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The Impact of Renewable Energy Consumption on Unemployment in Developed Countries

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ABSTRACT

The utilization of renewable energy resources has been increasing in alignment with sustainable development goals, generating significant effects on economic indicators. In this context, examining the impact of renewable energy consumption on unemployment is of considerable importance for both economic policymakers and academic researchers. The primary objective of this study is to determine whether renewable energy consumption has a reducing effect on the unemployment rate. While investments in the renewable energy sector are generally believed to enhance employment, the direction and magnitude of this relationship may vary across countries. Therefore, this study investigates the relationship between renewable energy consumption and unemployment in a sample of developed countries. To conduct the analysis, fixed effects and random effects models were applied using a panel data set. The findings indicate that renewable energy consumption contributes to a reduction in the unemployment rate. Additionally, GDP and trade openness, included in the model as control variables, exhibit statistically significant negative effects on unemployment. However, the effect of inflation on the unemployment rate is found to be insignificant. The results of this study are expected to contribute to a deeper understanding of the impact of renewable energy policies on employment. Furthermore, these findings provide valuable insights for assessing the role of energy policies in economic growth and labor market dynamics.

Keywords: Renewable Energy, Unemployment, Developed Countries, Panel Data Analysis
JEL Classifications: O40, Q43, Q40

1. INTRODUCTION

Energy is one of the cornerstones of economic growth and development, and plays a decisive role in a wide range from the production processes of countries to their social welfare levels. With the acceleration of industrialization, the need for energy has increased and fossil fuel-based energy systems have been the backbone of the global economy for many years. However, environmental problems arising from fossil fuel use, the threat of climate change and concerns about energy supply security have increased the importance of renewable energy sources. Today, renewable energy sources such as solar, wind, hydroelectric, biomass and geothermal are considered a critical tool in achieving sustainable development goals. However, countries are turning to supporting their energy supply with renewable energy systems in order to meet the increasing energy demand and to regulate fluctuating energy prices in a way that does not harm their national economies (Syzdykova et al.2021).

The widespread use of renewable energy creates a major transformation in terms of both its environmental advantages and its economic effects. In addition to increasing energy supply security, investments in renewable energy have significant effects on various economic indicators such as employment opportunities, industrial policies and regional development. In this context, the effects of renewable energy policies on the labor market are increasingly being investigated and their relationship with the unemployment rate is particularly emphasized.

Unemployment is one of the most critical indicators in ensuring economic stability and is one of the main factors that directly affects individuals' living standards and determines the level of social welfare. While reducing unemployment rates is of great importance for the sustainability of economic growth, the creation of new job opportunities is considered to be one of the most fundamental elements of this process. The renewable energy sector is thought to have the potential to create new employment opportunities by its nature. Both the construction of new facilities and the development and maintenance of renewable energy technologies can create a wide range of labor demand in different sectors. Some studies show that renewable energy production significantly reduces unemployment in European countries in the long term (Naqvi et al., 2021). However, the extent to which the renewable energy sector affects unemployment rates has not been clearly established. While renewable energy investments are thought to have employment-creating effects on one hand, it is also suggested that the job opportunities created due to the capital-intensive structure of the sector may be limited or that technological developments may reduce the need for labor in the long term. At this point, analyzing the impact of renewable energy consumption on unemployment in detail is of great importance in terms of economic and social policies.

Various studies have revealed important findings by examining this relationship. In their study for Germany, Lehr et al. (2008) showed that renewable energy can increase unemployment. However, a study by Ragwitz (2009) found that renewable energy policies positively affect employment throughout the European Union. A study by Khodeir (2016) in Egypt showed that renewable energy has a positive effect on unemployment in the long term. A study by Bulavskaya and Reynès (2018) in the Netherlands stated that the transition to renewable energy can increase employment and contribute to GDP. In a study by El Moummy et al. (2021) for Morocco, it has been empirically proven that renewable energy reduces unemployment. Rafiq et al. (2018) showed in their study covering 41 countries that renewable energy consumption increases unemployment.

This study aims to examine the impact of renewable energy consumption on unemployment rates in developed countries. Developed economies are in a leading position in the transition to renewable energy and provide an important sample in terms of determining the relationship between energy policies and employment. In the study, heterogeneity between countries will be taken into account by using fixed effects and random effects panel data analysis methods and the direction and magnitude of the relationship between renewable energy consumption and unemployment are determined.

2. LITERATURE REVIEW

When the studies on renewable energy consumption are examined, it is observed that these studies are generally carried out on the axis of renewable energy consumption-environmental degradation and renewable energy consumption-economic growth. It is seen that the studies examining the relationship between renewable energy consumption and unemployment are limited in the literature. The direction of the effect of renewable energy on employment is still a controversial issue. Factors such as the intensity of the labor factor related to renewable energy, cost increases and the availability of investments may cause the effect of renewable energy on employment to differ (Lambert and Silva, 2012).

In some of the studies examining the relationship between renewable energy consumption and unemployment, it has been found that increasing renewable energy consumption reduces unemployment (Dvořák et al., 2017; Ibrahiem and Sameh, 2020; Khobai et al., 2020), while in others, it has been found that renewable energy consumption increases unemployment (Rivers, 2013; Apergis and Salim, 2015; Khodeir, 2016; Rafiq et al., 2018; Muniyoor, 2020).

Rivers (2013) examined the impact of renewable energy policies on the natural rate of unemployment. In the two-factor version of the model created to represent the US economy, it was found that support policies for electricity production from renewable energy led to an increase in the unemployment rate. In the extended three-factor model, it was found that support policies for electricity production from renewable energy increased the natural rate of unemployment.

Meyer and Sommer (2014) argue that renewable energy use generally has positive net employment effects, but these effects vary depending on financing, competitiveness, and other economic factors, complicating the relationship between renewable energy consumption and unemployment in developed countries.

Apergis and Salim (2015) investigated the effects of renewable energy consumption on unemployment. In the study where data covering the period 1990-2013 belonging to 80 countries were included in the analysis, nonlinear Granger causality method and cointegration test were performed. As a result of the analysis, it was determined that renewable energy consumption and unemployment variable were positively related.

Khodeir (2016) analyzed the effect of electricity production from renewable energy sources on unemployment. In the study examining the Egyptian economy, data covering the period 1989-2013 belonging to Egypt were used. As a result of the analysis conducted in the study in which the ARDL approach was preferred, it was concluded that electricity production from renewable energy sources increased unemployment in Egypt in the long term.

Dvořák et al. (2017) investigated the relationship between renewable energy investment and employment. The impact of the development of the renewable energy sector in the Czech Republic on creating new job opportunities and establishing new economic sectors was examined for the period 2008-2013. The findings of the research show that although the expansion of renewable energy in the Czech Republic has provided a significant number of employment opportunities, job creation is strongly dependent on the continuation of financial incentives.

Rafiq et al. (2018) analyzed the relationship between renewable energy consumption and unemployment. In the study where current econometric techniques were applied, research was conducted in 41 countries for the period 1980-2014. As a result of the econometric analysis performed, it was found that renewable energy consumption increased unemployment in 41 countries for the specified period.

Gradziuk and Gradziuk (2018) found that increasing renewable energy consumption can create jobs, especially in rural areas where unemployment is high. However, due to the innovative nature of sectors such as solar and wind energy, their employment rates may decrease in the short term.

Ibrahiem and Sameh (2020) examined the long-term relationship and causality between unemployment and clean energy resources in Egypt. In the study using data covering the period 1971-2014 for Egypt, Johansen and Juselius, ARDL and VECM approaches were used. As a result of the analysis, the authors found that clean energy sources have a negative effect on unemployment.

Khobai et al. (2020) investigated the relationship between renewable energy consumption and unemployment in South Africa. In the study where data covering the period 1990-2014 for South Africa was used, the ARDL method was preferred to test long-term and short-term effects. As a result of the analysis, it was found that renewable energy consumption in South Africa has a negative and statistically significant effect on unemployment in the long term. However, they found a negative and statistically insignificant relationship between the variables in the short term.

Muniyoor (2020) examined the relationship between growth in investments in renewable energy sources and unemployment. As a result of the research covering the period 2017 to 2018 for India, it was found that despite the increase in India's investments in PV technology, the number of jobs created by the sector decreased from 164,000 in 2017 to 114,000 in 2018.

Musa and Maijama'a (2020) analyzed the causality relationship between renewable energy consumption and unemployment variables in Nigeria. In the study using data covering the period 1991-2015 for Nigeria, Toda Yamamoto causality test was conducted. As a result of the analysis, they determined a bidirectional causality relationship between renewable energy consumption and unemployment.

Bali Swain et al.(2022) found that the transition to renewable energy sources has a positive but small and significant net effect on average employment in the EU, and that renewable energy consumption contributes significantly to future changes in employment in the short and medium term. Osei et al.(2023) analyzed the impact of renewable energy production on employment in 50 European and 40 Asian countries from 2000 to 2018, finding a stronger positive impact on employment in European countries compared to Asian countries.

Yi et al. (2024) found that renewable energy technology positively impacts employment levels in the long term. According to the authors, policymakers should consider integrating renewable energy initiatives to improve employment and overall economic health. Souza et al. (2024) showed that renewable energy development can reduce unemployment rates in Ecuador's rural sector and positively affect the rural population, without significantly affecting agricultural production. According to the authors, job creation occurs directly through construction and maintenance and indirectly through increased productivity.

3. DATASET AND METHODS

In this study, in order to measure the effect of renewable energy consumption on unemployment, the leading developed countries in renewable energy consumption worldwide (USA, Canada, Germany, Japan, France, Norway, UK and Spain) were selected. The data set covers the period 2000-2023. The dependent variable is the unemployment rates in the mentioned countries (lnunp). The main independent variable is the share of renewable energy consumption in total energy consumption (lnrec) representing renewable energy consumption. In addition, control variables such as gross domestic product (lngdp), inflation (lninf) and openness to the outside world (lnopen) were added to the regression. The logarithms of the variables were used in the analysis. The model of the study is given below:

$$lnunp_{it} = \alpha_i + \beta_1 lngdp_{it} + \beta_2 lninf_{it} + \beta_3 lnrec_{it} + \beta_4 lnopen_{it} + u_{it} \quad (1)$$

All variables are expressed in US dollars, all dependent and independent variables are obtained using World Bank data. The possible effects of independent variables on the dependent variable (according to economic theory and previous studies) are given in Table 1.

Panel data sets include both cross-section and time series and are made for cross-sections of individuals, firms, sectors, countries, etc. The panel data method provides more advantages to the researcher compared to time series. First of all, since panel data methods are created by combining both cross-section and time series, they include a higher number of observations and ensure that the results are more reliable. Second, since panel data sets include more observations, the degree of freedom n-k (number of observations-number of parameters) is larger. The third advantage is that the problem of multicollinearity in time series analyses is broken in panel data sets. Panel data sets include cross-section and time series together and therefore the problem of multicollinearity is reduced to a lesser extent in panel data sets. Fourth, the inclusion of a fixed effect that is constant according to time but varies according to cross-section in panel data sets allows heterogeneity to be controlled and included in the model. Fifth, in some cases,

Table 1: Expected effect of parameters on dependent variable

Independent variables		Expected impact
lnrec	Renewable energy consumption	Positive/Negative
lngdp	GDP	Negative (employment increases)
lninf	Inflation	Positive (employment decreases)
lnopen	Trade openness	Negative (employment increases)

in cases where there are not enough time series of variables or insufficient cross-section, it allows research to be conducted. Sixth, the unit root problem, which is the most important problem in time series analysis, disappears when longer cross-sections and relatively short time series are used together in panel data sets. A general panel data model can be expressed as follows:

$$y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} + \ldots \beta_k x_{itk} + \alpha_i + u_{it};\ t = 1,2,\ldots\ldots,T \quad (2)$$

Here y_{it} represents the dependent variable, i represents the cross-section, and t represents the time dimension. $y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} + \ldots\beta_k x_{itk}$ represents the explanatory variables in the regression. ai in the regression is expressed as the unobservable effect or fixed effect. α_i includes all unobservable and time-invariant factors that vary according to the cross-section. u_{it} is the error term, which is also called the extraordinary error term, and includes all unobservable but time-varying factors. The biggest problem in the panel data method is that the fixed effect α_i causes correlation with the explanatory variables. The least squares method does not allow correlation between the explanatory variables and the fixed effect α_i Otherwise, the results will be biased and inconsistent. Therefore, fixed effects and random effects methods are used to solve this problem (Amini et al. 2012).

The goal of the Fixed Effects method is to remove the fixed effect from the regression. To see how this method works, let's consider a model with a single explanatory variable:

$$y_{it} - \bar{y} = \beta_1\left(x_{it} - \bar{x}\right) + u_{it} - \bar{u}_i, t = 1,2,\ldots,T \quad (3)$$

Now average this regression over time for each cross-section i:

$$\bar{y}_{it} = \beta_1 \bar{x}_{it1} + a_i + \bar{u}_{it} \quad (4)$$

Here, $\bar{y}_{it} = T^{-1}\sum_{t=1}^{T} y_{it}$ equals i.e. the regression is averaged over time.

Since the fixed effect is constant over time, even if we average the regression over time, the second regression is still visible. Now, for each t, the second regression (4) (the regression averaged over time) is subtracted from the first regression (3), and the new regression obtained when subtracted is as follows:

$$y_{it} - \bar{y} = \beta_1\left(x_{it} - \bar{x}\right) + u_{it} - \bar{u}_i, t = 1,2,\ldots,T \quad (5)$$

or to put it more simply $\ddot{y}_{\text{it}} = {}^2{}_1\ddot{x}_{\text{it}} + \ddot{u}_{\text{it}}, \text{t} = 1,2,\ldots,\text{T}$.

Here $\ddot{y}_{it} = y_{it} - \bar{y}_i; \ddot{x}_{it} = x_{it} - \ddot{x}_i$ and $\ddot{u}_{it} = u_{it} - \ddot{u}_i$ are the time averaged difference data.

As can be seen in the new model obtained with the fixed effects transformation, the fixed effect i a has been eliminated from the model. The new model transformed with fixed effects (6) can be estimated with the Least Squares method and the estimators will now be unbiased and consistent. By adding more explanatory variables to the regression, the Fixed Effects model can be expressed in general as follows:

$$y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} +. \beta_k x_{itk} + a_1 + u_{it,t} = 1,2,\ldots\ldots,T \quad (6)$$

If the average is taken over time for each explanatory variable and the error term in the general regression and removed from the general regression (7), the transformed fixed effects model can be expressed generally as follows:

$$\ddot{y}_{it} = \beta_1\ddot{x}_{it} + \beta_2\ddot{x}_{it} + \ldots\ldots\beta_k\ddot{x}_{itk} + \ddot{u}_{it}, t = 1,2,\ldots\ \ldots,T \quad (7)$$

The biggest reason for using panel data is to allow unobservable effects to be correlated with explanatory variables. Because in the Fixed Effects model, eliminating fixed effects from the regression leads to information loss in the regression and the results are less reliable than in the Random Effects model. The Random Effects model assumes all the assumptions of the fixed effects model and that the fixed effect is independent of all explanatory variables. In other words, according to the Random Effects model: $Cov\ (x_{it,k}, a_i) = 0, t = 1,2\ldots\ldots\ldots,k$

Therefore, the Random Effects model obtains unbiased and consistent estimates by keeping the fixed effects i a in the regression. However, the model uses the combined error term.

$$y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} + \ldots\ldots\ldots\beta_k x_{itk} + v_{iit} = 1,2,\ldots\ldots,T \quad (8)$$

$$v_{it} = a_i + u_{it}$$

Since the fixed effect is included in the combined error term in each period t, it v is serially correlated with respect to time: $Corr\left(v_{it}, v_{i,s}\right) = \sigma_a^2 / \left(\sigma_a^2 + \sigma_u^2\right), t \neq s$

The Least Squares method ignores this correlation in the error terms and may lead to high standard errors of the parameters and incorrect test statistics. Therefore, instead of LSQM, it uses Random Effects Generalized Least Squares to solve the serial correlation problem. The transformation is as follows:

$$\lambda = 1 - \left[\left(\sigma_a^2\right)/\left(\sigma_a^2 + \sigma_u^2\right)\right]^{\frac{1}{2}}\ 0 < \lambda < 1$$

The mean differenced data for each variable is as follows:

$$y_{it} - \lambda\bar{y}_i = \beta_0\left(1-\lambda\right) + \beta_1\left(x_{it1} - \lambda\bar{x}_{i1}\right) + ,\ \ldots\ \ldots, \beta_k\left(x_{itk} - \lambda\bar{x}_{ik}\right) + \left(v_{it} - \bar{v}_i\right) \quad (9)$$

While Fixed Effects subtracts the time mean from each variable in the regression, Random Effects subtracts a ratio of the time means from each variable to eliminate serial correlation in the error terms. The Random Effects model gives better results than the Fixed Effects model because it contains more information. In the Fixed Effects model, most of the important information is omitted. In practice, both the Fixed Effects model and the Random Effects model are calculated. Then the Hausman (1978) test is applied. Unless the Hausman (1978) test is rejected, the Random Effects is preferred. In case the Hausman (1978) test is rejected, it becomes mandatory to select the Fixed Effects.

4. ANALYSIS FINDINGS

The panel data set for selected developed countries was created between 2000–2023 to measure the impact of renewable energy consumption on unemployment. It should be decided whether to use fixed effects or random effects methods in the model. The Hausman (1978) test is the most important test used to choose between the two methods. Since unit and time effects are present together in our model, the Hausman test was performed to determine the two-way model. The null hypothesis of the test indicates the random effects model, while the alternative hypothesis indicates the fixed effects model. Table 2 shows the Hausman test results.

Since the Hausman test probability value is found significant, the null hypothesis is rejected. Therefore, it is decided that the fixed effects method is valid. In the fixed effects method, the assumption that the independent variables are uncorrelated with the error term is made, while the unit effect and independent variables are allowed to be correlated. After this stage, the basic assumptions of the fixed effect model will be tested. In this context, the Modified Wald test was performed for the heteroscedasticity assumption, the Durbin-Watson and Baltagi-Wu (1999) Locally Best Invariant (LBI) test of Bhargava et al. (1982) was performed for the autocorrelation assumption, and the CD test of Pesaran (2004) was performed for the cross-sectional dependence assumption. The test results are summarized in Table 3 below.

According to the D.Wald test result in the first column of Table 3, the null hypothesis indicating that there is no heteroscedasticity is rejected, therefore, there is a heteroscedasticity problem in the model. Since the D.Watson and Baltagi-Wu Test results in the second column are less than the critical value of 2, an autocorrelation problem is detected in the model. The Pesaran CD test results determining whether there is cross-sectional dependence are included in the last column. Accordingly, the null hypothesis suggesting that there is no cross-sectional dependence in the model is rejected, therefore, there is cross-sectional dependence in the model. Since the Driscoll\Kraay estimator and the Robust Fixed Effects estimator can give consistent estimates even in the presence of heteroscedasticity, autocorrelation and inter-unit correlation, it was decided to apply these methods. The Driscoll\Kraay and Robust Fixed Effects estimator results are given in Table 4.

Table 2: Hausman test results

Variables	Fixed effects	Random effects
lnrec	0.1248844	0.1282061
lngdp	0.2466819	0.2507885
lninf	0.0948051	0.2240061
lnopen	0.0842364	0.0694320
Hausman test	χ^2 (7)= 103.72 Prob=0.0000	

Table 3: Fixed effects method basic hypothesis tests

D. Wald test	D. Watson and Baltagi-Wu tests	Pesaran CD test
χ^2 (28) = 12976.49	Durbin-Watson= 0.42569873	Pesaran CD=4.768
Prob >χ^2=0.0000	Baltagi-Wu LBI=0.7597654	Pr=0.0000

In Table 4, the effects of the control variables *lngdp*, *lninf* and *lnopen* on the dependent variable *lnunp* are given in the first columns of the estimators. While the negative effects of GDP and openness on the unemployment rate are statistically significant, the effect of the inflation variable on the unemployment rate is insignificant. In the developed countries included in the analysis, a 1% increase in GDP reduces unemployment by 0.52% and a 1% increase in the openness rate reduces unemployment by 0.55%. GDP shows the amount of goods and services produced within the country. Therefore, an increase in the amount of production within the country naturally creates new employment opportunities and reduces unemployment. Openness measures a country's connection with the outside world. The more a country engages in export and import activities abroad, the greater its openness will be. Countries that are more open to the outside, i.e. countries with high export and import levels, have to produce more than they produce domestically in order to meet foreign demands. Therefore, it is expected that unemployment will decrease as openness increases. The analysis was expanded by adding the *lnrec* variable next to the control variables in the second column. When we look at the results, a 1% increase in renewable energy consumption reduces unemployment by 0.52%. This result shows that the renewable energy sector has the potential to create employment and that investments in this area can positively affect the labor market. An important issue that affects the possibility of renewable energy creating employment is whether the infrastructure in the country is suitable for renewable energy investments. In general, the developed countries included in the analysis are not countries that are dependent on foreign countries in terms of technology. Therefore, these countries easily adapt to renewable energy investments and the possibility of renewable energy investments

Table 4: Driscoll\Kraay and Robust fixed effects estimator results

Driscoll\Kraay fixed effects estimator			Robust fixed effects estimator		
Variables	Drisc/Kraay	Coefficients	Variables	Robust	Coefficients
lngdp	−0.5226*** (0.060)	−0.3065*** (0.017)	*lngdp*	−0.5226*** (0.049)	−0.3065*** (0.019)
lninf	1.9831 (0.960)	1.3107 (0.917)	*lninf*	1.9040 (0.901)	1.3042 (0.905)
lnopen	−0.5594*** (0.054)	−0.3494*** (0.027)	*lninf*	−0.5594*** (0.144)	−0.3494*** (0.089)
lnrec	-	−0.1805*** (0.018)	*lnrec*	-	−0.1805*** (0.013)
Constant	4.343*** (1.756)	12.12*** (0.576)	Constant	4.343*** (1.697)	12.12*** (1.834)
F	82.00**	242.63***	F	115.59	184.08***
R^2	0.76	0.91	R^2	0.93	0.94

Although the coefficients are the same in both estimation methods, there is a small difference between the standard errors. ***Indicates significant test results at the 1%, **at the 5% level. The figures in parentheses indicate standard errors creating jobs, especially for the young and dynamic population, increases.

5. CONCLUSION

In this study, the effect of renewable energy consumption on the unemployment rate in developed countries was examined and the analysis was carried out with fixed effects and random effects models using the panel data set for the years 2000–2023. The findings obtained reveal that renewable energy consumption has a reducing effect on the unemployment rate. This result shows that the renewable energy sector has the potential to create employment and that investments in this area can positively affect the labor market.

In the study, it was found that the GDP and openness variables included in the model as control variables negatively and statistically significantly affected the unemployment rate. This finding supports the positive effect of economic growth and international trade on the labor market. On the other hand, the effect of the inflation rate on unemployment was not found to be statistically significant. This suggests that the relationship between inflation and unemployment in developed countries may have historically different dynamics and that traditional theories such as the Phillips Curve may not be valid in every period and context.

The findings show that incentives and investments in the renewable energy sector not only increase environmental sustainability but also have the potential to reduce unemployment rates. In this context, it can be said that developed countries should also take into account the effects on the labor market when creating their energy policies. Future studies can detail the effects of renewable energy investments on employment by conducting more detailed analyses on a sectoral basis and provide more specific recommendations for policy makers.

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