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Renewable energies and economic development: a panel study

Abstract: The concerns with sustainability in environmental and social realm led to an expressive increase in generation of energy of renewable sources in last years. This paper addresses an investigation on possible associations between the increase of renewable energies generation and the economic and financial performance indicators of countries. The multiple linear regressions method is applied to a data panel of the period from 2005 to 2008, in 54 countries. The outcomes point to an association between higher generation of renewable energies and lower GDP growths, higher *per capita* income and higher investments in gross fixed capital formation, besides other interesting associations.

Keywords: Renewable energies, sustainability, economic development, linear regression.

1.INTRODUCTION

There is an increase of the consensus on the need for control measures of the impacts generated by current production processes and patterns of consumption on the environment. Since Kyoto Protocol (1997) the countries and their respective societies seek to determine which measures should be taken to protect the environment from negative impacts promoted by the contemporary process of economic growth.

Kojo and Wolde-Rufael (2010) have studied the causal relationship between carbon dioxide (CO2) emissions, renewable and nuclear energy consumption, and USA GDP for the period 1960-2007. It has been observed causality of nuclear energy consumption to CO2 emissions. It has not been identified causal relationship from renewable energy use to CO2 emissions. Econometric evidence suggested that nuclear energy consumption helps to reduce CO2 emissions. However, the renewable energy consumption has not reached a level that can significantly contribute to emissions reduction.

Mathiesen, Lund and Karlsson (2011) concluded that applying efficiency to energy consumption, to the use of more efficient renewable energies and to conversion technologies

might have positive socio-economic effects, generate employment and, potentially, lead to grate gains in exports. Use of 100% renewable energy systems will be technically possible in the future, and might even be economically advantageous in comparison with the energy system economically viable in current days.

Based on OECD/IEA (2007) report, Martinelli and Midttun (2010) observed that competition among OECD member states and developing countries has imposed a heavy ecological burden over the system we live in, and that it was the development of emerging countries like China and India that has promoted disturbances with worldwide effects in the environment.

In regard to the development of renewable energies as a factor that would help to decrease impacts of the current development model on the environment, Bursztyn (1993) supports that to Northern countries, more developed than Southern ones, and to Eastern countries, fall the burden of bearing more financial resources and technological adjustment in the control of environmental impacts in the field of generation and use of energy.

Lameira *et al*. (2012) point that countries in a further stage of development must be the countries that have promoted the greatest growth of renewable energies generation. Authors understand that countries with higher economic growth rates have economic conditions that allow them to take over the leadership in the development process of such energy sources. Likewise, they have observed that some parameters related to the capacity of gross capital formation and the consumption on the part of citizens, could be associated with the growth of renewable energies generation.

In this sense, it has been identified an absence of studies investigating possible associations between renewable energies generation, and economic and financial performance indicators of the countries. Thus, the present investigation promotes the study of possible associations between indicators of these variables in order to promote the discussion on possible associations between financial and economic components of the countries and renewable energies development.

It has been applied the method of multiple linear regressions on data of renewable energies generation, and economic and financial performance of some sample countries. A panel of the 2005 to 2008 period was elaborated in order to investigate such relationship.

This paper is organized in 5 sections. Section One contains the subject introduction, in Section Two is developed the literary review on proposed subjects. Section Three presents the methodology used in the study. Section Four addresses the outcomes and Section Five include the results and final comments, besides suggestions for feature researches.

2. BIBLIOGRAPHICAL REVIEW

The development of industrialized and emerging countries, according to OECD/IEA (2007) report, has given rise to an intense economic growth in last decades, culminating in an increase of CO2 emissions, worsening global warming. Since the most important component of this development was the large-scale production, with low costs, after China and other emerging countries enter the world scene, this process was fed with intensive use of energy.

Studying the relationship between development and the environment, Kolstad and Krautkaemer (1993) argue that, while the use of resources, especially the energy ones, generates quick gains for economy, the negative impact might take too long to be observed in the environment. In addition, the impacts produced can cause irreversible damages to the ecosystem. Thus, there is a dynamic link among the environment, the use of natural resources and the economic activity.

Using the environmental, macroeconomic and financial variables, along with indicators of the Kyoto Protocol, Tamazian *et al*. (2009) applied the methodology of linear regression analysis to data on a panel and examined a possible relationship between energy consumption, economic growth and environmental degradation. The authors advocate the hypothesis of the level of environmental degradation decreases as the countries develop, because of the attraction of foreign investments and development of researches and new technologies associated with renewable energies, for example.

The mentioned authors also found a change in the GDP composition of the country members of BRIC (Brazil, Russia, India and China), which during the last twenty years has been decreasing the participation of agriculture and increasing the participation of industry in GDP formation. It causes the investments in these countries to rise, as well as the energy consumption, unveiling a relationship among economic growth led by industrialization, energy

consumption rise and environment degradation. In their studies they evidenced that the economic growth variable exerts a positive correlation with energy consumption. This correlation was observed in BRIC countries, more intensively in Brazil, India and China, but Russia percentage was also statistically significant. However, the mentioned investigation does not associate development, whether of BRICs, whether of a larger group of countries, with renewable energies generation.

Studying the purchasing power and the environmental degradation, Grossman and Krueger (1992) stated there to be a relationship between the indices of pollution and income, intermediated by mediating variables that promote the association between environmental degradation and economic growth. Nevertheless, a good deal of the levels of environmental degradation and pollution depends on the energy mix they adopt. As regards the means used to generate energy and the energy mix featured by the country, Brien *et al*. (2007) observed that the State participation is essential to determine it. Percebois (2007), by other side, points a listing of factors that influence in the vulnerability of energy generation and relates several economic and financial factors to this indicator. At last, Hannesson (2009) concluded that a positive relation can be established between the growth of energy use and the economic growth. In this context, it seems like energy consumption is closely related to economic development, as Tamazian *et. al.* (2009) remark.

Renewable energy sources represent a powerful alternative to fossil energy resources, especially those derived from petroleum, besides enabling the mitigation of impacts on the environment, which is one of the paradigms of contemporary societies. The renewable energy, abundant and absolutely non-polluting, cheap, clean and permanently renewable, features multiple alternatives, as remarks Alves Filho (2003), but it must go through a path of technological evolution to become tangible. Climate changes, resource shortage and environmental pollution are the reasons for preoccupation when it comes to energy. One of the solutions for the problems derived from this inevitable rise of energy consumption, is the investment in new technologies of energy generation, which are clean, safe and inexhaustible, accomplishing thus the risks minimization and enabling economic growth to continue without the environment destruction. In this aspect, the renewable energies have given proof of being efficient and promising as Ottinger and Williams (2002) remark.

The diversity of renewable energies, especially in developing countries, has been demonstrating to be an alternative to electrical grids of energy generation, promoting reduction of the losses with transmission and distribution of electric power and, in addition, even playing a role in social inclusion. In this sense, Ottinger and Williams (2002) highlight that many rural locations of the world, not supplied with electric power, could benefit from such renewable sources. The authors point out that the most favorable measure, in this purpose, would be withdraw the subsidies associated with the oil and gas industry. However, Heal (2010) found in his studies that the major problem of renewable energies is the intermittent generation, and without the development of proper storage technologies, only the nuclear power, the efficient energy use and the carbon capture are appropriate mechanisms to face the climate changes and the environmental degradation. In alignment with this reasoning, Carson (2012) claims that, besides the intermittence and the impossibility of estimating the exact production of a renewable source, the use of soil for biofuels also affects the food production, the high cost of aeolian technology makes such projects financially impracticable. Some aspects related to the development of renewable energies influence the projects' profitability. Vergura and Lameira (2011) remarked that special conditions of energy sale, in this case solar energy in Italy, can change significantly the investment performance. This aspect evidences the importance of incentives and subsidies action. However, the existence of a policy related to renewable energies is of essential importance so that a set of investments are possible and is avoided the cannibalization of renewable energy companies and projects. In this sense, Fischer and Preonas (2013) highlight that elaborating a policy for the development of generation of several renewable energies is an important synergy source, and aggregates value to the overall renewable energy developed in each country.

Table 1 shows the distribution of the world consumption per source for the years of 1973 and 2010.

Table 1 – Final world energy consumption

Year	**1973**	**2010**
Energy Sources	**%**	**%**
Oil	48.1%	41.2%
Electric Power	9.4%	17.7%
Natural Gas	14.0%	15.2%
Renewable Energies	13.2%	12.7%

Mineral Coal	13.7%	9.8%
Others	1.6%	3.4%

Source: Key World Energy Statistics – IEA – 2012

The electric power consumption corresponds to 17.7% of the overall world energy consumption. This energy is generated by several primary sources, as shown in table 2.

Table 2 – Primary sources of electric power generation in 2010

Energy sources	**%**
Mineral Coal	40.6%
Natural Gas	22.2%
Hydroelectric Power	16.0%
Nuclear Power	12.9%
Oil	4.6%
Energies Geothermal, Solar, Aeolian, Biofuels and Thermal	3.7%
Total in 2010	21.431 TWh

Source: Key World Energy Statistics – IEA – 2012

In order to investigate the possible association between renewables generation and economic development, some indicators were selected to be measurement of what we understand as economic development. It was assumed that the gross fixed capital formation (GFCF), the domestic product growth (GDPG) and the *per capita* income (GDPPC) were indicators that denote a economy's capacity of wealth generation.

The gross fixed capital formation is the index that indicates how much the companies have increased its capital assets, i.e., those with duration of over a year, enabling the production of other assets and ensuring that the country's production base will have the means to raise its production capacity in the following years, causing no inflation, demonstrating that entrepreneurs are confident in the country's development and growth, and therefore will continue to invest.

As remarks Perroux (1961) apud Kon (1991), all economic progress is linked to the capital assets accumulation and its efficient employment, which raise the human work return and the real productivity of the society. Therefore, it is understood that the gross capital formation (GFCF) is an efficient indicator of the current and future development capacity of the economy and of the effort toward the expansion of its production potential.

For the other hand, the Gross Domestic Product Growth (GDPG) points the wealth generation capacity of a country in a period of time. Generally, the countries' products are measured every year, so to accomplish comparability in this indicator. However, in the individual's perspective, *per capita* income (GDPPC) indicates the individual's capacity to access goods and services and, thus, being actors promoting the sustainable growth of the economy in question.

Thus, in this paper it sought to study the relationship between the growth of renewable energies generation and the economic development. So it is assumed that such variables are aligned, as point Lameira *et al*. (2012).

3. METHODOLOGY

It was promoted a secondary data collection, by means of telematics, at the sites of World Bank, Social Science Research Network (SSRN), World Economic Forum (WEFORUM) and Energy International Agency (EIA), in order to build the indicators of this study's empirical investigation. The investigation period stretched from 2005 to 2008 and gathered a set of 54 countries in the sample investigated.

The method of linear regressions was applied for investigation of the possible statistic relationships between the indicators of renewable energies generation and others mentioned before, and the indicators representing the levels of countries economic growth. The study's objective is to find possible statistically significant relationships among such variables. The methodology of models for the data in panel combines characteristics of time series with cross-section data, and is widely applied to econometric studies.

Hsiao (1986) says that the panel models feature a series of advantages over the models of cross-section or the ones of time series, since those models control the heterogeneity present in the others. Another advantage, according to Hsiao (1986), is that the panel data enable the use of more observations, increasing the degrees of freedom and decreasing the collinearity among the explaining variables. Other advantage of the panel data is that they are capable of identifying and measuring effects that cannot be detected by means of cross-section data or time series separately.

To investigate such possible relationship, it was used some indicators related to renewable energies generation and measured in Joule x $10^{6,}$ and indicators of economic development like GDP, in billions of dollars, *per capita* GDP and the gross capital formation.

The dependent variables of the study are the indicators of renewable energies such as: a) aeolian energy generation, b) biodiesel production, c) ethanol production, d) biofuels production, e) renewable energy generation other than hydroelectric, f) energy generation from biomass and waste, g) geothermal energy generation, h) generation of hydroelectricity, i.e., energy generation from the energies solar, tidal and of waves.

3.1. Hypothesis

Aiming at coming to a conclusion about the possible association between renewable energies generation and economic development, the following hypothesis were tested:

H1: it is believed that higher generations of alternative energy are associated with countries presenting higher growths of GDP;

H2: it is believed that higher generations of alternative energy are associated with countries owning higher investments in infrastructures (GFCF);

H3: it is believed that higher generations of alternative energy are associated with countries whose *per capita* GDP is higher;

The expectation is that countries featuring larger infrastructures and more potential to grow need more energy sources, and this increases the chances of enabling a higher renewable energy production within the mix of new energy sources. In addition, a higher *per capita* GDP ensures the payment for the consumption of this energy to be generated, what usually, for being new technologies, are more expensive than those fossil energies and other polluting sources.

3.2. Models

The variables used in this research have already suffered transformations provided that their distributions need to meet the parameters of a normal distribution.

In the statistic tests carried out in the study, the equations have isolated each variable, relating then to the indicators of economic and financial development of diverse countries. For

each one of the dependent variables, transformations were tested to find distribution as close as possible of a normal distribution, i.e., it have been used the transformation generating the best outcome in the distribution normality analysis, which is a premise for the method application. Thus, the dependent variables have suffered the following final transformations. Then, the letter "L" before the variables related below means that the variable was transformed by applying the logarithmic function, the letter "S" indicates that the variable suffered transformation by applying the square root function and the letter "I" means that the inverse function was applied:

The models of study for each of the renewable energies are exposed as follows:

Leolian (Aeolian energy) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (1)

Igeothermal (Geothermal energy) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (2)

Lhydroelectric (Hydroelectric energy) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (3)

Ibiofuels (Energy from biofuels) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (4)

Ibiodiesel (Energy from biodiesel) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (5)

Ibiomasswaste (Energy from biomass and waste) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (6)

Iethanol (Ethanol) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (7)

Isolartidwaves (Energies solar, tidal and of waves) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (8)

Soverenener (Overall renewable energies) = c(1) + c(2) x GFCF + c(3) x LGDPG + c(4) x SGDPPC + ξ (9)

Whereas:

c(1) - constant of the regression equations:

c(2) - constant associated with the variable Gross Fixed Capital Formation (GFCF);

c(3) - constant associated with the variable GDP Growth;

c(4) - constant associated with the variable *Per capita* GDP.

ξ – error term of the equations

3. RESULTS AND FINAL COMENTS

In Table 3, it is shown the outcomes generated from the equations 1 to 9.

Table 3 – Tests outcomes

The symbols ***, ** and * represent, respectively, statistical significances of 0,1%, 1% and 10%.

	Soverenener	**Lhydro electric**	**Leolian**	**Isolar tidwaves**	**Igeo thermal**	**Iethanol**	**Ibio masswaste**	**Ibio diesel**	**Ibio fuels**
C	1.4852 (07899)	1.4299 (0.0792)	0.3487 (0.3829)	0.7800 (0.0000)	0.3611 (0.2530)	0.6505 (0.0973)	-0.6132 (0.0843)	-0.1878 (0.6111)	-0.2746 (0,5100)
GFCF	0.1529* (0.0149)	0.0149 (0.1022)	0.0173*** (0.0001)	-0.0020 (0.2423)	-0.0041 (0.2410)	-0134** (0.0025)	-0.0040 (0.3158)	-0.0063 (0.1272)	-0116* (0.0133)
LGDPG	0.0261 (0.9953)	-0.3472 (0.5932)	-0.6931* (0.0312)	0.2532* (0.0368)	0.5655* (0.0261)	0.3555 (0.2568)	1.3064*** (0.0000)	1.0084*** (0.0008)	1.0388** (0.0021)
SGDPPC	0.0054 (0.4400)	-0.0015 (0.1303)	0.0025*** (0.0000)	-0.0006** (0.0018)	-0.0003 (0.4666)	-0.0001 (0.9051)	-.0020*** (0.0000)	-0.0011* (0.0203)	-0.0005 (0.3436)
n	193	193	193	193	193	193	193	193	193
R2	0.0340	0.0272	0.2322	0.1181	0.0454	0.0498	0.2865	0.1375	0.0924
R2 adj	0.0186	0.0118	0.2201	0.1041	0.0303	0.0347	0.2751	0.1238	0.0780
D-W	1.6753	1.6518	1.8705	1.9047	2.1310	1.7725	1.4403	1.8102	1.7143

Table 4 presents a synthetic summary of the outcomes grouped for each of the variables regarding renewable energy generation.

Table 4 - Grouped tests outcomes with significance

The symbols ***, ** and * represent, respectively, statistical significances of 0,1%, 1% and 10%.

	GFCF	LGDPG	SGDPPCC
Soverenener	+*	+	+
Lhydroelectric	+	-	-
Leolians	+ ***	-*	+ ***
Isolartidwaves	-	+ *	-**
Igeothermical	-	+ *	-

Iethanol	-**	+	-
Ibiomasswaste	-	+ ***	-***
Ibiodiesel	-	+ ***	-*
Ibiofuels	-*	+ **	-
Total	4 with significance	6 with significance	4 with significance

With regard to outcomes consistency, it is possible to observe that the adjustment of the models, measured by values of $\mathbf{R^2}$ and $\mathbf{R^2}$ **adjusted** were good and compatible to an exploratory research. The outcomes of Durbin Watson test, regard to the information content existing in residuals demonstrated these residuals didn´t contain relevant information to explain the dependent variable and were also good.

Basically, the outcomes showed evidences that the rise of renewable energies use is related to lower GDP growths. This outcome is aligned with the expectation that the most developed countries become pioneers in the development of new energies. Such countries feature higher GDPs and lower growth rates. Thus, to have the renewable energies associated with lower GDP growths was expected.

By another side, the higher use of renewable energies is associated with the higher GDP *per capita.* It is GDPs *per capita* that grants to the population higher purchase power, and is this increase in demand that propels first the consumption, and then the investment. So higher GDPs *per capita* are associated with higher investments in machinery, equipment and infrastructures for production of consumption goods, i.e., it rises the investments in the gross capital formation, which represents the investments done to enlarge the capacity of consumption goods production such as cloths, household appliances, etc.

Analyzing individually the outcomes related to each type of renewable energy, it is observed that, in the case of hydroelectric energy, there is no significant relationship between the variable Lhydroelectric and the performance of the economic growth indicators.

As regards the energies: a) aeolian, b) solar, c) tidal and of waves, d) geothermal, e) ethanol, f) biomass and wastes, g) biodiesel and h) biofuels, it was found that the generation growth of this forms of energy are positively related with larger infrastructures (GFCF), inversely related with GDP growth and positively associated with higher *per capita* GDP.

Likewise, the overall renewable energies are positively related to higher infrastructures

(GFCF), higher *per capita* GDP and GDP growth.

The outcome of the test with the overall renewable energies verifies the hypothesis of that the most developed countries have left the rest of them behind in the renewable energies development as a generation form of non-polluting energy and as a long term strategy to change the energy generator Matrices.

In the same way, the higher use of renewable energies is associated with the higher gross capital formation on the part of countries. Such association provide evidences of that the countries featuring larger infrastructures are already investing in higher renewable energies production, aiming at conforming the composition of their energy matrices to a feature that bears enormous possibilities of energy.

It can be concluded yet that the higher the investments in infrastructure, necessary in the emerging countries, the higher will be the demand for energy to the formation of this infrastructure, and then to its use. This is why in developing countries the chances of GDP growth are higher than in developed countries. By other side, countries with higher *per capita* GDP have citizens with higher purchasing power and, therefore, can afford more to have cleaner energies.

For new researches, the suggestion is the inclusion of other factors that might be investigated as explicative factors of the renewable energies generation as: a) the property of larger reservoirs of fossil fuels, b) the existence of local industry with intensive production processes in energy, and c) the countries in different stages of development, among others.

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