THE DYNAMIC INTERPLAY BETWEEN THE RENEWABLE KUZNETS CURVE (RKC) AND ENVIRONMENTAL KUZNETS CURVE (EKC) HYPOTHESES: FRESH EVIDENCE FROM THE EUROPEAN UNION COUNTRIES

Olimpia Neagu[*]
„Vasile Goldiș" Western University of Arad, Romania
University of Oradea, Romania
Academy of Romanian Scientists, Bucharest, Romania
Email: neagu.olimpia@uvvg.ro

Andrei Marius Anghelina
„Vasile Goldiș" Western University of Arad, Romania
E-mail: anghelina.andrei@uvvg.ro

Samuel Nicoară
„Vasile Goldiș" Western University of Arad, Romania
University of Oradea, Romania
E-mail: nicoara.samuel@uvvg.ro

Abstract: The paper explores the interplay between the Environmental Kuznets Curve (EKC) (U-inverted shaped) and the Renewable Kuznets Curve (RKC) (U-shaped) in the European Union case; the validation of both hypotheses being investigated. The methodology consists of a panel data approach with the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models to estimate the polynomial regressions using the Greenhouse Gas (GHG) emissions as dependent variable and renewable energy, respectively. Based on data from 26 European Union countries for the period 1990 to 2022, the quadratic dependencies of Greenhouse Gas emissions and Renewable Energy on the Gross Domestic Product (GDP) per capita are validated, meaning that both, the Environmental and Renewable Kuznets hypotheses are confirmed. The value of GDP per capita corresponding to the threshold of renewable energy consumption predicts the value for which the increasing trend of greenhouse gas emissions is inversed. In the Central and Eastern European Union (CEE) countries, the threshold of renewable energy use is earlier attained (meaning at a lower level of GDP per capita) than in the Western European Union

---

[*] Corresponding author: Olimpia Neagu. *E-mail: neagu.olimpia@uvvg.ro.*

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC) Hypotheses: Fresh Evidence from the European Union Countries

countries and the distance between the two threshold points is longer. Policy implications regarding the use of renewable energy and environmental protection are also included.

Keywords: Renewable energy; environment; economic growth; cointegrating polynomial regression; panel data.

JEL Codes: Q42, O44, C23.

1. Introduction

Inspired by the work of Simon Kuznets (1955), who identified a quadratic dependency of income inequality on economic growth, the Environmental Kuznets Curve (EKC) hypothesis states that at an early stage of economic development, urbanization and industrialization can deplete natural resources, generate industrial wastes and thus, induce environmental degradation. Economic growth and pollution are positively correlated. The progress of industrialization generates improvement in services and technological advances and, as a result, pollution starts to decrease (Panayotou, 1993). Starting with the studies on EKC conducted by Grossman and Krueger (1991, 1995) and Shafik and Bandyopadhyay (1992) an impressive amount of research was focused on analyzing the pollution dependency on per capita income. Renewable energy consumption was introduced by Bölük and Mert (2014) in the analysis of the EKC hypothesis. Several further studies found that renewable energy consumption can significantly mitigate pollution (i.e., Bilgili et al., 2016; Destek and Sinha, 2020; Chien, 2022; Wang et al., 2023a). Later, Yao et al. (2019) proposed a hypothesis regarding the relationship between GDP per capita and renewable energy consumption, called the Renewable Energy Environmental Kuznets Curve (RKC). According to this hypothesis, a U-shaped relationship between GDP per capita and renewable energy consumption is identified. In the early stage of development, the share of renewable energy consumption is decreasing due to the promotion of demand for fossil fuels. After reaching a certain level and, with further economic growth, the share of renewable energy will increase and the energy structure will stimulate green development. Moreover, the turning point of RKC occurs before the turning point of the EKC, suggesting that promoting renewable energy use in the economy could stimulate the reach of the level of GDP per capita corresponding to an inversed dynamic of pollution (a decreasing trend).

The present paper explores the dynamic link between these two hypotheses in terms of the impact of economic growth on GHG emissions and renewable energy consumption in the European Union. It is highlighted that renewable energy use can be seen as a predictor of the level of economic output from which pollution decreases. The study provides empirical evidence in support of the validation of both hypotheses: the Environmental Kuznets Curve and Renewable Kuznets Curve, for

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

105

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC) Hypotheses: Fresh Evidence from the European Union Countries

panel data from 26 European Union countries. Moreover, the turning point of GDP per capita at which the evolution of renewable energy consumption (RKC) positively correlates with economic growth occurs earlier than the turning point of the EKC (from which pollution starts to decrease). The methodology is based on the use of Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models to estimate both polynomial regressions, with greenhouse gas emissions as dependent variable and, renewable energy consumption, respectively. Data covering the period of 1990-2022 were collected from the World Bank database and the European Environment Agency.

The paper contributes to the existing knowledge by adding valuable insights regarding the dynamic interplay between renewable energy use, pollution and economic growth for the European Union case, by pointing out that renewable energy consumption is a predictor of the moment when the trend of pollution is reversed. The differences in this prediction between Western and Central Eastern European Union countries are also highlighted and discussed.

The remainder of the paper is structured as follows. After the Introduction, the section of the Literature Review discusses relevant studies for the paper's topic, the Methodology section details the methodological approach, the Main Findings section details and discusses the study's results and the last section is Conclusions and Policy Implications.

2. Literature Review

There is an impressive and extended literature using the EKC framework to investigate the impact of renewable energy use on pollution mitigation. Most of them are focused on validating the EKC hypothesis and highlighting the role of renewable energy in reducing pollution.

The relevant studies can be divided into two groups: individual countries and multi-countries studies.

Bölük and Mert (2015) examined the EKC hypothesis in Turkey and found that renewable energy had a reducing effect on carbon emissions. In the case of the Pakistani economy, Danish et al. (2017) concluded that non-renewable energy contributed to the rising pollution while renewable energy use reduced it. A group of studies confirm the EKC hypothesis, such as: Baek (2016) for the USA, Sugiawan and Managi (2016) in Indonesia, Sarkodie and Samuel (2018) for South Africa, Bekhet and Othman (2018) in Malaesia, Sinha and Shahbaz (2018) for India, Pata(2018) for Turkey, Septhon and Mann (2016), Shabaz et al.(2017), Yilanci et al. (2023) and, Özbek and Naimoglu (2025) for United Kingdom, while others infirm it (i.e., Jebli and Youssef, 2018, for Tunisia; Zambrano-Monserrate et al., 2018, for Peru; Chen et al., 2019, for China; Koc and Bulus, 2020, for Korea; Beşe and

106

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC)
Hypotheses: Fresh Evidence from the European Union Countries

Kalayci, 2021, for United Kingdom; Rahman et al., 2024 for Bangladesh, Mutaşcu, 2025 for the USA).

In a panel data approach the hypothesis was confirmed by Kostakis et al. (2023) for a sample of Middle East and North Africa-MENA countries as well as by Wang et al. (2023a) for a panel of 208 countries. The EKC model was also, validated in the G20 countries by Luo and Sun (2024). Leal and Marques (2020) found also support for validating the EKC hypothesis in high-globalised OECD countries but not for the low-globalised group, while Alam (2024) found support for EKC in 24 selected OECD countries. According to Makarov and Alataş (2024), the EKC hypothesis is supported in countries that are net importers of carbon emissions and not in countries that are net exporters. The EKC was not validated for a set of West African countries by Abid et al. (2024).

In the case of the EU countries, Dogan and Seker (2016) and, Moutinho and Robaina (2016) found that renewable energy had a positive impact on carbon emissions reduction. Bölüt and Mert (2014) and Al-Mulali et al. (2016) report no validation of the EKC hypothesis in 16 European Union countries while Lopez-Menendez et al. (2014) and Balsalobre-Lorente et al. (2018) provide evidence for an N-shaped EKC. Menegaki and Tsagarakis (2015) and Balezentis et al. (2019) found validation of the EKC in EU countries.

The RKC hypothesis states that there is a negative relationship between economic growth and renewable energy in the early stages of economic development, due to the fact that the costs exceed those of fossil fuels, but as economies evolve and per capita income reaches a certain threshold, the costs of using renewable energy fall (Gielen et al., 2019). Yao et al. (2019) conducted a study on seven emerging economies and ten major developed countries and validated the EKC hypothesis and the U-shaped RKC (Renewable Energy Environmental Kuzntes Curve) hypothesis. They found also, that the turning point of RKC takes place before the turning point of EKC, suggesting that promoting renewable energy consumption is an effective means to accelerating the reversal of the pollution dynamics. Similar results were reported by Wang et al. (2023b) for 67 countries and Naqvi et al.(2021) for a group of high-income countries. Simionescu (2021) provides evidence in support of the U-shaped RKC validation in six Central and Eastern European Union economies, as well as Nabaweesi et al.(2024) for five East African nations. Pata et al. (2025) compared the validity of EKC and RKC for the United States, based on data from 1973 to 2022 and revealed that the RKC hypothesis must be seen as a prerequisite for the EKC hypothesis. In other words, economic growth first helps to deploy renewable energy and then contributes to the reduction of carbon emissions.

In conclusion, there are few studies on investigating the validation of the RKC hypothesis and its link with the EKC model.

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

107

Based on the above assertions two research hypotheses can be stated: (1) there is an inverted U-shaped relationship between GDP per capita and GHG emissions, as hypothesized by the Environmental Kuznets Curve (EKC), and a U-shaped relationship between GDP per capita and renewable energy consumption, as hypothesized by the Renewable Kuznets Curve (RKC), and (2) the turning point of the RKC will precede that of the EKC.

3. Data and Methodology
3.1. Data
The study includes 26 European Union countries (Austria, Belgium, Bulgaria, Croatia, Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden) based on data covering 1990-2021. Malta was excluded due to an incomplete data series.

Table 1. Variables and their sources

Acronym	Name	Explanation	Source
GHG	Greenhouse Gas emissions	Greenhouse Gas emissions per capita (CO_2 equivalent, total emissions UNFCCC)	European Environment Agency (EEA)
RE	Renewable Energy	Renewable Energy consumption: the share of energy consumption from renewable sources in the total final energy consumption (%)	World Bank Indicator code EG.FEC.RNEW.ZS
GDPpc	Gross Domestic Product per capita	Sum of gross value added by all resident producers in the country plus any product taxes minus any subsidies not included in the value of products Measurement unit: international 2021 dollars using purchasing power parity rates. (GDP per capita, PPP -constant 2021 international dollars)	World Bank Indicator Code NY.GDP.PCAP. PP. KD

Table 2 contains the descriptive summary statistics of variables under examination. The variables are considered in natural logarithms (ln). We notice that the standard deviation is generally low for all variables.

Table 2. Statistic description of variables

	$lnGDPpc$	$(lnGDPpc)^2$	$lnGHG$	$lnRE$
Mean	10.5154	110.8111	2.2787	2.4100
Median	10.5595	111.5044	2.2651	2.5336
Maximum	11.8337	140.0368	3.5408	4.0587
Minimum	9.2346	85.2784	1.4597	-12.0397
Std.Dev.	0.4932	10.3443	0.3612	0.9400
Skeweness	-0.1468	0.0090	0.4153	-0.7216
Kurtosis	3.2037	3.3976	3.2829	3.1709

Source: computation based on using E-Views 12.0 software

3.2. Methodology

Given the aim of the paper to check the validation of quadratic dependence between GDP per capita and renewable energy consumption and pollution, we will estimate the following regression equations:

$$lnGHG_{i,t} = \beta_0 + \beta_1 * lnGDPpc_{i,t} + \beta_2 * (lnGDPpc)^2_{i,t} + \mu_{i,t} \qquad (1)$$

$$lnRE_{i,t} = \lambda_0 + \lambda_1 * lnGDPpc_{i,t} + \lambda_2 * (lnGDPpc)^2_{i,t} + \varepsilon_{i,t} \qquad (2)$$

where: i is the cross-section (country); t is the time; RE means renewable energy consumption, GDPpc is Gross Domestic Product per capita and GHG represent the greenhouse gas emissions, β_0, λ_0 are constant, β_1,β_2, λ_1, λ_2 are coefficients of regressors, $\mu_{i,t}$ and $\varepsilon_{i,t}$ represent the errors.

Equation (1) illustrates the Environmental Kuznets Curve (EKC), stating that economic growth induces first an increase in environmental degradation and then, decreases it. We expect that: $\beta_2 < 0$ in order to validate the EKC hypothesis.

Equation (2) illustrates the Renewable Kuznets Curve (RKC), postulating a non-linear link between economic growth and renewable energy consumption, in the form of a U-shaped curve. When $\lambda_1 < 0$ the hypothesis is validated.

The methodology of the present study encompasses the following steps: (1) checking the cross-section dependency of the considered variables in a panel approach; (2) testing the stationarity of variables by using second-generation unit root tests; (3) identifying the existence of cointegration relationship among variables; (4) estimation of equations (1) and (2) by using the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models, and (5) results robustness check, by estimating the equations in two groups of countries.

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

109

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC) Hypotheses: Fresh Evidence from the European Union Countries

4. Main Findings and Discussion

Table 3 depicts the results of the cross-sectional dependence of the considered variables. The value of Prob is under 0.01 for all variables suggesting the rejection of the null hypothesis of no cross-sectional dependence and accepting the alternative, meaning that the cross-section dependence among variables is present.

Table 3. Results of cross-sectional dependence tests

	Breusch-Pagan LM	Pesaran Scaled LM	Bias-corrected Scaled LM	Pesaran CD
lnGDPpc	8297.399*	312.7009*	312.2815*	90.01792*
$(lnGDPpc)^2$	8282.056*	312.1014*	311.6821*	89.89975*
lnRE	4383.07*	159.1706*	158.7513*	53.02999*
lnGHG	6494.336*	241.9813*	241.5619*	78.3006*

Source: Authors' own computation based on EViews 12.0 software; Note: *p < 0.01

Table 4. Stationarity of variables

Variable	CIPS test		PES-CADF	
	CIPS statistic		Z(t-bar)	
	constant	*constant and trend*	*constant*	*constant and trend*
lnGDPpc	0.274	-3.332*	0.369	0.193
ΔlnGDPpc	-4.357*	-4.507*	-7.326*	-6.209*
$(lnGDPpc)^2$	0.336	-3.281*	-3.596*	-2.136**
$\Delta(lnGDPpc)^2$	-4.308*	-4.466*	-7.534*	-7.134*
lnRE	-1.460	-2.420	-1.921*	-2.167
ΔlnRE	-4.857*	-5.323*	-5.520*	-3.976*
lnGHG	-2.901***	-2.641***	-2.031	-2.756**
ΔlnGHG	-4.901*	-5.469*	-4.748*	-5.465*

Source: authors' computation based on Stata 15 software; Note: *p < 0.01; ** p < 0.05; ***p<0.1

As we can notice from Table 4, not all variable series are stationary at their level, but they are integrated at first order I (1), the Kao residual integration test is appropriate to identify the long-run relationship among the variables.

Table 5. Cointegration among variables

Kao Residual Cointegration test

Variables	t-statistic	Prob
lnGDPpc,$(lnGDPpc)^2$, lnGHG	-4.213706	0.0000
lnGDPpc,$(lnGDPpc)^2$, lnRE	-4.0323	0.0000

Source: author's own computation based on EViews 12.0 software

110

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

STUDIA UNIVERSITATIS ECONOMICS SERIES

"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC) Hypotheses: Fresh Evidence from the European Union Countries

The results displayed in Table 5 show that the null hypothesis of no cointegration among the examined variables is rejected (the values of Prob. are under 0.01 in both cases). This indicates that there is a long-run cointegration relationship among the variables.

We have estimated the equations (1) and (2) for the EU panel (26 countries) and, to ensure the robustness of the results we have also estimated them for two groups of countries: Western, developed countries (Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Luxembourg, Netherlands, Ireland, Italy, Portugal, Spain, and Sweeden) and Central and Eastern European countries (Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Slovakia, Slovenia, Poland, Romania).

The results of the estimation of equations (1) and (2) for the EU panel, Western countries, and CEE countries are displayed in Table 6.

Table 6. Estimation of equations (1) and (2)

Panel	Variables	Dependent variable lnGHG (equation 1)		Dependent variable lnRE (equation 2)	
		FMOLS	DOLS	FMOLS	DOLS
		coefficients		coefficients	
EU 26	lnGDPpc	5.4021*	5.0326*	-13.239*	-11.425*
	$(lnGDPpc)^2$	-0.2753*	-0.2554*	0.7196*	0.6264*
WESTERN countries (15)	lnGDPpc	8.9036*	15.0025*	-5.1626*	-26.94*
	$(lnGDPpc)^2$	-0.4336*	-0.7156*	0.3500*	1.3413*
CEE countries (11)	lnGDPpc	4.3536*	0.0342*	-0.3389*	-0.4082*
	$(lnGDPpc)^2$	-0.2236*	-0.0133*	0.0581*	0.0671*

Source: authors' own computation based on EViews 12.0 Software; Note: *p<0.01

We notice in Table 6 that in the estimation of equation (1) the coefficient of $(lnGDPpc)^2$ is negative in all panels (EU and the 2 sub-panels), showing a U-inverted dependence between lnGDPpc and lnGHG (the EKC hypothesis). For equation (2), as we expected, the sign of the coefficient of $(lnGDPpc)^2$ is negative, indicating the U-shaped curve, in other words, the RKC shape. We notice also that all the coefficients are statistically validated for 1% significance.

Our analysis shows that for the whole sample of 26 European Union countries a U-shaped RKC and an Inverted U-shaped EKC are identified, validating the first proposed hypothesis. The turning point of RKC takes place earlier then the threshold of EKC. This result supports Hypothesis 2, meaning that renewable energy consumption is beneficial for the arrival of the EKC turning point and, also for the greenhouse gases reduction. In other words, shifting renewable energy consumption

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

111

STUDIA UNIVERSITATIS ECONOMICS SERIES

"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC)
Hypotheses: Fresh Evidence from the European Union Countries

from a downward trend to an upward trend will accelerate the occurrence of the EKC turning point. This conclusion is in line with those of other relevant studies (Yao et al., 2019; Naqvi et al., 2021; Wang et al., 2023b).
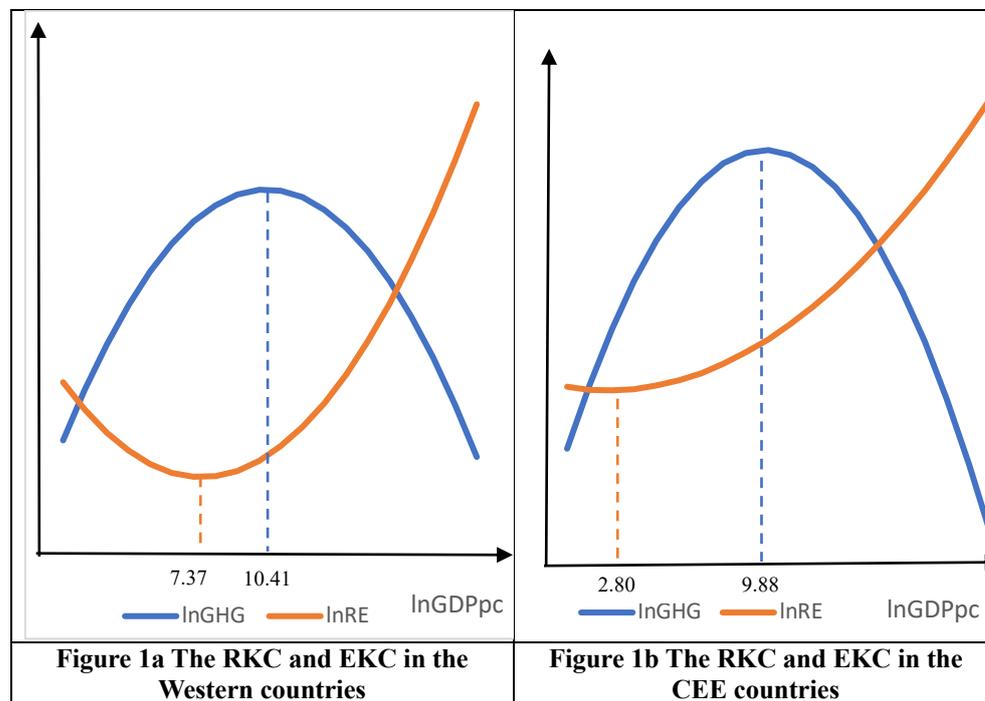

| **Figure 1a The RKC and EKC in the Western countries** | **Figure 1b The RKC and EKC in the CEE countries** |

Source: graphical representation of FMOLS equations

The results are maintained when the estimation is made in the two sub-panels (Western countries and CEE countries) (Table 6). The EKC and RKC hypotheses are also validated. It is important to discuss the differentiated results obtained in the two sub-panels. In CEE countries, the RKC and RKC thresholds are reached ahead of Western developed countries (Figure 1a and Figure 1b), as concluded by Yao et al. (2019) and Wang et al. (2023b). In CEE countries, the distance between the two threshold points is higher than in Western countries. It means that even though CEE countries can register an accelerated increase in renewable energy use, they need more economic growth efforts to reverse the dynamic of pollution. Developing countries should learn to use the advanced pollution reduction and energy-saving technologies and management experience from the developed countries, in order to avoid high pollution in the early stage of economic development.

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiș" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC) Hypotheses: Fresh Evidence from the European Union Countries

5. Conclusions, Policy Implications and Limitations

The study examined the validity of RKC and EKC hypotheses in the case of the European Union, by using the FMOLS and DOLS models, in panel data approach based on a time series covering the period of 1990-2022. The findings show that both hypotheses are validated and, the turning point of the RKC curve occurred before the turning point of the EKC model. This means that reaching the RKC turning point is a prerequisite for the corresponding EKC point. The explanation consists of the fact that increasing the use of renewable energy can promote the optimization of the energy structure so that the EKC achieves the turning point and the pollution decreases as the economic growth evolves. In developing countries (in Central and Eastern Europe), the RKC turning point is reached earlier (at lower levels of GDP per capita), but the distance to GHG emission reduction is longer than in the Western European countries. In these countries, the impact of the development of green technologies on mitigating pollution is more accelerated than in the CEE countries.

As for policy implications, there are two directions to be considered. Developed European Union countries should: improve the technological support for upgrading the industrial structure, strengthen European and international green trade cooperation, promoting the green economy. Developing economies (CEE countries) should design appropriate and effective policies to support the transition to technology-intensive industries, attract green investments from developed countries, expand the provision of financial support and subsidies for the adoption and use of renewable energy technologies, appropriate policy measures for internalizing the environmental costs of the activities that generate them, to give first priority to environmental protection in order to achieve carbon neutrality targets as soon as possible.

There are some limitations of the study. Firstly, we mention the consideration of total renewable energy consumption in the final energy consumption. Further studies can explore the RKC hypothesis for specific types of renewable energy sources (i.e., wind, solar, biomass). Another limitation is that other factors influencing renewable energy consumption are not taken into account, such as technological progress (i.e., R&D expenditures), urbanization, economic complexity, or digital technologies. For example, recent studies (i.e., Wang et al., 2023b), revealed that the digital economy in developing countries can accelerate reaching the EKC turning point of the EKC as soon as possible (i.e., at lower levels of economic development). Future studies can be focused on these research opportunities and add to the existing knowledge and new insights regarding the RKC and EKC. Finally, GHG emissions are considered an indicator of pollution in the study; future research may use ecological footprint to measure environmental depreciation.

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

113

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC) Hypotheses: Fresh Evidence from the European Union Countries

Acknowledgments

Author Contributions

The authors contributed equally to this work.

Disclosure Statement

The authors do not have any competing financial, professional, or personal interests from other parties.

References

1. Abid, L., Kacem, S., Saadoui, H., (2024), Addressing the Environmental Kuznets Curve in the West African countries: exploring the roles of FDI, corruption and renewable energy, Journal of Knowledge Economy, 15, 20491-20515.
2. Alam, F., (2024), Environmental Kuznets Curve and sustainable development in OECD countries: A panel data analysis, European Journal of Development Studies, 4(6), 9-15.
3. Al-Mulali, U., Solarin, S.A., Sheau-Ting, L., Ozturk, I., (2016), Does moving towards renewable energy causes water and land inefficiency? An empirical investigation, Energy Policy, 93, 303-314.
4. Baek, J., (2016), Do nuclear and renewable energy improve the environment? Empirical evidence from the United States, Ecological Indicators, 66, 352-356.
5. Balezentis, T., Streimikiene, D., Zhangh, T., Liobikiene, G., (2019), The role of bioenergy in greenhouse gas emission reduction in EU countries: an Environmental Kuznets Curve modelling, Resources Conservation and Recycling, 142, 225-231.
6. Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., Farhani, S., (2018), How economic growth, renewable electricity and natural resources contribute to CO_2 emissions?, Energy Policy, 113, 356-367.
7. Bekhet, H.A., Othman, N.S., (2018), The role of renewable energy to validate dynamic interaction between CO_2, emissions and GDP towards sustainable development in Malaysia, Energy Economics, 72, 47-61.
8. Bilgili, F., Kocak, E., Bulut, U., (2016), The dynamic impact of renewable energy consumption on CO_2 emissions: A revisited Environmental Kuznets Curve approach, Renewable and Sustainable Energy Reviews, 54, 838–845.
9. Bölük, G., Mert, M., (2014), Fossil and renewable energy consumption, GHGs (greenhouse gases) and economic growth: evidence from a panel of EU (European Union) countries, Energy, 60, 1-8.

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC)
Hypotheses: Fresh Evidence from the European Union Countries

10. Bölük, G., Mert, M., (2015), The Renewable Energy, Growth and Environmental Kuznets Curve in Turkey: an ARDL Approach, Renewable and Sustainable Energy Review, 52, 587–595.

11. Breusch, T., Pagan, A., (1980), The Lagrange Multiplier Test and its Application to Model Specification in Econometrics, Review of Economic Studies, 47(1), 239–253.

12. Chen, Y., Wang, Z., Zhong, Z., (2019), CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China, Renewable Energy, 131, 208-216.

13. Chien, F., (2022), How renewable energy and non-renewable energy affect environmental excellence in N-11 economies?, Renewable Energy, 196, 526–534.

14. Danish, Zhang, B., Wang, B., Wang, Z., (2017), Role of renewable energy and nonrenewable energy consumption on EKC: evidence from Pakistan, Journal of Cleaner Production, 156, 855-864.

15. Destek, M.A., Sinha, A., (2020), Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from Organisation for Economic Cooperation and Development countries, Journal of Cleaner Production, 242, 118537.

16. Dogan, E., Seker, F., (2016), Determinants of CO2 emissions in the European Union: the role of renewable and non-renewable energy, Renewable Energy, 94, 429-439.

17. European Environment Agency (EEA), (2025), Total greenhouse gas emissions per capita (https://www.eea.europa.eu/en/analysis/maps-and-charts/greenhouse-gases-viewer-data-viewers) accessed on 5.01.2025.

18. Gielen, D., Boshell, F., Saygin, D., Bazilian, M.D., Wagner, N.; Gorini, R. (2019), The role of renewable energy in the global energy transformation, Energy Strategy Reviews, 24, 38-50.

19. Grossman, G.M., Krueger A.B., (1991), Environmental Impacts of a North American Free Trade Agreement, Working Paper No. 3914, National Bureau of Economic Research.

20. Grossman, G.M., Krueger, A.B., (1995), Economic growth and the environment, Quarterly Journal of Economics, 110, 353–377.

21. Kao, C., Chiang, M., (2000), On the estimation and inference of a cointegrated regression in panel data, Advances in Econometrics, 15 (1), 109-141.

22. Kuznets, S., (1955), Economic growth and income inequality, American Economic Review, 45, 1–28.

23. Jebli, M.B., Youssef, S.B., (2015), The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia, Renewable and Sustainable Energy Review, 47, 173-185.

24. Koc, S., Bulus, G.C., (2020), Testing validity of the EKC hypothesis in South Korea: the role of renewable energy and trade openness, Environmental Science and Pollution Research, 27(23), 29043-29054.

25. Kostakis, I., Armaos, S., Abeliotis, K., Theodoropoulou, E., (2023), The investigation of EKC within CO2 emissions framework: Empirical evidence from selected cross-correlated countries, Sustainability Analytics and Modeling, 3, 100015.

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

115

STUDIA UNIVERSITATIS ECONOMICS SERIES
"Vasile Goldiş" Western University of Arad

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC) Hypotheses: Fresh Evidence from the European Union Countries

26. Leal, P.I., Marques, A.C., (2020), Rediscovering the EKC hypothesis for the 20 highest CO2 emitters among OECD countries by level of globalization, International Economics, 164, 36-47.

27. Luo, H., Sun, Y., (2024), The impact of energy efficiency on ecological footprint in the presence of EKC: evidence from G20 countries, Energy, 304, 132081.

28. Makarov, I., Alataş, S., (2024), Production-and consumption-based emissions in carbon exporters and importers: A large panel data analysis for the EKC hypothesis, Applied Energy, 363, 123063.

29. Menegaki, A.N., Tsagarakis, K.P., (2015), Rich enough to go renewable, but too early to leave fossil energy?, Renewable and Sustainable Energy Reviews, 41(C), 1465-1477.

30. Moutinho, V., Robaina, M., (2016), Is the share of renewable energy sources determining the CO2 kWh and income relation in electricity generation?, Renewable and Sustainable Energy Reviews, 65, 902-914.

31. Mutașcu, M., (2025), Beyond the EKC: Economic development and environmental degradation in the US, Ecological Economics, 232, 108567.

32. Nabaweesi, J., Kigongo, T.K., Buyinza, F., Adaramola, M.S., Namagembe, S., Nkote, I.N., (2024), Investigating the modern renewable energy-environmental Kuznets curve (REKC) hypothesis for East Africa Community (EAC) countries, Technological Sustainability, 3 (1), 76-95.

33. Naqvi, S.A.A., Shah, S.A.R., Anwar, S., Raza, H., (2021), Renewable energy, economic development, and ecological footprint nexus: fresh evidence of renewable energy environment Kuznets curve (RKC) from income groups, Environmental Science and Pollution Research, 28, 2031-2051.

34. Özbek, S., Naimoglu, M., (2025), The effectiveness of renewable energy technology under the EKC hypothesis and the impact of fossil and nuclear energy investments on the UK's Ecological Footprint, Energy, 322, 135351.

35. Panayoutou, T., (1993), Empirical tests and policy analysis of environmental degradation at different stages of economic development, ILO Working Papers, WEP 2-22/WP.238.

36. Pata, K.U., (2018), Renewable energy consumption, urbanization, financial development, income and CO2, emissions in Turkey: testing EKC hypothesis with structural breaks, Journal of Cleaner Production, 187, 770-779.

37. Pata, U.K., Bulut, U., Balsalobre-Lorente, D., Chovancova, J., (2025), Does income growth affect renewable energy or carbon emissions first? A Fourier-based analysis for renewable and fossil energies, Energy Strategy Reviews, 57, 101615.

38. Pesaran, M.H., Shin, Y., Smith, R.P., (1999), Pooled Mean Group estimation of dynamic heterogeneus panels, Journal of the American Statistical Association, 94 (446), 621-634.

39. Pesaran, M.H., (2004), General Diagnostic Tests for Cross Section Dependence in Panels, Cambridge Working Papers in Economics No. 0435, University of Cambridge, Faculty of Economics: Cambridge, MA, USA. Available online: https://www.repository.cam.ac.uk/handle/1810/446 (Accessed on 3 March 2025).

40. Pesaran, M.H., (2007), A simple panel unit root test in the presence of cross-section dependence, Journal of Applied Econometrics, 22, 265-312.

Neagu, O., Anghelina, A.M., Nicoară, S. (2025)
The Dynamic Interplay between the Renewable Kuznets Curve (RKC) and Environmental Kuznets Curve (EKC)
Hypotheses: Fresh Evidence from the European Union Countries

41. Rahman, H., Voumik, L. Ch., Rahman, M., Majunder, S. Ch., (2024), Scrutinizing the existence of the environmental Kuznets curve in the context of foreign direct investment, trade and renewable energy in Bangladesh: impeding from ARDL method, Environment, Development and Sustainability, 26, 12619-12638.

42. Sarkodie, S.A., Samuel, A., (2018), Renewable energy, nuclear energy, and environmental pollution: accounting for political institutional quality in South Africa, Science of Total Environment, 643, 1590-1601.

43. Shafik N., Bandyopadyay S., (1992), Economic Growth and Environmental Quality: Timeserves and Cross-Country Evidence, Background Paper for World Development Report, World Bank.

44. Simionescu, M., (2021), Revised environmental Kuznets Curve in CEE countries. Evidence from a panel threshold models for economic sector, Environmental Science and Pollution Research, 28, 60881-60899.

45. Sinha, A., Shahbaz, M., (2018), Estimation of environmental Kuznets curve for CO2 emission: role of renewable energy generation in India, Renewable Energy, 119, 703-711.

46. Sugiawan, Y., Managi, S., (2016), The environmental Kuznets curve in Indonesia: exploring the potential of renewable energy, Energy Policy, 98, 187-198.

47. Wang, Q., Zhang, F., Li, R., (2023a), Revisiting the Environmental Kuznets Curve hypothesis in 208 countries: The roles of trade openness, human capital, renewable energy and natural resource rent, Environmental Research, 216, 114637.

48. Wang, Q., li, C., Li, R., (2023b), Could digital economy increase renewable energy and reduce carbon emissions? Empirical evidence on EKC in 67 countries, Environmental Science and Pollution Research, 30, 77150-77164.

49. Yilanci, V., Gorus, M.S., Andreoni, V., (2023), Reinvestigating of the validity of EKC hypothesis extend with energy: A time-varying analysis for the United Kingdom, Journal of Cleaner Production, 428, 139284.

50. World Bank, (2025a), World Development Indicators. GDP per capita (NY.GDP.PCAP. PP. KD). (https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD?view=chart) accessed 11.01.2025.

51. World Bank, (2025b), World Development Indicators. Renewable energy consumption (EG.FEC.RNEW.ZS)

52. (https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS?view=chart) accessed 11.01.2025.

53. Yao, S., Zhang, S., Zhang, X., (2019), Renewable energy, carbon emissions and economic growth: A revised environmental Kuznets curve perspective, Journal of Cleaner Production, 235, 1338-1352.

54. Zambrano-Monserrate, M.A., Silva-Zambrano, C.A., Davalos-Penafiel, J.L., Zambrano-Mosenrrate, A., Ruano, M.A., (2018), Testing environmental Kuznets curve hypothesis in Peru: the role of renewable electricity, petroleum, and dry natural gas, Renewable and Sustainable Energy Reviews, 82, 4170-4178.

Studia Universitatis "Vasile Goldis" Arad. Economics Series Vol 35 Issue 4/2025
ISSN: 1584-2339; (online) ISSN: 2285 – 3065
Web: publicatii.uvvg.ro/index.php/studiaeconomia. Pages 104-117

117