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Research paper

Are renewable energy and nonrenewable energy substitutes or complementary for economic growth and environment quality: an international evidence

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Abstract

The aim of this paper is to examine the interrelationships between renewable energy, nonrenewable energy consumption, CO2 emissions and economic growth. It considers substitution and complementarity between renewable and nonrenewable energies, by means of dynamic panel data models in simultaneous-equations for a global panel consisting of 107 countries. The time component of our dataset is 2000–2017 inclusive. To make the panel data analysis more homogenous, we also investigate this interrelationship for a number of sub-panels, which are constructed based on the income level of countries. In this way, we end up with three income panels; namely, high income, middle income, and low income panels. In the empirical part, we draw on the growth theory and augment the classical growth model, which consists of capital stock, labor force and inflation, with CO2 emissions and energy. Generally, we show mixed results about the interrelationship between renewable energy, non-renewable energy consumption, CO2 emissions and economic growth.

Keywords: *Renewable Energy; Nonrenewable Energy Consumption; CO2 Emissions; Economic Growth; Dynamic Panel Data Analysis.*

1. Introduction

The depletion of natural resources, increasing climate change and the worsening environment have set alarm bells ringing and are part of policies aimed at combating climate change. In fact, the great part of these emissions resides, not only in the greenhouse gas, but also in the production and consumption of energies bad infrastructures Energy has always played a major and vital role for man and human societies. Human behavior is, however, subject to its availability or scarcity, its abundance or its scarcity. As a result, new challenges, in particular, of the environment and socio-economic balances will arise. Taking these issues into consideration, therefore, requires a more rational use of resources and an improvement in energy processes. The vast majority of these resources are produced from conventional sources, particularly oil, coal, gas and minerals. However, the use of these resources is responsible for 82% of greenhouse gas emissions. Given the stakes, concerns about climate risks, resource depletion and political and social pressure have risen to mitigate greenhouse effects. The increase in climate change and the worsening of the environment have set alarm bells ringing and are part of the policies aimed at combating climate change. In fact, the large part of these emissions lies, not only in greenhouse gases, but also in the production and consumption of energy and poor infrastructure. The problem stems from the depletion of exhaustible resources and the behavior of their management. It is important in this regard to resort to clean energies and energy efficiency, to seek new economic and governance models. The aim of this paper is to study the relationship between the consumption of renewable and non-renewable energies on the first two pillars of sustainable development, namely, economic growth and the environment. The goal behind the combination of these two components is to examine the Kuznets environmental curve. This curve relates economic growth to environmental damage as measured by CO2 emissions. To properly conduct this study, the sample studied is a panel of 107 over the period 1990-2017. This data panel is categorized according to their income level, and based on the World Bank ranking, namely, high income countries (HIC), upper middle income countries (UMIC), lower middle income countries (LMIC) and low income countries (LIC). However, despite the volume of empirical studies on the impact of the consumption of renewable energies, non-renewable energies, economic growth and CO2 emissions, it is important to point out that there are no studies integrating the rent from natural resources, renewable energies and non-renewable energies using the GMM method and simultaneous equations model to seek for the relationship between renewable energy and nonrenewable energy, that is they are substitutes or complementary, and classifying countries according to their level of development.

2. Literature review

The review of the present section shows that the relationship, short and long term, between energy production and development has been widely studied with standard econometric techniques of time series and panel, co-integration and causality. One of the advantages of this literature takes into account the multivariate models which make it possible to highlight the long-term relationship between energy and

other development indicators, in this case indicators for measuring the level of environmental quality and employment. This makes it possible to approximate the relationship between energy, sustainable development and well-being. Another advantage of these models is the possibility of validate the hypothesis of substitution vs complementarity between renewable energy and non-renewable energy.
In the following we will review to present various previous works examining the relationship between the consumption of renewable energy, non-renewable energy, economic growth and the environment.
The rest of the paper is organized as follows. Section 2 describes the data and the econometric methodology. Section 3 presents the results and discussion. Section 4 concludes this paper with some policy implications.

2.1. Renewable energy, nonrenewable energy and economic growth

Recent studies which consider both the sources of energies provide an analysis of the relationship between these different sources. Apergis and Payne (2012); Kahia et al (2017) used a dataset similar to that of Menegaki, A. N. (2011). This work covered 80 countries from 1990 to 2007, and they verified the relationship between the consumption of renewable and non-renewable energies and economic growth. They also used a unit root test by doing the Fisher ADF and the Fisher pp. For cointegration, they used the Pedroni technique (1999, 2004) and the fully modified OLS technique (FULLY MODIFIED OLS) to determine the long-term equilibrium relationship between the variables. Moreover, they additionally included capital and labor. Their results estimate the importance of renewable and non-renewable energies because the long-term relationship exists between all variables. They also discovered and as it is one of my centers of interest, a possible substitutability between the two types of energies, because there is a negative bidirectional causality between them. Wesseh et al (2016) used panel data for a group of ECOWAS countries over the period 1980 2011. The study informs that West African countries have the potential for substitution between renewable energies and non-renewable. Thus, the results of this study demonstrated remarkable growth records, largely thanks to non-renewable energies and the possibilities of energy conversion. Furthermore, the analysis of this study shows that investing in non-renewable energy will yield greater potential economic benefits than investing in renewable energy (as indicated by the squared terms of the model). Matei I (2017) studied the relationship between renewable energy consumption and economic growth for OECD countries between 1990 and 2014. He uses panel data techniques such as the Parametric Dynamic OLS Model (DOLS) proposed by Kao and Chiang (2000). He also enriches this analysis by applying the Pooled Mean Group (PMG) estimator from Pesaran, Shin and Smith [1999] and the Mean Group Model (MG) from Pesaran and Smith [1995]. The results show that in the short term, there are two-way causal tests between non-renewable energy consumption and economic growth, while renewable energy consumption affects it negatively. Malaczewski M (2020) studied the complementarity and substitutability of natural resources and physical capital. Unlike existing empirical research, which focuses on estimating the elasticity of substitution between energy and capital, the author focuses on macro data and the growth theory approach. The author considers standard long-term economic growth models with substitutability or complementarity between the use of natural resources and physical capital in the production process. From these models, he derives empirically verifiable theoretical relationships between their growth rates. The author also uses long-term cross-national data to test the correlation between these growth rates and finds evidence for gross complementarity between the factors of production examined at the macro level over the long term. The long-term negative impact of non-renewable energy consumption on renewable energy consumption suggests a substitutability between these two forms of energy sources. The potential substitutability is also underlined in the case of the impact of the use of renewable energies on the consumption of non-renewable energies. Bahera et al. (2019) studied the relationship between renewable and non-renewable energy consumption and economic growth in G7 countries (Canada, France, Germany, United Kingdom, Italy and United States) for the period 1990-2015. Examination of the second-generation unit root test of the Pesaran CADF panel verifies the stationary properties of the variables. To study the short-term and long-term dynamics, they used an autoregressive delay stage panel model (P-ARDL). The empirical results suggest a cross-sectional dependence between the variables. The ARDL panel model confirms that the price of energy, labor and the capital stock have a positive and statistically significant long-term impact on economic growth in the G7 countries. The short-term dynamics of the result advocate that there is a short-term causality between the consumption of non-renewable energy and economic growth and the capital stock to economic growth.

Table 1: Summary of Previous Studies : Renewable Energy and Non-Renewable Energy

Authors	Periode	Countries	Methodology	Results
Kumar (2015)	1995-2009	OECD countries	CES eslasticity of substitution, Distance Function	Complementary relationship from nonrenewable energy to renewable energy in eight industries, whereas a substitute relationship was maintained for four industries. In particular, the food and pulp industries had a strong complementary relationship.
Lazkano et al (2015)	1963-2011	Global level data	Fixed-effects Poisson estimator	Complementarity relationship between renewable and conventional energies
Marques et al. (2018)	1990-2014	10 European countries	(ECM) Error Correction Model	Substitution effect in solar PV and hydropower, but not in wind power sources. Indeed, the generation approach highlights the necessity for flexible and controllable electricity production from natural gas and hydropower to back up renewable sources. Moreover, the results prove that peaks of electricity have been an obstacle to the accommodation of intermittent renewable sources
Apergis (2012)	1990-2007	80 country	FMOS / DOLS	Substitution relationship. There exists a negative bidirectional relationship between renewable and nonrenewable energies.
Wesseh et (2016)	1980-2011	Communauté économique de l'Afrique Ouest	Données de panel	Substitution between REN and NRN
Matei et al (2017)	1990-2014	OCDE	Panel data	Substitution between ER et ENR in the long run

2.2. Economic growth and CO2 emissions

In the early 1990s, empirical studies highlighted the relationship between economic growth and environmental quality (North American free trade studies by Shafik and Bandyopadhyay (1992) for the International Bank for reconstruction and development (World Development Report 1992) and the Panayotou survey (1993) of the International Labor Organization). Researchers confirm the importance of economic growth for the environment. Thus, the growth of production will inevitably lead to an increase in the extraction of environmental resources from the economic system, and the stock of wastes discharged into the environment increases (Boulding, 1996). However, the natural environment is unable to absorb the waste produced by the economic system, making global economic growth unsustainable. Afterwards, economic growth continues to cause more damage to a region, a country, and even the global environment or will help improve the quality of the environment (Zhang, 2008). In order to better describe the relationship may exist between them, researchers have conducted many studies dealing mainly with the impact of economic growth on environmental pollution, in which the most important is the Kuznets environmental curve proposal (CEK) and empirically validated. Researchers state an inverse U-shaped relationship between economic growth and environmental pollution. Indeed, at the lower stage of economic development, environmental pollution lower. In fact, environmental pollution increases with industrialization. In the higher stage of economic development, the industrial economy of high pollutants transforms into the service economy or the technology-based economy with the changes in the economic structure of the country, and the degree of environmental pollution is declining (Grossman, 1992; Grossman, 1995). Most empirical work on EKC research (Hill and Magnani, 2002; Dinda, 2004; Stern, 2004) first assumes the existence of the EKC, which will later be validated by empirical data and methods. Studies that test for CEK can be linear (Shafik and Bandyopadhyay, 1992; Shafik 1994; de Bruyn et al., 1998), quadratic and cubic (de Bruyn et al., 1998; Heil and Selden, 1999; Holtz -Eakin et al., 1998) Selden, 1995; Moomaw and Unruh, 1997; de Bruyn and Opschoor, 1997; Roberts and Grimes, 1997; Han and Chatterjee, 1997; Friedl and Getzner, 2003; Canas et al, 2003). The relationship between per capita income and CO2 emissions, fail to give unanimous results. Dinda and Coondoo (2006) apply panel cointegration tests in a bivariate framework. Their results indicate that the dynamic link between CO2 emissions and income is suspected, suggesting a time series approach. In addition, CO2 emissions can prevent economic growth from a production point of view. It may even be possible to observe emissions preventing energy use if the power generation industry is responsible for a significant portion of a country's emissions. All of these concerns highlight the need for a flexible methodology that allows testing of how to prevent these emissions as suggested by Coondoo and Dinda (2002), and Dinda (2004).

Table 2: Summary of Previous Studies: CO2 Emissions and Economic Growth

Auteur	Pays	Période	Méthodologie	Résultats
Yuan et al. (2007)	China	1963-2005	Multivariate model (VAR)	GDP ↔ CO2
Lindmark (2002)	Hongrie	1870-1997	Time series data	CEK exists
Day et Grafton (2003)	Canada	1958-1995	Time series data	CEK exists
Egli (2004)	Germany	1966-1999	Time series data	CEK exists
Ang (2007)	France	1960-2000	Time series data	CEK exists
Akbostanci et al. (2009)	Turkey	1968-2003	Time series data	CEK doesn't exist
Fodha et Zaghdoud (2010)	Tunisia	1961-2004	Time series data	CEK exists
Jaunky (2010)	36 developed countries	1980-2005	Panel cointegration test	CEK exists for Malta, Portugal, UK
Arouri et al. (2012)	MENA region	1981-2005	Panel unit root, co-intégration tests	CEK exists
Sabouri t al. (2012)	Malaisie	1980-2009	Granger causality test	CEK exists
Esteve et Tamarit (2012)	Espagne	1875-2007	Linear regression model	CEK exists
Sabouri et Soulaiman (2013)	Malaisia	1980-2009	ARDL, Johansen-Juselius methodology	CEK exists
Shahbaz et al. (2013)	South Africa	1965-2008	ARDL	CEK exists
Soulaiman et al. (2013)	Malaisia	1980-2009	VECM, Granger causality test	CEK exists
Al-Mulati et Sheau-Ting (2014)	189 country	1990-2011	OLS	CEK exists
Farhani et al. (2014)	MENA region	1990-2010	Panel data methode	CEK exists
Cowan et al. (2014)	BRICS countries	1990-2010	Panel causality test	CEK exists
Mansah (2014)	6 African countries	1980-20000	Toda et Yamamoto precedure and Granger causality test	CEK exists
Onafowara et Owaya (2014)	8 devveloped countries	1970-2010	ARDL	CEK exists

2.3. Renewable energy, nonrenewable energy and CO2 emissions

Table 3: Summary of Previous Studies : Renewable Energy, Nonrenewable Energy and CO2 Emissions

Auteur	Pays	Période	Méthodologie	Résultats
Shfiei (2014)	OCDE countries	1980-2011	STIPRAT model	NR increase CO2 REN decrease le CO2
Liu (2005)	OCDE countries	1975-1990	Panel Cointégration test, Granger Causality test	CE → PIB CE → CO2
Ang (2007)	France	1965-2005	Panel Vector Error Correction Model	PIB → CE (long run) PIB → CO2 (long run) CE → PIB (short run)
Zhang et al. (2009)	China	1960-2005	Panel Vector Error Correction Model? Granger Causality test	CE → CO2
Apergis et Payne (2010)	Community of independent countries	1992-2004	Panel Vector Error Correction Model	CE → CO2 (short run CE → CO2(short run)
Lean et Smyth (2010)	ASEAN countries	1980-2006	Granger Causality test, EKC	CE → CO2
Shahbaz et al. (2010)	Pakistan	1971-2009	Granger Causality test, EKC	CE → CO2
Almulati (2011)	MENA region	1980-2009	Panel Unit Root test, and Panel cointegration test	CE → CO2

Chu et Chang (2012)	G7 countries	1981-2005	EKC, Panel Unit Root test, and Panel cointegration test	CE ↔ CO2 (short run)
Omri (2013)	MENA region	1980-2009	Simultaneous Equations Model	CE ↔ CO2 CE ↔ GDP
Salahuddin et Gow (2014)	GCC countries	1980-2012	Granger Causality test	CE ↔ CO2
Apergis et al. (2010)	G7 countries	1980-2005	Panel Vector Error Correction Model	ER # CO2
Menyah et WoldeRufael (2010°	USA	1960-2007	Granger Causality test	CO2 → ER
Salim et Rafiq (2012)	6 developed countries	1980-2006	Granger Causality test	ER ↔ CO2
Payne (2012)	USA	1949-2009	TY Approach	ER # CO2
Shafei et Salim (2014)	BRICS countries	1970-2010	ARDL and Vector error correction model	CO2 → ER

1) Methodology and Data
2) Econometric modeling

Unlike previous studies that use CES of substitution and MES Morishma eslasitcity of substitution, this paper uses a production function approach to estimate the long run elasticities relationship between energy consumption (renewable and non-renewable), economic growth and CO2 emissions. The extended Cobb-Douglas production framework makes it possible to explore the links between them. These variables are in fact endogenous. It is therefore useful to examine these relationships by considering them simultaneously in a modeling framework. For this purpose, we use the Cobb-Douglas production function including capital and labor as additional factors of production. Apergis and Payne (2010a), Apergis and Payne (2010b), Wolde-Rufael and Menyah (2010), and Marques and Fuinhas (2012), among others, include the two energy variables in their empirical model to examine their effects on Economic Growth. Their results show that the consumption of renewable energy and the consumption of non-renewable energy stimulate economic growth. To study the relationship between the two types of energy consumption and economic growth, the following augmented Cobb-Douglas production function is:

$$Y_{it} = AK^{\alpha}L^{ß} \quad (1)$$

Y is the output, K, L and A are capital, labor. α is the elasticity of capital; β is the elasticity of labor. With reference to Yilanci (2013), Khan et al (2013), energy can be included in the production function:

$$Y_{it} = AK^{\alpha}L^{ß}\, N^{Đ}\, R^{ʎ} \quad (2)$$

Y describes total production, K, L, A, N and R, are capital, labor, technology, non-renewable and renewable energy and are shown by their elasticities, α, ß, Đ and ʎ respectively. In addition, Omri et al (2014) presented financial development, foreign direct investment and trade openness as endogenous and the determinants of economic growth.

$$Y_{it} = N^{\alpha}R^{ß}FD^{ʎ}T^{Đ}FDI^{µ} \quad (3)$$

The logarithmic transformation gives:

$$ln\,Y_{it} = \alpha_0 + ln\,N_{it} + lnN_{it} + lnFD_{it} + lnFDI_{it} + lnT_{it} + \ lnK_{it} + lnL_{it} + \pi_{it} \quad (4)$$

This study uses the dynamic panel model as its reduced form.

$$ln\,Y_{it} = \alpha_0 Y_{it-1} + ln\,N_{it} + lnN_{it} + lnFD_{it} + lnFDI_{it} + lnT_{it} + \ lnK_{it} + lnL_{it} + \pi_{it} + \varepsilon_{it} + £_{it} \quad (5)$$

This study uses the dynamic panel model as its reduced form. Where, i denotes the country (i = 1, ..., 107), the time period t is (t = 1990, ..., 2017). Π, ε, and £ are times fixed effects, fixed country effects, and the stochastic error term, respectively.
Environment function is defined as:

$$C = \alpha_0 + \alpha_1 Y + \alpha_1 Y^2 \quad (6)$$

The recent literature sets up energy as a relevant variable to avoid the bias of omitted variables (Et, (2007, Apergis and Payne (2009), Omri et al (2014) which gives:

$$C = \alpha_0 + \alpha_1 Y + \alpha_1 Y^2 + \ N + R \quad (7)$$

In this way, Tiwari et al (2014) studied the determinants of CO2 emissions. The literature on the impact of renewable and non-renewable energies on CO2 emissions is not abundant. Economic growth, urbanization, foreign direct investment, financial development and trade are considered to be determinants of CO2 emissions.

$$C = \alpha_0 + \alpha_1 Y + \alpha_2 Y^2 + \alpha_3\, N + \alpha_4 R + \alpha_5 T + \alpha_6 U \quad (8)$$

The logarithmic transformation gives

$$C = \alpha_0 + \alpha_1 lnY + \alpha_2 lnY^2 + \alpha_3 ln\,N + \alpha_4 lnR + \alpha_5 lnT + \alpha_6 lnU \quad (9)$$

3. Panel data

$$C_{it} = \alpha_0 + \alpha_{1i} lnY_{it} + \alpha_{2i} lnN_{it} + \alpha_{3i} lnR_{it} + \alpha_{4i} lnY^2{}_{it} \alpha_5 lnT + \alpha_6 lnU + \varepsilon_{it} + \Pi_{it} + £_{it} \quad (10)$$

Where, i denotes the country (i = 1, ..., 107), the time period t is (t = 1990, ..., 2017). Π, ε, and £ are times fixed effects, fixed country effects, and the stochastic error term, respectively. α_0, ..., α_5 are income elasticities, non-renewable, renewable, income squared, trade and urbanization respectively. The dynamic panel shape is presented as follows:

$$C_{it} = \alpha_0 C_{it-1} + \alpha_{1i} lnY_{it} + \alpha_{2i} lnN_{it} + \alpha_{3i} lnR_{it} + \alpha_{4i} lnY^2{}_{it} \alpha_5 lnT + \alpha_6 lnU + \varepsilon_{it} \quad (11)$$

Where α_0 = ln (A0); the index i = 1, ..., N denotes the country and t = 1, ..., ..., T denotes the period of time. Variable Y is real GDP per capita; E, C, K and L indicate per capita energy consumption (ENC), inhabitant CO2 emission, capital and labor respectively by. A is for the level of technology and e is the residual term assumed to be the same, independently and normally distributed. The coefficients associated with energy consumption, CO2 emissions, capital and the and, are presented by α_1, α_2, α_3 and α_4 respectively. The logarithmic transformation makes it possible to linearize the shape of the Cobb-Douglas nonlinear production. It should be noted that the simple linear specification does not appear to provide consistent results. Therefore, to cover this problem, the log-linear specification is used to study the relationship between CO2 emissions, energy consumption and economic growth in some countries in the world. In what follows, it will be a question of defining the data as well as their sources. Then, we will check the variables of each model referring to the studies of Omri (2015), the objective of this study is to analyze the relationship between the consumption of renewable and non-renewable energies, economic growth and CO2 emissions. These two indicators are considered the first pillars of sustainable development. These three variables are in fact endogenous. As mentioned earlier, most of the existing literature generally assumes that economic growth is likely to lead to changes in CO 2 emissions. It is also established that energy use is often a determinant of carbon emissions. It is therefore useful to examine the relationships between the three variables by considering them a simultaneous equation estimation model. To this end, we employ the Cobb-Douglas production function to study the four causal links between energy consumption, economic growth, and CO2 emissions, including capital and labor as additional factors of production. . Ang (2008), Sharma (2010), Menyah and Wolde-Rufael (2010), and Shahbaz et al. (2012), among others, include energy and CO 2 emission variables in their empirical model to examine the impact of these two variables on economic growth. While they generally find that emissions and energy drive economic growth.

To successfully carry out this study, we will combine these studies and use a dynamic panel in simultaneous equation

$$CO2_{it} = \alpha_0 CO2_{it-1} + \alpha_{1i} GDP_{it} + \alpha_{2i} REN_{it} + \alpha_{3i} NRN_{it} + \alpha_{4i} GDP^2{}_{it} \sum_{j=1}^{4} \alpha \text{ variables de contrôle} + \pi_{it} \quad (12)$$

$$GDP_{it} = \alpha_0 GDP_{it-1} + \alpha_{1i} GDP_{it} + \alpha_{2i} REN_{it} + \alpha_{3i} NRN_{it} + \sum_{j=1}^{4} \alpha \text{ variables de contrôle} + \mu_{it} \quad (13)$$

$$REN_{it} = \alpha_0 REN_{it-1} + \alpha_{1i} GDP_{it} + \alpha_{3i} NRN_{it} + \sum_{j=1}^{2} \alpha \text{ variables de contrôle} + \phi_{it} \quad (14)$$

$$NEN_{it} = \alpha_0 NEN_{it-1} + \alpha_{1i} GDP_{it} + \alpha_{3i} NRN_{it} + \sum_{j=1}^{2} \alpha \text{ variables de contrôle} + \varepsilon_{it} \quad (15)$$

Equation (12) examines the impact of renewable energy consumption, non-renewable energy, economic growth and other variables on CO2 emissions. An increase in the consumption of non-renewable energy leads to an increase in GDP per capita, i.e. the level of energy consumption increases monotonically with the GDP per capita (Sharma, 2010) on the other hand, it increases CO2 emissions . Sharma assumes energy as an input into the production process, as used in transport, and (public sector) non-business activities. This means that energy has a direct link with the GDP of a country. The link could indeed be stimulated by consumption, investment or exports and imports. As a result, energy production and consumption affects all components of aggregate demand. In addition, the level of CO2 emissions can influence per capita GDP (Apergis and Payne, 2009; Saboori et al, 2012). This shows the impact of environmental degradation on economic growth, and a persistent decline in environmental quality can have a negative externality for the economy. In the same framework, we can also specify the determinants of energy consumption (renewable and non-renewable) and carbon dioxide emissions.

Eq. (13) examines the determinants of non-renewable energy consumption (NREN). Economic growth, which is a proxy of GDP per capita, is likely to have a positive impact on energy consumption, i.e. an increase in GDP per capita leads to an increase in energy consumption per capita (Lotfipour et al, 2010; Belloumi 2009; Halicioglu, 2009; Zhang and Cheng, 2009). Work examining the EKC shows that the level of CO2 emissions generally increases with energy consumption (Apergis and Payne, 2009; Halicioglu, 2009; Soytas and Sari, 2009; Lean and Smyth, 2010). Then, capital and labor are added as the main determinant of energy consumption (Sari et al, 2008; Lorde et al., 2010). Financial development (FD), which is measured by total credit as a fraction of GDP, is likely to have a positive impact on energy consumption (Islam et al., 2013). POP indicates the total population. Islam et al. (2013) underlined the importance of the population in determining the level of CO2 emissions.

Eqs. (14) postulates that the consumption of renewable energies can be influenced by economic growth, environmental degradation (CO2) and other determinants, such as the price of oil. Similarly Sadorsky (2009) and Lee and Chui (2011a), the variables to be included in this equation are selected in accordance with economic theory and data availability. Real GDP is included in the model to measure economic growth. Higher economic growth should lead to higher energy consumption and hence there should be a positive relationship between these two. In line with society's concerns about the greenhouse effect, the CO2 emissions variable is included as an important additional explanatory variable. The high CO2 emissions create the demand for a cleaner environment and encourages the use of alternative nuclear power and renewable energy that is free from this evil effect. Thus, a positive relationship between nuclear and renewable energy consumption and CO2 emissions is expected. Oil price and oil consumption are also included . Higher oil prices increase demand for nuclear and renewable energy, implying a positive relationship between demand for nuclear and renewable energy and the price of oil. In contrast, greater oil consumption decrease the demand for nuclear and renewable energy, implying a negative relationship between the demand for energy and the consumption of nuclear and renewable oil (Lee and Chui, 2011b). Eqs. (15) postulates that the consumption of renewable energy can be influenced by economic growth, environmental degradation (CO2), and the real price of oil (OP). Similarly Sadorsky (2009) and Lee and Chui (2011a), the variables to be included in this equation are selected in accordance with economic theory and data availability. Real GDP is included in the model to measure economic growth. A high level of GDP should lead to a higher energy consumption and therefore there should be a positive correlation between these two. In line with society's concerns about the greenhouse effect, the CO2 emissions variable is included as an important additional explanatory variable.

3.1. Panel unit root test estimation

The application of the unit root test on time series has become crucial in applied economics. Recently, this test is applied on panel data. Panel unit root tests have gained traction among econometrics researchers focusing on panel data structures because they are much more powerful compared to unit root tests for time series. Among the various panel unit root tests developed in the literature are those proposed by Levin, Lin and Chu (LLC) (2002) and Im, Pesaran and Shin (IPS) (1997, 2002, 2003). Both tests are inspired by ADF time series unit root tests. The CLL test assumes the homogeneity of all coefficients. He postulates the homogeneity of the autoregressive root. The null hypothesis posed by this test considers the absence of a unit root for all individuals, against the alternative hypothesis of the presence of a unit root. To address this concern, the test proposed by IPS considers a model with individual effects and without deterministic tendency. It takes into account the heterogeneity of the autoregressive root. Therefore, it is described as a "Heterogeneous Panel unit root test". According to Levin et al. (2002) the ADF is presented as follows:

$$\Delta y_{it} = \alpha_i + \text{ß}\Delta y_{i,t-1} + \sum_{j=1}^{p_i} \mu_{i,j}\Delta y_{i,t-1}\, \varepsilon_{it}$$

Under the hypothesis :

$H_0 : \text{ß}_1 = \text{ß}_2 = \text{ß} = 0$ and $H_1 : \text{ß}_1 = \text{ß}_2 = \text{ß} < 0$

The basic ADF specification of the LLC test

$$\Delta y_{it} = \alpha_i + \text{ß}_i\Delta y_{i,t-1} + \sum_{j=1}^{p_i} \mu_{i,j}\Delta y_{i,t-1}\, \varepsilon_{it}$$

Where yi, t (i = 1, 2, ..., N ;. T = 1,2, ..., T) denotes the number of panel series (the countries) i in t, μi is the lag number in the ADF regression, and ε Where, △ denotes the first difference operator, Y_it, is the dependent variable, ε_it is the error term. In this model, LLC test the null hypothesis H_0: β = 0 against the alternative hypothesis H_0: β = β_i = β_i <0, for all i = 1, … N)

$\text{ß}_i = 0$
$\text{ß}_i < 0$, where the stationary Yi,t is the alternative hypothesis

Estimation results
Descriptive statistics

	Stat des	GDP	CO2	REN	NRN	URBN	TRAD	FD	FDVP	K	L	CPI	POP
Global Panel	Obs	2954	2674	2764	2629	3006	2860			2715	3045	2954	2962
	Mean	8.62	0.61	2.94	3.92	3.97	4.19			23.67	15.68	4.02	16.53
	Std dev	2.16	1.56	1.39	0.74	0.45	0.64			1.97	1.59	1.77	1.56
	Obs		9.567	0.776	1.159	71.96	47.61			23.25	7.10		
HIC	Mean	4.385	9.567	0.776	1.159	19.37	71.96			47.61	23.25	7.10	2.28
	Std dev	0.380	4.171	1.416	0.525	2.86	13.39			22.37	4.51	0.68	3.52
	Obs												
UMIC	Mean	2.908	0.989	0.027	0.110	5.817	41.250			40.917	21.075	7.312	1.730
	Std dev	0 .29	3.30	0.133	0.270	0.291	12.93			64.85	5.521	0.604	4.008
	Obs												
LMIC	Mean	3.73	4.56	0.138	0.381	76.01	68.60			23.16	6.896	1.730	23.727
	Std dev	0 .29	3.30	0.133	0.270	12.93	64.85			5.521	0.604	2.006	16.247
	Obs												
LIC	Mean	2.908	0.989	0.027	0.110	41.250	40.917			21.075	7.312	3.186	19.251
	Std dev	0.209	0.849	0.024	0.092	8.747	16.258			5.235	0.615	4.633	13.846

- Panel unit root test

		H0 : All panel contain unit root					
	Variables	IPS		LLC		ADF	
Panel		Constant+trend	Constant	Constant+trend	Constant	Constant+trend	Constant
	CO2	-1.9208	-0.0221	-2..0920	0.2153	2.7092	2.1929
		(0.0274)	(0.4912)	(0.0182)	(0.5853)	(0.9966)	(0.9858)
	REN	-3.4343	-1.7793	-3.8945	10.9732	6.6511	2.6514
		(0.0003)	(0.0383)	(0.0.000)	(1.0000)	(1.0000)	(0.9960)
	NREN	2.9495	3.6805	2.3915	-1.1599	2.6026	5.6587
		(0.9984)	(0.9999)	(0.9916)	(0.1230)	(0.9954)	(1.0000)
	PIB	-1.3488	2.4665	0.3436	-3.2193	-3.7224	-0.1868
		(0.0887)	(0 .9932)	(0.6344)	(0.0006)	(0.0001)	(0.4259)
Niveau	PIB2	-1.3409	2.46666	0.3433	-3.2193	-3.7495	-0.6509
		(0.0887)	(0.9932)	(0.6343)	(0.0006)	(0.0001)	(0.2576)
		-4.3711	5.1279	-3.2911	-2.4100	-3.3754	-6.3601
	K	(0.0000)	(1.0000)	(0.0003)	(0.0080)	(0.0004)	(0.0000)
		0.0082	5.1297	1.6212	-3.8350	4.9637	-0.4926
	L	(0.5034)	(1.0000)	(0.9475)	(0.0001)	(1.0000)	(0.3111)
		-3.8181	-1.6064	1.1609	-6.0078	3.4468	-6.6614
	URBN	(0.0001)	(0.0543)	(0.8772)	(0.0000)	(0.9997)	(0.0000)
	TRADE	-2.3078	-1.6046	1.1609	-0.9282	0.0274	-2.8663

		(0.0105)	(0.0543)	(0.8772)	(0.1766)	(0.5109)	(0.0021)
	FDI	-2.6613	-1.1565	-2.6645	-7.5947	-2.7491	-5.8230
		(0.0039)	(0.1237)	(0.0039)	(0.0000)	(0.0030)	(0.0000)
	FDVP	0.8445	0.1971	0.3957	-1.0308	-8.8466	0.1066
		(0.8008)	(0.5782)	(0.5639)	(0.1513)	(0.1986)	(0.5425)
Première différence	CO2	-8.69898	-14.1566	-12.7557	-16.1960	-15.6780	-12.6120
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	REN	-11.4557	-13.2901	-11.4892	-11.4312	-17.4312	-15.6264
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	NREN	-7.6395	-9 .3811	-7.8880	-12.7567	-11.8949	-11.4226
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	PIB	-8.8390	-9.3299	-8.8065	-9.8053	-14.0645	-14.2485
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	PIB2	-9.5321	-8.8390	-9.3301	-8.8067	-14.8149	-13.8394
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
		-11.3185	-9.8084	-12.2044	-10.7295	-18.8815	-15.8536
	K	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
		-7.5455	-4.2461	-4.1486	-8.6669	-13.5236	-2.9303
	L	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0017)
		-10.7601	-9.6326	-9.6757	-7.8533	-12.3172	-10.7281
	URBN	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	TRADE	-12.3339	-10.8332	-12.3561	-10.5372	-2.0775	-16.6373
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	FDI	-7.6884	-4.5296	-13.2195	-11.0308	-17.9917	-12.4786
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
		-8.6059	-7.8887	-9.6105	-7.9392	-10.0689	-8.0970
	FDVP	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

- Correlation matrix

	lpib	lnrn	lren	lco2	ltrade	lurbn	ll	lk	lpop	lpci	lpibc
lpib	1.0000										
lnrn	0.3333	1.0000									
lren	-0.4285	-0.6384	1.0000								
lco2	0.7073	0.7574	-0.7069	1.0000							
ltrade	0.1343	0.0331	-0.1087	0.1226	1.0000						
lurbn	0.2608	0.2253	-0.2269	0.2954	0.2280	1.0000					
ll	-0.0004	0.0884	-0.0347	0.0556	-0.5661	-0.1729	1.0000				
lk	0.2530	0.2888	-0.2527	0.3685	-0.2303	0.4395	0.7029	1.0000			
lpop	-0.1406	0.0172	-0.0373	-0.1075	-0.0119	-0.0886	0.1449	0.0480	1.0000		
lpci	-0.0561	0.0808	-0.0957	0.1397	0.0070	-0.0129	-0.0106	-0.0126	0.0222	1.0000	
lpibc	0.9916	0.1422	-0.2937	0.4937	0.1154	0.1866	-0.0206	0.1624	-0.0675	0.0938	1.0000

- Results of static and dynamic panel (LnPIB dependent variable)

	Global panel		HIC		UMIC		LMIC		HIC	
	EF	SY-GMM	EF	SY-GMM	EF	SY-GMM	EF	SY-GMM	EF	SY-GMM
Y_{t-1}	-		-		-		-		-	
lnREN	0.0656 (0.016)	-0.0055 (0.188)	0.1121 (0.000)	0.0988 (0.000)	0.0410 (0.856)	0.2232 (0.000)	1.7898 (0.000)		0.0680 (0.000)	0.2638 (0.192)
lnNRN	-	0.0015 (0.348)	0.5739 (0.000)	0.6544 (0.000)	0.2537 (0.523)	0.2572 (0.000)	-0.0431 (0.004)	0.0410 (0.856)	0.5036 (0.000)	0.1084 (0.000)***
LnCO2	-0.0398 (0.170)	-0.0111 (0.214)	-	-	0.1525 (0.016)	-	-		-0.0316 (0.513)	0.2723 (0.809)
lnFDI	0.0263 (0.540)	-0.0336 (0.005)	0.0127 (0.004)	0.0119 (0.009)	-2.6359 (0.002)	0.0356 (0.000)	-0.0778 (0.013)		-	-0.0710 (0.151)
lnFD	0.0100 (0.000)	-	0.0136 (0.000)	0.0472 (0.019)	0.1803 (0.003)	-0.0812 (0.031)	-0.0226 (0.000)	0.1803 (0.003)	0.0127 (0.210)	-0.0100 (0.035)**
LnK	-	-	0.2413 (0.000)	0.2472 (0.000)	-0.3991 (0.000)	-0.2509 (0.049)	0.1312 (0.000)	-0.3991 (0.000)	-0.0449 (0.028)	-0.2598 (0.000)***
lnL	-	-	0.7186 (0.001)	-0.1429 (0.229)	4.7327 (0.000)	-0.3505 (0.000)	-	4.7327 (0.000)	-0.0443 (0.335)	-0 .1245 (0.008)*
C	0.0830 (0.137)	-0.5426 (0.001)**	-0.2069 (0.000)	-0.0118 (0.007)	-0.0289 (0.546)		-0.4772 (0.000)	-0.0424 (0.436)	-0.4030 (0.002)	-0 .2154 (0.000)***
R^2	0.4484 (0.025)	0.2130 (0.001)	-1.0881 (0.000)	-	-0.0424 (0.436)	-	-			
Bp test p-	2.2647 (0.108)	7.8704 (0.000)	0.66	0. 33	-67.755 (0.003)	12.201 (0.000)	-7.0223 (0.000)			
Haus-man	0.83	0.86	159.8 (0.000)		13.23 (0.000)	0.64				
Han-senJtest	2183.5 (0.000)	45.43 (0.000)	-0.1463 (0.005)		82.03 (0.000)	2183.5 (0.000)	83.43 (0.0000)			

	Global panel		UMIC		LMIC					
	EF	SY-GMM	EF	SY-GMM	EF	SY-GMM	EF	SY-GMM	EF	SY-GMM

Y_{t-1}	-		-		-		-		-	
lnREN	0.0656 (0.016)	-0.0055 (0.188)	0.1121 (0.000)	0.0988 (0.000)	0.0410 (0.856)	0.2232 (0.000)	1.7898 (0.000)		0.2306 (0.059)	0.2638 (0.192)
lnNRN	-	0.0015 (0.348)	0.5739 (0.000)	0.6544 (0.000)	0.2537 (0.523)	0.2572 (0.000)	-0.0431 (0.004)	0.0410 (0.856)	-0.0192 (0.963)	0.1084 (0.000)***
lnPIB	0.0578 (0.041)	-	0.1478 (0.204)	0.1097 (0.271)	5.6233 (0.013)	0.4816 (0.000)	0.1027 (0.001)	-2.6359 (0.002)	0.0206 (0.308)	0.0602 (0.000)***
LnPIB²	0.0398 (0.170)	-0.0111 (0.214)	-	-	0.1525 (0.016)	-	-		0.2565 (0.919)	0.2723 (0.809)
lnURBN	-	-	0.2413 (0.000)	0.2472 (0.000)	-0.3991 (0.000)	-0.2509 (0.049)	0.1312 (0.000)	-0.3991 (0.000)	-0.2811 (0.003)*	-0.2598 (0.000)***
lnTRADE	-	-	0.7186 (0.001)	-0.1429 (0.229)	4.7327 (0.000)	-0.3505 (0.000)	-	4.7327 (0.000)	-0 .1505 (0.010)*	-0 .1245 (0.008)*
lnPOP	-	-	-	-	0.0202 (0.631)		-		-0.7552 (0.017)	0.0240 (0.704)
LnPCI										
C	-	-			-0.0289 (0.546)		-0.4772 (0.000)	-0.0424 (0.436)	-0.4030 (0.002)	-0 .2154 (0.000)***
R²	0.4484 (0.025)	0.2130 (0.001)	-1.0881 (0.000)	-	-0.0424 (0.436)	-	-			
Bp test p-	2.2647 (0.108)	7.8704 (0.000)	0.66	0. 33	-67.755 (0.003)	12.201 (0.000)	-7.0223 (0.000)			
Hausman	0.83	0.86	159.8 (0.000)		13.23 (0.000)	0.64				
Hansen-Jtest	2183.5 (0.000)	45.43 (0.000)	-0.1463 (0.005)		82.03 (0.000)	2183.5 (0.000)	83.43 (0.0000)			

- Results of dynamic simultaneous equations

	HIC				UMIC				LMIC				LIC			
Dep.var	M (1) lnGDP	M(2) LnREN	M(3) LnNRN	M(4) LnCO	M(1) lnGDP	M (2) LnRE	M(3) LnN	M(4) LnCO2	M (1) lnGDP	M(2) LnRE	M(3) LnNR	M(4) LnCO	M(1) lnGDP	M (2) LnREN	M (3) LnNR	M(4) LnCO
Y_{t-1}	0.9952 (0.000)	0.9646 (0.000)	0.9960 (0.000)	0.8972 (0.000)	0.9972 (0.000)	0.9660 (0.000)	0.9867 (0.000)	0.3065 (0.000)	0.8872 (0.000)	0.9860 (0.000)	0.9867 (0.000)	0.9306(0.000)	0.9904 (0.000)	0.9957 (0.000)	0.8409 (0.000)	1.6224 (0.000)
LnPIB	-	0.0656 (0.016)	1.1328 (0.000)	0.7580 (0.002)	-	3.5150 (0.000)	1.1485 (0.000)	0.1736 (0.137)	-	0.0656 (0.016)	-0.0085 (0.178)	-0.0298 (0.622)	-	-0.0663 (0.107)	0.0683 (0.033)	0.0380 (0.471)
LnPIB²				-0.0325 (0.000)								-0.0778 (0.013)	-	-		
LnREN	-0.0087 (0.579)	-	0.0015 (0.348)	-0.0268 (0.587)	0.2260 (0.000)	-	-0.3170 (0.000)	-0.2354 (0.000)	0.0184 (0.068)	-	0.0029 (0.161)	-0.2354 (0.000)	0.0381 (0.042)	-	-0.1045 (0.000)	0.1083 (0.000)
LnNRN	0.1952 (0.004)	0.0578 (0.041)	-	0.3869 (0.090)	0.3316 (0.000)	1.0622 (0.000)	-	0.0606 (0.365)	-0.0036 (0.555)	-0.0319 (0.037)	-	-0.0590 (0.124)	0.0123 (0.322)	-9.1655 (0.000)	-	1.2478 (0.000)
LnCO2	0.3167 (0.000)	-0.0398 (0.170)	-0.0111 (0.214)	-	0.3413 (0.000)	1.3690 (0.000)	0.4887 (0.000)	-	-0.0044 (0.724)	-0.0092 (0.797)	0.0207 (0.054)	-	-0.0044 (0.724)	6.9443 (0.000)	0.7824 (0.000)	-
LnPCI	-	0.0263 (0.540)	-0.0336 (0.005)	-	-	-	-	-	-	-	-	-	-	-	-0.0336 (0.000)	-
lnFDI		-	-	--	0.0249 (0.157)	-	-	-0.2057 (0.000)	0.0139 (0.000)	-	-	-0.0866 (0.008)	0.2405 (0.000)	-	-	0.0138 (0.068)
LnFD	0.5753 (0.000)	-	-	--	-0.0692 (0.001)	-	-	0.0031 (0.951)	-0.0258 (0.001)	-	-	-0.0248 (0.356)	0.1025 (0.002)	-	-	-0.0206 (0.000)

LnK	0.0540 (0.000)	-	-	-	-0.8337 (0.000)	-	-	-	0.0103 (0.385)	-	-	-	0.4990 (0.000)	-	-	-
LnL	0.0150 (0.000)	-	-	-	-0.4404 (0.000)	-	-	-	0.0271 (0.000)	-	-	-	0.3260 (0.000)	-	-	-
LnURBN	-	-	-	-1.3577 (0.032)	-	-	-	0.7984 (0.005)	-	-	-	0.3314 (0.001)	-	-	-	-0.2476 (0.000)
LnTRAD	-	-	-	-0.0156 (0.000)	-	-	-	0.6490 (0.000)	-	-	-	0.2411 (0.001)	-	-	-	0.0554 (0.000)
LnPOP	-	-0.0416 (0.001)	0.0976 (0.000)	-	-	2.0287 (0.000)	0.6405 (0.000)	-	-	0.0370 (0.030)	0.0018 (0.694)	-	-	0.6114 (0.000)	0.0365 (0.000)	-
C	18.2816 (0.000)	36.533 (0.000)	-4.3237 (0.000)	4.5048 (0.118)	14.873 (0.000)	47.342 (0.000)	17.0065 (0.000)	-6.4823 (0.000)	-0.0344 (0.695)	-0.9140 (0.009)	0.0531 (0.539)	-1.9937 (0.001)	0.0344 (0.695)	-62.791 (0.000)	-6.3518 (0.000)	7.0700 (0.000)

- Results of dynamic simultaneous equations for global panel

Dep.var	Global Panel Model (1) lnGDP	Model (2) LnRENq	Model (3) LnNRN	Model (4) LnCO2
Y_{t-1}	0.9952 (0.000)	0.9646 (0.000)	0.9960 (0.000)	0.8972 (0.000)
LnPIB	-	-1.1822 (0.000)	1.1328 (0.000)	1.0401 (0.027)
LnPIB²				-0.0325 (0.000)
LnREN	-0.0087 (0.579)	-	0.1019 (0.000)	-0.1907 (0.312)
LnNRN	0.1952 (0.004)	(0.000)	-	0.0245 (0.623)
LnCO2	0.3167 (0.000)	-7.7133 (0.000)	0.8620 (0.000)	-
LnPCI	-	-0.3747 (0.396)	0.1186 (0.015)	-
lnFDI		-	-	1.2272 (0.000)
LnFD	0.5753 (0.000)	-	-	-0.0174 (0.913)
LnK	0.0540 (0.000)	-	-	-
LnL	0.0150 (0.000)	-	-	-
LnURBN	-	-	-	-1.3577 (0.032)
LnTRAD	-	-	-	-0.0156 (0.000)
LnPOP	-	-1.0103 (0.000)	0.0976 (0.000)	-
C	18.2816 (0.000)	36.533 (0.000)	-4.3237 (0.000)	4.5048 (0.118)
J test	150.721 (p = 0.0000)			

4. Results

Dynamic panel In this study, we also have a dynamic panel specification where the lagged variables of renewable energy, non-renewable energy, economic growth and CO2 emissions are taken into account using the GMM estimator. The consistency of the GMM estimator depends on the validity of the instruments. To solve this problem, we consider the specification test: the Hansen test over-identification of restrictions, which tests the global validity of the instruments (the null hypothesis is that the instruments are not valid); For high GDP countries Based on the GMM estimate, we find that a delayed value period (Y_ (t-1)) of the consumption of renewable energies, non-renewable energies, economic growth and CO2 emissions has a positive and significant impact on its current value at the 1% level. The result is in line with Omri et al (2014). Renewable energies and urbanization have a negative and significant impact on co2 emissions.

Indeed, a 1% increase in renewable energies and urbanization reduces CO2 emissions by 0.92 and 0.03% respectively. On the other hand, trade openness increases these emissions by 0.08%. For these countries, FDI, capital and labor have a positive and significant impact on economic growth. Indeed, a variation of 1% of FDI, capital and labor, varies economic growth by 0.009%, 0.03 and 0.01% respectively. Again, renewable energies and labor have a positive and significant impact on non-renewable energies. As a result, 1% of renewable energies is associated with 2.43 and 6.65% decrease of non-renewable energies and work respectively. However, CO2 emissions and capital have a negative and significant impact on the consumption of renewable energies in the order of 1%. Indeed, an increase in CO2 emissions, capital decreases the consumption of renewable energies by 0.213 and 0.01% respectively. On the other hand, non-renewable energies have a negative and significant impact on the consumption of renewable energies in the order of 1%. Indeed, an increase in the consumption of renewable energies decreases non-renewables by 0.03% and increases economic growth by 0.59%.

5. Conclusion and policy implications

For developed countries both renewable and non-renewable energy sources are important and the role of each source is important for economic growth Kaygusuz (2007), Shafei et al, (2014). For all the samples, we notice that the coefficient on the economic growth of non-renewable energies is higher than that of renewable energies and this can be justified by the fact that the investment in energy technology has given advantages. Still, the current financial crisis could decrease investment in this sector and hence, and research and development has not reached the point of increasing real GDP. For all the country panels, the consumption of renewable and non-renewable energies are complementary in terms of economic growth and co2 emissions. Indeed, these countries must develop renewable energy technologies to reduce CO2 emissions and adapt policies aimed at reducing the consumption of non-renewable energies, they must be exhausted and for economic growth to be sustained. The research results clearly show the correlation between energy consumption and economic growth in high-income countries for the periods. In addition to these important findings, the democratic structures and market economy of these countries played an important role in the choice of the particular area of interest for this study. Due to the rational governance of the economic, social and managerial difficulties and the possibilities of making the energy policies beneficial, significant results in relation to the political variables could emerge. OECD countries will demand more energy in the future, which means they need to find alternative and low-cost sources of energy in production processes. Without taking the necessary measures and precautions in alternative energy supply and environmental policies, OECD countries will struggle to develop non-renewable resources for future generations. In addition, the results of the panel analysis confirm the feedback effect between non-renewable energy consumption and economic growth, indicating that energy conservation policies can support economic growth in countries. of the OECD. OECD countries often have to invest in infrastructure and production technology because they consume too much energy. OECD countries have developed infrastructure resources, but this development requires additional efforts. A reliable supply of energy, operational efficiency and a better allocation of resources would also be ensured by the intensification of the public-private partnership. In addition, their performance also ensures the acquisition of import substitution targets which, otherwise, could create an adverse effect on the balance of payments in the countries concerned. The sustainable supply of energy to positively trigger the economy would be ensured by the strong will to find local energy sources and investment incentives, as well as initiatives to attract investment and, therefore, it could prevent the price of local energy from increasing. Otherwise, there could be a reduction in energy consumption which, in turn, would significantly affect the economic growth of the countries concerned. Since these sources are an important factor in economic growth, future decision-makers in economic development in OECD countries should update the progress and development of the energy sector. Low-income countries In the case of low-income countries, a two-way causality is observed between the consumption of non-renewable energies and economic growth. On the other hand, the results of our decomposition of variance analyzes show that in eleven of the seventeen countries, energy is only a factor contributing to the growth of output and not an important factor relative to capital and at work. Labor and capital are the most important factors in the growth of production in these countries. GDP results in the consumption of non-renewable energies, while energy consumption is the source of negative economic growth. Most of the weak countries belong to the African contain, heavily populated countries. These countries are net energy importers, but they are trying to diversify their energy sources by using renewable energies (hydro, wind, solar, etc.). The largest wind farm in the world was recently established in Ethiopia.

These results imply that energy sources are complementary for all panels. The optimal solution is to revise the use of nonrenewable resources and diversify the use of renewable resources.

6. Sample of the study

Faible revenu (PRF, N =30)	Revenu intermédiaire / tranche inférieure (PRF, N =29)	Revenu intermédiaire / tranche supérieure (PRF, N =33)	Revenu élevé (PRF, N =40)
Seuil PIB ≤$995	Seuil $996 $3895	Seuil $3896 $12055	Seuil GNI ≥ $12055
Benin, Burkina Faso, Burundi, Afrique centrale, Chad, Comoros, Republique démocratique du Congo, Gambia, Guinea, Guinea-Bissau, Madagascar, Malawi, Mali, Mozambique, Nepal, Niger, Rwanda, Senegal, Tanzania, Togo, Uganda	Angola, Bangladesh, Bolivia Cambodia, Cameroon, république de Congo, Cote d'Ivoire, Egypte, El Salvador, Georgie, Ghana, Honduras, Inde Indonesie, Kenya, Kyrgyz Republic, Mongolia, Maroc, Myanmar, Nicaragua, Nigeria, Pakistan, Philippines, Sri Lanka, Sudan, Tunisia, Ukraine, Vietnam, Zambia	Albanie, Algerie, Armenia Azerbaijan, Belarus, Botswana Brazil, Bulgaria, China, Colombia Costa Rica, Dominican Republic Ecuador, Gabon, Guatemala Iran, Islamic Republic, Jamaiique Jordan, Kazakhstan, Leban Malaysie, Mauritius, Mexique, Namibia, Paraguay, Peru, Romanie, Russie, Serbia, Afrique du Sud, Thailande, TunisieTurkie Venezuela, Argentine	Australia, Austria Belgium, Canada, Chile, Croatia Cyprus, République Czech, Denmark, Estonia, Finland, France, Allemagne, Greece, Hong Kong (SAR China) Hungary, Iceland, Ireland, Italie, Japan, Korée, Macao (SAR China), Netherlands, New Zealand Norway, Panama, Poland, Portugal, Seychelles, Singapore Spain, Sweden, Switzerland United Arab Emirates, United Kingdom United States, Uruguay

- Definition of variables and their sources

Variable	Définition	Mesure	Source
RE	Renewable energy consumption		

NRN	Renewable energy consumption	(Kg of Oil equivalent.	IEA (international energy agency (2017), Le BP Statistical Review of World Energy, (2016)
FD	Financial development	(Total credit to private sector (% of GDP)	GFDD, (2017)
GDP	Gross Dmestic Product Per capita	US constants de 2010 $	
FDI	Foreign direct investment		
Co2	Emissions de co2, tonne métrique par habitant	Metric tone per capita	
URBN	Urbanisation	% of urban population of total	
TRADE	Trade openess	% of exports and imports to GDP	
Price	Energy price		World Bank,WDI, (2017)
POP	Population totale		
K	Gross fixed capital stock (US constants de 2005 $)	US constants de 2010 $	
L	Total active population	% of total	

- Summary of descriptive statistics (after taking logarithm forms)

		CO2	PREV	POP	GNI	IMP	AGR	CROP
Algeria	Means	1.070	1.508	0.6347	26.468	3.2634	2.2337	3.8701
	Std.dev	0.147	0.4119	0.2590	0.2873	0.16.94	0.1730	0.5826
	CV							
Egypt	Means	0.6195	1.6724	0.7404	27.1448	3.3032	2.6790	4.2175
	Std.dev	0.2263	0.1091	0.1270	0.3692	0.1705	4.2117	0.3424
	CV							
Iran	Means	1.6750	1.6693	0.4406	27.3825	2.9668	2.2595	4.2773
	Std.dev	0.3300	0.0870	0.4154	0.2685	0.2889	0.2883	0.3006
	CV							
Jordan	Means	1.0804	0.9474	1.2536	24.7551	4.2564	1.2998	4.0624
	Std.dev	0.0784	0.1586	0.3915	0.4285	0.1550	0.3788	0.3777
	CV							
kuwait	Means	3.1016	0.9184	1.2158	26.1530	3.6459	-0.9639	3.6687
	Std.dev	0.1909	0.0092	0.8128	0.0698	0.3164	0.3054	0.8173
	CV							
lebenon	Means	1.2826	2.2311	0.7155	24.9067	4.0074	1.5225	4.6415
	Std.dev	0.2060	0.2473	0.9922	0.3955	0.2638	0.2740	0.1522
	CV							
Morocco	Means	0.2388	1.5978	0.3501	25.7712	3.5432	2.6018	4.2413
	Std.dev	0.2785	0.1811	0.2075	0.3473	0.2372	0.1225	0.3090
	CV							
Oman	Means	2.3236	2.1989	0.9851	25.2553	3.5597	0.7548	4.1763
	Std.dev	0.3854	0.1620	1.0108	0.2167	0.1328	0.3464	0.3486
	CV							
Suadi Arabia	Means	2.5998	1.5509	1.0408	27.8230	3.4067	1.3651	4.7788
	Std.dev	0.1527	0.1526	0.2665	0.1639	0.1639	0.4034	0.1390
	CV							
Tunisia	Means	0.7410	1.2300	0.2687	25.0619	3.8603	2.3783	4.2691
	Std.dev	0.1732	0.2295	0.4027	0.3311	0.1371	0.2316	0.2951
	CV							
UAE	Means	3.2502	1.6114	1.4660	26.9107	4.1022	0.1877	4.6806
	Std.dev	0.1938	0.4436	0.9829	0.2072	0.1949	0.2479	0.6264
	CV							
Turkey	Means							
	Std.dev							
	CV							
Global panel	Means	1.6229	1.6487	0.8239	26.0815	3.6029	1.5234	4.2621
	Std.dev	1.0085	0.4323	0.4257	1.0929	0.2457	1.0855	0.5381
	CV							

Notes : Std. Dev.: indicates standard deviation, CO2: indicates per capita carbon dioxide emissions, UAE indicates United Arab Emirates Ordinary least squared estimation

	Intercept	CO2	PREV	POP	GNI	IMP	AGR	CROP
Algeria								
Egypt								
Iran								
Jordan								
Kuwait								
Lebenon								

Morocco
Oman
Saudi Arabia
Tunisia
Turkey
UAE
Global
Panel (fixed effects)
Hausman test
R^2
Observations
Nb of countries

This table indicates that, Lebenon has the highest means pourcentage of the prevalence of undernourishment

7. Results and discussions

- Fixed effects

	Intercept	CO2	PREV	POP	GNI	IMP	AGR	CROP
Algeria								
Egypt								
Iran								
Jordan								
Kuwait								
Lebenon								
Morocco								
Oman								
Saudi Arabia								
Tunisia								
Turkey								
UAE								
Global								
Panel (fixed effects)								
Hausman test								
R^2								
Observations								
Nb of countries								

- Random effects

	Intercept	PREV	CO2	POP	GNI	IMP	AGR	CROP
Algeria								
Egypt								
Iran								
Jordan								
Kuwait								
Lebenon								
Morocco								
Oman								
Saudi Arabia								
Tunisia								
Turkey								
UAE								
Global								
Panel (fixed effects)								
Hausman test								
R^2								
Observations								
Nb of countries								

	Yt-1	Intercept	PREV	CO2	POP	GNI	IMP	AGR	CROP
Algeria									
Egypt									
Iran									
Jordan									
Kuwait									
Lebenon									
Morocco									
Oman									
Saudi Arabia									
Tunisia									
Turkey									
UAE									
Global									
Panel (fixed effects)									

Hausman test
R
Observations
Nb of countries

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