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The Impact of Energy Development of the European Union Euro Area Countries on CO_2 Emissions Level

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Abstract: In the last years, the fact of anthropogenic impact on climate change taking place in the world has become indisputable. Both countries and international organizations have taken steps to reduce GHG emissions, move to a low-carbon economy and implement solutions that reduce human impact on the environment. The EU, by intensifying its activities, has also prepared a strategy known as the European Green Deal. In implementing the EGD, it is important to analyze the impact of energy development in energy-intensive sectors of the economy (industry, transport, agriculture, services and other cores) on atmospheric pollution. Energy development is understood as the energy consumption percentage from all its consumption. In the article, complex correlation–regression analysis was implemented, which included not only energy development impact on the CO_2 emissions level (i.e., production-based CO_2 efficiency), but also its impact on economic growth. The research was conducted for the EU euro area countries. It was determined that the strongest positive correlation is to be found in the transport sector, which implies that with an increase in energy consumption in that sector, production-based CO_2 efficiency is increasing. On the other hand, this increment in efficiency was relatively small and was achieved with the rapid growth of the energy consumption. The implemented research confirmed that the transportation sector is the one which is polluting the atmosphere the most with CO_2 emissions in the Eurozone. The results of the implemented research could be used for the formation of targeted measures for the green growth strategy implementation, and also for ECB and EIB to support "green" projects.

Keywords: CO_2 emission; euro countries; European green deal; energy development; sustainable economic growth; environment pollution

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1. Introduction

Today, not only Europe but all the world is facing escalating environmental challenges related to climate change and the degradation of the environment. The growing scale of this problem requires urgent and radical solutions. Environmental and climate change policies implemented by global organizations have already brought some benefits. On the other hand, the growing use of natural resources linked to economic development poses a growing threat to the environment and climate change [1]. The European Union Commission's response to the deteriorating ecological situation is the European Green Deal. Its goal is to achieve sustainable economic growth. It is a new strategy to build a healthy and prosperous society based on a modern resource-efficient and competitive economy. It should achieve zero greenhouse gas emissions by at least 55% by 2030, compared with 1990 levels [2]. The European Union produced approximately 2.54 billion metric tons of carbon dioxide emissions in 2020. This was a reduction of 13% when compared to 2019 levels [3]. This was due to the outbreak of the COVID-19 pandemic. After a transitional period of lockdowns, CO_2 emissions began to increase again along with the post-crisis economic recovery.

The importance of ecological development in the green deal strategy is not accidentally emphasized. The solution for at least two fundamental human problems depends on this: the economical use of non-renewable natural resources and the improvement of the quality of life through a healthy environment. The measures taken to reduce greenhouse gas emissions are comprehensive measures aimed at the broadly understood energy transformation, with particular emphasis on support for the development of the renewable energy sector. A healthy environment is first and foremost the clean air. Constant breathing even in lightly polluted air gradually accumulates harmful substances in the human body. They become the cause of various types of chronic diseases such as lung diseases, cancers, allergies, etc. Hence, the special role of institutional support in supporting the energy transformation is emphasized. Without transnational action it will not be possible to solve the most important current problems of mankind.

One of the most polluting areas of human activity is the energy sector, which produces the most greenhouse gases, along with its main air-pollutant carbon oxides, CO and CO_2. It accounts for about 33% emissions of greenhouse gases in the atmosphere and contributes the most to climate change [4].

The OECD organization uses five main economic sectors related to the energy development industry, agriculture, transport, services and other sectors in defining green growth [5]. Special attention is dedicated to the industrial sector. The most dangerous source of atmospheric pollution in the industrial sector is the combustion process, which increases the amount of carbon oxides in the atmosphere. This process is typical for cement production, chemicals, oil refineries, power plants, boilers, etc. In the agricultural sector, livestock and poultry farms are the biggest polluters. In addition to carbon oxides they emit an abundant amount of ammonia and methane. The transport sector is a growing threat, especially for cities. The amount of carbon dioxide in the air is increasing due to the increase in traffic, the use of old cars, etc. The services sector is characterized by relatively lower emissions [4,5].

Research into the interaction between economic growth and energy development has been going on for a long time [6]; however, most of it examines this interaction at the country or international organization level [7]. Less attention is paid to the analysis of the impact of energy development of each economic sector on economic growth. Even fewer studies have focused on the effects of the atmospheric pollution.

Therefore, the goal of this article is to determine the impact of energy development in the economic sectors of the EU euro area countries on CO_2 emissions (environmental changes). To reach the goal, the correlation–regression analysis of the impact of energy development for the economic sectors of the European Union euro area countries on atmospheric pollution with carbon oxides was used. It highlighted the most carbon-polluting economic sectors of the economy, namely the transport and the agriculture sectors. This will also help to provide effective measures to increase the efficiency of energy development and to target measures for the green growth strategy implementation, but also for the European Central Bank and the European Investment Bank to support "green" projects.

2. Literature Review

Economic growth today is impossible without energy consumption. This interaction has been studied for a long time, since the 1960s [6]. The analysis is characterized by the fact that in previous studies energy development has been given a secondary role as a factor of economic development [8–10]. In recent studies on economic growth and energy consumption, the range of factors influencing interactions has been significantly expanded to include, among other things, the essential environmental aspect [11–16].

Environmental pollution, because of the interaction of energy development with economic development, has become an important object of research. In this way, these three phenomena—economic growth, energy development and environmental pollution—represent a single complex problem (Figure 1). The first component in the literature is described in two terms: economic growth or economic development. It is generally accepted that it is reflected in the gross domestic product per capita. In the green growth strategy, the energy development of the country's economic sectors is reflected as a percentage of the total energy consumption [17].

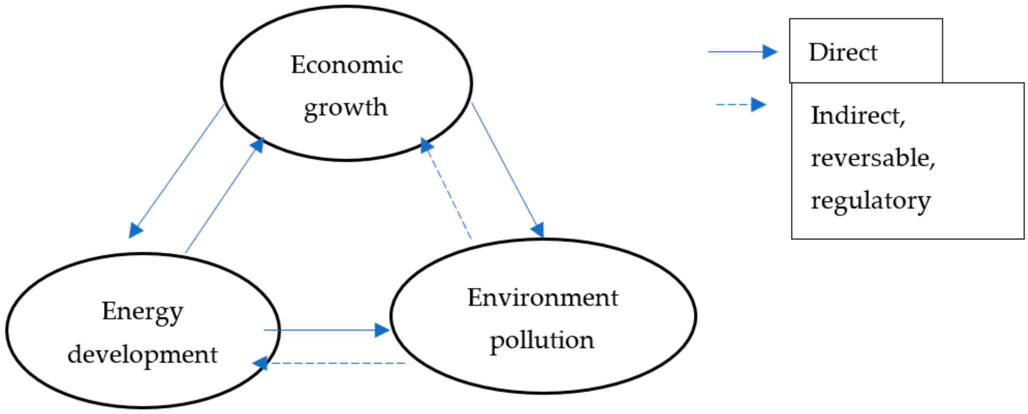

Figure 1. Economic growth and energy development impact on environment (source: Made by the authors).

Thus, in the context of a green growth strategy, the nature of the relationship between all three components needs to be identified. Research on environmental pollution has highlighted CO_2 emissions as a major cause of global warming. To reduce its impact, global and regional strategies are increasingly focusing on the use of green energy [18–20]. The European green deal was designed to reduce greenhouse gas emissions [1,2]. The European Commission proposed the green deal strategy aimed at transforming the EU into a modern resource-efficient society with a competitive economy. The activities undertaken by the European Union are aimed both at creating a legal framework for a just energy transition as well as a financial framework to support individual projects at the micro- and macroeconomic level.

The EU has led by example in setting ambitious targets for reducing net emissions by at least 55% by 2030 compared with 1990 and for being the first climate neutral continent by 2050 [21]. This means a transition to clean and technologically advanced energy. In this context, research focused on the interaction between energy development and CO_2 is becoming particularly relevant (Figure 1).

Today, the research on this topic is well enough developed [22–31], although it lacks complexity. In Figure 1 the presented three phenomena are not analyzed as one system. In these studies, it has been observed that when economic development is driven by energy development CO_2 emissions increase, but when they reach a certain level these emissions start to decrease [32]. It was concluded that there is a need for a certain economic growth level that neutralizes ecological problems.

This situation is described by a U-shaped curve named as the Kuznets environmental curve [33]. The author presents a hypothetical relationship between various indicators of environmental degradation and income per capita. In the initial stage of economic growth environmental pollution increases, but after reaching a certain level of high income of the population the opposite trend emerges and the ecological situation begins to improve. Thus, the environmental impact indicator of economic development is the inverted U-shape function of income per capita. The Kuznets curve is used by most authors to examine the interaction between economic development and the environment [34–37].

The U-shaped nature of this interaction can be explained by three factors [38]: economy of scale, economic structure (transition to the service sector) and innovative electricity generation technologies. The theoretical analysis of the relationship and interaction between economic growth and greenhouse gas emissions is dominated by two directions. The authors of the first direction focus on the analysis of economic growth in the context of the Kuznets curve and aim to test and validate hypotheses about pollution reduction with accelerating economic development [37,39–42]. Research regarding the other direction focuses on the relationship between economic growth and energy consumption and eliminates the environmental dimension. Emphasis is placed on economic growth at the expense of increasing energy consumption [43,44]. An essential aspect of research is the identification of the relationship type [22,34,43,45–47]. Thus, there is a lack of research linking economic growth, energy development and environment pollution (Figure 1). In the context of the green deal, it is essential to systematically analyze the economic growth, energy consumption and gas emissions when modeling adequate energy policy measures [26,48]. There are studies that analyze the combination of those three indicators [48–50]. The field of research implemented in this direction in the last years and the methods used are presented in Table 1.

Table 1. Fields of research.

Reference	Research Field	Sectors, Regions	Research Methods
[32]	A set of environmental indicators, air and water pollution is analyzed. The concept of the U-curve is presented	USA, GDP	Reduced-form relationship between per capita income and various environmental indicators
[34]	Long-term effects between per capita CO_2 emissions, per capita energy consumption, unemployment rate and GDP are examined	Turkey	Autoregressive distributed lag (ARDL)
[35]	Causal research between economic growth and CO_2 emissions	Malaysia, research data timeline 1980–2009	Autoregressive distributed lag (ARDL)
[37]	Studies on the ratio of CO_2 emissions (tonnes) to GDP (USD billion)	Croatia, 1992–2011	Autoregressive distributed lag (ARDL)
[39]	The impact of renewable energy on the interaction between CO_2 and economic growth and pollution	East Asia, Western Europe, Eastern Europe, Central Asia, Latin America, Middle East and North Africa, South Asia, Sub-Saharan Africa	Dynamic ordinary least squares method (DOLS), vector error corrections, Granger causality studies.
[51]	CO_2 emission, energy consumption, economic development relations	ASEAN countries, 1980–2006	Dynamic ordinary least squares method (DOLS), vector error corrections, Granger causality studies.
[52]	Research on the impact of CO_2 on economic growth	58 countries, 1992–2002	Dynamic panel data model estimated by means of the Generalized Method of Moments (GMM)
[48]	Research on CO_2, energy consumption, economic growth	116 countries, 1990–2014	Panel vector autoregressive (PVAR) along with a system generalized method of moment (System GMM)
[53]	CO_2, energy production, trade openness and economic growth research	Brazil	Fully modified ordinary least squares method (FMOLS) Dynamic ordinary least squares (DOLS)
[54]	CO_2 emissions, GDP, oil prices, trade openness, energy consumption	India	Nonlinear autoregressive distributed lag (NARDL) method

Source: Compiled by the authors.

The first table shows that, although studies of the different regions revealed a different situation, in the context of global economic growth the Kuznets curve was proven. The implemented research is characterized by the fact that in order to systematically confirm the positive impact of economic growth on the environment, a point where the nature of the curve begins to change is sought. Such research is particularly relevant for the developing economy countries, which are characterized by highly energy-intensive economic growth.

3. Data and Methodology

In order to define the impact of the energy development on the country's economic sectors' environmental pollution, it is necessary to select indicators that describe it. The needed indicators can be found in the OECD Green Growth Strategy indicator system [5]. It identifies five sectors of the economy and provides information on their energy consumption. The indicator of renewable energy supply was also included in the analysis to determine its impact on gas emissions (Table 2).

Table 2. Green growth energy consumption productivity indicators.

No.	Indicator description
1	Energy consumption in industry, % total energy consumption
2	Energy consumption in agriculture, % total energy consumption
3	Energy consumption in transport, % total energy consumption
4	Energy consumption in services, % total energy consumption
5	Energy consumption in other sectors, % total energy consumption
6	Energy intensity, TPES per capita
7	Renewable energy supply (excluding solid biofuels), % total energy supply

Source: OECD, 2011.

Out of the nine indicators reflecting CO_2 productivity provided in the above-mentioned system of indicators, four essential were taken into account (Table 3).

Table 3. Green growth CO_2 efficiency indicators.

	Indicator Name	Indicator Description
1	Production-based CO_2 productivity, GDP per unit of energy-related CO_2 emissions	Indicator is calculated as real GDP generated per unit of CO_2 emitted (USD/kg). Included are CO_2 emissions from combustion of coal, oil, natural gas and other fuels.
2	Production-based CO_2 emissions, Index	Production-based CO_2 emissions are also expressed as an index with values in 2000 normalized to equal 100.
3	Production-based CO_2 emissions	Production-based CO_2 emissions are expressed in million metric tons.
4	Demand-based CO_2 emissions	Indicator is measured in million metric tons. Demand-based emissions reflect the CO_2 from energy use emitted during the various stages of production of goods and services consumed in domestic final demand, irrespective of where the stages of production occurred.

Source: OECD, statistics.

Information on the values of energy development and CO_2 indicators is given in the OECD database [5]. Correlation–regression analysis was used to determine the impact of energy development and renewable energy supply on CO_2 productivity indicators in the country's economic sectors. Calculations were performed based on the model:

$$Y_i^T = f\left(X_{ijk}^T\right) \tag{1}$$

Y_i^T—indicator i reflecting changes in CO_2 productivity over the reference period T;
X_{ijk}^T—j country, k—economic sector energy development (renewable energy supply) during time T.

The aim of the article is to identify the impact of the energy development of the country's economic sectors on environmental changes. Consequently, it is important to analyze the changes that have taken place during the period, but not to consider these variables at a given point in time. It could be done using the following equations:

$$\Delta Q_{ijk}^{T} = Q_{ijk}^{TF} - Q_{ijk}^{TB} \tag{2}$$

$$\Delta S_{ijk}^{T} = S_{ijk}^{TF} - S_{ijk}^{TB} \tag{3}$$

ΔQ_{ijk}^{T} —j country, k—economic sector energy development during analyzed time T period;
Q_{ijk}^{TF}—j country, k—economic sector energy development, i—indicator at the end of analyzed time period;
Q_{ijk}^{TB}—j country, k—economic sector energy development, i—indicator at the beginning of the analyzed time period;
ΔS_{ijk}^{T}—j country, k—economic sector CO_2 productivity during analyzed time T period;
S_{ijk}^{TF}—j country, k—economic sector CO_2 productivity, i—indicator at the end of analyzed time period;
S_{ijk}^{TB}—j country, k—economic sector CO_2 productivity, i—indicator at the beginning of analyzed time.

The data was given a unified format in the calculations. The method of transforming the values of the indicators depends on how the electricity consumption changed at the end of the analyzed period T. The situation is compared to its beginning, whether it has increased or decreased. In the case of a value increase, the recalculation of the values was performed in this way:

$$X_{ijk}^{T} = \frac{\Delta Q_{ijk}^{(-)max} + \Delta Q_{ijk}^{(-)}}{\Delta Q_{ijk}^{(-)max}} \tag{4}$$

If values decrease, the following equation is applied:

$$\widetilde{X}_{ijk}^{T} = \frac{\Delta Q_{ijk}^{(-)max}}{\Delta Q_{ijk}^{(-)max} + \Delta Q_{ijk}^{(+)}} \tag{5}$$

X_{ijk}^{T} —j country, k—economic sector energy development during analyzed time T period, i—indicator transformed value, when situation improved;
$\widetilde{X}_{ijk}^{T}$ —j country, k—economic sector energy development during analyzed time T period, i—indicator transformed value, when values decreased.

Similarly, the values of CO_2 productivity indicators were transformed. If CO_2 emissions decreased during the period considered, the conversion was performed as the following equations:

$$Y_{ijk}^{T} = \frac{\Delta S_{ijk}^{max} + \Delta S_{ijk}}{\Delta S_{ijk}^{max}} \tag{6}$$

If values decreased:

$$\widetilde{Y}_{ijk}^{T} = \frac{\Delta S_{ijk}^{max} - \Delta S_{ijk}}{\Delta S_{ijk}^{max}} \tag{7}$$

Y_{ijk}^{T}—j country, k—economic sector CO_2 productivity during analyzed time T period, i—indicator transformed value, when situation improved.
$\widetilde{Y}_{ijk}^{T}$—j country, k—economic sector CO_2 productivity during analyzed time T period, i—indicator transformed value, when situation worsened.

We will get the impact of energy development of the country's economic sectors on CO_2 productivity by determining their generalized rank.

4. Empirical Results and Discussion

The basis for analyzing the interaction between energy development and CO_2 productivity in the economic sectors is the OECD framework for green growth indicators [5].

Correlation–regression analysis was based on the described Equation (1). Specific symbols were given to energy development and CO_2 productivity indicators (Table 4). Based on Equations (2)–(7), the values were transformed. The results of the calculations are provided in Table 5.

Table 4. Symbols of energy development and CO_2 productivity indicators for economic sectors.

Energy Development Indicators for Economic Sectors		CO_2 Productivity Indicators	
Energy consumption in industry, % total energy consumption	X1	Production-based CO_2 productivity, GDP per unit of energy-related CO_2 emissions	Y1
Energy consumption in agriculture, % total energy consumption	X2	Production-based CO_2 emissions, Index, 2000 = 100	Y2
Energy consumption in transport, % total energy consumption	X3	Production-based CO_2 emissions	Y3
Energy consumption in services, % total energy consumption	X4	Demand-based CO_2 emissions	Y4
Energy consumption in other sectors, % total energy consumption	X5		

Table 5. Transformed values of energy development indicators of the economic sectors of the euro area countries of the European Union.

Country	Values of the Indicators								
	Economic Sectors (See Table 4)					CO_2 Productivity (See Table 4)			
	X1	X2	X3	X4	X5	Y1	Y2	Y3	Y4
Belgium	0.68	1.08	1.37	1.06	0.96	1.14	1.15	0.09	0.19
Slovakia	0.41	1.00	0.45	2.00	1.18	1.50	1.08	0.02	0.19
Slovenia	0.50	1.04	0.41	1.23	1.79	1.20	1.32	0.02	0.03
Portugal	0.83	0.80	0.65	0.83	1.56	1.20	1.31	0.09	0.18
Germany	0.52	0.63	0.75	1.40	1.36	1.14	1.09	0.36	0.05
Estonia	1.87	0.73	0.53	0.79	1.32	1.08	0.82	−0.02	−0.02
Ireland	0.39	1.17	1.20	1.11	1.40	1.68	1.33	0.07	0.12
Greece	0.83	2.00	2.00	0.83	0.68	1.08	2.00	0.43	0.51
Spain	0.86	0.80	1.17	0.74	1.36	1.20	1.30	0.41	0.72
France	0.73	1.00	0.60	0.91	1.49	1.24	1.22	0.49	0.61
Finland	0.43	1.17	1.30	1.05	1.27	1.19	1.57	0.15	0.09
Italy	1.53	0.92	1.00	0.83	0.96	1.19	1.49	1.00	1.00
Cyprus	1.13	0.83	1.03	0.78	1.22	1.14	1.58	0.02	0.34
Latvia	0.35	0.62	0.75	1.00	2.00	1.20	1.00	0	1.00
Lithuania	0.91	1.17	0.42	1.21	1.38	1.30	1.08	0.005	0.005
Luxembourg	1.50	1.08	1.07	0.72	1.08	1.30	1.44	0.02	0.007
Malta	2.00	0.96	1.17	0.58	1.09	2.00	1.21	0.01	0.09
Austria	0.77	1.00	0.56	1.19	1.22	1.14	1.06	0.02	0.04
Netherlands	0.64	0.89	1.17	1.08	1.14	1.00	1.17	0.14	0.28

Source: Compiled by the authors.

The results of the correlation–regression analysis are presented in Table 6. It shows that the best results of economic development were obtained in the transport sector. This is followed by industry, agriculture and other sectors. Only in the services sector the situation is opposite, with an increase in energy consumption production-based CO_2 efficiency is declining. This relationship is probably due to the non-effective use of old technologies in the service sector. On the other side, good economic development results in the transport sector reflect the quantitative side of it. The qualitative side is reflected in the energy efficiency indicator Y1. It can be seen that the scale of GDP growth is slightly higher than the scale of growth of energy consumption, when evaluated in terms of the equation Y1 = f(X3) (Table 6). It can be seen that as energy consumption increases production-based CO_2 productivity also increases, and for the one unit of energy-related CO_2 emission higher GDP is related. On the other hand, this increase is small: with a 1% increase in energy consumption GDP increases by 1.4%. Considering that CO_2 emissions significantly increase the greenhouse effect, the economic benefits are unlikely to outweigh the environmental damage. In addition, GDP may increase for other reasons. Based on what kind of energy consumption the economic result was achieved, reveals the energy consumption in economic sectors impact on CO_2 emission indicators Y2, 3, 4.

Table 6. Impact of energy development of the economic sectors of the euro area countries of the European Union in the period 2004–2018 on CO_2 productivity.

Regression Equation	Correlation Coefficient	Rank
Y1 = −22.23 + 1.24X1	0.70	3
Y1 = −20.81 + 10.81X2	0.71	4
Y1 = −33.99 + 1.27X3	0.81	5
Y1 = −16.68 + 1.75X4	0.63	2
Y1 = 35.42 − 0.97X5	−0.98	1
Y2 = 0.97 + 0.30X1	0.73	2
Y2 = 0.83 + 0.44X2	0.55	3
Y2 = 0.74 + 0.54X3	0.85	1
Y2 = 1.33 − 0.05X4	−0.05	5
Y2 = 0.74 + 31X5	0.45	4
Y3 = −0.28 + 0.82X1	0.55	3
Y3 = −0.23 + 0.29X2	0.82	5
Y3 = −0.11 + 0.19X3	0.79	4
Y3 = 0.004 + 0.06X4	0.24	1
Y3 = −0.42 + 0.43X5	0.44	2
Y4 = −0.26 + 0.66X1	0.80	5
Y4 = −0.12 + 0.20X2	0.24	2
Y4 = −0.10 + 0.25X3	0.75	4
Y4 = 0.85 − 0.54X4	−0.57	1
Y4 = −0.26 + 0.35X5	0.25	3

Source: Compiled by the authors.

Table 6 shows that the highest production-based CO_2 productivity (Y1) is in the transport sector. This means that per one unit of CO_2 emissions most GDP value is generated. This is followed by the agricultural and industrial sectors. In this sense, the service sector is less efficient. Its CO_2 emissions do not have a major impact on GDP. The worst situation in other sectors, due to the increase in CO_2 emissions, GDP is declining.

The highest rates of CO_2 emissions are typical for the transport sector. This can be explained by the rapid increase in cars, especially second-hand cars. Better results are achieved in other sectors, where economic development is taking place in the face of declining energy consumption. On the other hand, this decline is conditional as the expansion of production at the expense of energy consumption, which is a condition for economic development, will continue to require energy resources, which will again have a negative impact on the environment. The current situation in the context is shown below (Figure 2) [55].

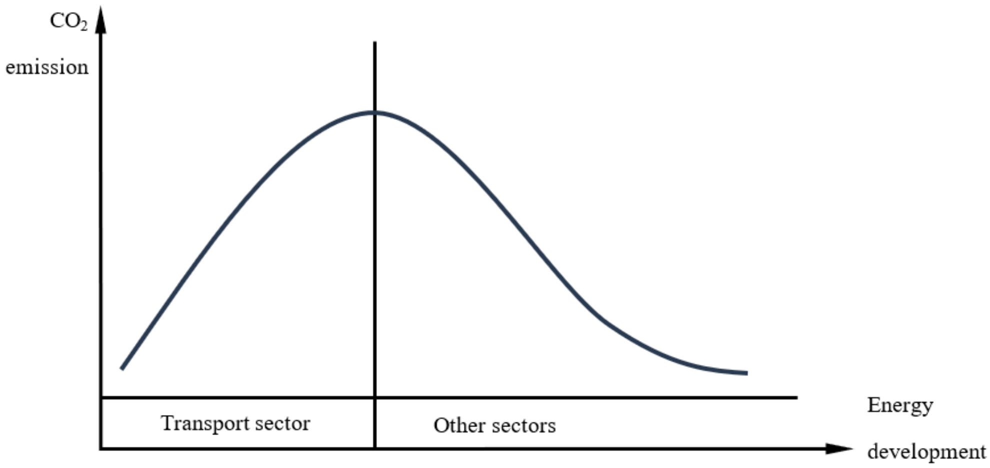

Figure 2. Current impact of energy development on CO_2 emissions (made by the authors).

The fact that the energy development of the transport sector is taking place at the expense of increasing CO_2 emissions is evidenced by the increasing emissions of these gases. In this sense, it significantly outperforms industry and other sectors of the economy.

The industry sector is the leader in on-demand based CO_2 emissions. This is not accidental, as it has energy-intensive branches that are characterized by combustion processes. During the researched period of 13 years, the industry sector demonstrated the highest amounts of CO_2 emissions. Vehicles operate based on other principles, they do not have some of the elements of the process, so in terms of the indicator they do not pollute the atmosphere as much. In the agriculture sector, the production process is prolonged and more gas is released into the atmosphere. The services and other sectors reflect a better situation.

After assessing the impact of the energy development of the individual economic sectors with CO_2 productivity indicators, a generalized picture of this interaction was obtained (Table 6). The services sector has the least impact on CO_2 productivity indicators, while transport and agriculture have the largest. The industry sector is a little bit behind them.

In summary, the correlation–regression analysis of the impact of energy development on CO_2 productivity in the euro area countries of the European Union, highlights the most carbon-polluting sectors of the economy: transport and agriculture. This means that the attention of the community institutions should be focused primarily on the introduction of cardinal measures in those sectors. In the transport sector, this is primarily the global shift to electric cars and the abandonment of diesel and old cars. In addition, priority should be given to train transport at the expense of air transport, which is the biggest producer of CO_2. The situation in agriculture could be improved by the application of modern energy-saving technologies in livestock and poultry farms.

Currently, the focus is on the industrial sector. The European industrial strategy prepared by the EU in 2020 provides a clear direction for its transformation; an ecological and digital transformation focused on the priorities of the implementation of the European Green Deal [2].

5. Conclusions

The implementation of the strategy for sustainable economic growth, which is the goal of the European Green Deal, to a large extent depends on energy development. On the other hand, this connection is contradictory as energy development poses growing environmental problems. The green growth strategy distinguishes five sectors of the country's economy, most of which are related to the energy development: industry, agriculture, transport, services and other sectors. Regarding the environmental impact of energy development, analysis first should be implemented at the level of economic sectors.

The correlation–regression analysis of the impact of energy development for the economic sectors of the European Union euro area countries on atmospheric pollution with carbon oxides highlighted the most carbon-polluting economic sectors of the economy. These are the transport and agriculture sectors. It has been established that the economic development of the transport sector is still taking place at the expense of increasing energy consumption, while in other sectors of the economy this development is taking place with a relative decrease in energy consumption. Despite the fact that production-based CO_2 efficiency is improving, the enhanced demand for transportation services still creates a burden for the EU economy when it comes to increased emissions of CO_2. The results of the analysis can be used at an EU level to formulate and implement targeted measures for a green deal strategy. Obviously, the transport sector should be a key area of the intervention; the promotion of train transportation at the expense of air transport seems to be unavoidable in the nearest future.

In further research directions, the general trends of the impact of energy development on CO_2 emissions set out in the article should be specified with detailed assessment of the individual sectors. Models should be developed that, in addition to the impact of energy development on air pollution, include the impact of this interaction on economic development. Further studies for the analysis of the interaction of economic sectors with CO_2 emissions in the context of the Kuznets curve could be seen as important.

Our analysis was conducted for the 2004–2018 period and for Eurozone countries only. In the case of research on energy development on atmospheric pollution it would be interesting to extend the empirical analysis further into the developing economies, especially in Africa and Asia. This direction of further research would also benefit from a more dynamic approach, which would enable investigation of the evolution of the energy development over time. Additionally, one obvious limitation of our approach was to not include the impact of the COVID-19 pandemic on the energy development. This is also a promising avenue for further studies.

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