






ANALYSIS OF THE LINK BETWEEN CO₂ OUTFLOWS, ENERGY UTILIZATION, AND ECONOMIC DEVELOPMENT IN A DEVELOPING COUNTRY: EVIDENCE FROM REPUBLIC OF CONGO

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ABSTRACT

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Developing country.

Developing countries play a number one role in international green-economic development as key holders of green products, and services. Nonetheless, these countries are not sufficiently concerned within the debates on expansion policies, due to their crucial implication in worldwide feasible development. This research aims to analyze the relationship between CO₂ outflows, energy utilization, and economic development in the Republic of Congo as well as the presence of a causative link between the factors by applying the Vector Autoregressive model, including as additional proxies' variables gross-fixed-capital-formation, and rural population. The data cover the period 1985-2018 using cointegration and causality techniques as a methodological approach. The Granger causality test outcomes of cointegrated variables showed that there is one-way Granger causality running from real GDP to Energy utilization, and running from dioxide outflows to real income as well as two-way causative link between Energy utilization and CO₂ outflows in Congo. The results also display a bidirectional causal link between the rural population and Energy utilization. Overall evidence confirms that the practice of energy conservancy approach may lead to a significant and negative effect on economic development.

Contribution/Originality: This study contributes in the existing literature by using modern econometric time series approaches to examine the nexus between CO₂ outflows, energy utilization and economic development. The findings showed that the governments should invest in renewable energy to cut-off CO₂ emissions.

1. INTRODUCTION

The consideration given to ecological issues is increasingly stressing and possesses a vital mediatic space. Indeed, worldwide warming due to the accumulation of Greenhouse Gases (GHGs), the main one being dioxide and is a major threat to human beings, and might harm the economy up to \$ 550 billion in event that politics do not take extreme action (Stern, 2006). Besides, a warming of 2 ° C could convoy to a permanent 4 - 5% decrease in yearly per capita expenditure in Africa, and Asia (William & Boyer, 2000) while the result would be negligible misfortune in greater earnings countries (Nordhaus, 2010). Conferring to World Bank, the changeable atmospheric conditions are likely to reverse hard-won the economic progress (Bank, 2010) and developing nations will pay the

highest price, between 75 and 80% of the costs of harm caused by the changing of atmospheric conditions (Hope, 2009). “Intergovernmental Panel on Climate Change (IPCC, 2007, 2013) estimated that environmental degradation quickening is mainly related to human activities. It should be noted that the analysis of environmental degradation factors has become highly attracting subject in economics research, and numerous of the works focused on verifying the “Kuznets Environmental Curve” hypothesis between economic development, economic indicators and degradation of environment (Gene, Grossman, & Alan B., 1995; Panayotou, 1993; Shafik & Bandyopadhyay, 1992). The interest of CEK is that it postulates the possibility for underdeveloped countries to progress the natural quality as they create, as the standard living of people moves forward and promotes the emergence of an environmental conscience (Bank, 1992). Various Scholars have proposed an accurate review of studies on the link between economic expansion and quality of environment (Dinda, 2004; Nourry, 2007). The diversification of researches confirmed how environmental issues are different from one area or country to another, making the proposed specific results to constrain environmental calamity. Considered a taboo in underdeveloped countries, environmental issues have become increasingly important since the first Rio summit was held in 1992. This realization is all the more pertinent since the increment in CO₂ quickened by economic development in developing regions, during 1990-2000, CO₂ emissions increased by 48% in these regions, and by 81% in the following decade (2000-2010), while in developed countries they decreased by 7% and 1%, respectively, during the same period (UN, 2013).

The Republic of Congo has immense potential hydropower, however, most of it remains unexploited to meet the needs of the national population. Despite the wealthy energy resources in Congo, the percentage of electrification is low, especially in pastoral areas, principally due to the lack of electrification infrastructures. According to the World Bank, only 37% of the population has a connection of energy power and around 2.5 million individuals are leaving without energy access (Bank, 2010).

The civil war in the Republic of Congo (1997-1999), has left the country with the damaged of transmission, and transportation of energy infrastructures, especially in Brazzaville, Niari Pool, and Bouenza departments, which has still not been restored yet. The state is looking to extend and re-establish a network of distribution, but until at that point, wood fuel remains preeminent, precisely in rural zones. In Figure 1, we can see that about 80% of primary energy consumption in Congo is provided by traditional biomass and waste. This highest share shows the utilization of biomass and squanders to meet off-grid warming and cooking needs, generally in pastoral areas. Natural gas, oil, and hydro represent respectively 11%, 7% and 1% U.S. Energy Information Administration (EIA) (U.S. A. E. I., 2014).

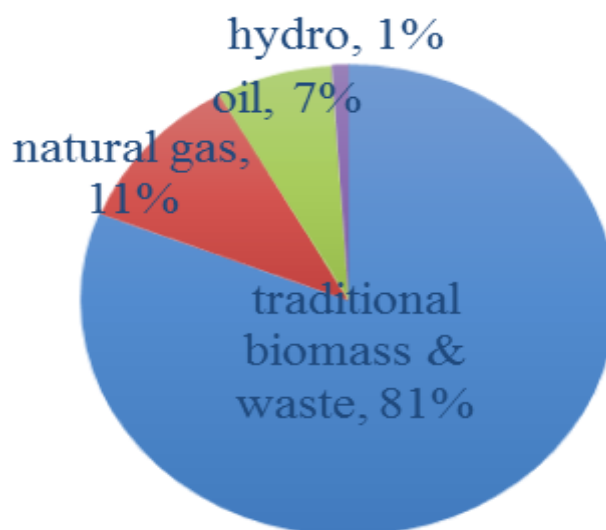


Figure-1. Energy consumption in Congo.

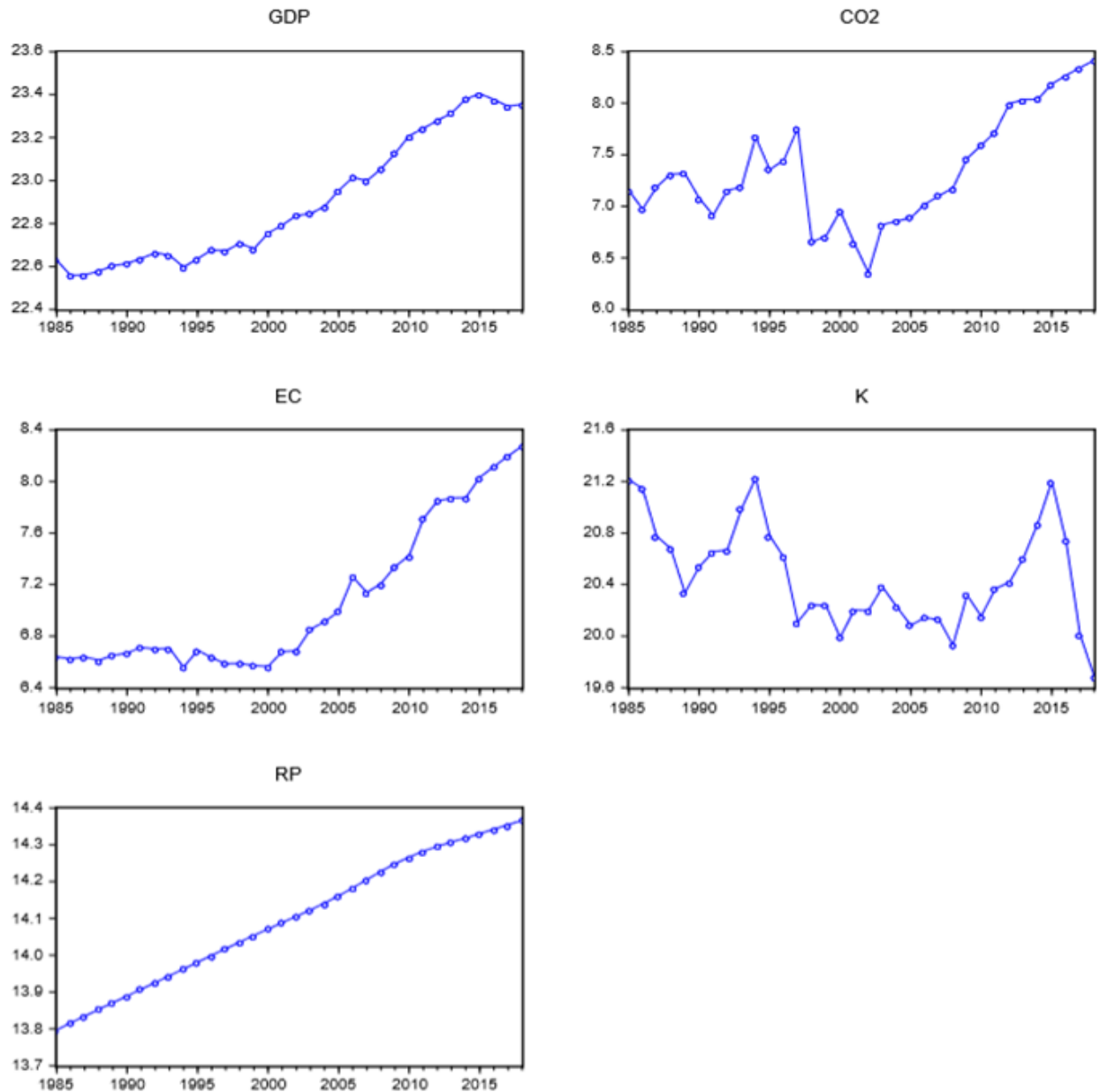


Figure-2. Trends of variables in logarithm.

Figure 2 tracks the evolution of CO₂ outflows in the Republic of Congo. Thus, afterward long-lasting fluctuations, there has been a positive expansion of CO₂ outflows in recent years. However, an analysis of the Congolese long-term economic performance displays that economic development since freedom has a small effect on population living conditions. The basic change or "emergence" of the country will, therefore, require breaks in dynamics of economic development and rebuilding of the mechanical devices, with dangers of basic increment in natural damage. Explaining and understanding the links between macroeconomic factors and atmospheric pollution are the main focus of this work, which aims to examine the nexus between CO₂ outflows, economic development, and energy utilization in the Republic of Congo by proposing structural transformation plans adaptable with climate change and "Sustainable Development Goals".

The empirical findings of this work are very important for resources related to the "green growth" perspective and the ecological economy because the economic theory of growth has a key role to play following the contribution of energy to economic growth, Stern. (2011). We conduct specific research on a single nation using modern econometric time series approaches to gain specific solutions to the problems encountered, because the works done

at the aggregate level do not take into account the environmental, economic, or institutional of all nations. The econometric methods utilized in our work can be expanded to incorporate other economically developing countries or variables, while the empirical results of this investigation may be unique and specialized in the context of the Republic of Congo, due to its particular regulation and advancement characteristics. Thus, it is necessary to notice that "differences in results and mixed evidence may be unavoidable due to differences in institutional characteristics in specific countries, econometric approaches, model specifications, variable selection and time" (Smyth & Narayan, 2014).

The link between GDP and energy-consuming, as well as the nexus between GDP and environmental pollution, has been one of the top subjects of many types of research in recent years, but evidence of empirical results remains ambiguous and cannot be applied to other countries. Therefore, this study is going to fulfill that gap by examining the nexus between CO₂ outflows, Economic development, and energy consumption in the Republic of Congo.

The rest of the article will be organized as: section 2 gives the literature, section 3 presents the methodological approach, section 4 deals with data, section 5 provides an analysis of the findings, and section 6 gives conclusions and recommendations in terms of environmental and economic policy.

2. LITERATURE REVIEW

Economic development is intently linked to the use of energy as greater economic development necessitates higher energy utilization, on the other hand, the more proficient utilize of energy, might lead to a lessening in energy utilization. Energy utilization required better economic development. Thus, a great economic development can be a catalyzer to energy proficiency. As a result, economic development and energy utilization can be mutually determined, but the sense of causality cannot be determined in advance.

A pioneering study of John, Kraft, and Arthur (1978) found a unidirectional causal link ranging from real GDP to energy use for the US from 1947 to 1974. Diverse scholars have taken expiration on this paper to investigate the causative relation between the factors for other nations and completely different time-periods utilizing distinctive econometric procedures. Some have confirmed, others have reversed the results of John et al. (1978). It was from the mid-1990s, and thanks to the development of time series techniques, that several authors became increasingly implicated in the cointegration nexus between income and energy use (Asafu-Adjaye, 2000; Cheng & Lai, 1997; Masih & Masih, 1996; Yang, 2000).

Similarly, abundant literature has explored the sense of causality between output and pollution, and this has given rise to hypothesis of "Environmental Kuznets Curve (EKC)", which hypothesizes that the level of degradation of environment increases with economic growth, but that from a certain level it starts to fall. This design, materialized by the curved structure in form of an upturned "U", was deduced from Kuznets' work which deals with the causal links between income inequality and the growth level of a specific country. This has inspired many economists who have sought to examine whether economic expansion is continuously leading by environmental degradation, through the examination of the nexus between environmental factors, and those of economic development. Moreover, literature review allows us to distinguish work that confirms the EKC hypothesis (Gene et al., 1995; Selden & Song, 1994) and those that do not verify it Friedl and Getzner (2003); Shafik and Bandyopadhyay (1992); Torras and Boyce (1998).

Diverse methods have been utilized to find out the nexus between energy use, economic development and/or CO₂ outflows. Some have adopted the approach in terms of correlation and others in terms of causality, sometimes both.

Using Engle and Granger's procedure of cointegration, Nachane, Nadkarni, and Karnik (1988) found a long-run link between energy use and economic development for eleven economically developing and five developed

nations. Applying Johansen's methods, [Masih and Masih \(1996\)](#) on a multitude of papers related to six Asian nations namely India, Indonesia, Malaysia, Pakistan, Philippines, and Singapore yield the following results:

- there was a long-run link between energy utilization and real GDP in the context of Indonesia India, and Pakistan; that in India energy utilization "causes" GDP; GDP "causes" energy use in Indonesia; there was a two-way causative link between Economic growth and energy consumption in Pakistan; for the remaining three nations (Malaysia, Singapore, and the Philippines), the adoption of VAR highlights the non-existence of a causal link between energy use and real GDP.

[Yang \(2000\)](#) studying the Taiwanese economy finds a bidirectional causal between energy consumption and economic growth over the period 1954-1997. Integrating employment into the production function and applying the Granger test, [Anjum and Mohammad \(2001\)](#) posits that economic development induces energy utilization in Pakistan.

In the context of a multivariate modeling integrating capital, labor force, energy use and real GDP for Korea during 1970 -1999, and using an error correction modeling, [Oh and Lee \(2004\)](#) found out a two-way long - term causality between economic growth and energy use and unidirectional short-run energy utilize toward economic development.

[Ghali and El-Sakka \(2004\)](#) have also found for Canada a two - way causal between energy utilization and economic development. In various works conducted in China, [Shiu and Lam \(2004\)](#); [Wang, Zhou, Zhou, and Wang \(2011\)](#) highlighted a one-way causal linkage from energy utilization toward economic development while ([Zhang & Cheng, 2009](#)) found an opposite finding. Similarly, in the case of the United States, [Bowden and Payne \(2009\)](#) found a unidirectional causal-link between energy utilization and economic development, [Payne \(2011b\)](#) indicated respectively the presence of unidirectional causality between consumption of energy (oil) and GDP on the one hand and a causal-link between GDP and energy utilize (natural gas) on the other. Nevertheless, [Payne. \(2011a\)](#) indicates an absence of a causal link between energy utilization (coal) as well as [Payne.. and Taylor \(2010\)](#) for the case of nuclear energy utilize and GDP.

[Chiou-Wei, Chen, and Zhu \(2008\)](#); [Tsani \(2010\)](#) also find unidirectional causality for the respective cases of Hong Kong and Taiwan, and Greece, from energy utilization to GDP. similarly, [Sa'ad \(2010\)](#) finds a unidirectional causal and, cointegration among income and energy in a work from Nigeria. However, [Apergis, Payne, Menyah, and Wolde-Rufael \(2010\)](#) using variables such as labor, capital formation, GDP and renewable energy consumption, have shown that in Eurasia there was two - way linkage relationship between utilization of renewable energy and real income (GDP). They confirmed the same result for OECD countries in 2010. [Lim and Yoo \(2012\)](#) find a bidirectional causal between real output and energy utilization (natural gas) in Korea. [Wang., Li, Fang, and Zhou \(2016\)](#) on their work "The relationship between economic growth, energy consumption, and CO₂ emissions: Empirical evidence from China", for the period 1990 to 2012, adopting cointegration, temporal dynamic and causality methods. The results revealed that variables used were cointegrated in the long - run, a bidirectional causal between energy utilization and GDP, and a unidirectional causal was also found from energy consumption to carbon dioxide (CO₂) outflows. [Wolde-Rufael \(2012\)](#) indicated a lack of causality link between utilization of energy (nuclear) and real output (GDP) in Taiwan.

Numerous studies concerning sub-Saharan Africa were also conducted by researchers. For instance, [Bartleet and Gounder \(2010\)](#) have highlighted the existence of a causal link from economic growth towards energy utilization for New Zealand. Similarly, [Mensah \(2014\)](#) displayed a one - way causal from output to energy utilization for Ghana, but for Nigeria, the linkage was showed from economic development to dioxide outflows. [Ouédraogo \(2010\)](#) and [Kouakou \(2011\)](#) respectively revealed a bidirectional causal between real income and energy utilization for Burkina Faso and Côte d'Ivoire.

Other authors have decomposed GDP into its main components to analyze the link between energy use and economic development. Thus, [Kebede, Kagochi, and Jolly \(2010\)](#) found that energy demand is driven by growth in agriculture share of GDP while the relationship is opposite when it comes to industry share of GDP.

Studying a panel of twenty-four countries in sub-Saharan Africa, [Mehdi, Slim, and Ilhan \(2015\)](#) found a causal link from trade (exports or imports) to the consumption of renewable energies.

Finally, applying the Granger causality test for the same country, some authors have obtained divergent results because of the differences between study periods and the lack of consideration of certain political changes, economic conditions in these countries, the functional form, without calling into question the methodology as a whole. So, in their “study on CO₂ emissions, economic growth, energy consumption, and foreign direct investment: causality analysis for sub-Saharan Africa”, [Kiviyiro and Arminen \(2014\)](#) found a linkage from energy use to economic development in Republic of Congo, while [Odhiambo, 2010](#) identifies a link in the opposite direction. Similarly, for Kenya, [Odhiambo \(2010\)](#); [Mensah \(2014\)](#) indicated a link of energy utilization to economic development, while [\(Kiviyiro & Arminen, 2014\)](#) showed no significant. For a study on a single country, [Owusu \(2018\)](#) focused his work on “Investigating the multivariate Granger causality between energy consumption, economic growth and CO₂ emissions in Ghana” accounting for 1960 - 2015 and adopted Granger causality and cointegration techniques. The empirical analysis showed that series were cointegrated and causality between energy utilization and carbon dioxide (CO₂) emissions were displayed. Similarly, [Victor, Emir, and Sarkodie \(2019\)](#) found a unidirectional causal from energy utilization to economic development on their work titled “Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa”. The results also depicted an inverse link between energy utilization and economic development in a long - run and confirmed the hypothesis, energy - led - growth.

3. METHODOLOGY

To test for causality we utilized the modified version of Granger's causality, [Toda and Yamamoto \(1995\)](#). Toda-Yamamoto (T-Y) approach uses a standard Autoregressive Vector (VAR) model at a variable level and their differences that consider long-run information which in many cases is ignoring in systems requiring early differentiation and pre bleaching [\(Clarke & Mirza, 2006\)](#). That approach employs a modified Wald test (MWALD) to limit VAR (k) parameters, where k denotes the system lag length. The Toda -Yamamoto procedure, basic ideas are to increase order (k) and greatest integration order, i.e. dmax. After that, a (k + dmax) order of VAR will be assessed and the coefficients of the final slack vectors dmax are overlooked. To apply T-Y version of Granger non-causality, for VAR (4) with k = 2 and dmax = 2, we estimated equation & system of equations as below:

$$z_t = \delta_z + \psi_1 z_{t-1} + \psi_2 z_{t-2} + \dots + \psi_p z_{t-p} + \dots + \psi_{p+d} z_{t-p-d} + \varepsilon_{zt} \quad (1)$$

In [Equation 1](#), we estimated the model which led us to come up with the second [Equation 2](#) and test different hypotheses.

Where, $Z_t = (\ln GDP_t, \ln CO_2_t, \ln EC_t, \ln K_t, \text{ and } \ln RP_t)$, δ_z denotes a constant vector (5 by 1), $\psi_{1,2,\dots,p+d}$ are 5 by 5 matrices of coefficients, ε_{zt} is terms of error with constant variance and zero mean and, $(\ln GDP_t, \ln CO_2_t, \ln EC_t, \ln K_t, \text{ and } \ln RP_t)$ denote respectively the logarithm of real output (GDP), CO₂ outflows, energy utilization, real gross-fixed-capital-formation, and rural population.

$$\begin{bmatrix} \ln GDP_t \\ \ln CO2_t \\ \ln EC_t \\ \ln K_t \\ \ln RP_t \end{bmatrix} = \delta_2 + \psi_1 \begin{bmatrix} \ln GDP_{t-1} \\ \ln CO2_{t-1} \\ \ln EC_{t-1} \\ \ln K_{t-1} \\ \ln RP_{t-1} \end{bmatrix} + \psi_2 \begin{bmatrix} \ln GDP_{t-2} \\ \ln CO2_{t-2} \\ \ln EC_{t-2} \\ \ln K_{t-2} \\ \ln RP_{t-2} \end{bmatrix} + \psi_3 \begin{bmatrix} \ln GDP_{t-3} \\ \ln CO2_{t-3} \\ \ln EC_{t-3} \\ \ln K_{t-3} \\ \ln RP_{t-3} \end{bmatrix} + \psi_4 \begin{bmatrix} \ln GDP_{t-4} \\ \ln CO2_{t-4} \\ \ln EC_{t-4} \\ \ln K_{t-4} \\ \ln RP_{t-4} \end{bmatrix} + \begin{bmatrix} \varepsilon \ln GDP_t \\ \varepsilon \ln CO2_t \\ \varepsilon \ln EC_t \\ \varepsilon \ln K_t \\ \varepsilon \ln RP_t \end{bmatrix} \quad (2)$$

In Equation 2 we are going to test the hypothesis that CO2 outflows ($\ln CO2_t$) Granger causes economic development ($\ln GDP_t$), in hypothesis as follows: $H_0 = \psi_{12}^1 = 0$, where ψ_{12}^1 denotes the coefficient of CO2 factor ($\ln CO2_t$) in equation one of the system Equation 2. likewise, the reversed causality can also be tested from economic development ($\ln GDP_t$) to CO2 ($\ln CO2_t$ in the hypothesis below: $H_0 = \psi_{21}^1 = 0$, where ψ_{21}^1 represents the coefficient of the economic development factor in equation two of the system Equation 2.

The same process will be conducted to find out the Granger causality from energy utilization ($\ln EC_t$) to economic development and from real gross-fixed-capital-formation ($\ln K_t$) to economic development like the hypothesis: $H_0 = \psi_{13}^1 = \psi_{14}^1 = 0$, where ψ_{13}^1 and ψ_{14}^1 are respectively the coefficients of energy consumption ($\ln EC_t$) and gross-fixed-capital-formation ($\ln K_t$) in the first equation of the system. The opposite causality can be tested in the hypothesis:

$H_0 = \psi_{31}^1 = \psi_{41}^1 = 0$, with ψ_{31}^1 and ψ_{41}^1 the coefficients of economic development in the third and fourth equations from the system in Equation 2.

4. DATA

The economic development model employed in this paper makes it possible to choose the factors. The neoclassical approach of economic development considered only two factors in production function namely labor and capital as main factors of production although, Solow (1956); Swan (1956) added exogenous factor "technology" to the production function. The base of this growth approach had not included natural resources, which generally occur in final stocks and flows of economically developing countries like the Republic of Congo.

The economic development of modernized perception is that the interrelationships between capital aggregation, natural debasement, and other development factors have a significant role to play in growth theory (Xepapadeas, 2005). Nevertheless, few studies have examined the causal links between economic development, CO₂ outflows, and energy consumption, including capital stock and labor force measures in their work as additional variables.¹

Data on economic development (GDP) and real gross-fixed-capital-formation (K) (both constant in 2010, US dollar), energy utilization (EC) (kt, of standard coal equivalent), rural population (RP) and CO₂ (CO2) (kt) emissions were used. All data cover the period 1985-2018 are employed, using the natural logarithm and were extracted from U.S. Energy Information Administration (EIA) and World Bank. The capital stock data were not available to cover a long period in the context of the Republic of Congo. Thus, the change in gross-fixed-capital-formation has been

¹In previous studies, some researchers have utilized the labor force as an intermediary for 'labor'. In any case, the data are not accessible to cover a longer period in the context of Congo.

considered as a reliable factor for capital stock, expecting a steady deterioration rate. Data on gross fixed capital formation in Congo are available only from 1985 to 2018. Earlier works (Nepal & Pajja, 2019; Soytaş & Sari, 2003; Zhang & Cheng, 2009) have also adopted gross fixed capital formation in their studies as a capital stock proxy. The urban population, total population, and labor force are variables often employed in the literature on the nexus between CO₂ outflows, real GDP and, energy utilization (Chiou-Wei et al., 2008; Ugur, Sari, & Ewing, 2007; Zhang & Cheng, 2009). In spite of that, no previous research has employed a rural population in a study of the interaction between CO₂ outflows, energy consumption and real GDP in the Republic of Congo context.

The nexus between economic development, and population growth is at the heart of classical economic growth theory, created more than 200 years by David (1817); Malthus (1798); Richard and Ghazi (1978). Nevertheless, the point views are shifted and stay far from being true in the case that population growth encourages or ruins economic development. In this paper, we are attending to examine the interface utilizing the rural population without divergence between workers and unemployed people. According to the neoclassical development hypothesis, we do not look at the impacts of population transformation whereas, knowing that the rate of dependence has been lightly declined in Congo. Besides, dependence and aging of the population are not anticipated to essentially hinder the pace of economic development in underdeveloped (Bloom, Canning, & Fink, 2010). Our choice is focused on CO₂ outflows (carbon dioxide) because is the dominant conservatory gas produced by activities related to human daily life. CO₂ outflows (from deforestation, manufacturing, use of fossil fuels, biomass decomposition) and others are considered to be larger or direct sources of Greenhouses Gas computing for about 75% of total greenhouse gas outflows global scale (IPCC, 2014).

Many of the previous academic researchers have considered per capita estimation in their work. However, employing per capita estimation, the factor is reduced as reported in empirical findings of a specific state (Ugur et al., 2007; Zhang & Cheng, 2009). Therefore, we are using total data in this study. Friedl and Getzner (2003) have moreover recommended using "total" rather per capita outflows by supporting "International Climate Agreements, Kyoto Protocol and Paris" that reduce the total level of emissions.

5. EMPIRICAL RESULTS

This section attends to report unit root and causality tests. The diverse unit root tests have been taken to explore not only the time - series maximum order integration but, also to check the unit-roots presence of different variables. The procedures of the causality test have been applied concerning whether the series were cointegrated or not in either irrational order. The causality test was taken afterward VAR maximum lag length order selection and following by some relevant diagnostic tests to verify the robustness of the V.A.R model.

5.1. Unit Root Tests

Inline to test Toda-Yamamoto (T-Y) causality, unit root tests must be taken to determine the maximum order of variables integrated.

The relevance and applicability of the T-Y test can be applied in the absence or existence of unit root. We used three different types of unit root tests such as Augmented Dickey-Fuller (A.D.F.), Phillips-Perron (P.P.) and Kwiatkowski-Phillips-Schmidt-Shin (K.P.S.S). Unit test results are shown in Table 1.

Therefore, the integration order of all factors does not seem to exceed 2, which enables us to define the maximum order equal 2.

Table-1. Unit root test results.

Integration Order	Variables	A.D.F.	P.P.	K.P.S.S.
Level.				
Intercept	GDP	0.741633	0.618002	0.632346*
	CO2	-0.872189	-0.783005	0.392459**
	EC	1.836011	2.068429	0.581894**
	K	-2.103612	-2.361021	0.357483***
	RP	-1.777209	-1.917000	0.679359**
Intercept & Trend	GDP	-2.669737	-2.633070	0.182246*
	CO2	-1.689324	-1.638067	0.167628**
	EC	-1.045707	-0.949534	0.203128**
	K	-2.260815	-2.559192	0.121997***
	RP	1.856297	0.164173	0.121187**
First difference				
Intercept	GDP	-4.976284*	-4.978298*	0.365980*
	CO2	-6.806123*	-6.850538*	0.218053
	EC	-5.427686*	-5.527614*	0.542792
	K	-4.543951*	-4.529760*	0.071357
	RP	0.174514	-1.122090	0.323297
Intercept & Trend	GDP	-4.848347**	-4.840668*	0.149581*
	CO2	-6.866131*	-7.009387*	0.073694
	EC	-6.757213*	-6.757213*	0.055978
	K	-4.457606**	-4.441934**	0.072038
	RP	-1.909517	-1.631222	0.125230
Second difference				
Intercept	RP	-4.127474**	-2.221056	0.114318
Intercept & Trend	RP	-4.462515*	-2.258097	0.061233

Note: Asterisks *, **, and *** indicate 1%, 5%, and 10% significances, respectively. Unit root tests (with exception of K.P.S.S.) used in this research support the hypothesis null that factors have unit root opposite of alternative. The null hypothesis of K.P.S.S in the contradictory shows that variables are stationary.

Table-2. VAR Lag order selection criteria.

Lag	Log(L)	L.R.	F.P.E.	A.I.C.	S.C.	H.Q.
0	60.83292	NA	1.66e-08	-3.722195	-3.488662	-3.647485
1	255.7853	311.9239	2.05e-13	-15.05236	-13.65116	-14.60410
2	309.1844	67.63879	3.60e-14	-16.94563*	-14.37676	-16.12382
3	381.2645	67.27482*	2.41e-15*	-20.08430	-16.34778	-18.88896*
4	451.6513	42.23204	3.37e-16	-23.11008	-18.20589*	-21.54119

Note: * Denotes lag order selected by the criterion; L.R: sequential modified LR test statistic (each test at 5% level); F.P.E: Final prediction error; A.I.C: Akaike information criterion; S.C: Schwarz information criterion; H.Q: Hannan-Quinn information criterion.

Table-3. Results of diagnostic tests.

Equations	Adj. R ²	J. B	B.G	ARCH - Test	White - test	Ramsey -Test
GDP	0.984457	1.763438	1.315604	0.836829 [4]	1.056029	0.371932
CO2	0.737459	5.834377	1.604950	0.100850 [1]	0.733977	0.310563
EC	0.968858	2.204724	1.621104	0.255669 [4]	2.334206	0.505088
K	0.526781	0.229884	0.490052	0.236545 [1]	2.098531	0.929974
RP	0.958575	0.630442	1.899894	1.568484 [3]	1.888326	-2.723408 *

The Jarque-Bera (J.B) test is normal. B-G test shows that the series does not have serial correlation until the lag selected. The ARCH LM test asserts that there are no ARCHs up to the lag selected. Lengths of lag are elected by Schwarz information criterion and displayed in brackets. The white test indicated that there is no presence of heteroscedasticity. Null of Ramsey RESET shows there is no existence of specific errors with a single term utilizing L.R. Asterisks * denotes the significance level at 5%.

5.2. Results of Granger Causality Long-Run Test

The results in Table 1 showed and confirmed that series employed in this investigation are not statistically integrating at identical order, therefore, the T-Y approach for testing Granger causality appeared as a fitted technique. Nonetheless, the V.A.R model lag-length optimum should be determined first and then to conduct the T-Y procedure.

There are 5 diverse lag-length-criteria to determine the optimum of lag-length such as Akaike information criterion (AIC), sequential - modified - Likelihood - ratio test statistic (LR), Schwarz-information criterion (SC), Final-prediction-error (FPE), and Hannan-Quinn-information-criterion (HQ). Lag-length-selection criteria of V.A.R results are reported in - Table 2.

LR, FPE, and HQ suggested the lag length of 3, while, AIC indicated VAR lag length optimum of 2 and SC suggested the Lag length of 4. However, the results from the diagnostic test for VAR imply that Augmented V.A.R (5) (p + d= 5) has not behaved well when checking the model stability.

Thus, we decided to conduct an estimation of Augmented “VAR (4); (p + d = 4)”, with $Z_t = (\ln GDP_t, \ln CO2_t,$

$\ln EC_t, \ln K_t,$ and $\ln RP_t)$ and employ numerous diagnostic tests for verifying the stability of the model, V.A.R (4).

Diagnostic test results are presented in Table 3.

The adjusted R² values are higher and lightly low than un-adjusted - R² values, indicating that the supplementary power of the equations may not include the use of a larger number of explanatory variables for the sample size.² Nevertheless, if Lag-Length is not properly selected in restricted sampling, there may be a trend to adjust the model VAR and, these models on adjusted indicate an expanded rate in the inaccurate positive Granger causality conclusions (Bruns & Stern, 2019). The outcome of the J. B test indicates that the residuals assume to have normality. The tests of Lagrange multiplier indicate the absence of autoregressive-conditional-heteroscedasticity (ARCH - L.M). The white test shows no heteroskedasticity in equations. The Breusch-Godfrey test results indicate the absence of serial - correlation in all of the equations at a significance - level 5%.

However, the results of Ramsey - RESET tests show that the parameter of Rural Population (RP) series seems unstable whereas the squared tests of CUSUM and CUSUM may not confirm the violation of stability. Therefore, AR - roots are in the unit circle and confirm that VAR (4) is perfectly stable.

Table-4. Causality test results.

Variables	GDP	CO2	EC	K	RP
GDP	-	32.64214 (0.0000) *	5.72521 (0.4209)	7.526192 (0.1106)	0.187595 (0.9959)
CO2	4.207412 (0.3787)	-	13.84210 (0.0078) *	8.891410 (0.0339) **	2.164263 (0.7056)
EC	11.45012 (0.0219) **	12.31665 (0.0151) **	-	30.09577 (0.0000) *	17.40058 (0.0016) *
K	7.018792 (0.1349)	4.40507 (0.61203)	6.095474 (0.1921)	-	2.898134 (0.5750)
RP	2.682348 (0.4828)	26.43818 (0.0000) *	22.19689 (0.0002) *	6.211805 (0.1839)	-

Note: Asterisks *, and ** indicate respectively significance at 1% and 5%, significance implied that column factor Granger affects row factor.

² Differently, we have run elective VAR symptomatic tests to lessening the number of parameters. The comes about do not recommend overfitting and can be given upon ask. The work of Bruns and Stern (2019) suggested a meta-regression modeling expressly regulates for overfitting predisposition in the inference of Granger causality.

In [Table 4](#), we proceeded to Granger causality tests satisfying diagnostics VAR (4). Another method modeling could be done by performing and comparing the results of a cointegration limit test approach based on the Autoregressive distributed Lag (ARDL) if the variables have been integrating into distinct orders ((I (0)) or I (1)) as previous works.

Nevertheless, the cointegration test has suggested that there is the presence of a cointegration equation that has given us robustness control to proceed to T - Y Granger's causality test.³ The results indicate that there is a one-way Granger causality running from Economic Development (GDP) to energy utilization (EC) at a 5% level of significance in Congo. In other words, an increment in Economic Development (GDP) will lead to an augmentation into energy consumption, although no other way around. This result confirms the findings found in some previous works ([Bartleet & Gounder, 2010](#); [John et al., 1978](#); [Masih & Masih, 1996](#); [Mensah, 2014](#); [Owusu, 2018](#); [Panayotou, 1993](#)). While, the opposite causal link has been found by [Kiviyiro and Arminen \(2014\)](#); [Tsani \(2010\)](#) ; [Victor et al. \(2019\)](#). However, an insignificant result was also observed by [Wolde-Rufael \(2012\)](#). The finding suggests that Energy preservation approaches such as enhancements of energy productivity ought to not delay economic development in the context of Congo, as energy utilization incorporates a long-term unbiased causal impact on economic development. The comparison to worldwide and territorial information illustrates not as it were the insufficiencies in terms of getting to energy and cutting-edge energy administrations in Congo, although too a huge intensity of energy emerges from wasteful energy utilization patterns.

The developing country like Congo has been engaged in a Reduction of Emissions related to Deforestation and Forest Degradation (REDD), with the inclusion of Sustainable Management of forests, conserving biodiversity and increasing carbon stocks just in 2016 and the policies of energy conservancy are empowered to compensate for the imbalance between the expanding need for energy and finite energy production. The REDD program supports the development of market-based energy proficiency administrations for the public and private sectors, supports the improvement and the achievement of progressed biomass stoves for country families ([Redd of the Republic of Congo, 2016](#)). Increased society understanding of the profits of demand management and improved energy efficiency is also desirable. Similarly, there is also a need for an institutional framework and coherent policies in the areas of environment and energy to promote energy production in the state.

Other significant results of the causality tests revealed that there is one-way causality from CO₂ outflows to economic development (DGP), indicating that the highest CO₂ outflows will lead to a tremendous increase in economic development. This finding is consistent with the one observed by [Mirza and Kanwal \(2017\)](#). While, [Loesse, Esso, and Yaya \(2016\)](#) have found a bidirectional causal link. The reasoning behind Granger's GDP-generating CO₂ outflows could be assigned to the over-dependence of commercial and residential sectors on the high level of energy productivity from CO₂ sources in Congo. The majority of the Congolese people still rely on biomass being their primary energy sources for heating, and cooking, utilizing either classical free -cost sources or "three-stone hearths" ([Redd of the Republic of Congo, 2016](#)). These are usually inefficient concerning energy consumption and emit hurtful emissions affecting the environment and human health. The gradualness transition to renewable energy, avoidance of affecting energy consumption, will cut down CO₂ outflows without damaging economic development. Nonetheless, the transformation to green economic development strategies will require adjustment between environmental and energy policies, taking into account the influences of investment in social capital and people in developing countries like Congo. In [Table 4](#), Granger causality test results also revealed that there is a two-way causal link between energy consumption and CO₂ emissions. Other results indicate a one-way causal relationship running from gross-fixed capital-formation to CO₂ and energy consumption respectively, as well as a two-way causal link between energy consumption and rural population. This confirms that the rural

³ The outcomes of the cointegration test besides the strength checking for the solidness of long-term interactions may be given on a request although not detailed within the paper.

population in Congo depends highly on biomass energy as shown in Figure 1. The result suggests that CO₂ outflows have a positive influence on GDP and energy utilization of Congo which implies that CO₂ emissions level contribute more to the atmosphere and lead to higher economic development and energy utilization. The findings also show that CO₂ outflows and energy consumption influence each other.

5.3. Generalized Impulse Response

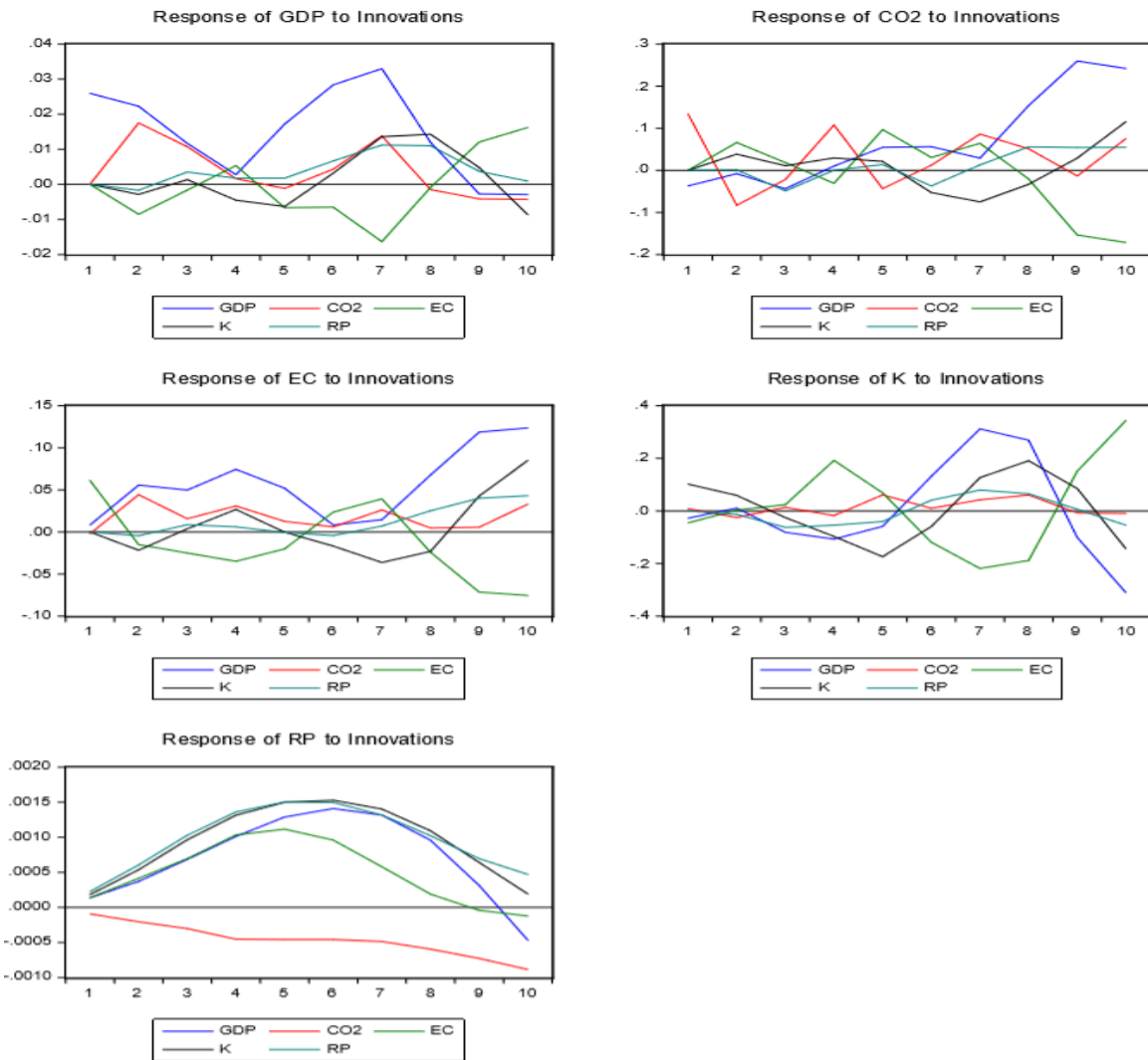


Figure-3. Generalized-impulse-response -of GDP, CO₂, EC, K & RP to Innovation.

The T-Y procedure is a possible way to test the long-term Granger causality link among series. In any case, the test comes about do not consider how factors in common react to advancements in other factors. Inline to look at how stun of each factor influences another one and, how the impact endures in the short run, we have utilized generalized motivation reaction (Mirza & Kanwal, 2017) in which conquered orthogonality issues in conventional out-of-sampling of Granger causality test. The results of generalized-impulse-response are presented in Figure 3.

In Figure 3, the stun in one of the four factors (GDP, CO₂, EC, and K) has a positive and significant introductory effects on the others, and the effects kick the bucket off over skylines. It is necessary to notice that the beginning effect of energy utilization on CO₂ outflows not as it was is somewhat greater, although it also endures longer than the others (Economic development and Gross fixed capital).

Other significant results showed that the stun in economic development has greater starting effects on energy consumption than the others and, final effects or may be smaller than those in gross-fixed-capital and CO₂ outflows.

Thus, the outcomes of the impulse-response test bolster that of the Granger-causality-test. It is curiously to note that the effects of RP stuns on GDP, CO₂, and EC are expanded over the skylines, even though beginning effects are not significant. It suggests that the overall rural population has positive impacts on energy consumption, economic development and CO₂ outflows in Congo.

6. CONCLUSION AND SUGGESTIONS

The changing climate and energy consumption have become inevitable challenges in many countries. This growing concern has brought importance to both energy use and economic development to the forefront of widest energy usage debates as well as CO₂ emissions reduction. Applying the T-Y method and generalized-impulse-response, this study explores the nexus between CO₂ outflows, Real Output (GDP), and Energy utilization in Congo from 1985-2018, in multivariate modeling including gross-fixed-capital-formation, and rural population to fill the current gap in literature. The findings reveal that there is a one-way causal link running from Economic development (GDP) to Energy utilization (EC) and running from CO₂ outflows to economic development as well as a two-way causality link between Energy utilization and CO₂ outflows in Congo. The results also highlight that there is a two-way causal link between Energy utilization and rural population. Overall evidence confirms that the implementation of the energy conservancy program may induce a significant and negative effect on economic development.

Given the importance of primary energy consumption in the habits of Congolese households and businesses, some recommendations emerge at the end of this study.

The State should not only play a critical role in the regulation and supply of energy to avoid an uncontrolled increase in prices that could lead to higher production costs for companies, an acceleration of inflation and the reduction of household welfare as well as shortages harmful to economic activity. It should also commit to promote rational use of energy, encourage people to reforest, reduce the uncontrolled felling of trees, diversify sources of energy productivity and encourage the use of renewable energy resources, especially biofuels. Measures to reduce the share of biomass in energy consumption should be encouraged as the use of this form of energy poses a real threat to the environment.

Further research can include other factors such as FDI, trade openness (Export and Import). Finally, future research can also extend the study once the data are available to cover a long period.

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