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The Renewable Energy Production-Economic Development Nexus

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ABSTRACT: As renewable energy requirements increases, its relation with development is controversial. In this study, by taking human development index for development level, the relationship between renewable electricity net generation values and development has been searched with panel analysis. Study covers two different time periods: 1980-2010 with 5 year data to analyze long term effects and 2005-2010 yearly data for short term effects. Unlike previous studies, energy generation has been taken into consideration for it is thought to be more related with economic development. It is found that in the long run economic development will be leading to renewable energy production, while in the short run there exists a bidirectional causal relationship between renewable energy production and economic development. In addition, the causal relationship between economic development and renewable energy production varies both in the long run and in the short run due to human development level of the countries.

Keywords: renewable energy; Human Development Index; causality
JEL Classifications: C10; N70; O150

1. Introduction

Within the global economy we are living in, the energy requirements have increased remarkably due to its widespread usage of agricultural, industrial and domestic activities, especially in emerging countries. In addition, advances in technology, increasing population and higher levels of consumption bring the problem of fulfilling the energy requirements which is higher than a decade ago. Moreover, generation of energy from fossil fuel resources not only are becoming scarce but also damage the environment by increasing carbon emissions to the atmosphere (Banos, et al., 2011). The use of energy from fossil fuels trough out ages, bring the environmental problems that we are facing today which also limits the sustainable development. Nowadays, more attention is given to renewable energy resources which appear to be the one of the most efficient and effective solutions to overcome the several energy related environmental problems as well as increasing the volume of the energy. As there is a close connection between renewable energy and sustainable development, the improvement of renewable energy technologies will assist sustainable development (Dincer, 2000).

In the twenty-first century this connection is also included in the agenda of the organizations such as United Nations Development Programme (UNDP), The Organisation for Economic Co-operation and Development (OECD) and World Bank. Both UNDP and World Bank give financial support to the projects that aim at improving the quality of rural life and providing electricity to remote by reducing the fossil fuel consumption and promoting the private sector power generation from renewable energy resources.[1] In addition, OECD has published a report of the research for the

[1] UNDP carries out the project with Republic of Palau whereas World Bank carries out the project with Sri Lanka.

impact of renewable energy on regional economies and suggests the ways to make renewable energy a driver for rural development (OECD, 2012).

Being aware of the fact that the renewable energy will improve development, in this study the relationship between the economic development and renewable energy will be analyzed. In previous studies, although the impact of renewable energy on economic development has been expressed clearly, social effects have been totally ignored due to focusing the analysis on the relationship between renewable sources and economic growth. In the following section, the literature survey about the relationship between renewable energy and economic growth will be given. In the third section, the model and data set used in this study will be introduced. In the fourth section, the results of the analysis will be given. And in the conclusion part the results of the analysis will be discussed.

2. Literature Survey

The causal relationship between economic growth and energy consumption primarily introduced by the study of Kraft and Kraft (1978). This early study that analyzed the causality for US economy had ended up with the findings that economic growth had been triggering the energy consumption. Later on, Yu and Choi (1985) applied a similar technique that of Kraft and Kraft (1978) for different countries and concluded that the existence of causal relationship and its direction gave different results for different countries. After these studies, especially in 21st century several studies are conducted to examine whether the use of energy leads to an economic growth or the level of energy consumption is determined by the level of production[2]. The introduction of renewable energy and nuclear energy in the agenda of this causal relationship is quite new with the study of Apergis et al.(2010). The study under consideration concludes that greenhouse gas emissions effect nuclear energy consumption positively and reflect a bidirectional causality with economic growth. Following this study Apergis and Payne (2010a, 2010b, 2011a, 2011b) mainly concentrated on renewable energy consumption whereas Apergis and Payne (2010c), Wolde-Rufael and Menyah (2010), Lee and Chiu (2011a, 2011b), Payne and Taylor (2010), Heo et al. (2011) and Wolde-Rufael (2010) mainly interested with the nuclear energy consumption. The examination of the literature about renewable energy consumption and economic growth shows that previous analysis mainly depends on panel data. Table 1 summarizes the literature survey for the causality between economic growth and renewable energy.

Table 1. Literature survey on economic growth and renewable energy nexus

Study	Period	Country	Causality
Apergis and Payne(2010a)	1985-2005	20 Countries in OECD	Bidirectional Causality
Apergis and Payne(2010b)	1992-2007	13 Countries in Asia	Bidirectional Causality
Apergis and Payne(2011a)	1980- 2006	6 Latin American countries	Bidirectional Causality
Apergis and Payne(2011b)	1990-2007	16 Developing Countries	One sided causality from economic growth to renewable energy
Menegaki (2011)	1997-2007	27 European Countries	No Causality
Bayraktutan et al. (2011)	1980- 2007	Countries in OECD	Bidirectional Causality
Yıldırım et al. (2012)	1949- 2010	USA	One sided causality from biomass-waste-derived energy consumption to real GDP
Tuğcu et al. (2012)	1980- 2009	G7 Countries	Bidirectional Causality for Classical Production Function

[2] See the study of Ozturk (2010) for a detailed literature survey on energy-growth nexus.

As can be seen from Table 1 above, in most of these studies a group of countries is chosen to find out the direction of the relation between economic growth and renewable energy. In literature not only the relationship between real GDP and renewable energy consumption is been examined, but intimacy between labor force, capital stock and real GDP have been researched also.

Apergis and Payne (2010a), Apergis and Payne (2010b), Apergis and Payne (2011a), have examined the relationship between renewable energy and economic growth for the countries of Latin America, Asia Minor and OECD, respectively, on the basis of multivariate panel analysis. Results obtained from Granger causality test conducted on Latin American countries have shown the existence of a collateral causality between economic growth and consumption of renewable energy. The results also hold in the same manner for Asian and OECD countries.

Apergis and Payne (2011b) also applied panel analysis for researching the relationship between economic growth and the consumption of electricity gained from renewable/nonrenewable resources in developing market economies. Contrary with their preceding studies, they observed that in the short run, causality had been found from economic growth to renewable electricity consumption; while bidirectional causality had been obtained, either in the short run or in the long run, between nonrenewable electricity consumption and economic growth.

The analysis of Menegaki (2011) that includes 27 European countries for the period 1997-2007 did not end up with the existence of either short-or long-run Granger causality from renewable energy consumption to economic growth. Accordingly, Mengaki (2011) concludes that the consumption of renewable energy played a minor role in the determination of GDP of these countries.

Bayraktutan et al. (2011) conduct a study that analyzes the relationship between electricity generation from renewable resources and economic growth in OECD countries for the period of 1980-2007 using panel-data method. According to their findings there is a long term positive relationship between renewable electricity generation and economic growth, and a bidirectional (reciprocal) causality between these variables. Depending on their analysis, the results they conclude that investments for renewable electricity generation will likely to boost economic growth in OECD countries.

Yıldırım et al. (2012) applied Toda–Yamamoto procedure and bootstrap-corrected causality test in order to examine the relationship between renewable energy consumption and economic growth for US economy. According to test results the only causal relationship was found from biomass-waste-derived energy consumption to real GDP. The study concludes that countries should concentrate on energy producing from waste as an alternative energy resource.

Tugcu et al. (2012) analyzed the relationship between economic growth and consumption of renewable and nonrenewable energy for G7 countries by using Autoregressive Distributed Lag (ARDL) approach. While a bidirectional relationship has been obtained between renewable / nonrenewable energy and economic growth for each country according to the classical production function, different conclusions have been revealed for each country. In addition, ARDL approach is applied to four Eastern and Southeastern European countries, Middle East and North Africa countries and Turkey by Ozturk and Acaravci (2010a, 2010b, 2010c). The authors find significant evidence to support the neutrality hypothesis which treats energy consumption as an insignificant part of economic output and assumes no causality between these variables.

3. Model and Data Set

The sample data covers 1980-2010 time period for 154 countries. In the study, data used are human development index values from United Nations Development Programme (UNDP) database as an indicator of development and total renewable electricity net generation values (Billion Kilowatt hours) from United States Energy Information Administration (EIA) as an indicator of energy. Unlike previous studies, in this study energy generation has been taken into consideration for it is thought to be more related with economic development and nature[3]. Study covers two different time periods:

[3] Production of energy from any form of primary energy sources not only has important externalities on environment and health, but also harms the ecosystems and cause global warming.

1980-2010 with 5 year data[4] that will show long term effects and 2005-2010 yearly data that will show short term effects for all countries. In the analysis, not only the relationship between electricity production and development but causality as well will be researched.

In the study main thesis is to determine the direction of the causality between renewable electricity production and economic development. Accordingly, the model used in the study is constructed similar to growth-renewable electricity production studies mentioned in the literature survey part. In this respect the model is given below:

$$ED_{it} = \alpha_{it} + x_{it} RE_{it} + \mu_{it}$$

ED_{it} : Human Development Index,
RE_{it} : Electricity production from renewable resources
i : 1, 2, …., 154, Number of countries
t : 1980, 1981, …., 2010, years.

This model is applied to 5 different country groups in order to determine whether the direction of causality changes between different development levels. These country groups are: All Countries including 157 countries: Very High Human Development Countries including 41 countries, High Human Development Countries including 37 countries, Middle Human Development Countries including 40 countries and Low Human Development Countries including 39 countries. The test results are given in Table 2.

Table 2. Long term Test Results for the period 1980-2010

Countries in the Model	C	Renewable Electricity	R-squared
All Countries	60.115*	0.014*	0.987
Very High Human Development	82.898*	-0.033*	0.954
High Human Development	66.366*	-0.00001	0.936
Middle Human Development	55.530*	0.017*	0.951
Low Human Development	35.858*	0.192***	0.896

*Significance level at the 1%,** Significance level at the 5%,*** Significance level at the 10%.

According to test results, in the model that contains all countries when total renewable electricity net generation (Billion Kilowatt hours) increases by 100 units, this will have positive impact on the development index and increases the index level by 1.4 units. When middle income countries considered, 100 units (Billion Kilowatt hours) increase in renewable electricity production increases the development index by 1.7 units. Although for low human development countries significance level is relatively high, but still acceptable and test results indicate positive relationship with renewable energy on the long term basis. The test results show that in high human developed countries the renewable electricity generation does not display any impact on development levels. However, examining the model for very high human developed countries show adverse impact of renewable energy on the development. When renewable energy generation increases 100 unit (Billion Kilowatt hours), this decreases the development index of countries that have very high human development by 3.3 units. This makes sense when the cost of investment in renewable energy is taken into account. According to Heal (2009), the generation of electricity from renewable resources is a costly process that takes longer time to see the effects of this technological progress and investment in a renewable energy station is a bet on the future values of the costs that can be summarized around four parameters which are; the costs of oil and other fossil fuels, the cost of carbon emissions, the cost of capital, and the incentives available to producers of green electricity. Also, in order to increase renewable energy, tax regulations should be favorable to them which in turn cause increasing welfare costs on tax payers by increasing energy prices. Since elasticity of demand for energy to own price changes is found to be inelastic in the study of Pashardes, Pashourtidou and Zachariadis (2014), much of the welfare loss fosters from the decreasing purchasing power of income. Similar findings are found between growth and environment taxes by applying panel causality in a recent study made by

[4] Since United Nations Development Programme (UNDP) database revised its arithmetic method of calculation by geometric method of calculation, the yearly data can only be obtained after the year 2005. For the period 1980-2010 UNDP reports 5 year data for Human Development Index.

Abdullah and Morley(2014) for European Union overall. Therefore, for very high human developed countries devoting much of their resources to renewable energy generation, instead of using these resources in other ways for a long time period, ends up with lower development levels.

Table 3. Long term Granger Causality Test Results for the period 1980-2010

Countries in the Model	Direction of Causality	F Value	Probability Value	Conclusion for Causality
All Countries	RE→ED	0.03573	0.8501	Does not Exist
	ED→RE	5.56093	0.0187	Exists**
Very High Human Development	RE→ED	1.63955	0.2020	Does not Exist
	ED→RE	1.37687	0.2421	Does not Exist
High Human Development	RE→ED	0.21043	0.6471	Does not Exist
	ED→RE	3.87014	0.0511	Exists***
Middle Human Development	RE→ED	12.1300	0.0006	Exists*
	ED→RE	4.47943	0.0358	Exists**
Low Human Development	RE→ED	0.15587	0.6935	Does not Exist
	ED→RE	0.71078	0.4004	Does not Exist

RE→ED: Renewable Electricity does not Granger cause Economic Development
ED→RE: Economic Development does not Granger cause Renewable Electricity
*Significance level at the 1%,** Significance level at the 5%,*** Significance level at the 10%.

In Table 3 the Granger Causality test results for country groups are given. For very high human development countries and low human development countries there is no causality between renewable energy production and economic development. However, for all countries and high human development countries it can be seen that economic development triggers renewable energy generation. And for middle human development countries, there is bidirectional causality between renewable energy generation and economic development. From the table it is clear that in a long time period, if the countries with low human development can succeed in reaching middle human development level then the causality between renewable energy generation and economic development would drag these countries along higher levels of development. When these low human developed countries reach high human development level, then the driving force would be economic development so as to reach higher levels of renewable energy production.

Table 4. Short term Test Results for the period 2005-2010

Countries in the Model	C	Renewable Electricity	R-squared
All Countries	64.599*	0.005*	0.999
Very High Human Development	86.488*	-0.006	0.993
High Human Development	72.986*	-0.00044	0.986
Middle Human Development	60.941*	0.007*	0.996
Low Human Development	40.209*	0.195*	0.996

Numbers in parenthesis show the number of countries included.
*Significance level at the 1%,** Significance level at the 5%,*** Significance level at the 10%.

In Table 4 short term test results for the model are given for country groups. In short term the result for all countries shows that when total renewable electricity net generation (Billion Kilowatt hours) increases by 100 units, this will have positive impact on the development index and increases the index level by 0.5 units. When middle income countries are considered, 100 units (Billion Kilowatt hours) increase in renewable electricity production increases the development index by 0.7 units. For low human development countries, 100 units (Billion Kilowatt hours) increase in renewable electricity production increases the development index by 19.5 units. What is more, the test results show that in both very high and high human developed countries, the renewable electricity generation does not display any impact on development levels. The table shows us that in short term the increase of the production of renewable resources mainly affects the low human developed countries. Therefore, for

the low high human developed countries which do not have enough sources to invest in renewable energy production must direct the foreign investment in their country to renewable energy generation in order to weather their vicious cycle of underdevelopment.

Table 5. Short term Granger Causality Test Results for the period 2005-2010

Countries in the Model	Direction of Causality	F Value	Probability Value	Conclusion for Causality
All Countries	RE→ED	7.95741	0.0049	Exists*
	ED→RE	4.05155	0.0445	Exists**
Very High Human Development	RE→ED	0.04834	0.8262	Does not Exist
	ED→RE	0.00679	0.9344	Does not Exist
High Human Development	RE→ED	0.25400	0.7760	Does not Exist
	ED→RE	2.78726	0.0647	Exists***
Middle Human Development	RE→ED	18.4271	0.00003	Exists*
	ED→RE	1.49973	0.2222	Does not Exist
Low Human Development	RE→ED	0.00542	0.9414	Does not Exist
	ED→RE	0.03896	0.8437	Does not Exist

In Table 5 the Granger Causality test results of country groups for short term are given. In short term very high human development countries and low human development countries do not display any causality between renewable energy production and economic development. However, for high human development countries it is seen that not only in long term but also in short term economic development triggers renewable energy generation. And for middle human development countries in short term renewable energy generation contributes to the economic development of these countries. When all countries are taken into consideration in the analysis, the short term results show that there is a bidirectional causality between renewable energy generation and economic development. According to test results, in short term when the countries are in middle human development levels renewable energy production investments end up with higher development levels for these countries and when these countries reach to high human development levels in that case the driving force reverses and higher levels of economic development leads to more renewable energy production. However, this relation does not exist for low human developed countries as well as very high developed countries. So, in short term low human developed countries must find a way to reach higher development levels other than the renewable energy production.

4. Conclusion

In this study, we took the renewable energy production into account and investigated the causal relationship between renewable energy and economic development. We apply basic model to different country groups which are determined by the human development levels. Then, we implemented Granger causality test to examine whether there is a causal relationships between the series.

Several conclusions emerged from our study. First, we found that for very high human developed and low human developed countries there is no causal relationship between economic development and renewable energy production both in long term and in short term. Since, the former ones usually emerge as capital intense countries and their development are high, while the latter are usually underdeveloped countries, the result is expactable. Second, in the long term there is bidirectional causal relation between renewable energy production and economic development for middle human developed countries whereas in short term there is evidence of unidirectional causality from renewable energy production to economic development. Also this result is plausible as these countries usually tend to be developing ones and less capital intense. Renewable energy is a complicated and capital intense investment, so any capital increase in these countries likely to foster growth which in turn increase development. Third, taking high human developed countries into consideration in both long term and short term there is one sided causality from economic development to renewable energy production. In high human development countries, the main concern

is environmental issues which includes, renewable energy, not development. Since these countries tend to be more fossil fuel consumers but also developed ones, the result is more likely to be acceptable. Fourth, when all countries are considered in long term economic development leads to renewable energy production whereas in short term there is evidence of bidirectional causal relationship between renewable energy production and economic development.

The close link between renewable energy production and economic development is also verified by the test results of this study. In addition, the findings reveal the fact that low human developed countries can reach higher development levels only if they can break the vicious cycle of underdevelopment. If these countries succeed in reaching middle human developed levels, renewable energy production will trigger the economic development and cause these countries to reach higher human development levels. As for this new development level, economic development will be the driving force for more renewable energy production. The findings of the study also show that the countries with lower human development levels must direct most of their resources and attract foreign direct investments to renewable energy production due to the fact that economic development is activated by this kind of energy production since it is a capital intense process.

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