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# The Relationship between Energy Production and GDP: Evidence from Selected European Economies

**Grażyna Szustak, Piotr Dąbrowski, Witold Gradoń and Łukasz Szewczyk ***

Department of Banking and Financial Markets, University of Economics in Katowice, 40-287 Katowice, Poland; grazyna.szustak@uekat.pl (G.S.); piotr.dabrowski@uekat.pl (P.D.); witold.gradon@uekat.pl (W.G.)
* Correspondence: lukasz.szewczyk@uekat.pl

**Abstract:** The aim of this article was to investigate the possible relationship between energy production and GDP growth. This problem is of a crucial importance because as a numerous studies show, it is difficult to give an unambiguous answer to the question of whether there is a relationship between GDP and energy production and what direction it takes if it exists, i.e., whether energy production drives GDP growth or GDP growth drives energy production. The research conducted by the authors used data on hourly power production in MWh/h averaged over a whole day, which were converted into total quarterly production. The data were divided in terms of the type of energy into conventional, renewable, other and total. Next, the correlation coefficient was calculated for proper data sets in order to determine whether there was a correlation between the variables. The main conclusion from the study is the fact that a correlation measured with the Pearson correlation coefficient is not reflected in the data. Changes in power production independent of the source of power do not influence the GDP directly. Naturally, in some countries, the connection between power production and GDP was stronger; however, comparing this to the rest of the researched countries, where correlation was low or even extremely low, it can be seen that the relationship is random. This study should be seen as an introductory one with a perspective of broadening research in terms of causality between variables, which, nowadays, has great application in terms of climate change and sustainable development.

**Keywords:** economic growth; energy production; conventional power sources (CNV); renewable energy resources (RES)

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## 1. Introduction

Economic growth is the overriding goal of any country's economic policy. The measure of economic growth—GDP—reflects the increase in the value of manufactured goods and services in a given country in a specific period (value of goods and services produced minus the value of goods and services used in production) [1,2]. It is worth remembering that the concept of "economic growth" is not the same as "economic development", which additionally includes qualitative changes accompanying economic growth, improving the competitiveness of a given economy [1]. GDP is commonly seen as an indicator of economic activity. However, even in the case of diagnosing economic well-being, it is not a comprehensive measure, because individual countries may estimate nominal GDP inaccurately or in a biased manner, e.g., by not taking into account the profits of multinational companies, the development of the digital economy and the activities of the "black market" or the price deflators separating nominal and real GDP may use a biased measure of inflation. GDP is not an indicator of social well-being, although it obviously contributes to its growth. Taking into account the above, it should not be treated as a universal indicator of the general progress of the economy [2,3]. The rate of economic growth is nothing more than the increase/decrease in real GDP in a given year compared to the previous/base year [4].

The reliable assessment of the results of national economies requires (apart from the assessment of the nominal value of GDP and the determination of what proportion of GDP growth resulted from the occurring inflation) answers to a number of additional questions, e.g., who creates GDP and how the generated income is used. Therefore, GDP is not a summary measure [5]. Mathematically, GDP is the sum of consumption, investment, government expenditure (excluding transfers) and exports, minus imports (the expenditure aggregation method) [6]. In the income approach, GDP is the sum of income from work, capital, state and depreciation. Additionally, in the case of the production method, GDP is the difference between the output of a given country and the indirect costs incurred in production. In this case, GDP is a measure of current production, not sales (production in a given period, regardless of the period in which it will be sold)—such an understanding was adopted, e.g., in the National Income and Product Accounts (NIPA—NIPA is a part of the national accounts in the United States of America. They are calculated by the Bureau of Economic of the Department of Commerce) [4].

An alternative way of estimating GDP may be the quantification of the amount of electricity produced, which is an indirect measure of the demand for electricity and ultimately the energy consumption of a given economy, which may possibly be slightly higher due to possible energy imports (conventional energy production is adjusted to the demand by reducing the power used) and power plants, especially when the country has a large amount of renewable energy resources. In addition, the cost of electricity storage is high, increasing the price of electricity [7].

Comparable economies should have similar energy consumption, which in this case allows one to eliminate the so-called paper part of the country's GDP, not reflected in energy production (also in its import) and then in electricity consumption. A separate problem is the efficiency of energy consumption (energy consumption of the economy), which is one of the most important determinants of the level of energy consumption. The remaining factors influencing the production and consumption of energy are usually the number of inhabitants and the degree of economic and civilization development of a given country [8].

A synthetic measure of the aforementioned energy intensity of the economy is the ratio of energy consumption per unit of GDP (energy consumed in tonnes of oil equivalent, in short, tpe/currency of GDP). The lower the indicator, the more efficiently the country uses energy [9]. Therefore, it becomes more competitive. By 2020, it is required to improve energy efficiency in the EU by 20%, and by 2030 by 32.5%, while in 2030, primary energy consumption in EU countries will not be able to exceed 1273 Mtpe, which is approximately 53.3 million TJ [10]. In Poland, in the years 2008–2018, energy consumption had a downward trend. Primary energy consumption decreased on average by 2.6% annually, and final energy consumption by 2% annually [11]. This is still higher than the average within the EU.

The production/consumption of energy and GDP interact with each other, because energy determines the economic and social development of countries, and GDP growth leads to an increase in energy demand [12]. Many studies conducted in recent decades confirm the strong relationship between these two variables [13,14].

However, it is difficult to give an unambiguous answer to the question of whether energy production drives GDP growth or GDP growth drives energy production. Such an attempt was made, among others, by Sanaú Villarroy, J.J., Sanz-Villarroy, I. and Perez y Perez, L. Their research (which, however, was accompanied by certain limitations) shows that it was the production of electricity in the analyzed period that stimulated economic growth in Spain. The cited studies also show that a small economy with limited resources (for example, Spain) is more susceptible to energy shocks. In addition, Spain is an energy-importing country, so its economic prospects depend on the availability of various sources of electricity. The supply shortage slows down the pace of economic growth [15].

Zanjani, Z., Macedo, P. and Soares, I. argue that economic growth is increasingly dependent on electricity consumption. The cited authors also point out other studies, such as the International Energy Agency (IEA), confirming the increase in global energy demand, although the 2020 lockdowns disrupted this trend. On the other hand, there are studies by Altinay and Karagol who, using the Granger Hsiao method for the 1950–2000 period in Turkey, did not find a causal relationship between energy consumption and GDP. Thus, the conclusions from the research differ depending on the methodology used by the researchers and the periods adopted [16].

In his study, Ashgar, Z. concentrated on the relationship between GDP and energy consumption in five South African States. The results are varied. In India, for example, there is no evidence of a casual relationship between GDP and energy consumption. As a result, lowering energy consumption will not have a positive effect on GDP. On the other hand, in Pakistan, the results showed that growth in GDP caused an increase in energy consumption [17].

In their research, Silva, S., Soares, I. and Pinho, C. investigated the relationship between the share of renewable energy and its impact on GDP using Structural Vector Autoregressive (SVAR) methodology. The sample consisted of countries which were on a different level of development (e.g., Denmark, which was on a great level of development, the USA, which is one of the biggest economies in the world and Spain, which is rather isolated due to its geographic location). The results have shown, inter alia, that increases in RES-E (electricity generated from renewable sources) may initially have a negative impact on economic growth (although they positively affect $CO_2$ emissions) [18]. According to Stern, D.I., who used cointegration analysis in his research, energy plays a significant role in explaining economic growth, because there is a cointegration between GDP, capital, labor and energy [19].

Kalyoncu, H., Gürsoy, F. and Göcen, H. showed that there is unidirectional causality between GDP per capita and energy consumption in one of the countries that was the subject of their study [20]. Among other studies in which the relation between energy and GDP growth is shown, one can also mention the research conducted by Soytas, U. and Sari, R. [21], who proved that there was a different type of causality in the researched countries, i.e., bi-directional, causality from GDP to energy consumption and from energy consumption to GDP. Ozturk, I. pointed out the fact that in the existing studies, there are different results covering the problem of causality between energy and GDP, both in terms of the general existence of such relations and their direction [22]. The specifics of different types of causality are presented in Table 1.

**Table 1.** Causality between energy consumption and GDP. Source: [22–24].

| Type of Relation | Description |
|---|---|
| No causality | No visible relation between energy consumption and economic growth (neutrality hypothesis). |
| Uni-directional causality | The relation running from economic growth to energy consumption (conservation hypothesis) or from energy consumption to the economic growth (growth hypothesis). |
| Bi-directional causality | Economic growth and energy consumption are jointly related (feedback hypothesis). |

Stern, D. pointed out that energy is a very important growth factor, because production is a function of capital, labor and energy, and the elasticity between energy and capital is low. Energy is also necessary to produce the other inputs to production. Energy is also available in finite quantities [25]. Deichmann, U. and others pointed out that the energy sector plays a crucial role in the economic development fostering economic growth. One should also remember that on the other hand, energy consumption is also associated with climate change because of the important role of fossil fuels in energy production. They also noticed that energy intensity increases at the early stage of development and decreases in later stages of development (transition to service economy). Those structural changes in the economy can be seen over a long period of time [26]. In this context, it is important to remember that improving energy efficiency has gained a growing amount of attention as an important aspect of sustainable development that can foster energy security while addressing climate change concerns. Increases in energy efficiency can be the result of more efficient production technologies or changes in the structural composition of the economy [27]. In their research, Alcantara, V. and Duarte, R. showed that the energy differences in Europe are strongly influenced by the energy intensity effect. It results in a consequence that the control of energy consumption in reduced sectors within the economy and in a group of countries can have a positive effect on the reduction in energy consumption in Europe [28]. In their research, Foon Tang, C. and Wah Tan, B. proved that there is a relationship between economic growth and energy consumption in Malaysia (energy consumption causes economic growth). The results also prove that Malaysia is an energy-intensive country [29]. Sheng-Tung, C. and others showed that the causality directions in selected Asian countries are mixed and that there is a uni-directional short-time causality between electricity consumption and economic growth [30].

## 2. Materials and Methods

The aim of the research was to show the relationship between energy production and GDP growth. The research was conducted on the following data for energy and GDP:

- Hourly power production in MWh/h averaged over a whole day [31],
- GDP in current prices [32],
- The raw data (both in terms of hourly power production and GDP in current prices) was converted into total quarterly production (Q1, Q2, Q3 and Q4 for 2018–2020 and Q1 for 2021),
- Quarterly changes year-over-year were calculated from total quarterly power production and for GDP,
- Quarterly raw data.

The sources of power were categorized as conventional (CNV), renewable energy resources (RES) and others (Oth).

Conventional power sources include coal, lignite, gas, oil, nuclear, biomass, garbage, peat (those three are sometimes qualified as RES; however, this is a type of thermal production) and combined sources.

Renewable energy sources include wind, hydro, water energy from rivers, photovoltaic, thermal, geothermal, season store and reservoir and pumped storage (which it is not a direct source of power, but rather energy storage used for an electric power system for load balancing). Among other power sources, some countries categorize garbage, pumped storage or peat sources.

The GDP data are accumulated, calculated and presented after the closure of each quarter. The power data are calculated continuously and are up to date. This is why power production information is more up to date than GDP data.

The theoretical approach assumes that changes in power production strongly influence the changes of GDP; this is why the Pearson correlation coefficient between energy and GDP was expected to be close to 1.

Moreover, due to the relatively stable and predictable nature of the short-term volume of power consumption, the power production between conventional sources and RES also should be strongly correlated; however, this should be in negatives (Pearson correlation coefficient close to $-1$). This results in the weather-dependent power production of RES and the (partial) ability to compensate surpluses and shortages of power by conventional power plants. That is why Pearson correlation coefficient was calculated for proper data sets:

- Year-over-year quarterly changes in the production of conventional power sources to changes in GDP,
- Year-over-year quarterly changes in the production of renewable power sources to changes in GDP,
- Year-over-year quarterly changes in the production of other power sources to changes in GDP,

- Year-over-year quarterly changes in the production of conventional power sources to changes in the production of renewable power sources.

## 3. Results

The changes in power production and in GDP quoted quarterly year-over-year with the results of the Pearson correlation coefficient are presented in the tables below. The descriptive statistics for the data are presented in Table 2.

**Table 2.** Descriptive statistics for the data. Source: own calculations on the basis of [31].

| | **Austria** | | | | **Belgium** | | | | **Bulgaria** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| Mean | 5.7% | 6.10% | 7.05% | 4.23% | 13.58% | 19.47% | −8.70% | 11.70% | −5.61% | −1.86% | 85.78% | −5.47% |
| Dev. | 45.97% | 14.07% | 23.39% | 13.86% | 31.12% | 14.16% | 14.23% | 21.93% | 6.94% | 32.74% | 207.23% | 5.75% |
| Min. | −45.18% | −14.24% | −29.02% | −14.09% | −21.63% | −0.30% | −31.56% | −16.00% | −12.38% | −37.31% | −20.79% | −13.67% |
| Max. | 99.98% | 23.19% | 50.88% | 32.33% | 66.77% | 48.28% | 15.96% | 49.46% | 7.20% | 70.97% | 632.58% | 3.93% |
| Med. | −0.15% | 9.71% | 5.97% | 4.83% | −2.32% | 18.02% | −7.49% | 4.26% | −8.71% | −8.76% | 16.11% | −7.54% |
| | **Czechia** | | | | **Finland** | | | | **France** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| Mean | −3.43% | 6.64% | 3.41% | −2.62% | 1.60% | 1.79% | −18.73% | 1.14% | −6.22% | 5.39% | −95.68% | −4.12% |
| Dev. | 5.30% | 15.58% | 13.28% | 4.53% | 8.29% | 13.49% | 35.08% | 10.57% | 9.11% | 17.62% | 142.56% | 5.63% |
| Min. | −12.82% | −13.78% | −11.32% | −10.87% | −11.50% | −18.80% | −60.40% | −16.10% | −21.05% | −14.61% | −414.32% | −13.80% |
| Max. | 5.19% | 27.33% | 31.62% | 4.63% | 15.90% | 24.30% | 48.20% | 17.60% | 5.33% | 33.83% | 48.30% | 1.14% |
| Med. | −2.82% | 12.32% | 4.24% | −2.22% | 1.20% | 0.70% | −26.30% | 0.90% | −2.29% | 3.94% | −56.61% | −1.71% |
| | **Germany** | | | | **Greece** | | | | **Hungary** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| Mean | −10.45% | 3.19% | −1.76% | −6.25% | −9.34% | 11.71% | 12.31% | −3.03% | 2.04% | 4.95% | −6.41% | 1.82% |
| Dev. | 15.83% | 14.97% | 10.76% | 5.10% | 11.78% | 22.90% | 66.10% | 11.20% | 4.88% | 21.87% | 18.61% | 5.09% |
| Min. | −26.07% | −29.03% | −15.46% | −14.26% | −25.90% | −9.68% | −53.51% | −19.98% | −3.98% | −21.58% | −37.18% | −4.36% |
| Max. | 24.30% | 22.75% | 18.29% | −0.57% | 9.53% | 63.56% | 152.94% | 14.25% | 8.91% | 46.33% | 24.27% | 9.65% |
| Med. | −12.60% | 4.14% | −3.96% | −6.24% | −10.89% | 9.70% | −7.02% | −4.44% | 0.16% | 3.29% | −3.46% | 0.82% |
| | **Ireland** | | | | **Italy** | | | | **Macedonia** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| Mean | −8.03% | 10.81% | −18.14% | −2.36% | 18.43% | 2.27% | −34.77% | −0.48% | −0.08% | −22.36% | – | −15.67% |
| Dev. | 12.89% | 14.90% | 45.97% | 8.24% | 33.29% | 6.84% | 19.16% | 6.82% | 35.69% | 48.87% | - | 17.00% |
| Min. | −24.22% | −13.10% | −72.32% | −12.55% | −17.14% | −9.18% | −55.73% | −9.44% | −43.01% | −79.83% | - | −49.71% |
| Max. | 9.74% | 31.49% | 69.27% | 10.63% | 78.73% | 10.55% | −3.98% | 8.04% | 67.77% | 52.82% | - | 3.06% |
| Med. | −9.47% | 4.47% | −18.48% | −4.05% | 2.25% | 2.73% | −34.31% | −2.21% | −12.32% | −33.63% | - | −8.52% |
| | **Poland** | | | | **Portugal** | | | | **Romania** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| Mean | −3.94% | 5.36% | 26.68% | −3.09% | −12.35% | 4.37% | 5.41% | −4.09% | −9.38% | −0.63% | - | −6.36% |
| Dev. | 7.21% | 15.76% | 25.66% | 5.37% | 16.54% | 22.48% | 25.26% | 13.05% | 3.01% | 17.38% | - | 7.85% |
| Min. | −13.73% | −24.48% | −9.37% | −12.30% | −40.01% | −26.81% | −33.99% | −21.15% | −14.44% | −26.32% | - | −19.65% |
| Max. | 10.93% | 35.28% | 68.32% | 5.22% | 8.47% | 37.93% | 33.43% | 15.99% | −5.45% | 21.86% | - | 4.09% |
| Med. | −5.90% | 7.13% | 30.07% | −4.03% | −13.35% | −0.24% | 10.07% | −1.60% | −8.69% | 2.48% | - | −6.60% |
| | **Serbia** | | | | **Slovakia** | | | | **Spain** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| Mean | 2.75% | 3.12% | 4.32% | 1.48% | 6.38% | 15.68% | 11.46% | 7.38% | −7.47% | 8.68% | −14.28% | −6.03% |
| Dev. | 5.26% | 27.30% | 33.15% | 6.40% | 22.32% | 22.45% | 18.67% | 15.61% | 15.10% | 17.48% | 176.52% | 7.96% |
| Min. | −6.57% | −27.91% | −40.99% | −8.48% | −30.21% | −22.46% | −14.96% | −22.70% | −28.15% | −16.13% | −99.29% | −17.91% |
| Max. | 7.89% | 53.16% | 68.50% | 9.48% | 56.13% | 39.79% | 39.87% | 34.45% | 17.81% | 30.48% | 445.91% | 7.30% |
| Med. | 4.72% | −8.59% | 2.66% | −0.84% | 5.74% | 14.97% | 10.82% | 8.95% | −12.45% | 10.22% | −81.46% | −4.38% |

**Table 2.** *Cont.*

| | Sweden | | | | Switzerland | | | | The Netherlands | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| Mean | −12.64% | 10.61% | −0.44% | 0.83% | −2.45% | 14.66% | 2.61% | 3.08% | 3.45% | 21.11% | 7.20% | 4.68% |
| Dev. | 17.63% | 9.69% | 5.32% | 10.33% | 12.18% | 14.58% | 18.29% | 10.00% | 14.62% | 26.98% | 79.28% | 12.41% |
| Min. | −40.40% | 0.20% | −7.80% | −13.00% | −20.22% | −3.28% | −22.61% | −12.75% | −15.91% | −5.22% | −64.34% | −8.22% |
| Max. | 10.50% | 30.40% | 7.60% | 20.40% | 15.04% | 40.82% | 39.05% | 17.63% | 30.33% | 78.85% | 202.80% | 30.21% |
| Med. | −5.50% | 9.40% | 0.10% | −1.20% | −3.09% | 10.25% | 0.26% | 4.28% | 1.84% | 14.99% | −11.58% | 5.57% |
| | **Turkey** | | | | | | | | | | | |
| | **CNV** | **RES** | **Other** | **Total** | | | | | | | | |
| Mean | −4.77% | 11.22% | - | −0.72% | | | | | | | | |
| Dev. | 16.15% | 28.49% | - | 5.48% | | | | | | | | |
| Min. | −30.66% | −22.48% | - | −13.51% | | | | | | | | |
| Max. | 19.67% | 60.74% | - | 5.29% | | | | | | | | |
| Med. | −6.09% | 1.12% | - | 0.24% | | | | | | | | |

In order to determine the relation between the energy production and GDP the Pearson correlation coefficient was calculated. The hypothesis test of the significance of the correlation coefficient was performed. The aim of this test is to determine if a linear relationship in a sample is statistically significant and can be used to model the relation in the whole population. Therefore, two research hypotheses were put forward:

- Null hypothesis: *H0*: $\rho = 0$, the correlation is not significantly different from 0, meaning that there is no relation between coefficients,
- Alternate hypothesis: *Ha*: $\rho \neq 0$, the correlation is significantly different from zero, meaning that there is relation between coefficients.

The significance level was 5%, $\alpha = 0.05$. The results are presented in Table 3.

**Table 3.** The results of the research. Source: own calculations on the basis of [31,32].

| | Austria | | | | Belgium | | | | Bulgaria | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| SRC-GDP | 0.70 | 0.72 | −0.50 | 0.79 * | 0.65 | −0.36 | −0.37 | 0.62 * | 0.74 | −0.43 | 0.08 | 0.36 * |
| *p*-value | 0.034 | 0.027 | 0.17 | 0.01 | 0.05 | 0.34 | 0.33 | 0.07 | 0.02 | 0.2519 | 0.8279 | 0.3395 |
| CNV-RES | 0.43 | | | | −0.30 | | | | −0.26 | | | |
| *p*-value | 0.2463 | | | | 0.4291 | | | | 0.5029 | | | |
| | **Czechia** | | | | **Finland** | | | | **France** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| SRC-GDP | 0.44 | −0.07 | 0.07 | 0.43 * | 0.52 | 0.59 | −0.82 | 0.56 * | 0.77 | −0.31 | - | 0.74 * |
| *p*-value | 0.2366 | 0.8613 | 0.8658 | 0.2488 | 0.0195 | 0.4751 | 0.5273 | 0.11 | 0.0146 | 0.4098 | - | 0.023 |
| CNV-RES | 0.68 | | | | 0.75 | | | | −0.57 | | | |
| *p*-value | 0.0442 | | | | 0.0195 | | | | 0.1115 | | | |
| | **Germany** | | | | **Greece** | | | | **Hungary** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| SRC-GDP | −0.02 | 0.37 | −0.73 | 0.19 * | 0.28 | −0.29 | −0.44 | −0.05 * | 0.58 | 0.41 | 0.67 | 0.66 * |
| *p*-value | 0.96 | 0.3314 | 0.027 | 0.6151 | 0.4605 | 0.2492 | 0.2386 | 0.90 | 0.099 | 0.2699 | 0.0485 | 0.052 |
| CNV-RES | −0.79 | | | | 0.04 | | | | 0.25 | | | |
| *p*-value | 0.0115 | | | | 0.0195 | | | | 0.1115 | | | |
| | **Ireland** | | | | **Italy** | | | | **Macedonia** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| SRC-GDP | −0.06 | 0.10 | −0.76 | −0.23 * | 0.63 | −0.05 | −0.27 | 0.73 * | 0.46 | −0.79 | - | −0.11 * |
| *p*-value | 0.8762 | 0.7932 | 0.0167 | 0.5453 | 0.0691 | 0.8942 | 0.4851 | 0.0257 | 0.2099 | 0.0122 | - | 0.7725 |
| CNV-RES | −0.58 | | | | −0.18 | | | | −0.59 | | | |

**Table 3.** *Cont.*

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *p*-value | 0.0991 | | | | 0.6399 | | | | 0.0936 | | | |
| | **Poland** | | | | **Portugal** | | | | **Romania** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| SRC-GDP | 0.01 | 0.38 | 0.77 | 0.15 * | 0.30 | −0.23 | −0.41 | −0.08 * | 0.36 | 0.03 | - | 0.21 * |
| *p*-value | 0.9795 | 0.3156 | 0.0152 | 0.6958 | 0.4276 | 0.5502 | 0.2761 | 0.8420 | 0.3374 | 0.9328 | - | 0.5848 |
| CNV-RES | −0.55 | | | | −0.33 | | | | 0.12 | | | |
| *p*-value | 0.1264 | | | | 0.3863 | | | | 0.7658 | | | |
| | **Serbia** | | | | **Slovakia** | | | | **Spain** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| SRC-GDP | −0.17 | 0.06 | −0.42 | −0.07 | 0.03 | 0.66 | 0.26 | 0.26 | 0.71 | −0.36 | −0.38 | −0.26 |
| *p*-value | 0.6654 | 0.8838 | 0.2570 | 0.866 | 0.9345 | 0.0526 | 0.4937 | 0.4963 | 0.0317 | 0.3341 | 0.3075 | 0.5048 |
| CNV-RES | −0.66 | | | | −0.05 | | | | −0.78 | | | |
| *p*-value | 0.0538 | | | | 0.9067 | | | | 0.0137 | | | |
| | **Sweden** | | | | **Switzerland** | | | | **The Netherlands** | | | |
| | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** | **CNV** | **RES** | **Other** | **Total** |
| SRC-GDP | 0.40 | −0.10 | −0.11 | 0.23 * | 0.27 | 0.47 | 0.46 | 0.52 * | 0.18 | −0.39 | 0.02 | 0.12 * |
| *p*-value | 0.291 | 0.798 | 0.7809 | 0.5519 | 0.4758 | 0.1964 | 0.217 | 0.1539 | 0.6507 | 0.3042 | 0.9602 | 0.7524 |
| CNV-RES | 0.33 | | | | 0.27 | | | | −0.36 | | | |
| *p*-value | 0.3814 | | | | 0.4744 | | | | 0.3395 | | | |
| | **Turkey** | | | | | | | | | | | |
| | **CNV** | **RES** | **Other** | **Total** | | | | | | | | |
| SRC-GDP | −0.01 | 0.10 | - | 0.05 * | | | | | | | | |
| *p*-value | 0.9803 | 0.8 | - | 0.9015 | | | | | | | | |
| CNV-RES | −0.88 | | | | | | | | | | | |
| *p*-value | 0.0019 | | | | | | | | | | | |

* The relation between total energy production and GDP is in bold to point out the fact that the statistical relation between those two variables is of the most crucial importance from the author's perspective (as it includes all energy sources in a particular jurisdiction).

## 4. Discussion

Correlation measured with the Pearson correlation coefficient is not reflected in the data. Changes in power production, independently from the source of power, do not influence the GDP directly. Naturally, in some countries, the connection between power production (as a total production) and GDP is stronger, with the Pearson correlation coefficient being at quite high levels—e.g., Austria (0.79), France (0.74), Great Britain (0.68), Hungary (0.66—although here the relationship is statistically insignificant) and Italy (0.73). However, when comparing these results to the rest of the researched countries, where correlations are low or even extremally low, we find the relationship to be random.

The correlations between conventional (CNV) power production and GDP or RES and GDP are also very weak and do not show straightforward dependency. The exceptions here are Austria (the correlation between RES and GDP is 0.72) and Poland (the correlation between other sources and GDP is 0.77).

Better results are obtained with "visual" analysis, which means that the poor performance of GDP accompany lower dynamics of power production and vice versa. The highest growths of GDP were covered with the highest growths (or lowest decreases) of power production, and the worst economical periods represented by GDP collapse in 2020Q2 and 2020Q3 due to COVID lockdowns appeared after strong slow-downs of power plants resulting from falling energy consumption.

The hypothesis of balancing the production of RES by conventional power sources is mostly negatively verified. Pearson correlation coefficients between conventional (CNV) and RES are, in the majority of cases, extremely low (close to 0). There are only a few countries where this mechanism works: Germany (−0.79), Spain (−0.78) and Turkey

(−0.88). Obviously, Germany and Spain are big power producers (32% production among all researched countries); however, it is not enough to generalize the rule about conventional sources vs. RES balancing and it can only work in specific areas. This could be the result of power production structure, where RES production has a high share in total power production, and results from the abovementioned countries usually confirm this.

The research conducted by the authors of this article contribute to studies regarding the significant problem related to the relationship between energy and GDP. The conclusion which was derived from this research is that this relationship is not as significant as can be assumed. The authors are aware of the limitations of this study. These are mainly connected with the method (as Pearson correlation is rather simple, even if it is implemented with statistical significance analysis). The future research in this subject will relate to the attempt to evaluate the causality between those categories. It will enable us to better understand the direction between energy production and GDP growth. In this area, it is important to remember that numerous studies show that using the same variables and only changing the time periods may result in conflicting results [33]. Focusing more on energy production instead of energy consumption may be of some significance in future research.

It is obvious that economic growth should also take into account care for the natural environment. The structure of the sources of produced energy will have an increasing, long-term impact on energy production and GDP growth. It has become necessary to reduce carbon dioxide emissions, especially as energy consumption is increasing. This means moving away from conventional, exhaustible energy sources that pollute the environment (coal, oil), because the cost of climate change is unacceptable, even for countries in the Middle East, which are the main suppliers of crude oil. As a matter of fact, this region, or more precisely its deserts (with appropriate investment outlays for this purpose) is also capable of producing renewable energy (solar) that would easily supply at least some other regions of the world with renewable energy [34]. Directive 2009/28/EC considers energy from renewable sources, in addition to the aforementioned solar radiation energy—wind energy, aerothermal energy, geothermal energy, hydrothermal energy, ocean energy, hydropower, energy obtained from biomass and biogas, the source of which is landfills, sewage treatment plants and biological sources [35].

Apart from renewability, the features of such energy, e.g., wind energy, include: abundance, cleanliness, low environmental impact and relatively low energy-production costs. Of course, the investment costs are important, as is the prior unambiguous answer to the question about the feasibility of building, for example, a wind farm in a given area. Making a decision requires the estimation of the real energy potential, which in the case of, e.g., wind energy, is possible thanks to the analysis of the frequency distribution of wind speed (wind energy is proportional to the wind speed cube), and then the density of wind power and wind turbines [36]. The pre-investment process itself can therefore be lengthy and costly, not to mention the stage of proper implementation of the planned investment. This is an important factor in slowing down the shift to renewable energy production for many less prosperous countries. Meanwhile, in the directive already mentioned, we read that EU Member States were instructed to ensure that the share of renewable energy in the gross final energy consumption in the community in 2020 was 20% [37]. By 2030, the share of energy from renewable sources is expected to be 32% [37].

When we look at the energy mix in the selected countries, it can be seen that it varies significantly between countries. The highest level of conventional energy sources can be observed in Hungary (94.6%), Poland (88.6%), Bulgaria (83.9%), Czechia (87.3%) and the Netherlands (88.2%). On the other hand, among countries with the highest level of renewable sources we can see Latvia, Denmark, Estonia and Norway (100%), as shown in Table 4.

**Table 4.** Energy mix-calculated on the averaged production of 2018–2021. Source: own work on the basis of [31].

| | CNV | RES | Oth |
|---|---|---|---|
| Austria | 21.4% | 71.0% | 7.6% |
| Belgium | 74.2% | 18.3% | 7.5% |
| Bosnia and Hercegovina | 68.2% | 31.8% | 0.0% |
| Bulgaria | 83.9% | 15.2% | 0.9% |
| Czechia | 87.3% | 5.3% | 7.4% |
| Denmark | 0.0% | 100.0% | 0.0% |
| Estonia | 0.0% | 100.0% | 0.0% |
| Finland | 34.1% | 64.5% | 1.4% |
| France | 77.7% | 22.4% | −0.1% |
| Germany | 59.2% | 38.7% | 2.1% |
| Great Britain | 78.4% | 21.4% | 0.2% |
| Greece | 65.7% | 32.9% | 1.3% |
| Hungary | 94.6% | 2.9% | 2.5% |
| Ireland | 55.5% | 43.0% | 1.5% |
| Italy | 49.5% | 36.0% | 14.6% |
| Latvia | 0.0% | 100.0% | 0.0% |
| Lithuania | 0.0% | 81.1% | 18.9% |
| Macedonia | 68.8% | 31.2% | 0.0% |
| Montenegro | 46.8% | 53.2% | 0.0% |
| Norway | 0.0% | 100.0% | 0.0% |
| Poland | 88.6% | 10.8% | 0.6% |
| Portugal | 46.4% | 46.5% | 7.2% |
| Romania | 58.1% | 41.9% | 0.0% |
| Serbia | 67.2% | 29.5% | 3.3% |
| Slovakia | 67.8% | 14.6% | 17.6% |
| Slovenia | 66.0% | 32.4% | 1.5% |
| Spain | 50.1% | 46.0% | 3.9% |
| Sweden | 36.2% | 61.0% | 2.8% |
| Switzerland | 53.2% | 31.4% | 15.4% |
| The Netherlands | 88.2% | 10.1% | 1.6% |
| Turkey | 64.8% | 35.2% | 0.0% |

As is derived from the table, reaching the required level of energy obtained from renewable energy may be a big challenge for some countries, but the growing costs of extracting conventional fuels and excessive $CO_2$ emissions, which mean high financial penalties for exceeding the pollution limits, which increases the costs of electricity production, and therefore its price, and then the costs of economic activity—also have a negative impact on the GDP growth rate. The report of the Jagiellonian Institute shows that switching to low-emission energy in Poland by 2040, despite the necessity to incur investment costs (between PLN 250 and 400 billion), will be able to provide the economy with stable development for up to 30 years and contribute to significant GDP growth (by about PLN 200–310 billion) [38].

To conclude, the energy policy of European countries is diversified, although each one is strategically focused on increasing energy production from renewable energy sources and improving energy efficiency. For example, Austria does not use nuclear energy, relying on hydropower (50% of energy production), but the potential for its expansion is limited, hence Austria opens up to other sources of green energy [39]. Austria plans to achieve carbon neutrality by 2040 at the latest.

France, on the other hand, bases its energy policy on low-emission nuclear energy, while being its largest supplier/exporter in Europe (it is also one of the world's leading suppliers of nuclear power plants and reactors). Attention is also paid to the activity of France in the field of counteracting the effects of climate change [40].

Italy is dependent on energy imports (it is planned to reduce its share to 68% by 2030). The Italian climate plan for 2030 is focused on renewable energy and increasing energy efficiency, and its implementation is to result in a 33% reduction in greenhouse gas emissions (coal withdrawal by 2025). Reaching the 22% share of renewable energy sources is to be achieved thanks to the quota for advanced biofuels, as well as four million electric vehicles and two million hybrid vehicles, although this task will be difficult to implement [41].

In summary, changes in the energy policy will undoubtedly affect the economy of European countries in the future (both in the short and long term), and in this context, research on the relationship between energy issues and their impact on macroeconomic figures should be continued.

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