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# Economic growth, $CO_2$ emissions and energy consumption: What causes what and where?

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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 cause 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.



## 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 and 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 and Galmarini, 2016; Sohag et al., 2015).

It is estimated that the overall cost associated with climate change due to carbon emissions is equivalent to about 5% reduction in GDP each year, now and forever and even 20% 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 et al., 2010; Hourcade and 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 and Binti Che Sab, 2012; Asafu-Adjaye, 2000; Mahadevan and Asafu-Adjaye, 2007; Omri, 2013; Omri et al., 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 and Krueger, 1995). Thus, an increase in economic growth will initially increase carbon emissions and eventually falls as economic growth increases. Extensive empirical studies exist

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on the pollution-economic growth nexus with inconsistent findings (see Ahmad et al., 2017; Al-Mulali et al., 2016; Alam et al., 2016; Anastacio, 2017; Apergis and Ozturk, 2015; Awad and Abugamos, 2017; Ben Jebli et al., 2016; Dinda, 2004; Dogan and Ozturk, 2017; Huang et al., 2008; Jardón et al., 2017; Keho, 2017; Narayan and Narayan, 2010; Ozcan, 2013; Özokcu and Özdemir, 2017; Saboori et al., 2012; Stern, 2004; Stern and 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 and Long, 1980; Yu and Hwang, 1984). However, recent studies have been using multivariate models and advanced time series estimation approaches but their findings have been conflicting (see Apergis and Payne, 2010; Asafu-Adjaye, 2000; Cong et al., 2011; Dagher and Yacoubian, 2012; Dergiades et al., 2013; Huang et al., 2008; Kandemir Kocaaslan, 2013; Lee, 2006; Lee and Chang, 2007; Mahadevan and Asafu-Adjaye, 2007; Mutascu, 2016; Narayan and Smyth, 2008; Oh and Lee, 2004; Ozturk, 2010; Zhang-Wei and Xun-Gang, 2012; Zhang, 2011; Zhixin and 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 and 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 et al., 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 et al., 2001; Cole, 2006; Ghani, 2012; Ren et al., 2014; Sadorsky, 2011, 2012; Shahbaz et al., 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)[1] 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 4.1.

## 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 and Ozturk, 2015; Fodha and Zaghdoud, 2010; Holtz-Eakin and 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 and Sari, 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 et al. (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.

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