Analysis of the Renewable Energy Development Situations Among Twenty-Seven EU Countries

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Abstract. Currently, renewable energy development can help to solve climate change and many countries around the world are busy with extract the potential of renewable energy sources. However, there is a significant difference in renewable energy share in final energy consumption among EU twenty-sever countries. This study employed a multiple regression function with renewable energy share in final energy consumption as dependent variable, operable nuclear capacity, real GDP per capita, and environmental conditions (wind, solar, geothermal intensity and precipitation) as independent variables in twenty-seven EU countries in 2016, 2018 and 2020. The results show that there is a negative correlation between renewable energy share and environmental conditions and real GDP per capita in the countries without nuclear capacity (e.g., Austria, Croatia, Cyprus, etc.). Also, for the countries which has operable nuclear capacity, there is a positive correlation between nuclear capacity and renewable share, while a negative correlation between environmental conditions and renewable energy share. The results recommend that EU countries should fully utilize their renewable energy sources. Also, due to the limitation of this study, it was more reasonable to analyze EU countries individually to get comprehensive renewable energy development strategy.

Keywords: Renewable energy · European Union · Real GDP per capita

1 Introduction

Climate change has always been a hot topic around the world. Most countries, including EU countries, are making efforts to develop renewable resources or clear energy to replace the non-renewable in order to reduce carbon emission. In addition, the war between Ukraine and Russia has caused a big problem of the supply of non-renewable resources for EU countries currently. Therefore, finding a substitute of non-renewable source is the most important thing for EU countries under such circumstance. The renewable energy is environmentally friendly as it produces less greenhouse gas. Although the crude oil can satisfy people's demand for the energy, it will produce carbon dioxide intensifying the global warming. And it will also worsen the air quality. However,

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the renewable energy can solve this problem perfectly. Combining all the advantages of renewable resources, we research on the correlation between the share of renewable energy in gross final consumption and real GDP per capita in the European Union, helping EU countries to adapt renewable resources and reducing their carbon emission meanwhile.

Vos found that Europe tries to reduce carbon dioxide emissions by reducing emissions. They found that emissions from private cars are a big part of that. Therefore, rules were made to limit emissions from family cars [1]. Pavlovic et al. studied that the leaders of the European Union decided to pass legislation to reduce the use of non-renewable resources, because they found that they rely heavily on non-renewable resources, and non-renewable resources contribute to global warming. So they started subsidizing renewable resources to encourage people to use renewable resources [2]. Malfettani et al. proposed to use WLTP standard to limit vehicle emissions and NEDC program to detect vehicle emissions. So, they did an experiment and found that NEDC could not detect emissions well in real life, so they constantly improved WLTP to make it better able to detect emissions in real life [3].

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Lea mentions that the lubricating oil industry has always played a very important role in Europe. In the past, In order to produce lubricants, Europe has continuously used non-renewable resources, causing a great impact on the environment. More recently, they have been able to extract lipids from vegetable oils to produce lubricants, which is a great help in the use of renewable resources [6]. Hoefnagels et al. mentioned that Europe has great import dependence on natural gas, oil and other resources. In order to get rid of this dependence and protect the environment, Europe began to use bioenergy, a renewable resource, to replace natural gas and oil. According to the poem survey, the use of bio-energy is also increasing every year [7].

Willke and Vorlop mentioned the problem of plastic, which has always been an important material, but has caused serious pollution to the environment. Therefore, in order to solve this problem, a new type of polymer material has been invented to replace the use of plastic, and this kind of polymer is recyclable and environmentally friendly [8]. Belgacem and Gandini mentioned an element that can decompose pollutants in some materials. Then these resources become renewable resources, used over and over again. It takes a lot of pressure off the environment [9].

This paper wants to explore the drivers of renewable energy development among twenty-seven EU countries. In order to achieve that, this paper employ operable nuclear capacity, real GDP per capita and environmental conditions as explanatory variables. The structure of this study is the following: firstly, the methodology of this study is explained, including data and model description; secondly, the results from multiple

regression are analyzed; lastly, we explain the results and discuss the limitation of this, also make the recommendation for EU countries renewable development.

2 Methodology

2.1 Data

This project employs the share of renewable energy in the final consumption (%) as dependent variable, with the capacity of nuclear operable reactors and real GDP per capita environmental conditions (i.e., we employ wind speed at 50 m, solar shortwave downward irradiance on the all-sky surface, precipitation and geothermal temperature at 2000 m to quantify each countries' environmental conditions related to renewable energy. In order to aggregate four environmental factors into one variable, Min-Max normalization method (X-Xmin) / (Xmax-Xmin) was employed as shown in Table 1. Due to the min and max value of our data source is clear, so we don't need to use z-score method) as independent variables. Data for these variables were collected for a sample of twenty-seven EU countries (excluding Britain) in 2016, 2018 and 2020. The renewable energy share in gross final consumption, real GDP per capita and precipitation was obtained from Eurostat Database. The solar intensity and wind speed were obtained from NASA Power. The capacity of nuclear operable reactors was obtained from World Nuclear Association and geothermal temperature at 2000 m were obtained from EuroGeographics.

2.2 Model Description

The aim of this article is to use the multiple linear regression method to explain the correlation between renewable energy share in final consumption and independent variables (nuclear, environmental conditions and real GDP per capita) among twenty-seven EU countries. In order to explore the drivers of renewable energy deployment, panel data model based on mixed effects model was employed. Real GDP per capita, environmental conditions, capacity of nuclear operable reactors, which is represented by real GDP, total-env and nuclear respectively. The multiple regression with three independent variables:

$$\text{renewshare}_{it} = \beta_0 + \beta_1 \text{total\_env}_{it} + \beta_2 \text{realGDP}_{it} + \beta_3 \text{nuclear}_{it} + u_i \quad (1)$$

where, i is index of country, t is index of year, β_0, β_1, β_2 and β_3 are regression coefficient and u_i is random error term. Considering that some countries have almost no installed nuclear power capacity, such as Austria, Croatia, Cyprus, etc., for these countries only the relationship between two independent variables (real GDP per capita and environmental conditions, excluding nuclear capacity) and the share of renewables in final energy consumptions will be analyzed. The regression without nuclear capacity in on the following:

$$\text{renewshare}_{it} = \beta_0 + \beta_1 \text{total\_env}_{it} + \beta_2 \text{realGDP}_{it} + u_i \quad (2)$$

3 Results

For all EU countries, their real GDP per capita all have the growth trend from 2016 to 2018. However, the overall trend of real GDP per capita show a decrease trend from 2018 to 2020 mainly due to the outbreak of Covid-19. Furthermore, although there has fluctuation of real GDP per capita, the overall trend of renewable energy share in final consumption is increase from 2016 to 2020. Also, the environmental condition among EU countries have always changing due to the increasing unprecedented extreme weather events. The development of nuclear energy has also stalled as calls for its elimination grow. Some EU countries don't have operable nuclear reactors in 2016, 2018 and 2020.

Therefore, the aim of this empirical analysis was achieved:

For countries that do not use nuclear energy, find the relationship between the renewable energy share in final consumption and two independent variables (the real GDP per capita and environmental situation).

For countries that use nuclear energy, identify the correlation between the development of renewable energy sources and three independent variables (real GDP per capita, environmental conditions and operable nuclear capacity).

Above all, to make the data smoother and to minimize the covariance and heteroskedasticity of the model, the natural logarithms of real GDP per capita and nuclear energy capacity were taken for the regression analysis. For the Group 1 countries (non-nuclear countries), the correlation between renewable energy share in final consumption and independent variables, environmental conditions and real GDP per capita are shown in Table 1. The model indicates that renewable energy share in final energy consumption has negative correlation with environmental condition and real GDP per capita. Obviously, the result also has other influence factors, such as environmental policy, renewable tariffs, Covid-19 outbreak, etc.

For Group 2 countries, the results are shown in Table 2, nuclear capacity and environmental conditions are at 10% level of significance. The correlation between nuclear capacity and renewable energy share in final consumption is positive, while the correlation between environmental condition and renewable energy share in final consumption in negative, which indicates the countries with increasing nuclear capacity also have the potential to develop renewable energy. The results further show that the country with nuclear capacity have the lower risk to be affected by fossil fuel market, thus have the capability to develop renewable energy.

Clearly, the results for two groups all showed negative correlation between environmental conditions and renewable energy share in final energy consumption. As environmental conditions this empirical employed is an integrated variables which include four

Table 1. Results of Group 1 countries

Variables	Coef.	p-value	Significance F
total env	−8.76**	0.03	0.001
Real GDP per capita	−0.0002***	0.01	

Note: Robust t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2. Results of Group 2 countries

Variables	Coef.	p-value	Significance F
Nuclear	3.53*	0.09	0.046
total env	−7.736**	0.02	
Real GDP per capita	5.34	0.13	

Note: Robust t-statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

indicators: wind speed, solar irradiation, geothermal heat at 2000 m and precipitation, which all related to the mainstream source of renewable energy development. There are mainly two reasons to explain this scenario. First, the extreme weather events frequently appear in recent years due to global warming, which cause flood mostly in Germany, France Austria, Belgium. Second, some countries have huge potential for renewable energy development but are underutilized, such as Hungary with its rich geothermal energy savings.

4 Discussion

Environmental conditions, including precipitation, wind speed, solar irradiation, and geothermal heat, are directly related to renewable energy. "Moreover, there are many studies explaining the relationship between the energy consumption and a number of macroeconomic indicators,……, technological innovation, urbanization, carbon dioxide emissions, and financial development," according to Simionescu [14]. Another hypothesis was the effects of increasing efficiency of utilizing natural (environmental) resources surpassed the negative impacts brought by pandemics and other adverse factors to the EU countries' economies.

Real GDP per capita showed decreasing trend for the 2018 to 2020 period, whereas renewable energy shares increased from 2016 all the way to the year 2020 in the EU countries. Since the result failed to verify the hypothesis, several limitations infinitely contributed to the distortion of the results. Firstly, the results have limited accuracy, particularly by current day standards. The data involved in the research process was confined to the years 2016, 2018, and 2020, which may not apply to revealing trends in renewable energy development. And it was impossible to infer correlations from the past decade and predict future possibilities. Additionally, the research hypothesis was highly influenced by secondary sources, which suggested certain levels of correlation between renewable energy shares and real GDP. Simionescu and Strielkowski's research report concluded that the data models employed in the case from 2007 to 2017 interval yielded low but yet positive correlations between real GDP and shares of renewable energy in final consumption for the countries in the EU (Simionescu, 2020). It was more reasonable to expect a more scattered result data because of the inconsistency of modeled years. Furthermore, the result simultaneously reflected that nuclear energy can be an interferential variable. Because nuclear capacity represented a positive correlation with GDP in final consumption, its correlation was proven to be negative with the renewable energy shares. In addition, it was difficult to conclude that the nuclear capacity was

directly related to the increase of renewable energy shares solely based on the model and data adopted in this research. This was the reason the countries with increasing nuclear capacity also have the potential to develop renewable energy remains a conservative hypothesis. Discussing nuclear energy's potential influence independently in another research is more sensible. However, the employed methodology did an excellent job explaining potentially strong correlations with renewable energy except for the real GDP (e.g., various environmental sources of RE), which is helpful for countries developing a particular type of renewable energy source. However, different types of RE sources have different economic values and effects. "It can be expected that ongoing technological learning would trigger additional cost decreases and, consequently, reduce the need for support in forthcoming years also for the most costly technologies such as PV and wind onshore. In contrast, the ongoing market deployment of various renewables including solar and wind demonstrates an opposing tendency that may ultimately cause an increase in the need for financial support:" (Sunna, 2016, p. 208). Also, as suggested by Shivakuma and his model, Germany was the only country that achieved continuous success in wind power deployment, characterized by stabilized and increasing capacity of this type of renewable energy within the nation till 2020 (Shivakuma, 2019). It is also worth noting that future research can engage an in-depth exploration of individual environmental conditions such as wind and solar power's contribution to renewable energy. Additionally, nuclear energy is one of the largest substitutions for renewable energy. Hence, the research results discussing renewable energy and nuclear energy can be valuable to countries considering the adaptation of one of these new energy sources.

5 Conclusion

This paper employed the data of renewable energy share in final consumption, real GDP per capita, operable nuclear capacity and environmental conditions among twenty-seven EU countries. From the analysis of this paper, the negative correlation between two independent variables, real GDP per capita and environmental conditions and renewable energy share in final consumption among fourteen non-nuclear EU countries. Also, for other thirteen countries with nuclear capacity, the positive correlation between nuclear capacity, while negative correlation between environmental conditions and renewable energy share in final consumption.

Overall, according to the results, there are countries has a strong potential for renewable energy development, due to their abundant renewable source, such as Hungary which has an ample amount of untapped geothermal energy. Also, the overall renewable share of most European countries is on the rise, despite the instability of real GDP per capita during the epidemic, which indicate EU countries commit to renewable energy and make it a key target.

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