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RESEARCH ARTICLE

Dynamics affecting renewable energy: A panel quantile regression approach*

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Abstract

The effective use of energy resources, energy production and consumption are accepted as one of the most basic indicators of development in recent years. It has become important to use these energy resources in an environmentally friendly manner and have a positive and efficient effect on the economy.

The relationship between renewable energy consumption (LREC) and economic factors such as growth rate of GDP per capita (LGDP)), fixed capital investment (LFCI), total labor (LTL), total amount of waste per capita (LWCA) is examined in this study. Data on those variables are collected for the period of 2012-2020 for OECD countries. A panel quantile regression approach method is employed to examine the association between renewable energy consumption (REC) and economic factors.

The effects of independent variables on renewable consumption have been interpreted depending on the estimation results obtained in the analysis. Firstly, the panel unit root tests are determined for stationarity. As a result, a panel quantile approach is adopted. The results of the analysis show that all economic variables used in the model have a statistically significant effect on renewable energy consumption in the last two quantiles.

Keywords: Renewable Energy, Economic Growth, Economic Factors, Panel Quantile Regression

JEL Codes: C5, C51, C52

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1. INTRODUCTION

The resources used to meet the energy requirements could be divided into two groups: a) non-renewable energy sources and b) renewable energy sources. Renewable energy resources such as wind, water and sun are constantly found in nature as these energies are obtained from natural sources (Spurgeon and Flood 2010: 43). The renewable energy consumption production reduces the volatility and supports economic and social development (Irena 2013: 12). Economic development and environmental problems have an important place in sustaining economic growth.

Energy production and consumption are also necessary for production ~~in~~ for many economies. The studies investigating energy consumption and GDP relationship rely on a wide range of economic factors. The results of those studies show that certain economic factors and their effects vary from country to country. Moreover, the majority of these studies employed time series and causality tests to investigate this relationship. Different from previous studies, this study investigates this relationship between energy consumption and basic economic factors such as GDP per capita annual growth rate (%) along with fixed capital investments and total labor via a panel quantile regression model for OECD countries from 2020 to 2021.

An introduction on energy consumption and the relationship with economic fundamentals is initially provided. In the second section, the previous literature is presented. Third section provides information about data and econometric methods. The empirical results are further reported in the same section. Finally, the fourth section concludes and provides inferences based on the results.

2. LITERATURE

A new system taking into account the use of natural resources and minimizing them should be established. It is important to discuss that the unlimited economic growth is not possible due to the environmental factors. It is evolving to take H. Daly's (1973, 2007) model as a reference to ecological and physical realities. It could be stated that the concept of circular economy is shaped around two basic ideas. The first one is traditional or linear economics. Pearce and Turner (1990) point out that their models lack the idea of recycling used in an economic model. According to the authors, this shortcoming is due to the economy and the environment. It violates the functional relationship that exists between them. The second model suggests that the environment provides a resource base, where its functions include an input for the economy, both in terms of renewable and non-renewable resources. The goal set by circular economic models considers waste to be reused as a resource. (Institute Montaigne 2016: 9).

The causality between energy consumption and economic growth is examined in a study by Oh and Lee (2004) where two multivariate time series models were included. They reported that there was no causal relation between energy and GDP. However, they found that there was a unidirectional causality from GDP to energy in the long run.

Investors who are fascinated by the renewable energy technologies are recommended to maintain the increase in the manufacturing capacity of OPV technologies along with identifying numerous countries to point out and prioritize monetarily appealing settings for PV self-consumption (Chatzisideris et al. 2017)

The association between energy consumption and capital formation along with the real GDP among G7 countries was examined by Narayan and Smyth (2008) via panel unit root and panel cointegration analyses. Odhiambo (2009) determined the causality between economic growth and energy consumption in Tanzania.

Căutişanu et al. (2018) examined the impact of per capita municipal waste and waste recycling rate on economic growth in OECD countries using clustering, correlation and path analyses. The study suggested that economic growth; average years of education and waste management were significantly correlated. The research further reported significant relationships between R&D expenditures, waste management and waste recycling rate.

Inglesi-Lotz (2015) used panel data. The dependent variable was GDP, and RES consumption, RES percentage of energy mix, R&D (research and development) costs, labor force and capital formation were considered as the independent variables in the dataset.

Another study by Caraiani, Lungu and Dascalu (2015) found an overall long-run relation between GDP and renewable energy consumption among developing European countries. However, they reported a short-run two-way relationship is stated for Turkey, Romania, Hungary and Poland.

Overall, one can suggest that income and consumption are closely related so do income and consumption of energy. Therefore, it is possible to see that the pioneering work of Kraft and Kraft (1978) could have been influenced by this relationship.

An econometric study by Adebeyo, Rjoub and Akinsola (2022) provides new evidence for Sweeden on the asymmetric effects of renewable energy consumption and trade openness on carbon emissions via a quantitative regression.

3. DATA AND METHODS

The number of OECD countries used in this study is 38 based on the availability of the data. The data were obtained from the BP Statistical Review (2021) and the World Bank Database. The data set consists of indicators for economic structures at the country level. Australia, Austria, Belgium, Brazil, Canada, Chile, China, Czech Republic, Colombia, Costa Rica, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Latvia, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Russia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States are included in the analysis for the years from 2020 to 2021.

Table 1. Variables and Abbreviations

Dependent Variable	LREC (Logarithmic Renewable Energy Consumption)
Independent Variables	
LGDP	Logarithmic Growth Rate of GDP per capita
LFCI	Logarithmic Fixed Capital Invesment
LTL	Logarithmic Total Labor
LAWC	Logarithmic Amount of Waste of Capita

Firstly, the fixed effects panel regression model was estimated, then the panel quantile regression analysis was undertaken. As a result, one can make a comparison between these two models.

The reduced form of the panel data model is given below:

$$LREC_{\ it} = \alpha_0 + \alpha_1 LGDP_{it} + \alpha_2 LFCI_{it} + \alpha_3 LTL_{it} + \alpha_4 LAWC_{it} + u_{it} \quad (1)$$

where i refers to an OECD country and t represents time.

$LREC_{it}$ represents the dependent variable (energy consumption). u_{it} is the error term and is defined as $u_{it} = \mu i + \nu_{it}$. μ is the individual country effect that is constant over time but varies across cross-sections. ν is the time effect that varies by each cross-section unit. These panel data models with such type of error term is called one-sided error component regression model (Baltagi 2005; Koc & Sahin 2015).

However, the most typical problem in a classical regression model is the existence of extreme values that could arise from the effects of events such as crises or any policy shocks. In such cases, the error term ~~are~~is not normally distributed. As a result, the reliability of the estimation based on the average would be weakened. Therefore, a quantile regression model based on the minimization of deviations was developed by Koenker and Basset (1978).

Instead of estimating the conditional mean based on the sample mean or a single value, the method provides an analysis of several different regression curves in different quantiles rather and does not take the conditional mean distribution into account.Therefore, it is possible to identify and obtain a detailed picture of all quantiles (Koenker and Hallock 2001)

$$Qant_{\theta} = (\frac{LREC_{it}}{X_{K,it}}) \quad (2)$$

Equation 2 shows the conditional distribution quantile of the dependent variable associated with the independent variables. t is the time period and i indicates country. expresses the conditional distribution ofwith respect to the dependent variable.

The quantiles to be used in this study are the values above and below the mean for each quantile and is determined as τ = {0.25, 0.50, 0.75, and 0.90}.

The descriptive statistics of dependent and independent variables are shown in Table 2.

Tablo 2. Descriptive Statistics

	LGDP	LREC	LFCI	LTW	LAWC
Mean	3.2145	8.4213	5.4522	0.4567	0.5543
Standard Deviation	0.8723	0.5639	0.9823	0.4500	0.3409
Skewness	-0.8723	-0.3490	-0.4500	0.7834	0.6723
Kurtosis	3.2312	2.8933	2.9056	1.4509	1.6789
Jarque-Bera	13.8934	22.1349	17.2894	11.7392	8.4583
No. of Observations (N)	304	304	304	304	304

Table 2 shows that almost all variables including especially renewable energy do not have a normal distribution. Therefore, the analysis is less sensitive to extreme values than classical panel regression. The estimation of the panel quantile regression model seems to be appropriate.

In this study, in order to make a comparison with the panel quantile regression analysis, first of all, the classical panel regression estimation was made. The Hausman test was applied to decide which of the random effects panel regression estimates to use.

As a result of the test, 3 degrees of freedom test statistics calculated $\chi 2$ = 38.634503, and the probability value $Prob > \chi 2$ = 0.0000 is found.

In this case, the Random Effects Panel Regression model was estimated by rejecting the Ho hypothesis expressed as been taken.

Table 3. Random Effects Model

Dependent Variable: LREC (Logarithmic Renewable Energy Consumption)				
Variables	**Coefficients**	**Standard Errors**	**t statistics**	**p values**
LGDP	0.328915	0.032918	9.99669	0.0000
LFC	0.145894	0.021634	6.741656	0.0000
LTL	0.573421	0.04577	12.5470	0.0000
LAWC	-0.203673	0.05782	-3.56248	0.0000
	R^2 = 0.8337	$\bar{R}^2$= 0.8821	F statistics = 430.2642	Prob(F stat.) =0.0000

Table 3 shows that all variables statistically have a very high level of significance to explain renewable energy. Logarithmic total labor and logarithmic fixed capital investment have positive effects on logarithmic renewable energy consumption. There is a negative relationship between logarithmic amount of waste per capita and logarithmic renewable energy consumption. Accordingly, the one unit changement ratio of total labor reduces renewable energy consumption by about 0.5 percentage points.

The mean of the sample or the conditional mean of a single value is used in the panel regression estimations. At this point only when considering different quantiles below or above the mean, rather than an average, it is important to determine whether or how the results would change.

As this study investigates the association between economic fundamentals and energy consumption via a panel quantile regression approach, the panel quantile regression results are summarized in Table 4.

The quantile regression models allow researchers to account for unobserved heterogeneity and heterogeneous covariates effects and the availability of panel data provides an advantage to be able to include fixed effects in order to provide more controls for some unobserved covariates (Canay 2011).

Table 4. The Panel Quantile Regression Model Results

Dependent Variable: LREC					
Independent Variables	**Coefficients**	**Standard Errors**	**t-statistics**	**p values**	**Quantiles (τ)**
LFCI	2.3687	1. 7351	1.3651	0.0641	0.25
	3.7822	2. 3070	1.6384	0.1344	0.50
	1.5634	0.2128	7.4285	0.0000**	0.75
	1.5432	0.0865	19.258	0.0000**	0.90
LGDP	2.7432	0.3821	7.1708	0.0000*	0.25
	1.4790	0.4520	3.2721	0.0000*	0.50
	1.5790	1.2189	1.2164	0.06464	0.75
	1.8930	1.3490	1.2975	0.06453	0.90
LTL	1.0437	1.2684	0.8253	0.6732	0.25
	0.4739	0.3423	1.3823	0.5921	0.50
	-0.5644	0.0326	-17.300	0.0000**	0.75
	-0.4572	0.0021	228.50	0.0000**	0.90
LAWC	2.6046	0.5941	4.4406	0.0000**	0.25
	0.5689	0.1153	5.0907	0.0000**	0.50
	2.8782	0.3281	8.7532	0.0000**	0.75
	1.5411	0.2489	6.2096	0.0000**	0.90

Note: *1%, **5% statistical significance levels respectively.

Table 4 shows the coefficients of LFCI are statistically significant at upper quantiles where τ = 0.75 and 0.90 respectively. Moreover, logarithmic fixed capital investment on renewable energy consumption is going down at the upper quantiles of fixed capital investment. In 0.75 and 0.90 quantiles, the coefficients of gross domestic product are statistically significant.

However, in the 0.25 and 0.50 quantiles of renewable energy consumption (where τ is defined as 0.25; 0.50 respectively), the coefficient of total labor is not statistically significant. Considering the 0.75 and 0.90 quantiles (τ = 0.75; 0.90), the coefficients of total labor are found to be statistically significant. The LAWC is more effective than other variables on countries' renewable energy consumption.

The total labor has a negative effect on renewable energy consumption. The negative effect of total labor is reduced for high renewable energy consumption level rate for OECD countries. The effect of total labor is not statistically significant at all quantiles. The coefficients of LFCI are statistically significant at the 0.75 and 0.90 quantiles where τ = 0.75 and 0.90 respectively. The LGDP has a positive effect of renewable energy consumption.

4. CONCLUSION

Today, renewable energy consumption and environmental problems have increased gradually, especially since the last quarter of the twentieth century. This has led to the focus on the causes and solutions of the problems.

In a panel quantile regression, all independent variables affect renewable energy consumption in the last two quantiles. Moreover, one of the results of the models is that as growth rises in countries in general, all the positive effects of independent variables on sustainable energy consumption is gradually increasing. In the panel quantile regression, which is not based on the conditional mean of the entire sample and considers all distributions of the response variable, we found that the independent variables (logarithmic growth rate of gdp per capita, logarithmic fixed capital ınvesment, logarithmic amount of waste of capita) had a positive effect on sustainable energy consumption. Even the fact that economic growth is not statistically significant for the last two quartiles, this might also be an indication of the fact that this situation progresses differently in some countries or that the growth effect does not have the same effect for all countries.

The share of labor income, its distribution in GDP of countries and the environmental, economic variables effect the renewable energy distribution for all individual countries. The empirical examination of the effects on the variables is important for the development of this field. The countries have to assist in the development and the consumption of non-fossil energy so that the government can encourage the supportive policies of renewable energy. The energy efficiency and consumption with many circular economics which protect energy saving in sectors should be handled carefully to prevent the heating demand.

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