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Economic Growth in the European Union: The Importance of Renewable Energy Consumption

Keywords: impact of RES; GDP; regression analysis; RES in the European Union

JEL: O13; P48; Q20

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Abstract

Theoretical background: The studies on the links between renewable energy consumption and economic growth are of great interest. A search of the literature on the subject reveals a diversity of studies in many respects, including but not limited to the search for a unidirectional or reciprocal relationship. The results of the studies often vary depending on the research method used and the period of analysis, which determines subsequent attempts to understand the issue.

Purpose of the article: The aim of this article is to determine the relationship between the consumption of renewable energy sources and economic growth in European Union member states between 2004 and 2020.

Research methods: The study was based on the data from the Eurostat database for the period 2004–2020. The study made use of data normalization using the min-max method. The linear regression method was used to assess the relationship between GDP per capita and the electricity indicators available for final consumption and renewable energy sources.

Main findings: The study did not find a significant trend between renewable energy consumption and economic growth. However, this fact cannot be taken as establishing the absence of a relationship between the two indicators. Although no strong correlation was observed, some interactions are visible depending on the EU member state, which entitles us to partially confirm the research hypothesis. The differences between the groups of EU-15 and EU-10 countries are not distinct, and extending the set of monitored variables (i.e. carrying out modelling for EU-27 countries) does not have a significant impact on the results of the study, which are similar.

Introduction

The exhaustibility of conventional energy sources and their destructive impact on environmental well-being are the main reasons for the transition to clean energy technologies. The energy dependence of many economies on fossil fuel imports and the threatened security of supply provide another important reason for the search for an alternative way to meet energy needs, which appears to be renewable energy sources. These factors are at the heart of the global discussion on the energy transition towards the implementation of clean and accessible energy to counteract negative climate change. The negative environmental impact of burning fossil fuels through the emission of harmful greenhouse gases can be reduced through the use of renewable energy sources such as hydropower, wind energy, solar energy, geothermal energy and biomass, for example. Improvements in energy efficiency resulting from the implementation of renewable energy sources are not only positively reflected in terms of positive environmental impact, but also form the basis for sustainable economic growth. However, opportunities and interest in the use of renewable energy sources vary between economies. This is due to a number of factors, including geographical location, natural resources and the specifics of energy policy. The growing popularity of renewable energy on a global scale gives hope not only for the trend to continue, but also for a complete shift away from fossil fuels in the future.

The European Union has a rich tradition of promoting and developing renewable energy which manifests itself through a range of activities, including: coordinating projects aimed at tackling adverse climate change, creating incentives for the transition to a low-carbon economy and stimulating economic growth (Soava et al., 2018). The ori-

entation of the European Union's energy policy towards the development of renewable energy sources is a result of its transformation, which now emphasizes environmental and social aspects in addition to the originally considered security of supply of energy resources (Adamczewska & Zajączkowska, 2022). The European Union significantly influences the energy policies of the member states in many of its areas with a particular focus on renewable energy sources. This influence is reflected in the development strategies, objectives and priorities, as well as the existing legislation in the individual member states, which correspond with the EU guidelines (Tanil & Jurek, 2019).

According to the EU Renewable Energy Directive (Directive (EU) 2018/2001), established in 2018, the aim is to achieve their share in final energy consumption of 32% by 2030 (The European Parliament and the Council of the European Union, 2018). Among the European Union Member States that have already reached the mentioned target in 2021 are Sweden, Finland, Latvia, Estonia, Austria, Denmark and Portugal, with Croatia narrowly missing the target (Eurostat, 2023) (Figure 1). Nevertheless, this target may soon be modified to 42.5%, with a view to achieving 45%, due to the preliminary agreement obtained by the European Parliament and the European Council in the area mentioned (The European Commission, 2023).

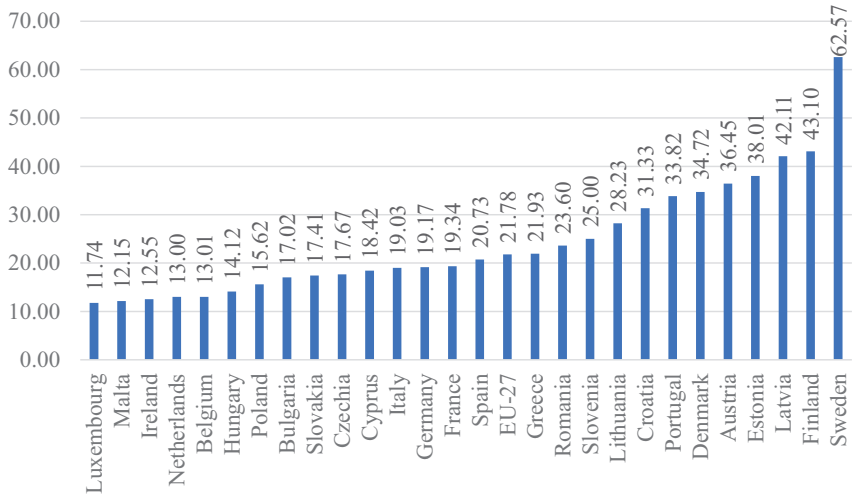

Figure 1. Share of renewable in gross final energy consumption in the European Union countries (%) in 2021

Source: (Eurostat, 2023).

The economic transformation of developed countries from an intensive agricultural to an intensive industrial structure determines the increasing importance of energy in the economic growth process. It is accompanied by environmental pollution, global warming and climate change, which prompts particular attention to the importance and type of energy in the economic growth process (Uçan et al., 2014). Economic growth and development are significantly determined by the evolution of final energy

consumption, and a dynamic causal relationship is observed between energy in general and economic growth (Wada, 2017). The development of renewable energy, together with improvements in energy efficiency, provide a remedy to the mentioned environmental and climate changes, while also stimulating economic growth. This is due to the very nature of renewable energy, which becomes the foundation for both development and social well-being, as well as a future sustainable economy (Saad & Taleb, 2017). The production and consumption of renewable energy also has a positive impact on the development of new technologies, which is reflected in new opportunities for investors and the economy as a whole. Furthermore, the production and consumption of renewable energy determines the existence of a multiplier effect both in the energy sector itself, as well as for any projects related to the sector (Can & Korkmaz, 2019).

An understanding of the mentioned interdependencies is particularly important in terms of the creation and implementation of environmental and energy policies (Ocal & Aslan, 2013), which should be appropriately adapted to the operating conditions of individual economies. For many European economies that rely heavily on energy consumption, a compromise can be made in favor of increasing energy efficiency and reducing emissions while supporting economic activity. In contrast, such a compromise will not exist for economies where it is not possible to decouple economic growth from energy consumption and reforms to move away from traditional fuels to renewable energy sources should be less impactful on economic actors (Marinaș et al., 2018).

A search of the literature covering studies of the relationship between energy and economic growth indicates that it can be represented by 4 hypotheses (Al-mulali et al., 2013; Omri et al., 2015). The growth hypothesis indicates that the relationship is unidirectional and that an increase in energy consumption positively affects economic growth. The behavioral hypothesis states that there is a unidirectional relationship between economic growth and energy consumption. In such a situation, a reduction in energy consumption will have little or no impact on economic growth. The behavioral hypothesis postulates that an increase in real GDP implies an increase in energy consumption. The feedback hypothesis indicates a bidirectional relationship between energy and economic growth. In this case, it is hypothesized that a reduction in energy consumption will adversely affect economic growth, while a decrease in economic growth will negatively affect energy consumption. The neutrality hypothesis postulates that energy consumption has little or no effect on the economic growth process and *vice versa* (Apergis & Payne, 2012; Ocal & Aslan, 2013; Uçan et al., 2014).

The aim of the article is to determine the relationship between the consumption of renewable energy sources and economic growth in the European Union member states between 2004 and 2020. The study's contribution to the literature is due to two issues. Firstly, an analysis of the known relationship for the new time frame was undertaken. Secondly, the phenomenon was examined for three selected areas: the EU-15, the EU-10 and the EU-27, which, to the best of our knowledge, have not been studied together in previous work. The results of our study can provide guidance to national

policy makers on the impact of renewable consumption on economic growth, which can support the design and implementation of appropriate energy policy measures.

The research carried out is presented in the article in several sections. The introductory section synthesizes the essence of renewable energy sources, the European Union's energy policy in their area and identifies their possible significance for growth and economic development. The next section provides an overview of the research, edited on the basis of a literature search. The next chapter contains a description of the research methods. The subsequent chapter covers the results of our own research. Their juxtaposition with the results of the research cited in the earlier part of the paper provides the foundation for the discussion contained in the penultimate section of the paper. The conclusions at the end of the paper include, among other things, implications for economic policy and directions for future research.

Literature review

The rate of economic growth in any economy fluctuates over time. Economic growth can be rapid in some periods, slow in others and sometimes even decrease (Mankiw & Taylor, 2016). One of the most commonly cited theories of economic growth in the literature is the neoclassical model developed by Solow (1956, 1957). However, this model does not account for resources and the sole cause of continuous economic growth is exogenous technological progress (Stern, 2000). The accumulation of abstract labor and abstract capital that are supported by technological progress are the only variables in the Solow model, as well as in other variants of the model (Kasperowicz et al., 2020). Marinaș et al. (2018) point out that the emergence of oil shocks in the 1980s sparked researchers' interest in incorporating energy into the production function along with traditional factors of labor and capital as exemplified by studies (Tintner et al., 1977; Berndt & Wood, 1979). Interesting research in this area was also carried out by Jorgenson (1981, 1984), who attempted to develop a production function based on four factors – capital, labor, energy and materials. In contrast, a production function involving only three factors (including endogenous energy) has been estimated in the work of (Hannon & Joyce, 1981), among others.

The studies on the relationship between renewable energy consumption and economic growth are highly popular. A literature search reveals a diversity of research in several aspects, among which are: looking for a unidirectional or bidirectional relationship, using different econometric methods, using different indicators of renewable energy consumption, introducing additional variables into models or conducting analyses for different time periods (Table 1).

The studies covering the territorial scope of all European Union member states have been presented in a number of works. The study (Menegaki, 2011) covering the 27 member states of the European Union between 1997 and 2007 attempted to establish a causal relationship between economic growth and renewable energy by

enriching the study with additional exogenous variables (final energy consumption, greenhouse gas emissions and employment). It proved that there was no relationship between renewable energy consumption and economic growth. On the other hand, the study (Camacho Ballesta et al., 2022) proved a negative impact of economic growth on renewable energy consumption in 28 European Union member states between 2001 and 2015. In contrast, a study (Soava et al., 2018) conducted for 28 European Union member states between 1995 and 2015 proved a positive impact of renewable energy consumption on economic growth.

Table 1. Overview of studies on the relationship between renewable energy sources and economic growth

Author/s	Publication year	Years of research	Number of EU countries	Methodology
Menegaki	2011	1997–2007	27 EU countries	Panel VEC
Uçan et al.	2014	1990–2011	15 EU countries	Panel cointegration
Alper and Oguz	2016	1990–2009	8 EU countries	Asymetric causality
Saad and Taleb	2018	1990–2014	12 EU countries	Panel VEC
Soava et al.	2018	1995–2015	28 EU countries	Cointegration
Marinaş et al.	2018	1990–2014	10 EU members from Central Eastern Europe	PMG estimator for error correction models
Busu	2020	2004–2017	28 European countries	Autoregressive Distributed Lag Models
Kasperowicz et al.	2020	1995–2016	29 European countries	Panel VEC
Li and Leung	2021	1985–2018	7 EU countries	Panel tests (unit root, cointegration)
Camacho Ballesta et al.	2022	2001–2015	28 EU countries	Feasible Generalized Least Square (FGLS)

Source: Authors' own study based on the literature review.

The proven relationship was characterized by unidirectionality or bidirectionality for each country included in the study. Busu (2020) constructed an explanatory model of sustainable economic growth in the 28 European Union member states from 2004 to 2017 based on a number of renewable energy variables. The results show a stimulating effect of wind, solar, hydro, geothermal and biomass energy production on economic growth with a particular focus on the latter. In contrast, Kasperowicz et al. (2020), studying 29 European countries between 1995 and 2016, found a bidirectional relationship between renewable energy consumption and economic growth in the long term.

The studies on a selected group of the European Union member states are also popular in the literature. Uçan et al. (2014) investigating a group of 15 countries belonging to the European Union prior to its enlargement in 2004 proved that increased consumption of renewable energy supported economic growth between 1990 and 2011, while a study (Alper & Oguz, 2016) was conducted on a sample of 8 countries (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Poland, Romania and Slovenia). The results of the study covering the period 1990–2009 signal a positive impact of renewable energy consumption on economic growth, although the relationship was proven to be statistically significant only for Bulgaria, Estonia, Poland and Slovenia. Saad and Taleb (2017) conducted an analysis of the relationship between renewable energy consumption and economic growth on a sample of

12 European Union member states (Austria, Denmark, Finland, France, Germany, Italy, Netherlands, Poland, Portugal, Romania, Spain and Sweden), the selection of which was dictated by the availability of empirical data between 1990 and 2014. The results indicate a stimulating role for economic growth in terms of renewable energy consumption in the short term. In the long term, on the other hand, a bidirectional causal relationship between the analyzed variables was observed. On the contrary, Marinas et al. (2018) conducted a study of 10 European Union member states from Central and Eastern Europe (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia) adopting the years of analysis 1990–2014. The researchers proved the positive importance of renewable energy consumption for economic growth in Hungary, Lithuania and Slovenia in the short term. Nevertheless, in the long term, they established a bidirectional relationship between the above-mentioned variables considering the whole analyzed group of countries and individually for seven countries (excluding the Czech Republic, Romania and Hungary). In a study (Li & Leung, 2021) covering seven EU member states (Spain, the Netherlands, Germany, Poland, Turkey, the United Kingdom, Italy) between 1985 and 2018, an explanatory model of renewable energy consumption was constructed based on several selected variables. Among other things, it proved the positive role of economic growth in terms of its impact on renewable energy consumption in the long term. The inverse relationship, i.e. the impact of renewable energy consumption on economic growth in the long term, was not confirmed.

Research methods

Gross domestic product at market prices (Euro per capita) and renewable energy sources (Percentage) from the Eurostat databases were used for the study, corresponding to the results for 27 countries, namely: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden (EU-15 countries), Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia (EU-10 countries), Bulgaria, Croatia and Romania for the period 2004–2020.

The normalized, within-country results used in the linear regression modelling were used for the study. Normalization was done using the min-max method, i.e.:

$$f(x) = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{1}$$

where x denotes the observations of a given year in the selected country. This method is commonly used to prepare data for further analysis in the field of economics.

A linear regression method was used to assess the relationship between the value of GDP per capita and the renewable energy sources indicator (Percentage), the form of which was taken as:

$$y = \beta x_t + \varepsilon_t \tag{2}$$

where y denotes the normalized value of GDP per capita, ε_t are the error terms, and x_t denotes the normalized value of the index of renewable energy sources (Percentage).

The study adopts the research hypothesis that increasing renewable energy consumption has a positive impact on economic growth.

Results

Figure 2 shows 2 graphs shaping the values of individual (included in the survey) indicators. On the one hand, they indicate the strong diversity of the surveyed set: there are high discrepancies between minimum and maximum values between countries for all indicators. On the other hand, the countries leading in individual measures (e.g. Luxembourg and Ireland (GDP per capita), or Sweden (renewable energy sources) are not at the forefront of the other measures, seemingly indicating a non-existence of relationships between the surveyed variables.

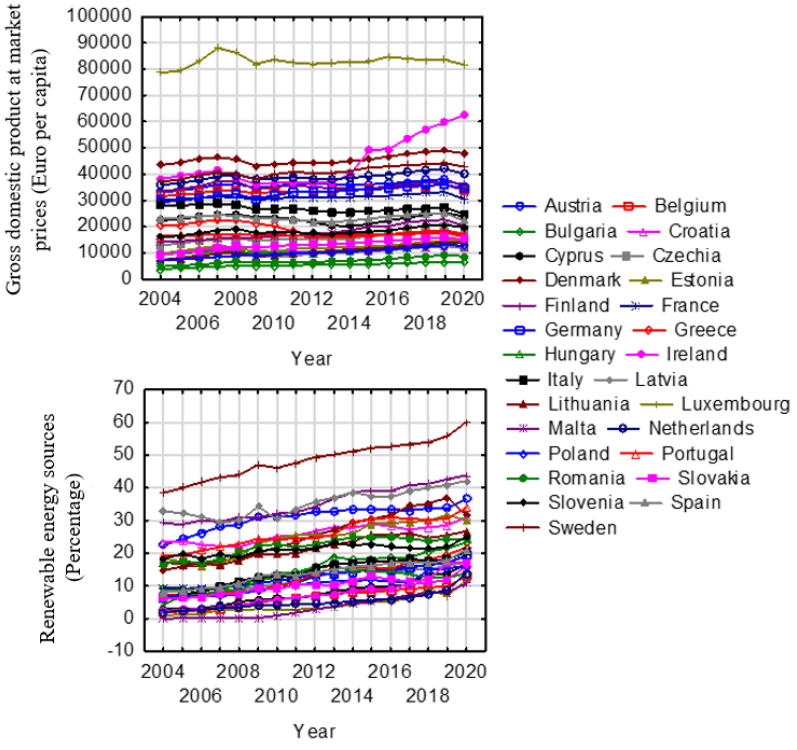

Figure 2. Development of indicators values: GDP per capita, renewable energy sources (Percentage)

Source: Authors' own study based on (Eurostat, 2022a).

In the following part of the study, a process of normalization of the data was carried out according to the previously presented formula, and an attempt was made to build appropriate models in order to determine the relationship in terms of individual countries. A measure of the quality of the fit of the models was tested with the coefficient of determination R^2.

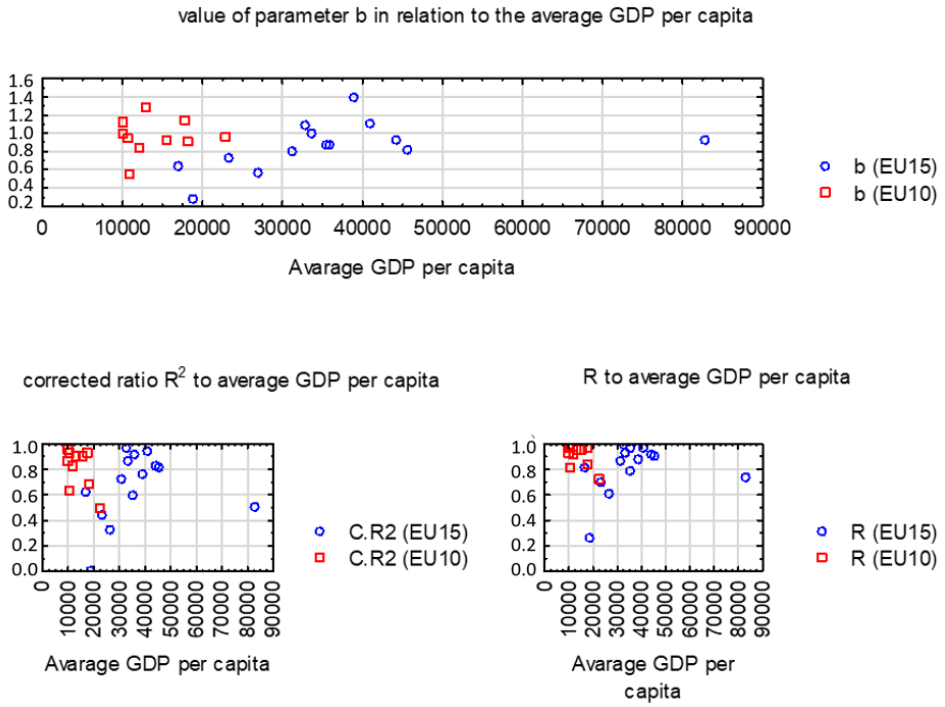

Figure 3. Models results for renewable energy sources (Percentage) impact (groups EU-15, EU-10)

Source: Authors' own study based on (Eurostat, 2022b).

The variation between the EU-15 and EU-10 sets of countries in the relationship between GDP per capita and renewable energy sources (Percentage) is not significant. In the EU-10 group of countries, three cases with lower levels of model fit can be identified (i.e. Cyprus (0.49), Hungary (0.63), Slovenia (0.68), while in the EU-15 group of countries, the dispersion of results is also at different levels. It can be observed that the strength of the relationship as measured by parameter b of the model did not show a significant trend in the value of GDP per capita. It can be assumed that a particular clustering of results is evident for the EU-10 countries. This means that the unit growth of renewables is more associated with an increase in GDP per capita in those countries with a lower baseline. For the EU-15 countries, low values were obtained for Greece, whose strength of relationship was only 0.27 with a low value of the level of fit (R2) of only 0.01. In the case of this group of countries,

Luxembourg is also noteworthy, as its GDP per capita diverges significantly from the other EU Member States, which can be seen in particular in Figure 3. The degree of the relationship, defined by the parameter b for this country, can also be considered significant, as it amounted to 0.92. Moreover, in the case of Poland, the results of the relationship between the indicators in question were satisfactory, with the parameter b amounting to 1.11 and a high level of fit (R2) of 0.95.

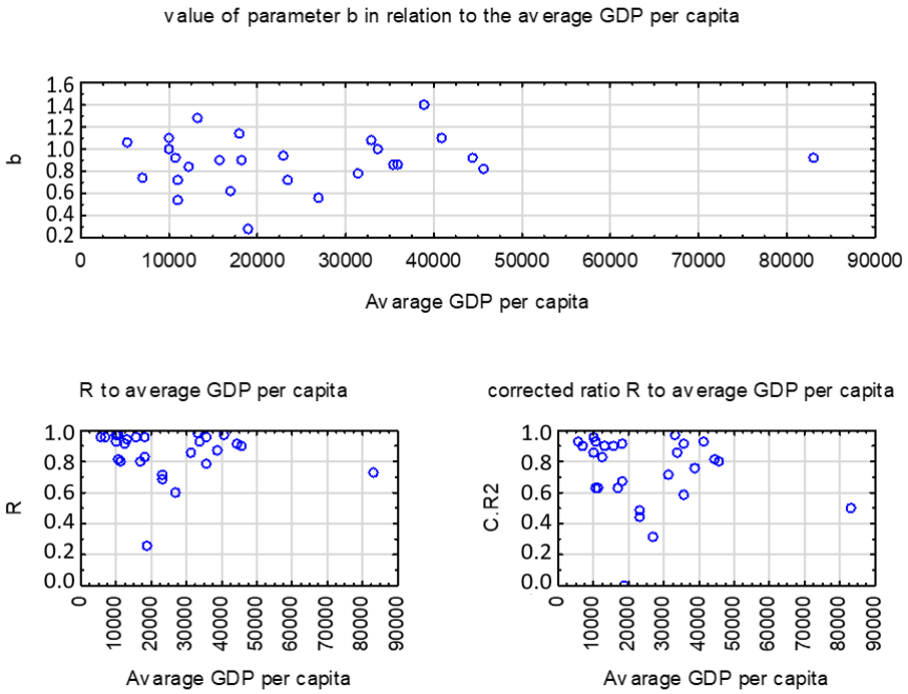

Figure 4. Models results for renewable energy sources (Percentage) impact (groups EU-27)

Source: Authors' own study based on (Eurostat, 2022b).

Expanding the set of observed variables (i.e. carrying out modelling for the EU-27) does not significantly affect the results of the study. Similar to the results presented earlier, Figure 4 shows that the relationship between GDP per capita and the renewable energy sources indicator (Percentage) is present for selected countries, but does not show a relationship between the strength of this relationship and the value of the GDP per capita indicator. For the 3 non-EU-10 and EU-15 countries, relatively high values of the b parameter were obtained (Bulgaria: 1.06, Croatia: 0.73 and Romania: 0.73). Assuming that the values of the coefficient of determination (R2) cannot be less than 0.9 in order to accept the results of the model as satisfactory (Aczel & Sounderpandian, 2018), in this study only 10 countries from the entire EU meet the specified threshold: Bulgaria (0.93), Czechia (0.90), Lithuania (0.93), Malta

(0.92), Poland (0.95), Romania (0.90), Slovakia (0.90), Austria (0.91), Germany (0.97) and Sweden (0.94). It should be noted that the strength of the relationship measured by the parameter *b* for these countries was above 1.0. The exceptions are 4 countries: Lithuania (0.93), Czechia (0.91), Austria (0.87) and Romania (0.73).

Discussions

When reviewing the literature on the topic presented, one encounters many statements depicting that GDP per capita often co-occurs with aspects of societal development or industrialization (Elfaki et al., 2021). Countries basing their economy on industrial aspects, infrastructure or technology require more energy to function. This article examines the empirical relationship between GDP per capita and the indicator of renewable energy sources. The study did not obtain a significant trend between the two indicators. The failure to obtain a significant trend cannot be taken as establishing the absence of a relationship between the two indicators. Although no strong relationship was observed, some interactions are evident depending on the European Union Member State. This confirms the results of a study by Menegaki, among others, where no causal relationship between the two indicators was obtained (Menegaki, 2011). The results of the research analysis indicate that most EU member states do not show a direct relationship between the share of renewable energy sources (RES) and gross domestic product. These results are in line with a study conducted by another team of researchers (Szustak et al., 2022). In the case of the results of the study by other researchers, checking the relationship of the mentioned indicators on a sample of 8 EU countries, a positive impact of the two indicators was found, but confirmation in statistical significance was only obtained for half of the countries (Alper & Oguz, 2016). Busu's research indicated a stimulating effect of renewable energy production on the economic growth in the EU countries, which was noted for countries from the EU-10 (Busu, 2020). The similar findings are presented by Burke, who suggests that economic growth will continue to put upward pressure on energy consumption, particularly in the transport, industrial and service sectors (Burke, 2016). His research focused on overall energy consumption not necessarily generated from RES. Undoubtedly, in some countries the relationship between the analyzed indicators was more distinct. Nevertheless, compared to the other countries studied, where this relationship was not very apparent, it can be concluded that the collinearity or causality is coincidental or random. The analyses presented above and the reference to the world literature do not make it possible to conclude unequivocally that there is a relationship between GDP per capita and the RES indicator. It should also be borne in mind that the use of the same variables for different research periods may result in contradictory results (Karanfil, 2009).

In the case of the European Union Member States, most of which are considered developed, the lack of the impact of renewable energy consumption on GDP indicates that measures aimed at increasing its use will not increase economic growth.

In developing countries, on the other hand, observations may be different due to the fact that the development of renewable energy can be a tool to improve energy availability which should translate into increased production capacity. Moreover, there is a possibility that the development of renewable energy may not translate significantly into increased economic growth, which may simply be due to the substitutability between conventional and non-conventional energy sources (Li & Leung, 2021).

In contrast, in the case of developing countries, the negative impact of renewable energy consumption on economic growth can be explained by inadequate energy policies in the area of RES that do not fully exploit their potential. Despite the undoubtedly beneficial impact of renewable energy development on environmental well-being and energy availability, one has to bear in mind the need for significant investment costs in this area (Ocal & Aslan, 2013). The success of the energy transition towards renewables may in the short term depend on a number of factors and require economic actors to, *inter alia*, incur significant investment costs, meet stringent regulatory requirements or have to pay higher prices for renewable energy, which may be reflected in a weakening of economic activity. Moreover, the targeting of public funds for investment in RES and the development of demand and supply in this market may have a crowding-out effect on productive investments in the economy. The result of these potential events could have an adverse impact on economic growth (Marinaș et al., 2018).

Each year there is a noticeable increase in the share of renewable energy sources in the EU member states. This is due, among other things, to the adopted EU targets for increasing the share of "green energy" in the energy mix of all member states. The current EU directive sets as a binding target at least a 32% RES share by 2030 (for the EU as a whole) (Directive (EU) 2018/2001). The aspect of forecasting the RES share has been addressed by a number of researchers (Firlej & Stanuch, 2023; Brodny et al., 2020), where different directions of development of this sector have been pointed out. If we assume that RES have a positive impact on economic growth and further dynamic growth of the "green energy" sector is visible (based on forecasts), then the European Union has the opportunity to create a sustainable energy economy, which is particularly important in times of energy crisis. Aiming to increase the share of RES can not only help to combat the problems associated with the depletion of fossil fuel reserves, but also strengthen the energy independence of the countries belonging to the European Union. A consistent investment in the development of "green energy" is a step towards a more sustainable energy future, particularly with regard to its generation.

Conclusions

The development of REs is an integral part of the energy policy of the European Union, which includes this issue in its development strategies. The popularity of renewable energy is due to a number of aspects – including the non-renewability of traditional fossil fuels, less negative impact on environmental well-being than

conventional fuels, a positive impact on improving energy efficiency and reduced dependence on foreign fuel imports.

The aim of the article was to determine the relationship between the consumption of renewable energy sources and the economic growth in the European Union member states between 2004 and 2020. The study found no significant trend between the two indicators. However, this fact cannot be taken as establishing the absence of a relationship between the two indicators. Although no strong relationship was observed, some interactions are evident depending on the EU member state, which entitles us to partially confirm the research hypothesis. The differences between the groups of EU-15 and EU-10 countries are not distinct and extending the set of monitored variables (i.e. modelling for EU-27 countries) does not have a significant impact on the results of the study. The results of the study are similar.

Based on the results of the study, recommendations can be made for the economic policy. Due to the ambiguity of the results for all member states, it should be noted that national policies for the development of RES should be designed taking into account a number of economic, social and environmental factors. The identification of these determinants enables the implementation of effective instruments to support the development of RES. Depending on the identified determinants of the development of individual economies, these may include, for example, intensification of cooperation on renewable energy with neighboring countries, expansion of infrastructure for RES, creation of financial and non-financial incentives for private entities, promotion in the mass media.

The limitations of our research are due to several aspects. Firstly, the results of the study relate to the selected countries and the study period adopted. Secondly, the study used one exogenous variable and one exogenous variable. Any limitations were due to the availability of the data for the longest possible period for the countries selected for analysis. A continuation of the study within the framework of the issue undertaken could take into account a larger number of variables and a wider period of analysis.

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