The relationship between economic performance and energy consumption at EU level

Andrei Teofil POSTOLACHI*

Abstract

Starting from the premise that an increase in the use of energy determines a corresponding economic growth, this article aims to determine if at the community level of the European Union there is a causality between energy consumption and economic performance. Thus, using the multiple regression analysis, we sought to determine if, at the level of all 28 member states of the EU, the economic performance, measured through GDP, can be explained by the simultaneous variation in the consumption of the 5 types of primary energy: solid fuels, electricity, natural gas, oil and renewable energy. The results, of particular importance in the development of measures through the European energy policy, show a significant impact of the use of electricity, oil and renewable energy on the European GDP, while the influence of coal and natural gas consumption has a low intensity.

Keywords: EU energy policy, economic performance, energy consumption, solid fuels, oil, natural gas, electricity, renewable energy

Introduction

In the economic sciences, researchers are always looking for answers to questions that arise from the desire to understand, as comprehensively as possible, the phenomena that occur both at the level of individuals, at the microeconomic level, and the determinants of macroeconomic manifestations. This approach, therefore, seeks to identify a possible causal link between the macroeconomic development of the European Union (EU) over the last 25 years, which we will quantify using the aggregate indicator Gross Domestic Product (GDP), and the usage of various energy products (solid fuels, oil, natural gas, renewable energy).

Given the emphasis in European energy policy on reducing the use of polluting fossil fuels and replacing them with renewable sources, establishing a meaningful link between energy consumption and economic growth becomes essential in developing and implementing strategies and guidelines by the European authorities, at least in the short and medium term. To underpin any debate on energy

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policy it is essential to understand that there is a strong correlation between economic growth and energy consumption. This link is recognised and validated in studies by Kraft and Kraft (1978), Masih A. and Masih (1996), Glasure and Lee (1997), Asafu-Adjaye (2000), Stern (1993 and 2000), Soytas and Sari (2003), Jumbe (2004), Lee C. (2005).

Measuring and testing the links between the two indicators has been the subject of numerous other studies, with the literature providing various attempts by researchers to capture possible connections that can be made between macroeconomic outcomes and the energy required to achieve them (Ozturk, 2010). However, most of the analyses consider countries, groups of countries or regions outside Europe (the United States, South-East Asian countries, Turkey, North-African countries, and others). Soava et al. (2018) is one of the recent research study that analysed at data from all 28 EU member countries and, although he reached results that statistically assessed a low impact, the study confirms the link between GDP and renewable energy consumption. At the same time, Nasreen and Anwaar (2014) conducted a similar analysis for 15 Asian countries, and the empirical results confirmed a co-integration of the variables, with a significant dependence between energy consumption and economic growth at the level of the countries analysed.

The context of the analysis is characterised by the current situation at Community level, where the effects of the measures taken during the Covid19 pandemic and the complex consequences of the war in Ukraine are strongly affecting the EU's economic performance. In these circumstances, the study aims to identify whether and to what extent the energy consumption influences economic growth process, since energy is a key element in the dynamics of any type of economic activity and one of the significant inputs. For this purpose, this analysis considers two major variables, GDP and energy consumption, the last being divided into five primary category of energy resources: solid fuels (coal), oil, natural gas, electricity, and renewable energy. Therefore, this paper proposes to study whether the consumption of these five types of energy influence the economic performance of the EU as a whole, using data from 1995 to 2021.

1. Literature overview

In the previous research efforts reviewed, numerous studies examine the potential links between energy and economic growth. Stern (2004) considers that the choice to study this connection, and moreover choosing between theories regarding the determinants of economic growth among energetic resources must be based on both scientific opinions as well as empirical evidence.

The pioneers of the energy consumption - economic growth relationship are the researchers Kraft and Kraft (1978). In their view, their results provide evidence in support of unidirectional causality between economic growth (analysed through the Gross National Product indicator) and energy consumption in the case of the United States between 1947 and 1974. However, Akarca and Long (1980) failed to obtain a causal relationship between energy consumption and economic growth, given the shorter period of analysis. They argued that the results of the study by Kraft J. and Kraft A. are unstable in terms of temporality. On the other hand, using the Granger causality test, Abosedra and Baghestani (1991) confirmed the causal relationship between the American GNP and energy consumption for the period 1947 to 1987.

Over time, numerous researchers have continued to contradict or confirm the results of the Kraft and Kraft study. Yu and Jin (1992) tested the co-integration between energy consumption, economic growth and unemployment. They found that there was no well-determined relationship between these variables. However, the authors conclude by stating that the lack of a long-run equilibrium relationship between energy consumption and economic growth does not reject the hypothesis that there is no causal relationship between these variables.

There are studies in the literature that find a unidirectional causality between energy consumption and economic growth, including Glasure and Lee (1997) and Bowden and Payne (2009). On the other hand, there are studies that illustrate the existence of a unidirectional causal relationship between economic growth and energy consumption (Yu and Choi, 1985; Soyta and Sari, 2003) or studies that find causality running in both directions (Yang, 2000; Glasure 2002). In other words, Oztuk (2010) identifies four scenarios from this point of view, which he divides into four distinct working hypotheses. The first is the neutrality hypothesis, which assumes that there is no correlation between GDP/GNP and energy consumption. Feedback hypothesis is the second, which confirms a two-way causality; economic growth and energy consumption are mutually determined and influenced at the same time. On the other hand, the other two hypotheses indicate a unidirectional influence. The conservation hypothesis assumes that improved economic performance will lead to an increase in energy consumption, thus leaving the possibility for policy-makers to implement measures to reduce energy consumption without significantly affecting future economic performance. Finally, the growth hypothesis considers energy as complementary to labour and capital and as a significant contributor to economic growth. The growth hypothesis stresses that any policy decision leading to lower energy consumption will determine a deterioration in overall economic performance. For these considerations, this paper takes into account the growth hypothesis.

Regarding the neutrality hypothesis, which indicates the absence of a significant link between the variables, several analyses and papers have led to its confirmation (Akarca and Long, 1980; Yu and Hwang, 1984). Fatai et al. (2002) applied several statistical tests (Granger causality, ARDL - autoregressive distributed lag, Toda and Yamamoto test) in the case of the New Zealand economy. At the same time, Altinay and Karagol (2004) used Granger causality, while Soytas and Sari (2009) applied Toda-Yamamoto causality test for Turkey. All these papers obtain results infirming a significant influence of energy consumption on economic performance.

Mutual dependence has however been established for some countries in relatively recent analyses. For Taiwan, Hwang and Gum (1991) using co-integration and error correction models and later Glasure (2002) adding the variance decomposition of the two models in the case of South Korea confirm the feedback hypothesis. Ghali and El-Sakka (2004) for Canada, Paul and Bhattacharya (2004) for India, Erdal et al. (2008) for Turkey or Belloumi (2009) for Tunisia (in the long run), through application of co-integration and Granger causality methods confirm that an economic growth or decrease implies an increase or decrease in energy consumption. At the same time, a change in the structure of consumption in the energy sector determined proportional changes in the same direction of macroeconomic performance.

Unidirectional dependence scenarios assume that the two variables influence each other in one direction, while the mutual dependence relationship is not valid at the same time. Thus, Aqeel and Butt (2001) testing data for Pakistan, Ang (2008) for Malaysia, Karanfil (2008) for Turkey, Zhang and Cheng (2009) for China, used different methods of statistical analysis (the Granger causality test or Johansen co-integration test). The results led to the approval of the conservation hypothesis for the analysed countries, a fact that enables policy-makers to implement energy policies that can constrain energy consumption, without it subsequently affecting economic outcomes.

The dependence relationship from energy consumption to economic performance is one of the most tested hypotheses in the literature. This is validated by a multitude of studies, applied for vast periods, for an increased number of states and which assumed a diversity of applied statistical methods. Stern (1993) analysed data from the period 1947-1990 in the United States, applying multivariate VAR (vector autoregressive) model, and later (Stern, 2000) obtained the same dependence relationship within the American economy using Co-integration and Granger causality tests. Later, Bowden and Payne (2009) confirmed these results by applying the Toda-Yamamoto causality test to data for the United States from 1949 to 2006. Using the same methods, authors found similar results for Asian countries, such as South Korea (Oh and Lee, 2004), Taiwan (Lee and Chang, 2005) and Indonesia (Sriyana, 2019). In addition, Wolde-Rufael (2004) used the same methods for Shanghai and Soytas et al. (2001) in the case of Turkey, obtaining the same outcomes. Belloumi

(2009) applied the same methods for Tunisia and, in this case, the dependence is valid in the short term.

Streimikiene and Kasperowicz (2016) proposed a similar analysis, looking for statistical results confirming the link between the same indicators at EU level. Thus, using data for 14 countries within the European Union, for the period 1995-2012, and panel unit root tests, panel co-integration test, fully modified ordinary least squares (FMOLS) estimator and dynamic ordinary least squares (DOLS) estimator, they confirmed the existence of a positive relationship between energy consumption and economic growth process.

Testing data for two countries, Romania and Spain, Pirlogea and Cicea (2012) identified a positive long-run (1990-2010) link between energy consumption from oil sources and economic growth, measured by GDP per capita in constant prices. The authors also found that in the short term, for example in the case of Romania, renewable energy consumption influences economic performance, but the relationship is not valid in the reverse direction. In other words, economic growth will not lead to an increase in renewable energy consumption. The same conclusions are valid for Spain, taking into account natural gas consumption. Tang et al. (2016) established a similar level of co-integration between variables for Vietnam's economy.

The different results obtained by the authors can easily be attributed to methodological factors: different time intervals for which the analyses were done and the introduction of additional variables in the test (foreign investment, foreign trade operations, unemployment, and inflation). Elements related to the economic structure can certainly influence the results, as it is evident that national economies have different productivity structures: industrialised economies are more energy intensive, developing economies have lower energy consumption, or tertiary-oriented economies have rather low energy consumption relative to the value of final goods and services obtained.

2. Data and methods

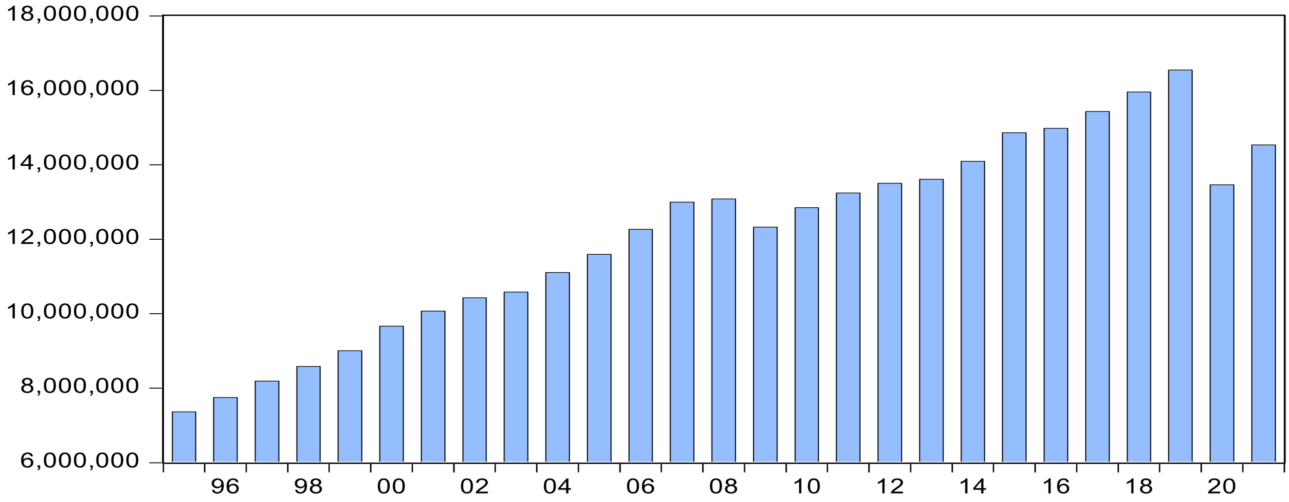
Starting from the premise that an increase in living standards cannot be achieved without a corresponding increase in energy consumption, the aim of this empirical study is to assess the impact of energy consumption in the five main energy markets (solid fuels, electricity, natural gas, oil, and renewable energy market) on economic growth in the European Union. Therefore, using a multiple regression model, it will be analysed whether the simultaneous variation in the consumption of solid fuels, electricity, natural gas, oil, and renewable energy explains changes of the Gross Domestic Product.

Therefore, in the present study we decided to restrict the analysis to one of the four working hypotheses mentioned above, namely the growth hypothesis, in order to assess the effects that changes in the structure of energy consumption have on final macroeconomic outcomes.

The period of analysis is from 1995 to 2021 and the sample used is taken from the Eurostat database. The dependent variable included in the analysis is Gross Domestic Product (GDP), expressed in millions of euro, while the independent variables used are solid fuels consumption, electricity consumption, natural gas consumption, oil consumption and renewable energy consumption, expressed in terajoules. The methodology involves a logarithmic process for all series and the SPSS statistical software in order to process the collected data. In addition, the methodology implies the using of the X12 procedure implemented by the US Census Bureau for all series in order to remove seasonal factors.

As can be seen from Figure 1, the evolution of economic performance at the EU level, measured in this case by the GDP indicator, shows increases in most of the years analysed, with the exception of 2009 and 2020.

Figure 1. The EU Gross Domestic Product between 1995- 2021 at market prices (Millions of Euro)

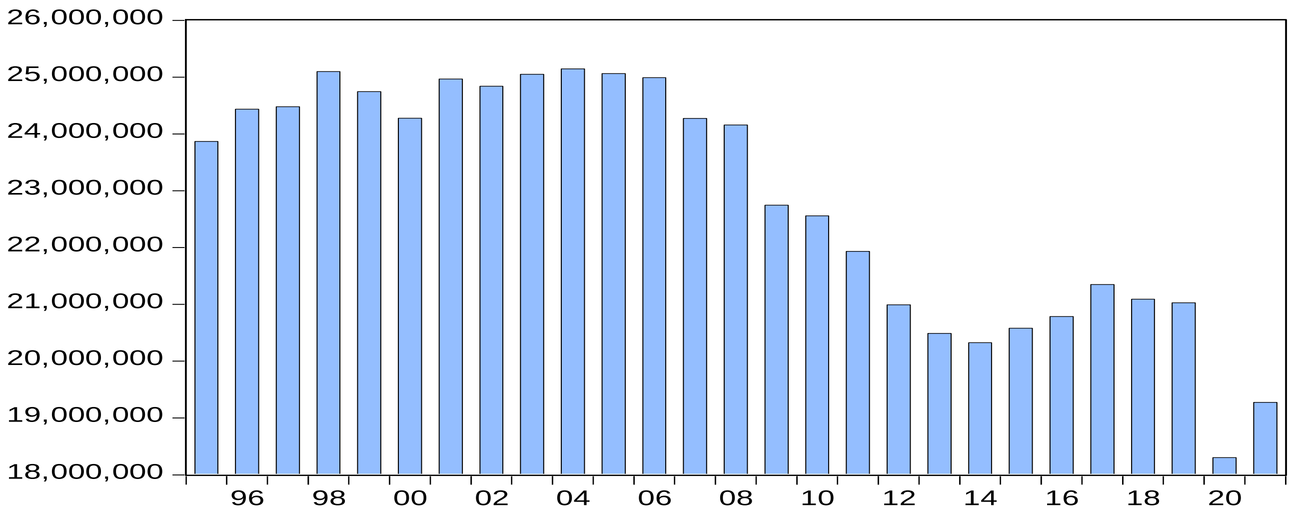


Source: own representation based on Eurostat data

On the one hand, the effects of the economic crisis of 2008-2010 on economic performance at the global level lead to the decrease recorded in 2009, from this point of view the European economy being, like most world economies, affected by this negative period. On the other hand, the results for 2020 are significantly lower than for 2019. The measures taken by the authorities in the initial period of the Covid-19 pandemic are causing this drop in GDP. These measures involved, especially in the first part of the year, the restriction of entire sectors of economic activity, which led to a deterioration in the results for the initial year of the pandemic, compared to the previous year. At the same time, the GDP level for 2021 is lower than in 2019, a sign that the pandemic has produced much larger impact that could not be fully covered in the following year.

Oil is one of the primary energy resources that is very important in the energy mix of any economy. This is mainly due to its use as a fuel for the means of transport that ensure national and international distribution of all categories of products, and it is an essential input in the transport industry. In addition to transport, other industries such as chemicals, petrochemicals, steel, and so on use consistently this resource. The consumption of oil resources in the European Community shows two distinct periods, according to Figure 2. The first from 1995 to 2008 shows a relatively constant rate of consumption, with low volatility from one year to the next. The second is from 2010 onwards, when the trend becomes downward, with oil use declining and reaching its lowest value in 2020.

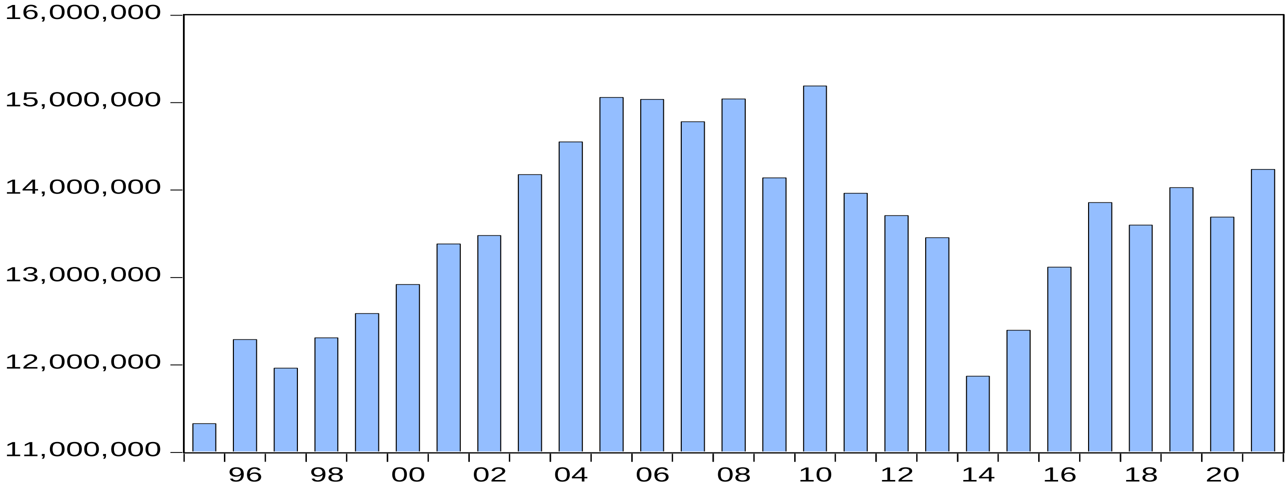
Figure 2. The EU Oil Consumption in 1995-2021 (Thousands of Terajoules)



Source: own representation based on Eurostat data

Figure 3 reveals numerous fluctuations in natural gas consumption at EU level. The period 1995-2021 has 3 phases. The first phase is one of growth, in which natural gas consumption increases from 1997 to 2010, exceeding 15 billion of terajoules and having two episodes of decreases in 2007 and 2009, as an effect of the economic crisis of that period. The second phase shows a downward trend from 2011 until 2014, when the level of natural gas consumption returns to the 1997 level. The growth in the next phase, starting in 2015, had two interruptions in 2018 and 2020, so that the upward trend was not strong enough to match the peak levels of 2005-2010.

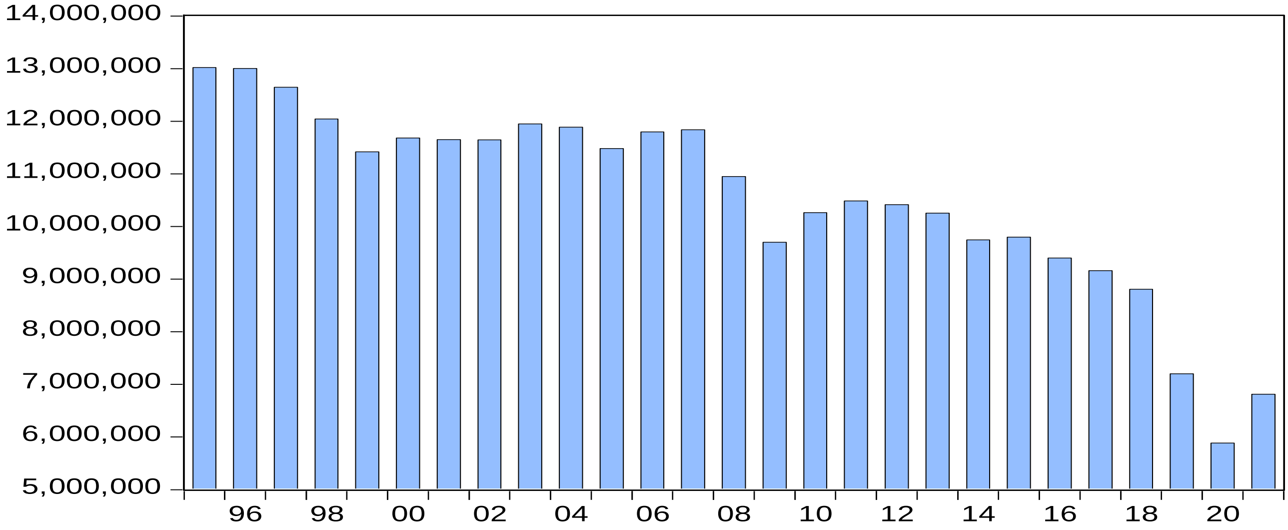
Figure 3. EU Natural Gas Consumption in 1995-2021 (Thousands of Terajoules)



Source: own representation based on Eurostat data

European measures from energy policy are part of the global approach to reducing greenhouse gases, focusing on replacing the use of polluting fossil fuels with less polluting renewable sources. In this respect, the trend in the consumption of solid fuels, especially solid fuels, shows the positive results of these measures. According to Figure 4, the consumption of solid fuels is steadily decreasing over the period analysed, with values in 2021 approximately half those of 1995. This trend suggests that consumption of this type of resource is steadily decreasing in the European Union, with Member States gradually replacing increasing amounts of solid fuels with renewable energy resources.

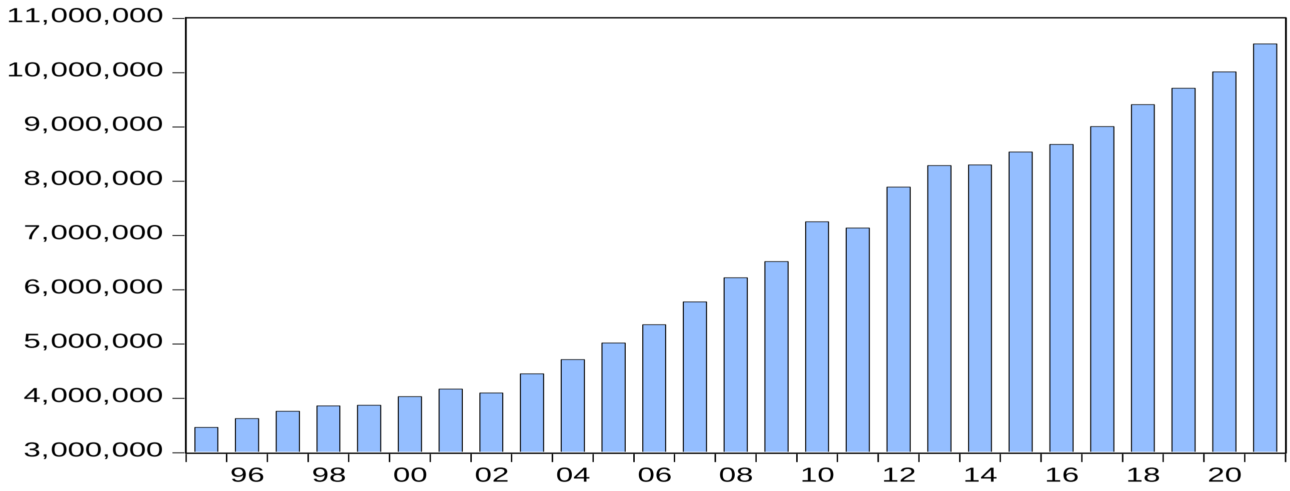
Figure 4. EU Solid Fuels Consumption in 1995-2021 (Thousands of Terajoules)



Source: own representation based on Eurostat data

In contrast to the previous data, Figure 5 highlights this trend, while the renewables are increasingly becoming a part of the EU energy mix. The evolution of renewable energy consumption is steadily improving, with the values three times higher in 2021 than at the beginning of the period analysed.

Figure 5. EU Renewable Energy Consumption in 1995-2021 (Thousands of Terajoules)



Source: own representation based on Eurostat data

Comparing data on renewable energy consumption with data on GDP development, a clear similarity appears in the trends of the two indicators, which may underline a strong positive link between these two. However, taking into account that the data are taken at EU level and that Member States have quite different economic performances and energy mixes, a more detailed analysis of the correlation between these two indicators will be the subject of future studies.

Comparing the evolution of coal consumption with that of renewables, the value of renewable energy exceeds that one of solid fuels from 2019 onwards. This highlights once again the results of European energy policy, which seeks to decouple economic activity from the use of polluting energy resources and replace them with renewables.

3. Econometric analysis

In this study, we examined whether simultaneous changes in solid fuels, electricity, natural gas, oil and renewable energy consumption influence the GDP at the EU level, using a multiple regression model.

3.1. Exploratory analysis of variables

Table 1 presents the main indicators of the descriptive statistics for the analysed variables. At the level of the European Union, the average GDP for the period 1995-2021 was 12.152,35 billion euros, with a minimum of 7.363,52 billion euros (in 1995) and a maximum value of 16.545,38 billion euros (in 2019). As regarding solid fuels consumption, the average is 10.553,69 thousand terajoules. The maximum value was recorded in 1995 (13.020,37 thousand terajoules).

Table 2. Descriptive analysis of variables

	Descriptive Statistics							
	N	Minimum	Maximum	Mean	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
GDP	27	7.363,52	16.545,38	12.152,3536	-0,280	0,448	-0,895	0,872
Solid fuels	27	5.887,87	13.020,37	10.553,6855	-0,999	0,448	0,680	0,872
Electricity	27	-65,05	62,22	5,0854	-0,333	0,448	-0,304	0,872
Natural Gas	27	11.327,64	15.191,48	13.561,8034	-0,305	0,448	-0,716	0,872
Oil	27	18.303,96	25.146,25	22.846,3717	-0,498	0,448	-1,113	0,872
Renewable energy	27	3.467,69	10.528,41	6.434,6654	0,248	0,448	-1,434	0,872
Valid N (listwise)	27							

Source: own processing in SPSS based on data provided by Eurostat

The average electricity consumption was 5,085 thousand terajoules, with a maximum of 62,22 thousand terajoules in 2009. In the case of natural gas consumption, the average at the level of the European Union for the period 1995-2021 was 13.561,80 thousand terajoules, with a minimum recorded value of 11.327,64 thousand terajoules in 1995. As regarding oil and petroleum products, the average consumption at EU level for 1995-2021 is 22.846,37 thousand terajoules, with a minimum value of 18.303,96 thousand terajoules and a maximum value of 25.146,25.

Table 2 shows the major differences between Member States in terms of energy consumption in 2021. Poland is the largest consumer of solid fuels in the European Union, consuming around 42% of the EU total. In the same ranking are Germany, the Czech Republic, France, Romania and Belgium, with consumption levels exceeding 1 billion tonnes for each country. At the opposite pole are Luxembourg, Cyprus, Slovenia, Latvia, Portugal and Estonia, with consumption levels below 100 million tonnes per country, while Malta has no consumption of solid fuels in 2021.

Table 2. Final consumption of energy resources in 2021 for the EU members

EU Member	Solid fuels	Electricity	Natural gas	Oil
	Million tonnes	**Gigawatt-hour**	**Terajoule**	**Million tonnes**
Austria	513.07	66.861,49	245.303,76	11,34
Belgium	1.082,50	83.068,70	518.147,50	20,19
Bulgaria	818.87	32.088,80	68.676,11	4,32
Croatia	171.60	16.854,40	66.398,89	2,92
Cyprus	66.42	4.656,27	0,00	1,07
Czech Rep.	3.528,63	61.303,99	259.788,62	9,51
Denmark	216,36	33.602,44	75.717,89	5,66
Estonia	3,50	8.134,59	12.034,76	1,06
Finland	189,40	83.301,00	37.986,00	7,41
France	1.915,56	442.322,44	1.415.340,38	68,45
Germany	6.760,70	505.174,50	2.777.954,91	95,61
Greece	336,66	50.554,44	68.930,97	8,72
Hungary	273,00	43.387,00	308.281,00	7,93
Ireland	371,50	29.659,30	90.240,33	6,43
Italy	457,73	300.887,06	1.673.234,38	45,65
Latvia	26,99	6.930,29	16.356,58	1,54
Lithuania	261,60	11.953,60	66.874,00	2,52
Luxembourg	72,83	6.392,85	28.307,74	2,69
Malta	0,00	2.583,17	0,00	0,37
Netherlands	273,95	112.348,57	921.162,19	24,81
Poland	15.027,60	157.314,15	592.321,94	30,40
Portugal	13,65	48.116,52	89.364,01	8,57
Romania	1.564,54	49.623,17	320.094,15	9,79
Slovakia	763,00	26.457,00	144.551,00	3,75
Slovenia	42,44	13.550,05	28.956,28	2,27
Spain	603,00	235.025,00	713.125,12	44,07
Sweden	520,00	131.028,00	37.988,30	9,82
EU27	**35.875,07**	**2.563.178,76**	**10.577.136,82**	**436,89**

Source: Eurostat. Supply, transformation and consumption – commodity balances

In terms of electricity consumption, Germany is the largest consumer in the European Union, consuming around 20% of the EU total. France, Italy, Spain, Poland, Sweden and the Netherlands follow in the same list of largest consumers in the EU, with consumption levels exceeding 100.000 gigawatt per hour for each country. On the other hand, Estonia, Latvia, Luxembourg, Cyprus, and Malta are the smallest consumers, each having a consumption level below 10.000 gigawatt per hour. As regarding natural gas, the top list is almost the same. Germany, Italy and France are the largest consumers in the EU, followed by the Netherlands, Spain and Poland. For Germany, the natural gas consumption represents more than 26% of the EU total and three times higher than the Netherlands. However, there are also cases of low consumption, such as Latvia and Estonia, while Cyprus and Malta have no consumptions of natural gas in 2021. Finally, the same countries appear in the top of the largest oil consumers and in the top of the smallest oil consumers. Germany consumes almost 437 million tonnes of oil, representing 22% of the EU level. The top continues with France, Italy, Spain and Poland, each consuming more than 30 million tonnes of oil. Most of countries have a level consumption lower than 10 million tonnes, while Latvia, Cyprus, Estonia and Malta consume less than 2 million tonnes of oil.

3.2. Estimation of model parameters

The multiple regression model that expresses the link between the dependent variable and the five independent variables is of the form:

$$GDP_t = \beta_0 + \beta_1 solid\ fuels_t + \beta_2 electric_t + \beta_3\ natural\_gas_t + \beta_4\ oil_t + \beta_5 renewable_t + \varepsilon$$

where:

GDP = gross domestic product at market prices;

Solid fuels = solid fuels consumption;

Electric = electricity consumption;

Natural gas = natural gas consumption;

Oil = oil consumption;

Renewable = renewable energy consumption;

$\beta_{j,\ j = 0....5}$ = the parameters of the proposed model;

ε = the error term;

t = the year for the collected indicator.

Table 3 presents the results obtained after processing the data in SPSS software.

Table 3. Coefficients values of the regression model

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Bet			Tolerance	VIF
1	(Constant)	-31.822,551	5.411,995		-5,880	0,000		
	Solid fuels	0,493	0,170	0,345	2,901	0,009	0,136	7,366
	Electricity	9,123	4,842	0,109	1,884	0,073	0,579	1,727
	Natural gas	-0,237	0,200	-0,098	-1,184	0,250	0,282	3,540
	Oil	1,168	0,244	0,950	4,790	0,000	0,049	20,423
	Renewable energy	2,370	0,244	2,108	9,713	0,000	0,041	24,456

a. Dependent Variable: GDP

Source: own processing in SPSS based on data provided by Eurostat

According to the previously results, the estimated model, through which the connection between the considered variables is illustrated, is the following:

$$GDP = -31.822,6 \; + \; 0,493 * solid\ fuels \; + \; 9,123 * electricity \; - \; 0,237 * natural\ gas \; + \; 1,168 * oil \; + \; 2,370 * renewable\ energy$$

According to Table 3, the variables consumption of solid fuels, oil and renewable energy have influence on GDP (value Sig<0.05 for each factor), while the influence of electricity is statistically significant for a significance threshold of 10%. The regression model parameter estimates have the following meaning:

- Estimate $b_1=0,493$: an increase in solid fuels consumption by one thousand terajoules causes an increase, on average, by 0,493 million euros in GDP, under the conditions in which the other independent variables remain constant;
- Estimate $b_2=9,123$: an increase in electricity consumption by one thousand terajoules causes an increase, on average, by 9,123 billion euros of GDP, under conditions in which the other independent variables remain constant;
- Estimate $b_4=1,168$: an increase in oil consumption by one thousand terajoules causes an increase, on average, by 1,168 billion euros of the GDP, under conditions in which the other independent variables remain constant;
- Estimate $b_5=2,370$: an increase in the consumption of renewable energy by one thousand terajoules causes an increase, on average, by 2,370 billion euros of the GDP, under conditions in which the other independent variables remain constant.

The parameters values obtained are of significant importance in understanding the energy footprint of the European economy. On the one hand, the low value of the parameter for the variable related to coal consumption has the lowest value, which indicates the lowest impact of coal consumption on the EU GDP, closely related to its downward trend. The negative value of the parameter for natural gas is given by the high volatility of gas consumption in the analysed period.

Given the value-added components involved in the renewables industry, we note that the impact of an increase in their consumption is more than double that of oil. At the same time, the parameter with the highest value, which shows us a significant impact, is the one corresponding to the electricity variable, since the sources of its production are on the one hand traditional ones (oil, natural gas, coal) or on the other hand, in significant growth, the renewable ones.

The equation sheds light on a rather interesting situation, on the one hand the European economy can register significant increases with a higher electricity consumption, an amplified effect if their source is renewable. At the same time, a decrease in energy consumption from fossil sources can be easily covered, without affecting the economic output, by replacing them with renewable sources.

3.3. Testing the model parameters

Testing the model parameters involves several stages. The first stage surprises the formulation of the following hypotheses:

H_0: $\beta_0 = 0$ ($M(Y) = 0 \mid X_1, X_2, X_3, X_4, X_5 = 0$)

H_1: $\beta_0 \neq 0$ ($M(Y) \neq 0 \mid X_1, X_2, X_3, X_4, X_5 = 0$)

H_0: $\beta_i = 0$, $i=\overline{1,5}$ (the independent variable *i* has no partial linear influence on the dependent variable)

H_1: $\beta_i \neq 0$ (the independent variable *i* has a partial linear influence on the dependent variable).

The second stage presents the choosing of the significance threshold (α) and the test statistic. On the one hand, the significance threshold takes the value 0.05. On the other hand, the analysis considers the t-Student statistic. The third stage implies the calculation of the test statistic values. In this regard, Table 3 presents the values of the t-Student statistic, being determined as follows:

- For the β0 parameter: $t_{calc}=\frac{b_0}{s_{\hat{\beta}_0}}$= -31822,6 / 5411,995 = -5,880
- For the β1 parameter: $t_{calc}=\frac{b_1}{s_{\hat{\beta}_1}}$= 0,493 / 0,170 = 2,901;
- For the β2 parameter: $t_{calc}=\frac{b_2}{s_{\hat{\beta}_2}}$= 9,123 / 4,842 = 1,884;
- For the β3 parameter: $t_{calc}=\frac{b_3}{s_{\hat{\beta}_3}}$= -0,237 / 0,200 = -1,184;
- For the β4 parameter: $t_{calc}=\frac{b_4}{s_{\hat{\beta}_4}}$= 1,168 / 0,244 = 4,790;
- For the β5 parameter: $t_{calc}=\frac{b_5}{s_{\hat{\beta}_5}}$= 2,370 / 0,244 = 9,713.

The penultimate stage is to find the theoretical values of the test statistic, which for $t_{\alpha/2;n-5}$ are read from the t-Student table. For a significance threshold of 0.05 and a sample of n = 27, the value $t_{0,025;22}$ = 2.05 is read. The final stage implies the establishing of the decision rule. According to Table 3, the Student test for the parameters solid fuels, oil and renewable energy consumption indicates a value Sig. t < 0.05. This suggests the rejection of the null hypothesis for these parameters, with a probability of 95%.

3.4. Model testing

Testing the model implies the same stages as testing the model parameters. For the first stage, the hypotheses are the following:

H_0: $\beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$ (the model is not statistically significant)

H_1: Not all regression coefficients are simultaneously equal to zero (the model is statistically significant)

Table 4 presents the modelling results.

Table 4. ANOVA

Model		ANOVA(b) Sum of Squares	df	Mean Square	F	Sig.
1	Regression	169.064.908,535	5	33.812.981,707	99,683	0,000
	Residual	7.123.305,339	21	339.205,016		
	Total	176.188.213,874	26			

a. Predictors: (Constant), Renewable energy, Natural gas, Electricity, Solid fuels, Oil
b. Dependent Variable: GDP
Source: own processing in SPSS based on data provided by Eurostat

The second stage implies the choosing of the significance threshold (α) and the test statistic. Again, the significance threshold takes the value 0.05, while the analysis considers the Fisher statistic in order to test the significance of the multiple linear regression model. Then, the calculation of the test statistic value, according to which F_{calc} = (ESS/RSS)*((n-k) / (k-1)) = 99,683. After that, the theoretical value $t_{\alpha/2;n-5}$ are read from the t-Student table. For a significance threshold of 0.05 and a sample of n=27, the value $t_{0,025;22}$ = 2.05 is read. The theoretical value $F_{\alpha;k-1;n-k}$ is read from the Fisher table and is equal to 2.69.

The final stage implies the establishing of the decision rule, according to which F_{calc} = 99,683 > $F_{\alpha;k-1;n-k}$ = 2.817. This result leads to the decision to reject the hypothesis H0. Therefore, the multiple linear regression model is statistically significant, with a level of 95% probability. Table 5 shows the correlation ratio and determination ratio values.

Table 5. Estimation of correlation ratio and determination ratio

Model Summary(b)					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	0,980	0,960	0,950	582,41310	0,960	99,683	5	21	0,000	1,181

a. Predictors: (Constant), Renewable energy, Natural gas, Electricity, Solid fuels, Oil
b. Dependent Variable: GDP
Source: own processing in SPSS based on data provided by Eurostat

According to Table 5, the probability Sig. associated with the Fischer test value from the ANOVA table is less than 0.05 (Sig = 0.000), which means that the proposed model is statistically significant in order to explain the dependence between the variables. Therefore, the independent variables explain the variation of the dependent variable, GDP, with a probability of 95%. At the same time, the estimated value of the correlation ratio is R =0.980, which indicates the existence of a very strong link between the dependent variable GDP and the independent variables considered in the analysis. Also, the value of R^2=0.960 indicates that 96.0% of the variation of the dependent variable, GDP, is explained by the simultaneous variation of the independent variables.

3.5. Hypothesis testing of regression model errors

The estimated linear model requires validation by testing the assumptions regarding the modelling errors, namely the average of the errors is zero, normality, homoscedasticity, respectively the non-correlation of the errors. Formally, these assumptions are written as follows:

- M(ε_i) = 0, which means that the mean of errors is zero;
- $\varepsilon_i \rightarrow$ N(0, σ^2), expresses the normality hypothesis;
- V(ε_i) = σ^2, suggests the homoscedasticity hypothesis;
- cov (ε_i, ε_j) = 0, shows the hypothesis of non-correlation or independence of errors.

Table 6 presents the output resulted after testing the hypothesis regarding the mean of errors, according to which M (ε_i) = 0.

Table 6. One-Sample Test

One-Sample Test						
	Test Value = 0					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Unstandardized Residual	0.000	26	1.000	0.00000000	-207.0598644	207.0598644

Source: own processing in SPSS based on data provided by Eurostat

The value associated with the Student statistic (Sig. = 1.000 > α = 0.05) supports the decision to accept the null hypothesis (H_0: M (ε) = 0), guaranteed with a confidence level of 95%. Thus, the hypothesis that the mean of the errors does not significantly differ from the zero value is accepted.

Given that the modelling errors do not follow a normal distribution law, the estimators built based on the least squares method do not, in turn, follow a normal distribution law. Table 6 surprises the non-parametric Kolmogorov-Smirnov test, used for testing of the normality of the regression model errors, according to which $\varepsilon_i \rightarrow$ N (0, σ^2)

Table 7. Kolmogorov-Smirnov test

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		27
Normal Parameters(a,b)	Mean	0.0000000
	Std. Deviation	523.42457172
Most Extreme Differences	Absolute	0.120
	Positive	0.080
	Negative	-0.120
Kolmogorov-Smirnov Z		0.624
Asymp. Sig. (2-tailed)		0.831

a. Test distribution is Normal.
b. Calculated from data.
Source: own processing in SPSS based on data provided by Eurostat

According to Table 7, the probability value associated with the calculated test statistic is lower than the threshold of 0.05 (Sig. = 0.831), a result that leads to the decision to accept the null hypothesis (H_0: $\varepsilon_i \rightarrow$ N $(0, \sigma^2)$). Thus, the distribution of the errors of the estimated regression model follows a normal distribution law, guaranteed with a level of 95% confidence.

Next, the analysis reveals the test of homoscedasticity. According to the assumption of homoscedasticity, the error variance must be constant. To test it, the following statistical hypotheses are necessary in order to test the homoscedasticity:

- H_0: hypothesis of homoscedasticity (V (ε_i) $= \sigma^2$);
- H_1: hypothesis of heteroscedasticity (V (ε_i) $= \sigma_i^2$).

For this step is necessary to test the non-parametric correlation between the estimated modelling errors (expressed in absolute magnitude) and the values of the independent numerical variables. The analysis implies the Spearman test statistic to test the assumption of homoscedasticity. For the considered regression model, Table 8 resumes the results for solid fuels, electricity, oil and renewable energy consumption after data processing in SPSS.

Table 8. Spearman tests

			Unstandardized Residual	Solid fuels	Electricity	Oil	Renewable energy
Spearman's rho	Unstandardized Residual	Correlation Coefficient	1000	-0.162	-0.060	-0.064	0.102
		Sig. (2-tailed)	0.0	0.418	0.767	0.751	0.613
		N	27	27	27	27	27

Source: own processing in SPSS based on data provided by Eurostat

The value of the Spearman correlation coefficients are -0.162 for solid fuels consumption, -0.060 for electricity, -0.064 for oil and 0.102 for renewable energy. At the same time, for solid fuels consumption, the value of Sig. = 0.418 shows that the hypothesis of homoscedasticity is accepted with a probability of 95%. Applying the same approach to the other analysed independent variables, the results show that Sig > 0.05 in all cases. Therefore, the errors of the analysed regression model are homoscedastic, guaranteed with a probability of 0.95.

Finally, the analysis considers the test of hypothesis for autocorrelation of errors, according to which cov (ε_i, ε_j) = 0. Two hypothesis are necessary, such as:

- Null hypothesis (H_0): there is no autocorrelation of errors;
- The alternative hypothesis (H_1): there is autocorrelation between the errors of the estimated model.

Autocorrelation of errors can be tested through several methods, the most used of which are Durbin Watson and Runs test. This paper opts for the Runs test, while Table 9 presents the results of testing the autocorrelation of error.

Table 9. Runs test

	Unstandardized Residual
Test Value(a)	47.69233
Cases < Test Value	13
Cases >= Test Value	14
Total Cases	27
Number of Runs	13
Z	-0.386
Asymp. Sig. (2-tailed)	0.700

a. Median

Source: own processing in SPSS based on data provided by Eurostat

The value of Sig. = 0.700 associated with the calculated test statistic is greater than the significance threshold of 0.05. Thus, the decision is to accept the null hypothesis with a confidence level of 0.95, which means that the model errors do not record the autocorrelation phenomenon.

As conclusion, the analysis is valid, considering the compliance with all assumptions regarding the errors of the regression model.

Conclusions

The paper scope is to identify, based on data recorded at EU level, whether the energy consumption influences economic performance across the EU. The result is one of the essential prerequisites in addressing the EU energy policy, which together with the approach to all other joint actions, is in a delicate situation given the rather unstable economic outlook.

The consumption of electricity, natural gas, oil and renewable energy have a significant influence on economic development at the level of the European Union, an intuitive result from an economic point of view. Therefore, the correlation between the consumption of electricity, oil, and renewable energy, on the one hand, and economic growth, on the other hand, proves, empirically, to be directly proportional. There is a generally association between the high values of the consumption of electricity, natural gas, oil and renewable energy and positive rates of economic growth. For solid fuels consumption, the results are statistically insignificant. The explanation for the lack of correlation is that the variable represented by solid fuels consumption is the only one that registers a continuous downward trend in the analysed model during the period 1990-2015.

The results obtained through the statistical analysis highlighted the fact that, for the European Union, the level of economic development has profound energy valences. With the exception of solid fuels, the impact of the consumption of the other types of energy analysed is a considerable one on economic growth. That is why ensuring a sufficient supply of energy resources to support any growth will influence the prospects for economic growth that the European Union imposes on itself. However, the previous results explain influences at the Community level, and consequently the energy approach of the European policies must take into account the fact that the pressure of energy consumption may vary from country to country within the EU.

The energy consumption always accompanies directly proportional the evolution of the economic growth, most often related to the increases in the productivity of an economy. This paper suggests that for the period between 1990 and 2015, the consumption of energy from renewable sources registers the most spectacular increases. The increasing trend is amplified after the year 2010, a sign of the awareness that a sustainable economic development is closely related to a continually increasing use of this type of resource. At the same time, the results show that the evolution of the use of renewable energy sources are positive, with a significant increase until 2020.

It should be borne in mind that the analysis followed EU-wide data, and the dependency relationship established is valid at the EU level as a whole, with the typicality of each Member State's economy, both in terms of economic performance and energy resource use, being quite heterogeneous. Therefore, we cannot translate the results for individual Member States. However, the results underline once again that the upward trend in economic performance at European level is dependent on an increasing use of energy resources. In other words, European energy policy must consider this correlation, so that the measures and policies adopted enable the economic environment to have easier access to these resources, thereby increasing the chances of overcoming the current difficult period as quickly and cheaply as possible.

Based on the results, a decrease in fossil fuel consumption at EU level can lead to a decrease in productivity, so economic growth can indeed be supported by a reduction in the use of coal, oil or natural gas, as long as this is offset by an increase in the use of renewable resources. To these we add their significant impact, as determined by the present statistical analysis, and the fact that renewable industry is constantly evolving, innovative and capable of stimulating sustained regional development. This is closely linked to the common vision on European energy policy for a more connected, less dependent on external supplies and greener energy market.

Future studies should aim to apply similar statistical methods to see whether the correlation we have obtained at EU level is valid at the individual level of all Member States. Certainly, given the significant differences between Member States' economies (area and geographical position, population, macroeconomic structure, availability of domestic energy resources, structure of energy imports) the challenges of an integrated energy policy are significant.

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