The Importance of Renewable Energy in Economic Growth: Evidence from a Panel of Emerging Countries

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The purpose of this paper is to estimate the impact of renewable energy consumption from combustible renewable and waste sources on economic growth in emerging countries. We analyze the stylized facts of renewable energy and emerging countries related to four regions (Africa, Europe, Latin America, and Asia). We use recent data in the cob-Douglas function and applying a non-stationary panel model for 15 emerging countries covering the period (1990-2011). The Granger causality test showed that there is no causal relationship between renewable energy consumption of combustible renewable and waste sources and economic growth that confirm the neutrality hypothesis. The results supported a positive and significant effect of renewable energy consumption of this source on economic growth in emerging countries. The absence of a causal relationship can be explained by the inefficient use of combustible renewable and waste in the majority of those emerging countries.

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The consumption of low variability renewable energy such as renewable and waste stimulates economic growth in emerging countries.

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Introduction

Recent years, several countries have tried to follow up effective strategically in order to decrease the proliferation of destructive effects of climate change. "Anthropogenic warming could have abrupt or irreversible consequences depending on the scale and pace of climate change» announced the IPCC[3]in 2007. This also affects the quality and the efficiency of natural resources. In fact, the object of the economics of climate change is namely the reduction of the emission of greenhouse gases. In this context, many economists tried to examine the causal relationship between the use of renewable energy and economic growth. This study aims to investigate the relationship between economic growth and renewable energy consumption on emerging countries during the period 1991-2011. We choose the combustible renewable and waste as a one of the renewable energy source. We try to show the effect of this type of source on economic growth in emerging countries. After using the Granger causality test, we show that there is no causal relationship between renewable energy consumption of combustible renewable and waste source and economic growth. So our results confirm the hypothesis neutrality.

[3] The Intergovernmental panel on climate change was established on 1988. It is a scientific intergovernmental body under the auspices of the nations under the auspices of the United Nations.

After the introduction, as provided above in section 1, literature review is carried out in section 2, data sources and methodology are discussed in section 3 and the results are discussed in section 4.

1. Literature review

Several studies have addressed the question of the relationship between energy consumption and economic growth (Dagher and Yacoubian (2012), Apergis and Payne (2010), Apergis and Payne (2009), Soytas et al. (2007)). Those studies used different period, different countries and different method of estimation (ARDL approach, FMOLS, DOLS...). Their results showed that there are four assumptions related to the causal relationship between energy consumption and economic growth: the conservation hypothesis, the feedback hypothesis, the growth hypothesis, and the neutrality hypothesis. The conservation hypothesis states that economic growth boosts consumption of energy. Soytas and Sari (2003) found a unidirectional relationship of GDP to energy consumption in Italy and Korea. Ben Amar (2013) confirmed this hypothesis for Africans countries. In the case of growth assumption, the energy consumption is considered one of the most important factors of economic growth. Soytas and Sari (2003) confirmed that the energy consumption per capita causes GDP per capita in Turkey, France, Japan and Germany. Apergis and Payne (2009) proved the existence of a short-term and a long term causal relationship from energy consumption to economic growth. The feedback hypothesis means the existence of a bidirectional relationship between economic growth and energy consumption. Apergis and Payne (2010), Dagher and Yacoubian (2012) showed this hypothesis in their research. The neutrality hypothesis means no interaction relationship between energy consumption and economic growth, Soytas et al. (2007) confirmed this hypothesis.

There is no doubt that natural resources represent a main factor of economic growth. So, the problem of exhaustible natural resources (such as non renewable energy) represents a handicap to promote economic growth. As an alternative, the exploitation of renewable energy sources will be essential to ensure the energy security. According to IPCC (2011), energy security provides several advantages such as resource availability and reliability of energy supply. So, renewable energy represents a significant potential that lies in all countries without exception and less concentrated way where the hypothesis of reduced risk.

New sources of renewable energy, which are normally characterized by the lower green house gas emissions, in relation to traditional energy sources, represent, according to the theory of green growth, a driving force for the GDP log-term growth. In this context, several studies have begun to explore the relationship between economic growth and renewable energy consumption (Pao and Fu (2013) , Aslan et al. (2012), Menegagui (2011) Apergis and Payne (2010), Payne (2009)). Their results are mixed and different from a study to another. Payne (2009) sought the causal link between renewable energy consumption, non-renewable and real GDP in the United State for the period (1949-2006). This study confirmed the hypothesis of neutrality. Apergis and Payne (2010) examined the relationship between consumption of renewable energy and economic growth in 20 OECD countries over the period 1985-2005. They showed that the increase of renewable energy consumption by 1% can increase real GDP by 0,76%. Menegagui (2011) examined the causal relationship between economic growth and renewable energy for 27 European countries for the period 1997- 2007. They confirmed the hypothesis of neutrality because their results did not find a causal relationship between renewable energy and economic growth. Aslan et al. (2012) showed a unidirectional relationship from the consumption of biomass derived by waste to economic growth. Pao and Fu (2013) explored the causal relationship between real GDP and four types of energy consumption: consumption of non-hydro renewable energy, consumption of non-renewable energy, consumption of total primary energy and total consumption of renewable energy of the Brazilian economy in the period 1980-2010. They showed a unidirectional causal relationship from the consumption of non-hydro renewable energy to economic growth confirming the growth hypothesis. Furthermore, a bidirectional relationship has been explored between economic growth and the total consumption of renewable energy. The results of the ARDL approach used by Ocal and Aslan (2013) for the case of Turkey covering the period 1990-2010 noted a negative relationship ranging from renewable energy consumption to economic growth. However, the results of the Toda-Yamamoto approach revealed a unidirectional relationship of economic growth in renewable energy consumption hence the confirmation of the conservation hypothesis. Zeb et al (2014) investigated the short- and long-term causal relationship between electricity production from renewable energy, CO2 emissions, degradation of natural resources, GDP and poverty for SAARC countries (Bangladesh, India, Nepal, Pakistan and Sri Lanka) covering the period 1975-2010. Their results revealed a positive relationship between GDP and electricity production from renewable energy that confirmd the growth hypothesis. Ohler and Fetters (2014) focused on the causal relationship between GDP and electricity production from six renewable energy sources for 20 OECD countries during the period 1990-2008. Their results showed that the biomass, hydro, waste and wind have a positive impact on the long-term GDP, A bidirectional relationship in the short-term is recorded between hydropower and waste and GDP.

2. Presentation of the model and methodology of estimations

2.1. Model presentation

Our objective in this section is to study the effects of renewable energy on GDP per capita for a sample of emerging countries[4]. The first stage is the choice of an adequate model. To attain such a target, we will follow the approach of Mankiw, Romer and Weil (1992).

We retain the Cobb-Douglas production function:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta} \quad (1)$$

with; $L_t = L_o e^{n_t}$ and $A_t = A_0 e^{g_t + \rho_t \theta}$

where, Y is the real output, K is the stock of physical capital, H is the stock of human capital, L is the labor, A is the factor reflecting the level of technology and the efficiency in the economy, n is the rate of labor force growth, g is the rate of technological progress supposed constant, ρ is the vector representing industrial development and other factors that can affect the level of technology and economic efficiency, θ is the vector of coefficients related to these variables, the subscript t indicates time. It is assumed that $\alpha + \beta < 1$.

The technological progress (A_t) can really explain the relation existing between renewable energy consumption and economic growth. We consider that industrial development can encourage a faster reconstruction of capital and this thanks to the new technologies.

2.2. Model demonstration

The evolution of the economy is represented by:

$$\dot{K}_t = \frac{dK_t}{d_t} = s_k Y_t - \delta K_t \ \& \ \dot{H}_t = \frac{dH_t}{d_t} = s_h Y_t - \delta H_t \quad (2)$$

Where, s_k and s_h are respectively the rate of investment in physical capital and the rate of investment in human capital.

We suppose that: $\dot{K}_t = I_t - \delta K_t$ and $I_t = S_t$

[4] Argentina, Brazil, China, Colombia, Egypt, India, Indonesia, Malaysia, Mexico, Morocco, Philippines, Russian Federation, South Africa, Tunisia, Ukraine.

Where, δ is the rate of the physical capital depreciation.
We consider that the production by unit of labor, the physical capital stock by unit of labor and the human capital stock by unit of labor are given by:

$y_t = \frac{Y_t}{AL_t}$; $k_t = \frac{K_t}{AL_t}$ and $h_t = \frac{H_t}{AL_t}$

After all developments, we obtain:

$$\dot{k_t} = s_k y_t - (n + g + \delta)k_t \quad (3)$$

$$\dot{h_t} = s_h y_t - (n + g + \delta) \quad (4)$$

We consider that the gross domestic product per effective worker is written as follows:

$$y_t = \frac{Y_t}{AL_t} = k_t^{\alpha} h_t^{\beta} \quad (5)$$

The substitution of (5) in (3) and in (4), produces:

$$\dot{k_t} = s_k k_t^{\alpha} h_t^{\beta} - (n + g + \delta)k_t \quad (6)$$

$$\dot{h_t} = s_h k_t^{\alpha} h_t^{\beta} - (n + g + \delta)h_t \quad (7)$$

At the equilibrium, we have: $\dot{k_t} = \dot{h_t} = 0$
This result conducts us to the following relations:

$$s_k k_t^{\alpha} h_t^{\beta} = (n + g + \delta)k_t \quad (8)$$

$$s_h k_t^{\alpha} h_t^{\beta} = (n + g + \delta)h_t \quad (9)$$

On dividing (8) by (9), we obtain:

$$h = \frac{s_h}{s_h} k \quad (10)$$

The substitution of (10) in (9) and (8), shows us to the following relation:

$$k^* = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta}} \quad (11)$$

$$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta}} \quad (12)$$

The relations (11) and (12) reveal the steady state of the economy.

While taking into account the relation (5), we will have:

$$\left(\frac{Y}{AL}\right)^{*} = (k^{*})^{\alpha}(h^{*})^{\beta}$$

It means that:

$$\left(\frac{Y}{L}\right)^{*} = (y)^{*} = A^{*}(k^{*})^{\alpha}(h^{*})^{\beta} \qquad (13)$$

The relation (13) represents the output by worker to the equilibrium.
At the equilibrium, the technological progress is represented by:

$$A^{*} = A_{0}e^{\rho\theta} \qquad (14)$$

Where, ρ represents the variables that correspond to the factors that can influence the technological progress. In our study, ρ regroups the variables reflecting the renewable energy consumption.
The substitution of (11), (12) and (14) in (13), produces:

$$(y)^{*} = A_{0}e^{\rho^{*}\theta}\left(\frac{s_{k}^{1-\beta}s_{h}^{\beta}}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha-\beta}}\left(\frac{s_{k}^{\alpha}s_{h}^{1-\alpha}}{n+g+\delta}\right)^{\frac{\beta}{1-\alpha-\beta}} \qquad (15)$$

To have a linear relation, we apply the logarithm:

$$Ln(y)^{*} = Ln\left[A_{0}e^{\rho^{*}\theta}\left(\frac{s_{k}^{1-\beta}s_{h}^{\beta}}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha-\beta}}\left(\frac{s_{k}^{\alpha}s_{h}^{1-\alpha}}{n+g+\delta}\right)^{\frac{\beta}{1-\alpha-\beta}}\right] \qquad (16)$$

If we add the subscript of the time and the individual, we can write the following relation:

$$Ln(y_{it})^{*} = Ln(A_{0i}) + \theta_{i}\rho_{it} + \frac{\alpha}{1-\alpha-\beta}Ln\left(s_{k_{it}}\right) + \frac{\beta}{1-\alpha-\beta}Ln\left(s_{h_{it}}\right) - \frac{\alpha+\beta}{1-\alpha-\beta}Ln(n_{it} + g + \delta) \qquad (17)$$

where, g and δ are supposed constant for all the countries and in the time and their sum is equal to 0.05 (Mankiw and al., 1992). The variable $Ln(A_{0i})$ involves the structural factors and the factors of the economic environment possessing an influence on the economic growth. Therefore, our regression is based on the following relation:

$$\boldsymbol{GDP_{it} = \alpha + \beta RE_{it} + \lambda\, CAP_{it} + \gamma EDU_{it} + \varepsilon_{it}} \qquad (18)$$

where, i indicates the countries (i = 1, 2,..., N) and t represents the time (t = 1,…, T), *GDP*: the logarithm of the GDP per capita calculated in constant dollars of 2005; *RE*: the logarithm of the renewable energy consumption; *CAP*: the logarithm of the capital accumulation per capita; *EDU*: the logarithm of the secondary schooling rate.

We estimated econometrically the last equation with the method of non stationary panel model data for a sample of 15 emerging countries during the period 1990-2011.

$(\beta, \boldsymbol{\lambda}, \gamma)$: A vector of the coefficients to estimate;

ε_{it}: Is the error term.

2.3. Presentation of the variables and their sources

The variables taken in our study are: the real gross domestic product per capita as an endogenous variable, physical capital stock per capita, education and renewable energy consumption.

Dependent variable:

We use the gross domestic product (GDP) per capita as a dependent variable which reflects the economic growth. We have chosen the GDP per capita to explore effect of renewable energy (combustible renewable and waste) on the production per capita. The data relative to this variable, for the 15 countries of our representative sample.

Independent variables:

We take the education and physical capital because this tow variable represents among the main factors of economic growth.

Physical capital stock per capita:

We calculate the physical capital stock by using the method described by Van Pottelsberghe (1997). The stock of physical capital "K" of the year “t” is equal to its stock at “t-1” adjusted by a depreciation rate plus the investment "I" at “t”: $K_t = I_t + (1 - \delta)K_{t-1}$. When, I_t is the Gross Fixed Capital Formation and δ is the capital depreciation rate ($\delta = 6\%$).

The initial physical capital stock K_0 is equal to the initial investment I_0 divided by the sum of the yearly growth rate of the investment I_t and the physical capital depreciation rate δ: $K_0 = I_0/(\varphi + \delta)$. The physical capital stock per capita is the physical capital stock calculated, divided by the total population.

Education is presented by secondary school enrollment.

Renewable energy measured by combustible renewable and waste (metrics tons of oil equivalent). The energy represents among the main factor of economic growth. All of works, focused to examine many types of renewable sources. However, the effect of combustible renewable and waste on economic growth is still not done using the cob-Douglas function.

All variables are extracted from the World Development Indicators (2014).

2.4. Methodology of estimations

Panel unit root test

A series of unit root tests became a current step for the analysis of the stationary of the panel series. We examine our data by performing several unit root tests in a panel framework: Im and al. (2003) .There are the more frequently used, when the temporal dimension is limited. The authors propose tests permitting to detect the presence of unit root in the models using Fisher-ADF statistics.

In this paragraph, we study the order of integration of the series and the relations of cointegration between the variables. To study the non stationary, we use the IPS test presented by the following equation.

$$\Delta y_{it} = \rho y_{it-1} + \sum_{j=1}^{k_i} \varphi_{ij} \Delta y_{it-j} + \mu_i + \delta_i t + \varepsilon_{it} \quad (19)$$

When, k represents the lag chosen in order to eliminate the auto-correlation of the residue.
The IPS test is calculated like being the statistic t as an average of the Dickey-Fuller regressions with or without trend. The alternative statistic t-bar permitting to test the null hypothesis of unit root for all individuals ($\beta_i = 0$) is the following:

$$t_{NT}(\rho_i) = \frac{1}{N}\sum_{t=1}^{N} t_{iT}\,(\rho_i) \qquad (20)$$

With, $t_{iT}(\rho_i)$: estimated ADF tests, N: number of individuals and T: number of observations.
Im et al. (2003) propose to use the following standardized statistics:

$$Z_i = (N)^{1/2}\left(t_{NT} - E(t_{NT})\right)/\left(var(t_{NT})\right)^{1/2} \qquad (21)$$

When, $E(t_{NT})$: arithmetic average and $var(t_{NT})$: variances of individuals ADF statistics.
The study of IPS shows that this standardized statistic converges slightly toward the standard normal distribution, which allows comparing the critical values of the distribution N (0, 1). The application of the IPS test is presented in the following table:

Table 1

Unit Root Test results (IPS, 2003)

Model	**Without trend**				**With trend**			
Variables	GDP	RE	CAP	EDU	GDP	RE	CAP	EDU
Level	4.907	2.709	4.69	0.905	1.515	2.436	-0.056	-0.225
First difference	-5.246*	-5.282*	-1.45***	-7.084*	-3.426*	-4.671*	-1.77**	-2.596*

* Significant at 1%; ** Significant at 5%; *** Significant at 10%.
Source: Calculations by authors according to the results of the IPS test.

The verification of the non stationary properties for all variables of the panel leads us to study the existence of a long term relation between the variables.

Cointegration test

To study the existence of a cointegration relation, we refer to Pedroni studies (1999, 2004), whose null hypothesis is to test the absence of cointegration based on the test of unit roots on the estimated residues. Pedroni (2004) developed seven tests of cointegration on panel data. These tests take into account the heterogeneity in the cointegration relationship to say that for each individual there is one or more cointegrating relationships that are not necessarily identical for each individual panel. Each of the seven statistics follows a standard normal distribution for sufficiently large N and T.

$$\frac{Z_{NT}-\mu\sqrt{N}}{\sqrt{\vartheta}} \to 0 \quad (22)$$

Where, Z_{NT}: One of the 7 statistics; μ and ϑ value of the moments presented by Pedroni.

Table 2

Cointegration Test result (Pedroni, 2004)

Statistics	Without trend	With trend
Panel v-Statistic	-3.962371	-5.918430
Panel rho-Statistic	4.573903	5.929728
Panel PP-Statistic	0.862767	-1.421476***
Panel ADF-Statistic	-2.251066*	-1.532431***
Group rho-Statistic	5.260544	6.398432
Group PP-Statistic	-4.088953*	-10.19110*
Group ADF-Statistic	-3.025322*	-3.073607*

* Significant at 1%; ** Significant at 5%; *** Significant at 10%.

Source: Calculations by authors according to the results of the Pedroni test.

The simulations made by Pedroni show that for values of T higher than 100, the seven statistics give comparable results in terms of potentiality. For smaller sample sizes, the panel-ADF and group-ADF tests have better properties than the other tests. From the results of the Pedroni cointegration tests, we confirm the existence of a cointegration relationship.

Estimation and interpretation

To estimate systems of cointegrated variables on panel data, it's indispensable to apply an efficient estimation method. We identify different techniques: FMOLS method (Fully Modified Ordinary Least Squares) used by Pedroni, DOLS method (Dynamic Ordinary Least Squares) and GMM method (Generalised Method of Moments). Kao and Chiang (2000) suggest a Fully Modified (FM) and DOLS estimators in a cointegrated regression and show that their limiting distribution is normal. They showed that the DOLS estimator may be more promising than OLS or FM estimators in estimating the cointegrated panel regressions.
This technique consists to include advanced and retarded values of the cointegration relation, in order to eliminate the correlation between the explanatory variables and the error term:

$$Y_{it} = \alpha_i + \beta X_{it} + \sum_{j=-r_1}^{r_2} c_{ij} \Delta X_{it-j} + \varepsilon_{it} \qquad (23)$$

The use of the DOLS method implies an arbitrary choice of lags which represent an interesting question but that exceed our objective in this work. We chose to keep the same number of lags for all countries[5].
In This table we summarize the estimations by the FMOLS and DOLS methods.

[5] We take in our analysis: r=-1 and r=-2.

Table 3

Results of FMOLS and DOLS regressions
Endogenous variable is GDP

Variables	RE	CAP	EDU
FM-OLS	0.418*	0.935*	0.041**
DOLS	1.087*	0.746*	0.565*

* Significant at 1%; ** Significant at 5%; *** Significant at 10%.
The lags used in the DOLS method are r = -1 and r = -2.

The results of our estimation confirm that the level of RE exercises a positive and statistically significant effect on the level of GDP per capita in our sample constituted by 15 emerging countries. We find that a 1% increase in RE increases real GDP by 0.418 (FMOLS) and1.087% (DOLS). This result can explain and justify the contribution of the evolution of renewable energy consumption of combustible renewable and waste source of emerging countries during the last years of their economic growth. An evolution that is due to a number of economic reforms[6]. Thus, the fruits of these reforms are justified by the positive effect of physical capital and human capital accumulation on economic growth.

The effect exerted by renewable energy consumption, confirmed by our econometric study, can also contribute to the transformation of these countries potential into concrete achievements in the coming years but they must use efficiency in their renewable sources. Emerging countries have achieved high performances in terms of economic growth, but the most important issue is continuity on the one hand, and the development of the endogenous factors of wealth creation, on the other hand.

[6] Privatization of the public companies, reduction of trade barrier, tax relief and consolidation of the legal systems.

Conclusion

This study investigates the impact of renewable energy consumption of combustible renewable and waste and economic growth in 15 emerging countries covering the period (1990-2011). Stylized facts showed that the use of combustible renewable and waste in emerging countries is progressing slowly that weakly affect GDP per capita. The Granger causality test results showed that there is no causal relationship between renewable energy consumption of combustible renewable and waste source and economic growth. So our results confirm the hypothesis of neutrality. The results of the FMOLS and DOLS models supported a positive and significant effect of renewable energy consumption of combustible renewable and waste source on economic growth. The absence of a causal relationship may arise due to inefficient use of this source of renewable energy. Policy makers, in emerging countries, can base the environmental policy on combustible renewable and waste as a source of renewable energy in the mix energy to ensure energy supply. However, the nature of the instrument used and the laws enacted to encourage investment in this renewable energy source play a crucial role to realize an efficient use that grant economic performance in those emerging countries.

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