Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 7, S. 501-506, 10, 2023

Araştırma Makalesi

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 7, pp. 501-506, 10, 2023

Research Article

https://alls-academy.com/index.php/ijanser
ISSN: 2980-0811

How Renewable Energy Affect Economic Growth in a Member State of the European Union? VECM Evidence from the Netherlands

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(Received: 30 October 2023, Accepted: 30 November 2023)

(2nd International Conference on Contemporary Academic Research ICCAR 2023, November 4-5, 2023)

REFERENCE: Seyhan B. & Yurttançıkmaz, Z. Ç. (2023). How Renewable Energy Affect Economic Growth in a Member State of the European Union? VECM Evidence from the Netherlands. *International Journal of Advanced Natural Sciences and Engineering Researches*, 7(10), 501-506.

***Abstract* –** Energy has an important quality considering that it provides opportunities to compete in international markets and triggers growth mechanisms. In this respect, both non-renewable and renewable energy sources are important cost elements in production functions, and on the other hand, they are also an important manufacturing input. In addition to the fact that fossil energy resources are not infinite in nature, global and environmental problems have led the world to search for new energy sources. This search has led humankind to renewable energy sources that exist in nature, do not cause environmental degradation, and can quickly renew themselves in case of depletion. The problems arising from the use of non-renewable energy resources and their disadvantages in terms of sustainability have recently increased the importance given to renewable energy resources. In this context, analyzing the relationship network between renewable energy and economic growth has critical importance in determining more efficient and effective growth strategies and policy alternatives. The aim of this study is to investigate the effects of renewable energy supply, renewable energy R&D expenditures and technological innovations in renewable energy on economic growth in the example of the Netherlands which is a member state of EU. The findings obtained as a result of the VECM model applied for the 1990-2021 research period show that the developments in renewable energy supply and renewable energy technologies in the Netherlands has a positive impact on economic growth.

Keywords – Renewable Energy, Economic Growth, Technological Development, Time Series Analysis, Vector Error Correction.

I. INTRODUCTION

Energy sources used in all areas of life for different purposes are a factor analyzed by many branches of science from various disciplines. One of the branches of science that most frequently deals with energy resources as a research topic is economics. Being a natural resource, being one of the components of the production function as a production input, creating environmental impacts and externalities, directing policy alternatives and affecting international economic relations, and directly concerning political decision-making authorities, constitute the functioning mechanisms of the relationship between energy and economy. Each of these operating mechanisms has significant effects on the economic growth performance of countries. In this context, the nature of the relationship between energy resources and

economic growth emerges as an area that needs to be investigated.

Energy has an important role in terms of competitiveness and activating the locomotive of growth. In this context, whether non-renewable or renewable energy sources, on the one hand, are important factor costs, and on the other hand, they are important manufacturing inputs. The negativities arising from the use of non-renewable energy resources and their disadvantageous situations in terms of sustainability have increased the importance attached to the use of renewable energy resources in recent years. From this perspective, analyzing the relationship network between renewable energy resources and economic growth is of great importance in terms of determining more efficient and effective policy alternatives.

Renewable energy resources, which have been studied in many areas for the future and whose many benefits have been mentioned, have not yet reached the desired level of use in the global energy sector. The reasons for this situation are that renewable energy operates at higher costs than fossil resources and that countries are reluctant to change the traditional order based on fossil fuels.

Energy supply can be affected by many reasons such as political relations, diplomatic crises and wars. In this respect, ensuring energy security has a great importance for a country. Many international organizations have made evaluations on this issue. For example, this issue was discussed in the "Green Book" (1995) titled European Union Energy Policies and many risks regarding energy supply have been highlighted. These risks are: geological risks (resource depletion, cost of energy production), technical risks (problems that may be encountered during the transportation of energy), economic risks (supply-demand imbalances), geopolitical risks (suspension of relations as a result of factors such as political reasons, war), etc. (De Paoli et.al. 2010).

Member states of the European Union are parties to the Kyoto Protocol, which has been effective since 2005 and has been accepted as an annex to the United Nations Climate Change Convention, which is important for renewable energy. According to renewable energy statistics published by the European Commission Eurostat in 2020, the Netherlands was the last among the EU member states in the shift away from global warming-inducing energy sources (European Commission, 2020).

This study aims to investigate the effects of renewable energy supply, renewable energy R&D expenditures and technological innovations in renewable energy on economic growth in the example of the Netherlands which is a member state of the European Union.

II. Materials and Method

In this section, the method used in the study and the relevant empirical literature are briefly summarized and the findings obtained as a result of the application are presented to the readers.

A. Methodology and Empirical Literature

Whether there is a cointegration relationship between two variables is a research problem. However, if the research hypothesis is not supported by economic theory, it does not make any sense to conduct cointegration analysis in practice (Charemza ve Deadman, 1997: 157).

In cointegration analysis, after determining that the variables are cointegrated at the end of the first stage, which represents the long term, the second stage is started. The second stage is the modeling of the short term, that is, the creation of a difference model. According to Engle and Granger, a lag of the error terms obtained by estimating the first static regression model is included in the regression model as an error correction term in the next stage and is estimated with the ECM method. (Granger, 1986: 226-7).

In this method, if two variables are integrated from the first level, the estimated error term may be stationary and a long-term causality relationship may emerge as predicted in theory. In other words, even if the variables are not stationary, they may become stationary within the difference time path. In fact, there is a mechanism called error correction mechanism that prevents the difference between variables in the time path from widening. These variables move together over time, and in case of deviations from balance, the error correction mechanism comes into play. Engle and Granger (1987) named this theory Granger Representation Theory. Although the cointegration concept shows the existence of a long-term relationship between variables, it does not provide information about the direction of causality. Engle and Granger (1987) state that if there is cointegration between variables,

there will be at least a one-way causality relationship between the variables. However, by detecting cointegration, it is also possible to use the vector error correction mechanism (VECM). (Engle and Granger, 1987).

In order to determine the cause of the causality relationship resulting from VECM, it is necessary to look at the Wald test applied to all coefficients in the explanatory variables and the t test results applied for the coefficients of the error correction terms. As a result of the Wald test, the fact that the explanatory variable coefficients are statistically significant according to the F statistic value or the coefficients of the error correction terms are significant according to the t statistic value indicates the existence of a causality relationship. In short, VECM is an additional channel used to determine the direction of causality. If the presence of cointegration is detected and the coefficient of the error correction term is significant, if classical causality tests are used, it can be concluded that there is actually a causality relationship, but there is not. This situation will lead to misleading results in the causality relationship. In this context, it is recommended to use VECM in cointegrated series (Demirhan, 2005: 81-82).

Apergis and Payne (2010), Bulavskaya and Reynes (2018), Dogan et al. (2020), Kartal et. al. (2023), Khobai and Le Roux (2017), Kopnina (2017), Li and Leung (2021), Mulder and Scholtens (2013), Olmo et al. (2020), Omri et al. (2015), Papiez et al. (2019), Radmehr et al. (2021), Saad and Taleb (2017), Scheepers et. al. (2022) and Shahbaz et al. (2020) are just some of the studies exploring the relationship between renewable energy and economic growth. Table 1 shows a summary of selected literature.

Table 1. Empirical Literature Review

Authors	Content	Finding
Bulavskaya and Reynes (2018)	Netherlands	transition to renewable energy creates new employment opportunities
Kartal et. al. (2023)	Netherlands	assessing the network of linkages between renewable energy and economic growth and political stability
Kopnina (2017)	Netherlands	evaluation of the effects of a critical approach to sustainable development education
Mulder and Scholtens (2013)	Netherlands	modest effect of using renewable energy sources on electricity prices
Scheepers et. al. (2022)	Netherlands	different scenarios for the energy system in the period until 2050
Li and Leung (2021)	7 EU countries	existence of a significant nexus with the impact of nonrenewable energy prices
Olmo et al. (2020)	26 European Union countries	existence of a nexus with the effect of spatial dependency especially in neighboring countries
Papiez et al. (2019)	European Union countries	relationship depends on the level of development in the renewable energy sector
Radmehr et al. (2021)	European Union countries	existence of unidirectional relationship between variables
Saad and Taleb (2017)	12 European Union countries	unidirectional causality in the short run, bidirectional causality in the long run
Apergis and Payne (2010)	20 OECD countries	bidirectional causality between variables
Dogan et al. (2020)	OECD countries	different relationship networks for different quantile regressions with the new econometric techniques
Khobai and Le Roux (2017)	South Africa	unidirectional causality between variables
Omri et al. (2015)	17 developed and developing countries	unidirectional causality between variables
Shahbaz et al. (2020)	38 renewable-energy-consuming countries	existence of a relationship between variables

B. Empirical Findings

Annual data for the period 1990–2021 was used in the research. In the model, GDP representing economic growth was used as the dependent variable, RESUP representing the renewable energy supply in the total energy supply, RERD representing the share of R&D expenditures related to renewable energy in GDP, and RETI representing technological innovations related to renewable

energy were used as explanatory variables. All variables are in logarithm form so that elasticities can be interpreted directly. EViews 9.0 econometric softwares were used in the analysis. Phillips-Perron Stationarity test was used to test the stationarity of the variables.

Table 2. Phillips-Perron Unit Root Test

Variables	PP test values	PP prob. values
GDP	-1.477776	0.5313
RESUP	2.659948	1.0000
RERD	-0.977647	0.7487
RETI	-2.866499	0.1885
Δ GDP	-4.623895	0.0009
Δ RESUP	-3.602081	0.0407
Δ RERD	-7.968309	0.0000
Δ RETI	-5.215255	0.0003

In the results obtained; the variables GDP, RESUP, RERD and RETI are stationary at their first difference, not at level. As a result of the applied unit root tests, it was determined that the series were not stationary, and stationarity was reached if their first differences were taken. When moving to the cointegration analysis stage, the existence of cointegration is first tested with cointegrating regression estimation.

Table 3. Cointegrating Regression

Dependent variable: GDP		
Method: Cointegrating Fully Modified Least Squares (FMOLS)		
Sample: 1990-2021		
Variables	**Coefficients**	**t stat (prob. value)**
RESUP	1.414577	3.101551 (0.0050)
RERD	-1.851032	-4.522460 (0.0002)
RETI	13.58620	30.44563 (0.0000)

According to the estimation results, all variables in the model are statistically significant and their signs are compatible with theoretical expectations.

Table 4. Johansen System Cointegration Test (Trace)

Unrestricted Cointegration Rank Test (Trace)			
Hypothesized Number of CEs	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**
None *	0.974066	125.2048	47.85613
At most 1 *	0.735280	41.20429	29.79707
At most 2	0.244658	10.63538	15.49471
At most 3 *	0.166251	4.181920	3.841466

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

As a result of the regression estimation, a significant relationship was detected in the short run and the next stage, the Johansen System Cointegration Test, was started.

Table 5. Johansen System Cointegration Test (Maximum Eigenvalue)

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
Hypothesized Number of CEs	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**
None *	0.974066	84.00055	27.58434
At most 1 *	0.735280	30.56891	21.13162
At most 2	0.244658	6.453457	14.26460
At most 3 *	0.166251	4.181920	3.841466

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

According to the results of both trace and maximum eigenvalue tests, there are at least two cointegrated vectors in the long run. At this point, Vector Error Correction Mechanism, the most important component of the analysis, was performed.

According to VECM results, the error correction term ECTt-1 has a negative sign and is statistically significant, in line with theoretical expectations. The fact that the error correction term ECTt-1 is statistically significant, between 0 and 1, and has a negative sign guarantees that there is at least one unidirectional causality between the GDP, RESUP, RERD and RETI variables.

Table 6. Vector Error Correction Mechanism

Variables	Coefficients	t stats
ECTt-1	-0.713021	-6.67919
Δ GDP	0.630799	-3.32068
Δ RESUP	0.126460	0.56028
Δ RERD	0.328302	-2.30751
Δ RETI	0.033792	-1.27855
R^2= 0.591006, Adj. R^2= 0.422597, F= 3.509350		

When the coefficients obtained as a result of VECM are interpreted, in the Netherlands if R&D activities in the field of renewable energy increase by one percent on average in the long term, economic growth is expected to increase by 0.32 percent, and if technological innovations in the field

of renewable energy increase by one percent, growth is expected to increase by 0.03 units.

Auto regressive residual tests were performed to determine whether the VECM model operated satisfied the structural stability conditions.

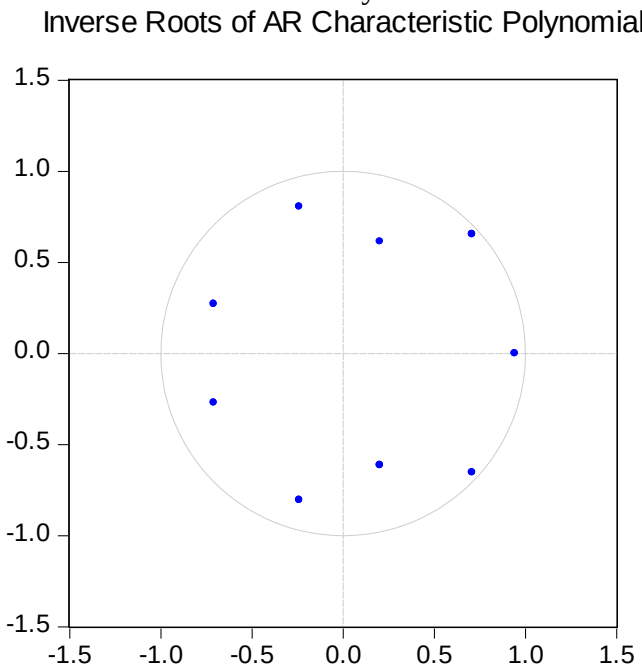

Fig 1. AR Characteristic Polynomial Circle

According to figure 1, all equation roots are within the characteristic circle. No root lies outside the unit circle. Table 7 gives the modulus of the AR Polynomial. All modulus are smaller than 1. VECM satisfies the stability condition.

Table 7. AR Roots Modulus Table

Roots	Modulus
0.707803 - 0.654232i	0.963849
0.707803 + 0.654232i	0.963849
0.942547	0.942547
-0.238775 - 0.804895i	0.839565
-0.238775 + 0.804895i	0.839565
-0.707631 - 0.271163i	0.757806
-0.707631 + 0.271163i	0.757806
0.201827 - 0.612880i	0.645256
0.201827 + 0.612880i	0.645256

Finally, variance decomposition was performed to determine which variable caused the change in the long term and to what extent.

Table 8. Variance Decomposition of VECM

Period	S.E.	GDP(-1)	RESUP(-1)	RERD(-1)	RETI(-1)
1	0.806453	100.0000	0.000000	0.000000	0.000000
2	1.170521	96.81681	0.424997	0.622230	2.135965
3	1.454148	82.72238	10.33485	0.456694	6.486076
4	1.796371	60.59111	34.02402	0.374010	5.010866
5	2.303017	38.35316	57.28405	0.604369	3.758426
6	2.972929	23.73851	70.87120	1.299669	4.090624
7	3.655689	16.32631	77.88124	1.850703	3.941745
8	4.291674	12.44492	81.94508	2.096604	3.513386
9	4.892034	10.08302	84.48099	2.248412	3.187578
10	5.484991	8.434011	86.14705	2.401569	3.017367

According to the results of variance decomposition of VECM analysis, 8.43 percent of the fluctuations in economic growth in the long run originate from GDP itself, 86.14 percent originate from RESUP, 2.40 percent originate from RERD and 3.01 percent originate from RETI. This result reveals that for the Netherlands, renewable energy supply has a greater importance than the development efforts in renewable energy technologies in case of short and long-term shocks.

III. CONCLUSION

Results reveals that renewable energy will have positive contributions to economic growth in the long term, based on the sample created for the research period in the Netherlands.

Although the Netherlands ranks last among the European Union members in shifting away from the energy sources that create carbon emissions, it can still show a positive performance in the long term within the framework of the economic growth forecast model based on renewable energy created specifically for this study.

This study was developed for investigating how selected variables related to renewable energy will affect economic growth in the Netherlands, which is a member of the European Union, although it is among the lowest countries in the union in terms of renewable energy at some points.

It is evaluated that advances in renewable energy supply, renewable energy research and development activities and brand-new renewable energy technologies will contribute positively to economic growth in the Netherlands in the long term.

Undoubtedly, the results obtained may vary depending on the sample compiled, the preferred analysis method, the variables included in the model created, and the research period. However, the findings obtained as a result of the empirical

analysis carried out in this study undoubtedly reveal that the Netherlands, a member of the European Union, which is an economic and political union, can obtain positive contributions from the use of renewable energy in the long term, with the influence of the strategic structural reform decisions taken by the union, especially in the field of energy.

ACKNOWLEDGEMENT

This article is an improved version of the abstract presented at the 2nd ICCAR and was developed regarding the subject of the PhD thesis project with ID number SDK-2022-11281 supported by Ataturk University Scientific Research Projects Coordination Unit.

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