	0
1	.0078801	.3373333	.6547866	0
2	.0136176	.353989	.6278172	.0045762
3	.0143224	.3612692	.619193	.0052154
4	.0148153	.3626895	.6170774	.0054178
5	.0148904	.3631641	.616485	.0054605
6	.0149357	.3632556	.6163341	.0054746
7	.0149435	.363288	.6162909	.0054775
8	.0149477	.3632939	.61628	.0054785
9	.0149485	.3632961	.6162767	.0054787
10	.0149489	.3632964	.616276	.0054787
dlogMtra				
0	0	0	0	0
1	.0340586	.0471176	.0343928	.8844309
2	.0259581	.108513	.2238682	.6416607
3	.026456	.1245608	.2265334	.6224498
4	.0263999	.1284716	.2274084	.6177201
5	.0264464	.1294919	.2277797	.616282
6	.0264469	.1297614	.2278323	.6159593
7	.0264521	.1298321	.2278587	.6158572
8	.0264525	.1298508	.227862	.6158347
9	.0264531	.1298557	.2278639	.6158273
10	.0264531	.129857	.2278641	.6158258

Table A. 5: Sub-Saharan Africa variance decomposition

Forecast	Impulse variable

horizon	dlogSrgdpg	dlogSencpc	dlogSCO2GDP	dlogStra
dlogSrgdpg				
0	0	0	0	0
1	1	0	0	0
2	.9069699	.0409901	.0107122	.0413278
3	.8701418	.062304	.0101226	.0574317
4	.8627542	.0669471	.0100407	.060258
5	.8615963	.0677038	.0100339	.0606661
6	.8614259	.0678168	.010033	.0607243
7	.8614009	.0678335	.0100328	.0607328
8	.8613972	.0678359	.0100328	.060734
9	.8613967	.0678363	.0100328	.0607342
10	.8613966	.0678364	.0100328	.0607342
dlogSencpc				
0	0	0	0	0
1	.0140714	.9859287	0	0
2	.0159401	.970582	.0000221	.0134559
3	.0161663	.9683469	.000216	.0152708
4	.0162037	.9681513	.0002379	.015407
5	.01621	.9681321	.000239	.0154189
6	.016211	.9681295	.0002391	.0154204
7	.0162111	.9681292	.0002391	.0154206
8	.0162112	.9681291	.0002391	.0154206
9	.0162112	.9681291	.0002391	.0154206
10	.0162112	.9681291	.0002391	.0154206
dlogSCO2GDP				
0	0	0	0	0
1	.0441848	.1030111	.8528041	0
2	.0396371	.1649013	.7433467	.0521149
3	.0392844	.1692045	.7372956	.0542155
4	.039276	.1693609	.7371156	.0542475
5	.0392765	.1693663	.7371088	.0542483
6	.0392766	.1693667	.7371082	.0542485
7	.0392766	.1693667	.7371082	.0542485
8	.0392766	.1693667	.7371081	.0542485
9	.0392766	.1693667	.7371081	.0542485
10	.0392766	.1693667	.7371081	.0542485
dlogStra				
0	0	0	0	0
1	.0058146	.000859	.0362927	.9570336
2	.0063249	.0092293	.0512837	.9331621
3	.0064221	.0092414	.051606	.9327304
4	.0064285	.0092926	.0516012	.9326777
5	.0064292	.0092982	.0516012	.9326714
6	.0064293	.0092986	.0516012	.9326709
7	.0064293	.0092987	.0516012	.9326708
8	.0064293	.0092987	.0516012	.9326708
9	.0064293	.0092987	.0516012	.9326708
10	.0064293	.0092987	.0516012	.9326708

Figure A. 1: Global stability Graph

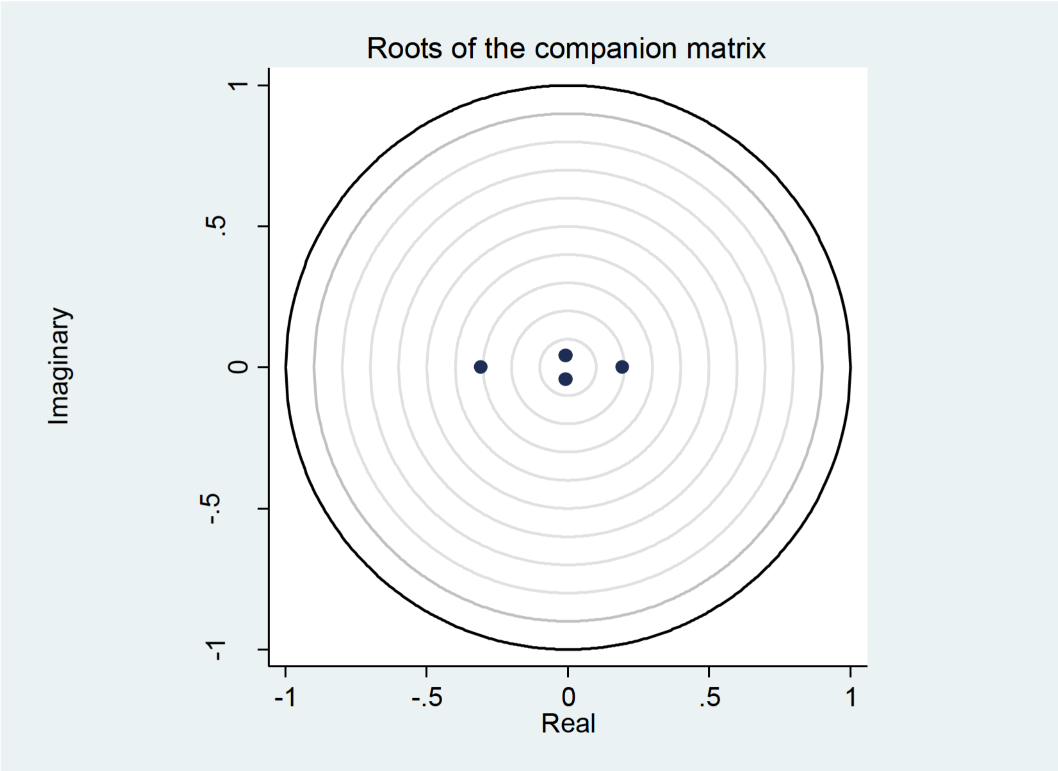


Figure A.2: Asia-Pacific stability graph

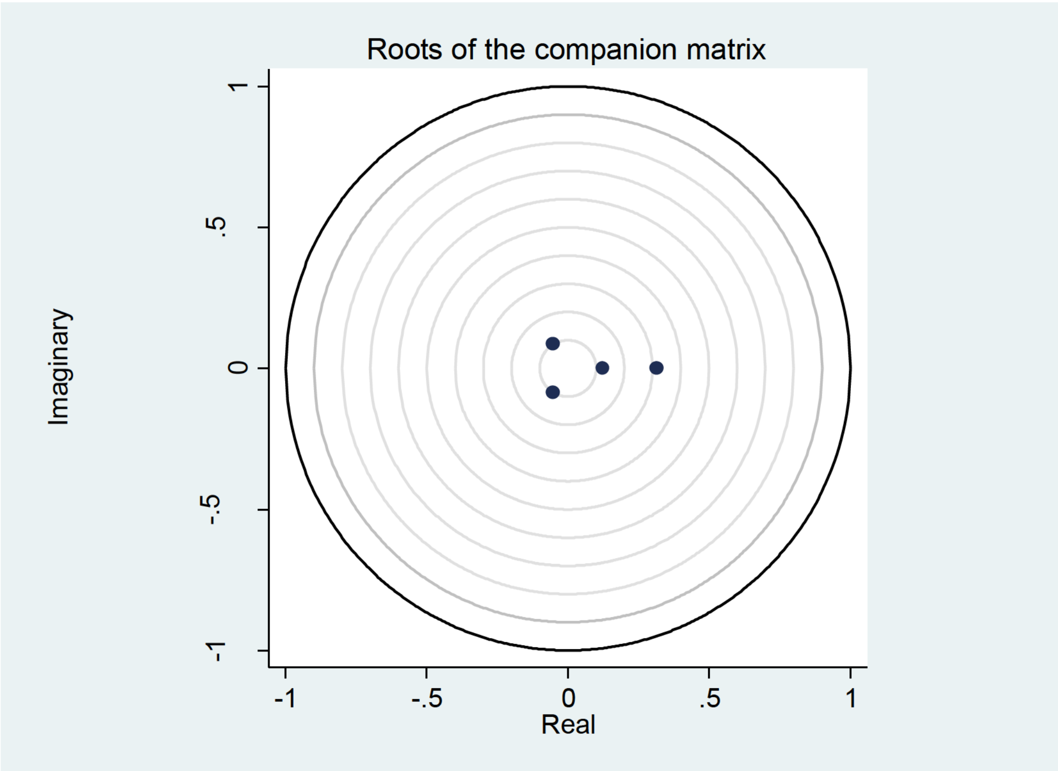


Figure A.3: Caribbean-Latin America stability graph

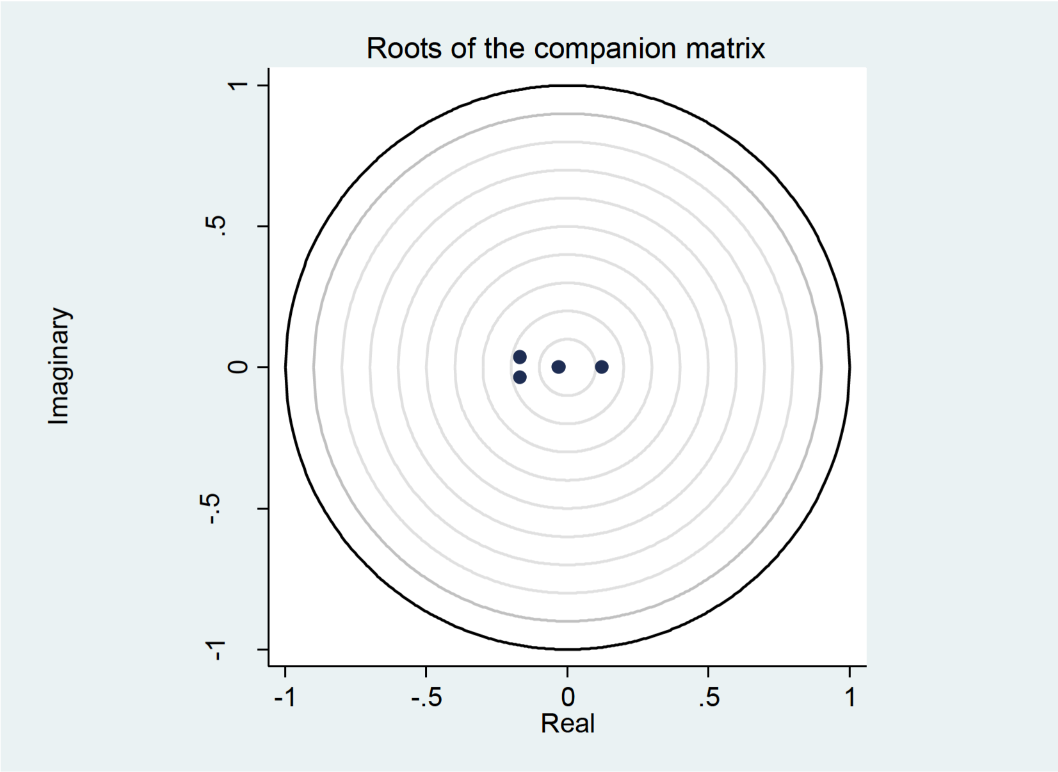


Figure A.4: MENA stability graph

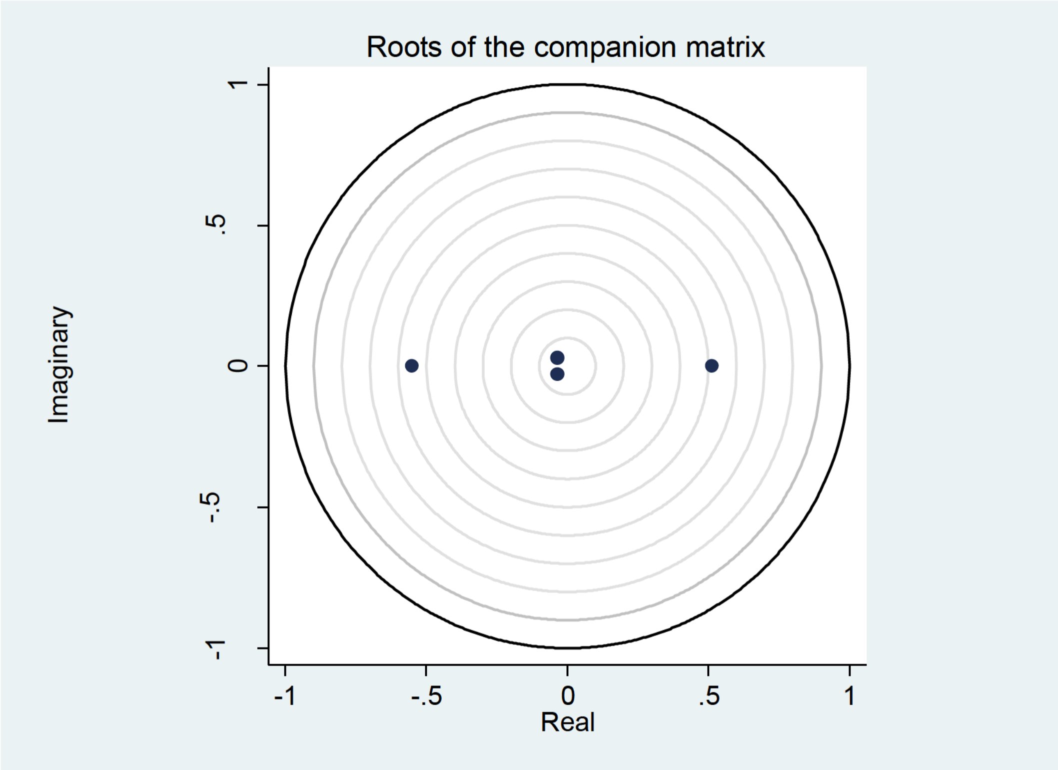


Figure A. 5: Sub-Saharan Africa stability graph

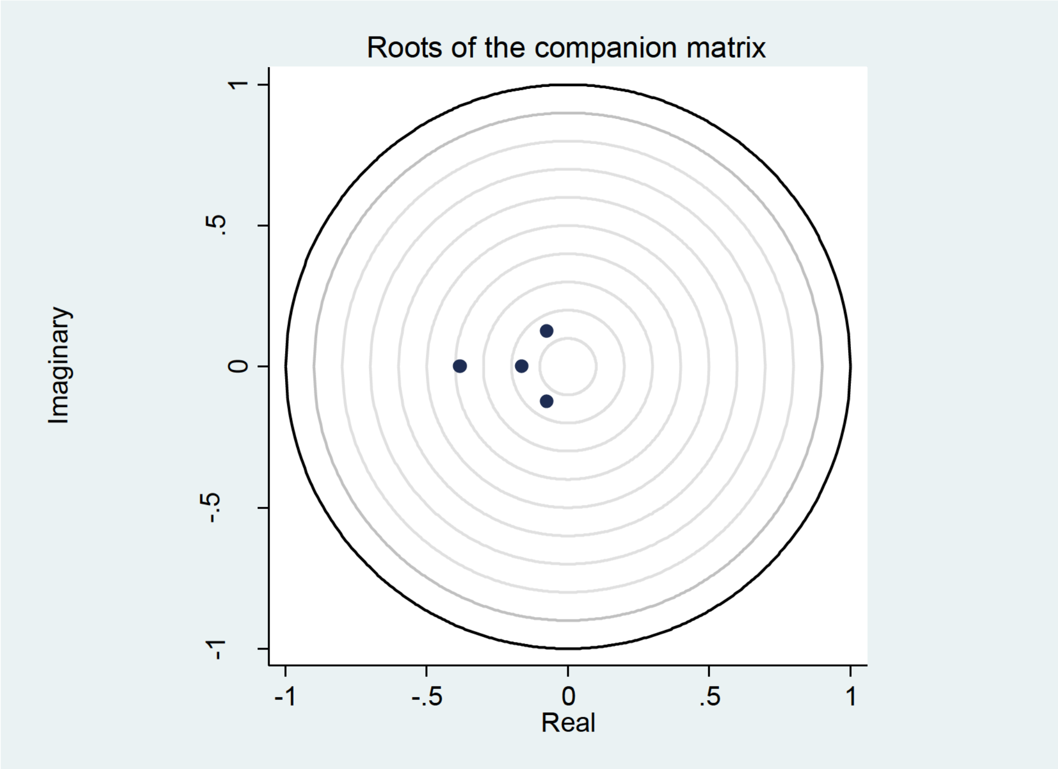


Table B.1 List of countries included in the study

Caribbean and Latin America (33)
Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay and Venezuela
Sub-Saharan Africa (34)
Angola, Benin, Botswana, Cabo Verde, Cameroon, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Kenya, Lesotho, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, Seychelles, South Africa, Sudan, Swaziland, Sao Tome and Principe, Tanzania, Togo, Zambia and Zimbabwe

Asia-Pacific (30)

Australia, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Fiji, Hong Kong SAR, China, India, Indonesia, Japan, Korea, Rep., Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Timor-Leste, Tonga, Vanuatu and Vietnam.

Middle East and North Africa (MENA) (19)

Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates and Yemen, Rep.

References

Abrigo, M. R. M., & Love, I. (2015). *Estimation of panel vector autoregression in stata: A package of programs*. Paper presented at the Panel data conference.

Adewuyi, A. O., & Awodumi, O. B. (2017). Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications. *Renewable and Sustainable Energy Reviews, 69*, 275-291. doi:https://doi.org/10.1016/j.rser.2016.11.178

Ahmad, N., Du, L., Lu, J., Wang, J., Li, H.-Z., & Hashmi, M. Z. (2017). Modelling the CO 2 emissions and economic growth in Croatia: Is there any environmental Kuznets curve? *Energy, 123*, 164-172. doi:10.1016/j.energy.2016.12.106

Ahmed, K., Bhattacharya, M., Shaikh, Z., Ramzan, M., & Ozturk, I. (2017). Emission intensive growth and trade in the era of the Association of Southeast Asian Nations (ASEAN) integration: An empirical investigation from ASEAN-8. *Journal of Cleaner Production, 154*, 530-540. doi:https://doi.org/10.1016/j.jclepro.2017.04.008

Ahmed, K., Rehman, M. U., & Ozturk, I. (2017). What drives carbon dioxide emissions in the long-run? Evidence from selected South Asian Countries. *Renewable and Sustainable Energy Reviews, 70*, 1142-1153. doi:https://doi.org/10.1016/j.rser.2016.12.018

Akarca, A. T., & Long, T. V. (1980). On the relationship between energy and GNP: A reexamination. *Journal of Energy Development 5*(2), 326–331.

Al-mulali, U., & Binti Che Sab, C. N. (2012). The impact of energy consumption and CO2 emission on the economic and financial development in 19 selected countries. *Renewable and Sustainable Energy Reviews, 16*(7), 4365-4369. doi:10.1016/j.rser.2012.05.017

Al-mulali, U., Lee, J. Y. M., Hakim Mohammed, A., & Sheau-Ting, L. (2013). Examining the link between energy consumption, carbon dioxide emission, and economic growth in Latin America and the Caribbean. *Renewable and Sustainable Energy Reviews, 26*(Supplement C), 42-48. doi:https://doi.org/10.1016/j.rser.2013.05.041

Al-Mulali, U., Ozturk, I., & Solarin, S. A. (2016). Investigating the environmental Kuznets curve hypothesis in seven regions: The role of renewable energy. *Ecological Indicators, 67*, 267-282. doi:https://doi.org/10.1016/j.ecolind.2016.02.059

Alam, M. M., Murad, M. W., Noman, A. H. M., & Ozturk, I. (2016). Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators, 70*, 466-479. doi:https://doi.org/10.1016/j.ecolind.2016.06.043

Amano, A. (1993). *Macroeconomic costs and other side-effects of reducing CO2 emissions*.

Anastacio, J. A. R. (2017). Economic growth, CO2 emissions and electric consumption: Is there an environmental Kuznets curve? An empirical study for North America countries. *International Journal of Energy Economics and Policy, 7*(2), 65-71.

Andreoni, V., & Galmarini, S. (2016). Drivers in CO2 emissions variation: A decomposition analysis for 33 world countries. *Energy, 103*(Supplement C), 27-37. doi:https://doi.org/10.1016/j.energy.2016.02.096

Andrews, D. W. K., & Lu, B. (2001). Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models. *Journal of Econometrics, 101*(1), 123-164. doi:https://doi.org/10.1016/S0304-4076(00)00077-4

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

Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is free trade good for the environment? *The American economic review, 91*(4), 877-908.

Apergis, N., & Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators, 52*(Supplement C), 16-22. doi:https://doi.org/10.1016/j.ecolind.2014.11.026

Apergis, N., & Payne, J. E. (2010). Energy consumption and growth in South America: Evidence from a panel error correction model. *Energy Economics, 32*(6), 1421-1426. doi:https://doi.org/10.1016/j.eneco.2010.04.006

Apergis, N., & Payne, J. E. (2015). Renewable energy, output, carbon dioxide emissions, and oil prices: Evidence from South America. *Energy Sources, Part B: Economics, Planning, and Policy, 10*(3), 281-287. doi:10.1080/15567249.2013.853713

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies, 58*(2), 277–297.

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error component models. *Journal of Econometrics, 68*(1), 29–51.

Arouri, M. E. H., Ben Youssef, A., M'Henni, H., & Rault, C. (2012). Energy consumption, economic growth and CO2 emissions in Middle East and North African countries. *Energy Policy, 45*, 342-349. doi:10.1016/j.enpol.2012.02.042

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy Economics, 22*(6), 615-625. doi:https://doi.org/10.1016/S0140-9883(00)00050-5

Aşıcı, A. A. (2013). Economic growth and its impact on environment: A panel data analysis. *Ecological Indicators, 24*, 324-333. doi:https://doi.org/10.1016/j.ecolind.2012.06.019

Awad, A., & Abugamos, H. (2017). Income-carbon emissions nexus for Middle East and North Africa Countries: A semi-parametric approach. *International Journal of Energy Economics and Policy, 7*(2), 152-159.

Ben Jebli, M., Ben Youssef, S., & Ozturk, I. (2016). Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. *Ecological Indicators, 60*, 824-831. doi:https://doi.org/10.1016/j.ecolind.2015.08.031

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics, 87*(1), 115-143. doi:https://doi.org/10.1016/S0304-4076(98)00009-8

Čeh Časni, A., Dumičić, K., & Tica, J. (2016). The panel VAR approach to modelling the housing wealth effect: Evidence from selected European post-transition economies. *Naše gospodarstvo/Our economy, 62*(4). doi:10.1515/ngoe-2016-0021

Cole, M. A. (2006). Does trade liberalization increase national energy use? *Economics Letters, 92*(1), 108-112. doi:https://doi.org/10.1016/j.econlet.2006.01.018

Cong, W., Aidong, W., & Chongqi, W. (2011). Analyze the relationship between energy consumption and economic growth in China. *Energy Procedia, 5*, 974-979. doi:10.1016/j.egypro.2011.03.172

Dagher, L., & Yacoubian, T. (2012). The causal relationship between energy consumption and economic growth in Lebanon. *Energy Policy, 50*, 795-801. doi:10.1016/j.enpol.2012.08.034

Dergiades, T., Martinopoulos, G., & Tsoulfidis, L. (2013). Energy consumption and economic growth: Parametric and non-parametric causality testing for the case of Greece. *Energy Economics, 36*, 686-697. doi:10.1016/j.eneco.2012.11.017

Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics, 49*(4), 431-455. doi:https://doi.org/10.1016/j.ecolecon.2004.02.011

Dogan, E., & Ozturk, I. (2017). The influence of renewable and non-renewable energy consumption and real income on CO2 emissions in the USA: evidence from structural break tests. *Environmental Science and Pollution Research, 24*(11), 10846-10854. doi:10.1007/s11356-017-8786-y

Ertugrul, H. M., Cetin, M., Seker, F., & Dogan, E. (2016). The impact of trade openness on global carbon dioxide emissions: Evidence from the top ten emitters among developing countries. *Ecological Indicators, 67*, 543-555. doi:10.1016/j.ecolind.2016.03.027

Fan, Y., Zhang, X., & Zhu, L. (2010). Estimating the macroeconomic costs of CO2 emission reduction in China based on multi-objective programming. *Advances in Climate Change Research, 1*(1), 27-33. doi:https://doi.org/10.3724/SP.J.1248.2010.00027

Farhani, S., & Ozturk, I. (2015). Causal relationship between CO2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. *Environmental Science and Pollution Research, 22*(20), 15663-15676. doi:10.1007/s11356-015-4767-1

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. doi:https://doi.org/10.1016/j.enpol.2009.11.002

Ghani, G. M. (2012). Does trade liberalization effect energy consumption? *Energy Policy, 43*, 285-290. doi:10.1016/j.enpol.2012.01.005

Giles, J. A., & Williams, C. L. (2000). Export-led growth: a survey of the empirical literature and some non-causality results. Part 1. *The Journal of International Trade & Economic Development, 9*(3), 261-337. doi:10.1080/09638190050086177

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353-377. doi: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. doi:https://doi.org/10.1016/j.enpol.2008.11.012

Hamilton, J. D. (1994). *Time series analysis*. Princeton: Princeton University Press.

Holtz-Eakin, D., & Selden, T. M. (1995). Stoking the fires? CO2 emissions and economic growth. *Journal of Public Economics, 57*(1), 85-101. doi:https://doi.org/10.1016/0047-2727(94)01449-X

Hourcade, J.-C., & Robinson, J. (1996). Mitigating factors: Assessing the costs of reducing GHG emissions. *Energy Policy, 24*(10), 863-873. doi:https://doi.org/10.1016/S0301-4215(96)00071-7

Huang, B.-N., Hwang, M. J., & Yang, C. W. (2008). Causal relationship between energy consumption and GDP growth revisited: A dynamic panel data approach. *Ecological Economics, 67*(1), 41-54. doi:10.1016/j.ecolecon.2007.11.006

Jahangir Alam, M., Ara Begum, I., Buysse, J., & Van Huylenbroeck, G. (2012). Energy consumption, carbon emissions and economic growth nexus in Bangladesh: Cointegration and dynamic causality analysis. *Energy Policy, 45*, 217-225. doi:10.1016/j.enpol.2012.02.022

Jardón, A., Kuik, O., & Tol, R. S. J. (2017). Economic growth and carbon dioxide emissions: An analysis of Latin America and the Caribbean. Atmósfera, 30(2), 87-100. doi:https://doi.org/10.20937/ATM.2017.30.02.02

Kandemir Kocaaslan, O. (2013). The causal link between energy and output growth: Evidence from Markov switching Granger causality. *Energy Policy, 63*, 1196-1206. doi:10.1016/j.enpol.2013.08.086

Karekezi, S. (2002). Poverty and energy in Africa—A brief review. *Energy Policy, 30*(11), 915-919. doi:https://doi.org/10.1016/S0301-4215(02)00047-2

Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. *Economic Modelling, 44*, 97-103. doi:10.1016/j.econmod.2014.10.022

Kaya, Y., & Yokoburi, K. (1997). *Environment, energy, and economy: Strategies for sustainability*. Tokyo: United Nations Univ. Press.

Keho, Y. (2017). Revisiting the income, energy consumption and carbon emissions nexus: New evidence from quantile regression for different country groups. *International Journal of Energy Economics and Policy, 7*(3), 356-363.

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

Kyophilavong, P., Shahbaz, M., Anwar, S., & Masood, S. (2015). The energy-growth nexus in Thailand: Does trade openness boost up energy consumption? *Renewable and Sustainable Energy Reviews, 46*, 265-274. doi:10.1016/j.rser.2015.02.004

Lean, H. H., & Smyth, R. (2010a). Multivariate Granger causality between electricity generation, exports, prices and GDP in Malaysia. *Energy, 35*(9), 3640-3648. doi:https://doi.org/10.1016/j.energy.2010.05.008

Lean, H. H., & Smyth, R. (2010b). On the dynamics of aggregate output, electricity consumption and exports in Malaysia: Evidence from multivariate Granger causality tests. *Applied Energy, 87*(6), 1963-1971. doi:https://doi.org/10.1016/j.apenergy.2009.11.017

Lee, C.-C. (2006). The causality relationship between energy consumption and GDP in G-11 countries revisited. *Energy Policy, 34*(9), 1086-1093. doi:10.1016/j.enpol.2005.04.023

Lee, C.-C., & Chang, C.-P. (2007). Energy consumption and GDP revisited: A panel analysis of developed and developing countries. *Energy Economics, 29*(6), 1206-1223. doi:10.1016/j.eneco.2007.01.001

Love, I., & Zicchino, L. (2006). Financial development and dynamic investment behavior: Evidence from panel VAR. *The Quarterly Review of Economics and Finance, 46*(2), 190-210. doi:10.1016/j.qref.2005.11.007

Lu, W.-C. (2017). Renewable energy, carbon emissions, and economic growth in 24 Asian countries: evidence from panel cointegration analysis. *Environmental Science and Pollution Research, 24*(33), 26006–26015.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics, 22*(1), 3-42.

Lutkepohl, H. (2005). *New introduction to multiple time series analysis*. New York: Springer.

Mahadevan, R., & Asafu-Adjaye, J. (2007). Energy consumption, economic growth and prices: A reassessment using panel VECM for developed and developing countries. *Energy Policy, 35*(4), 2481-2490. doi:https://doi.org/10.1016/j.enpol.2006.08.019

Martinho, V. J. P. D. (2016). Energy consumption across European Union farms: Efficiency in terms of farming output and utilized agricultural area. *Energy, 103*(Supplement C), 543-556. doi:https://doi.org/10.1016/j.energy.2016.03.017

Menyah, K., & Wolde-Rufael, Y. (2010). Energy consumption, pollutant emissions and economic growth in South Africa. *Energy Economics, 32*(6), 1374-1382. doi:https://doi.org/10.1016/j.eneco.2010.08.002

Mirza, F. M., & Kanwal, A. (2017). Energy consumption, carbon emissions and economic growth in Pakistan: Dynamic causality analysis. *Renewable and Sustainable Energy Reviews, 72*(Supplement C), 1233-1240. doi:https://doi.org/10.1016/j.rser.2016.10.081

Mutascu, M. (2016). A bootstrap panel Granger causality analysis of energy consumption and economic growth in the G7 countries. *Renewable and Sustainable Energy Reviews, 63*, 166-171. doi:10.1016/j.rser.2016.05.055

Narayan, P. K., & Narayan, S. (2010). Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. *Energy Policy, 38*(1), 661-666. doi:https://doi.org/10.1016/j.enpol.2009.09.005

Narayan, P. K., & Smyth, R. (2008). Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. *Energy Economics, 30*(5), 2331-2341. doi:10.1016/j.eneco.2007.10.006

Nasreen, S., & Anwar, S. (2014). Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries. *Energy Policy, 69*, 82-91. doi:10.1016/j.enpol.2014.02.009

Odhiambo, N. M. (2009). Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. *Energy Policy, 37*(2), 617-622. doi:https://doi.org/10.1016/j.enpol.2008.09.077

Oh, W., & Lee, K. (2004). Causal relationship between energy consumption and GDP revisited: The case of Korea 1970–1999. *Energy Economics, 26*(1), 51-59. doi:10.1016/s0140-9883(03)00030-6

Omri, A. (2013). CO2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy Economics, 40*, 657-664. doi:10.1016/j.eneco.2013.09.003

Omri, A., Nguyen, D. K., & Rault, C. (2014). Causal interactions between CO2 emissions, FDI, and economic growth: Evidence from dynamic simultaneous-equation models. *Economic Modelling, 42*, 382-389. doi:10.1016/j.econmod.2014.07.026

Ouedraogo, N. S. (2013). Energy consumption and economic growth: Evidence from the economic community of West African States (ECOWAS). *Energy Economics, 36*(Supplement C), 637-647. doi:https://doi.org/10.1016/j.eneco.2012.11.011

Ozcan, B. (2013). The nexus between carbon emissions, energy consumption and economic growth in Middle East countries: A panel data analysis. *Energy Policy, 62*, 1138-1147. doi:10.1016/j.enpol.2013.07.016

Özokcu, S., & Özdemir, Ö. (2017). Economic growth, energy, and environmental Kuznets curve. *Renewable and Sustainable Energy Reviews, 72*, 639-647. doi:10.1016/j.rser.2017.01.059

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

Redding, S. (1999). Dynamic comparative advantage and the welfare effects of trade. *Oxford Economic Papers, 51*(1), 15-39.

Ren, S., Yuan, B., Ma, X., & Chen, X. (2014). International trade, FDI (foreign direct investment) and embodied CO2 emissions: A case study of Chinas industrial sectors. *China Economic Review, 28*, 123-134. doi:10.1016/j.chieco.2014.01.003

Saboori, B., Sulaiman, J., & Mohd, S. (2012). Economic growth and CO2 emissions in Malaysia: A cointegration analysis of the Environmental Kuznets Curve. *Energy Policy, 51*(Supplement C), 184-191. doi:https://doi.org/10.1016/j.enpol.2012.08.065

Sadorsky, P. (2011). Trade and energy consumption in the Middle East. *Energy Economics, 33*(5), 739-749. doi:https://doi.org/10.1016/j.eneco.2010.12.012

Sadorsky, P. (2012). Energy consumption, output and trade in South America. *Energy Economics, 34*(2), 476-488. doi:https://doi.org/10.1016/j.eneco.2011.12.008

Saidi, K., & Hammami, S. (2015). The impact of CO2 emissions and economic growth on energy consumption in 58 countries. *Energy Reports, 1*, 62-70. doi:10.1016/j.egyr.2015.01.003

Salahuddin, M., Alam, K., Ozturk, I., & Sohag, K. (2018). The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. *Renewable and Sustainable Energy Reviews, 81*, 2002-2010. doi:https://doi.org/10.1016/j.rser.2017.06.009

Salahuddin, M., & Gow, J. (2014). Economic growth, energy consumption and CO2 emissions in Gulf Cooperation Council countries. *Energy, 73*(Supplement C), 44-58. doi:https://doi.org/10.1016/j.energy.2014.05.054

Shahbaz, M., Nasreen, S., Ling, C. H., & Sbia, R. (2014). Causality between trade openness and energy consumption: What causes what in high, middle and low income countries. *Energy Policy, 70*, 126-143. doi:10.1016/j.enpol.2014.03.029

Sims, C. (1980). Macroeconomics and reality. *Econometrica, 48*(1), 1-48. doi:doi:10.2307/1912017

Sohag, K., Begum, R. A., Abdullah, S. M. S., & Jaafar, M. (2015). Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia. *Energy, 90*(Part 2), 1497-1507. doi:https://doi.org/10.1016/j.energy.2015.06.101

Soytas, U., & Sari, R. (2009). Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. *Ecological Economics, 68*(6), 1667-1675. doi:10.1016/j.ecolecon.2007.06.014

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

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development, 32*(8), 1419-1439. doi:https://doi.org/10.1016/j.worlddev.2004.03.004

Stern, D. I., & Common, M. S. (2001). Is there an environmental Kuznets curve for sulfur? *Journal of Environmental Economics and Management, 41*(2), 162-178. doi:https://doi.org/10.1006/jeem.2000.1132

Stern, N. (2007). *The economics of climate change: The Stern review*. UK: Cambridge University Press.

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy, 37*(1), 246-253. doi:https://doi.org/10.1016/j.enpol.2008.08.025

Wandji, Y. D. F. (2013). Energy consumption and economic growth: Evidence from Cameroon. *Energy Policy, 61*(Supplement C), 1295-1304. doi:https://doi.org/10.1016/j.enpol.2013.05.115

Wolde-Rufael, Y. (2009). Energy consumption and economic growth: The experience of African countries revisited. *Energy Economics, 31*(2), 217-224. doi:https://doi.org/10.1016/j.eneco.2008.11.005

World Bank. (2016). The world development indicators. Retrieved 15th August, 2017 https://data.worldbank.org/data-catalog/world-development-indicators

Young, A. (1991). Learning by doing and the dynamic effects of international trade. *Quarterly Journal of Economics, 106*(2), 369-405.

Yu, E. S. H., & Hwang, B.-K. (1984). The relationship between energy and GNP: Further results. *Energy Economics, 6*(3), 186-190. doi:https://doi.org/10.1016/0140-9883(84)90015-X

Zhang-wei, L., & Xun-gang, Z. (2012). Study on relationship of energy consumption and economic growth in China. *Physics Procedia, 24*, 313-319. doi:10.1016/j.phpro.2012.02.047

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

Zhang, Y.-J. (2011). Interpreting the dynamic nexus between energy consumption and economic growth: Empirical evidence from Russia. *Energy Policy, 39*(5), 2265-2272. doi:10.1016/j.enpol.2011.01.024

Zhixin, Z., & Xin, R. (2011). Causal relationships between energy consumption and economic growth. *Energy Procedia, 5*, 2065-2071. doi:10.1016/j.egypro.2011.03.356

Research Highlights

- Economic growth has no causal effect on energy consumption.
- Energy consumption uni-directionally causes economic growth.
- A bi-directionally causality exists between carbon emissions and economic growth.
- A causal relationship exists between energy consumption and carbon emissions.
- There is regional variation in the causal relationship between GDP-carbon–energy.