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MARIUSZ PYRA[1]

John Paul II University in Biala Podlaska, Poland

THE ROLE OF THE GREEN ECONOMY IN SHAPING ECONOMIC GROWTH IN POLAND

Key words: green economy, economic growth, energy intensity, correlation, Poland

ABSTRACT. The aim of this paper is to examine and understand the impact of various green economy indicators on economic growth in Poland from 2010 to 2021. The study focused on a select number of indicators, including the final energy intensity of the economy, expenditures on environmental fixed assets in relation to gross domestic product (GDP), the share of renewable electricity in gross final electricity consumption, primary energy intensity of GDP, and the percentage of urban green areas. The relationship between green economy indicators and economic growth, expressed as gross domestic product *per capita*, was examined using regression analysis, time series analysis and correlation analysis. Data for the analysis were taken from the Central Statistical Office. Time trend analysis showed that the economy's final energy intensity and the share of renewable energy improved steadily over the period under review, with a positive impact on GDP *per capita*. Correlation analysis demonstrated a robust inverse correlation between energy intensity and GDP *per capita*, along with a positive association between the share of renewable energy and economic growth. In linear and multiple regressions, the economy's final energy intensity, expenditures on environmental fixed assets, and the share of renewable energy exhibited a significant impact on GDP *per capita*. The study's conclusions underscore the necessity of sustained and intensified efforts towards a green economy in Poland, which is pivotal for ensuring long-term economic growth and sustainable development.

[1] Corresponding author: m.pyra@dyd.akademiabialska.pl

INTRODUCTION

The transformation of the economy toward a more sustainable model is a key element of global strategies for sustainable development. The green economy, defined as an economy that promotes growth and development while preserving natural capital and minimizing negative environmental impacts, plays an important role in this process. In the context of Poland, studying the impact of the green economy on economic growth is an important research area that can provide valuable information for economic and environmental policy.

The concept of a green economy is multifaceted and encompasses various aspects. Two other related terms are green growth and sustainable development. Green economy refers to the state and structure of the economy, its nature and the way it functions. Green growth, in contrast, is dynamic in nature and refers to the use of green factors to enlarge economic effects (manufacturing resources, production, consumption, income) that can lead to development [Bąk and Cheba 2020].

The concept of a green economy was first proposed by David Pearce, Edward Markandya and Anil Barbier [1989], but it was not until the 21st century that the category began to be analysed in greater depth. The UNEP report [UNEP 2009] emphasised that the green economy should focus primarily on the efficient use of renewable energy sources, increased energy efficiency in buildings, sustainable transportation, green infrastructure, ecotourism and sustainable agriculture.

The OECD Council identified the necessity for the development of a green growth strategy, which would facilitate green investment and technological innovation, with the objective of contributing to economic recovery in the short term and the establishment of an environmentally neutral economy in the long term [OECD 2011].

In the European Union, the concept of the green economy emerged relatively late. The most significant documents in the EU pertaining to the green economy are the "Europe 2020 Strategy" and climate and energy policy documents, such as the "European Green Deal" [Pomykała and Raczyński 2020].

The potential of the green economy to stimulate economic growth was also underscored in academic research, which highlighted the capacity of the green economy to foster innovation and technology that can drive long-term economic growth and sustainability [Bowen and Frankhauser 2011, Janicke 2012, Egorova at al. 2015, Zenghelis 2016, Sulich 2021].

The aim of this article is to examine the impact of the green economy on economic growth in Poland from 2010-2021. The analysis was conducted using statistical data on green economy indicators. The article employed statistical methods, including regression analysis, time series analysis and correlation analysis, to identify key relationships and draw practical conclusions for economic and environmental policy.

RESEARCH METHODS AND DATA SOURCES

The green economy in Poland is the subject of systematic statistical surveys conducted by the Central Statistical Office. These surveys, based on methodology developed in accordance with international standards, are designed to monitor changes in the environment, economy and society. A number of key indicators of the green economy have been identified, including items such as natural capital (biodiversity, land use, forest resources, mineral resources), environmental production efficiency (water management, waste management, energy management, renewable energy, greenhouse gas emissions), and environmental quality. The quality of life for the population is also a key indicator of the green economy, encompassing issues such as gaseous and particulate air pollution, noise, access to drinking water, and the availability of green areas. Furthermore, economic policies and their implications are also relevant, including environmental expenditures, eco-innovation, green technologies, and green households [Daniek 2020].

The selection of green economy indicators for analysis of their impact on economic growth in Poland between 2010 and 2021 was based on several key criteria: their relevance to sustainable development, the availability of data, and their widespread use in the scientific literature. A focus on the final energy intensity of the economy, expenditures on environmental fixed assets in relation to GDP, the share of electricity from renewable energy sources (RES) in gross final consumption of electricity, primary energy intensity of GDP or the percentage of urban green space allows for a comprehensive assessment of various aspects of the green economy.

The final energy intensity of the economy reflects the amount of energy consumed per unit of GDP and is directly related to the energy efficiency of the entire economy. The ratio of expenditures on environmental fixed assets to GDP is an indicator that measures the value of investments in fixed assets to protect the environment relative to GDP. The share of renewable energy in total energy consumption is an indicator of the economy's transition to low-emission energy sources. The primary energy intensity of GDP refers to the amount of primary energy consumed per unit of GDP. The percentage of urban green space is an indicator that measures the percentage of green space, such as parks, squares and other green areas, in relation to the total urban area [Godlewska et al. 2023].

The study employed a range of statistical techniques to assess the impact of green economy indicators on Poland's economic growth between 2010 and 2021. These included regression, time series and correlation analysis.

All analyses were conducted using computer tools in the form of the Python language, version 3.12.3 (64-bit), and dedicated libraries. The following libraries were utilised: Pandas was employed for data processing and analysis, Matplotlib for graphing and data visualization, and Statsmodels for conducting regression analysis and time series modeling. Scripts in Python were written to automate the process of data analysis and graph generation.

The data used in the study was obtained from reliable and official sources that regularly publish statistics on various aspects of the green economy and macroeconomics. The data used in this study primarily originates from the GUS's (CSO) report on green economy indicators in Poland, as well as a report containing macroeconomic indicators. The 2010-2021 range was selected due to the availability of data on the CSO website, which publishes detailed data. The data from earlier years would not have been as pertinent, given the evolving technologies and policies related to the green economy. Furthermore, data for subsequent years (i.e., from 2022 onwards) was not available at the time of writing this work.

RESULTS

The figures 1-3 illustrate the evolution of green economy and economic growth indicators in Poland between 2010 and 2021. They present trend graphs for each indicator. Figure 1 illustrates a clear downward trend in the final energy intensity of the economy. In 2010, the index was 46.2, while in 2021 it fell to approximately 29.8. This indicates that over the period, energy intensity decreased by approximately 35%. Although the overall trend is downward, some years (e.g. 2016-2017) show stabilization or small increases. However, following 2017, energy intensity began to decline markedly once more.

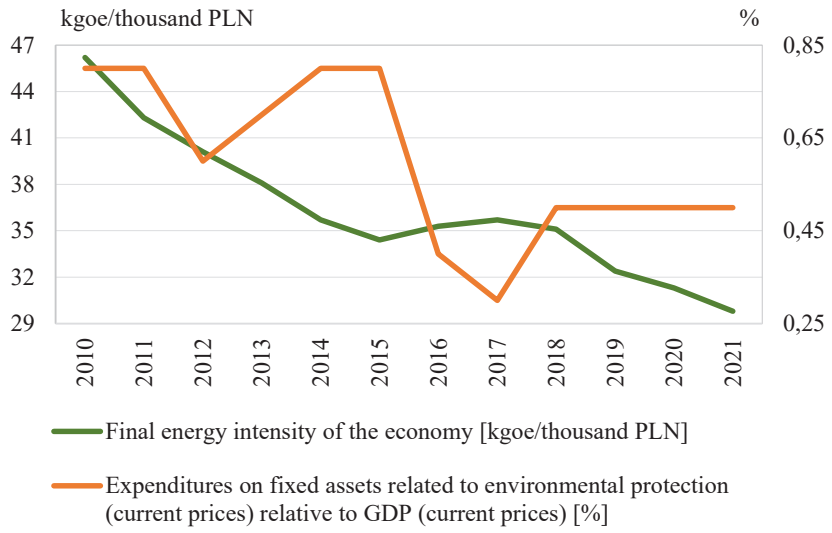

Figure 1. Trend for the indicator final energy intensity of the economy and expenditures on environmental fixed assets in relation to GDP

Source: own compilation based on the CSO data [GUS 2022]

During the 2010-2011 and 2014-2015 periods, expenditure on environmental fixed assets remained stable at approximately 0.8% of GDP. In 2012, there was a decline in outlays to approximately 0.6% of GDP. In 2015-2016, we observe a significant decline to approximately 0.3% of GDP in 2016. As of 2018, outlays on environmental fixed assets have stabilized at approximately 0.5% of GDP and remain at this level until 2021.

The GDP *per capita* demonstrates a consistent and sustained increase throughout the observation period, rising from approximately PLN 37,240 in 2010 to PLN 69,263 in 2021. This growth in GDP *per capita* is particularly evident after 2018, as illustrated in Figure 2.

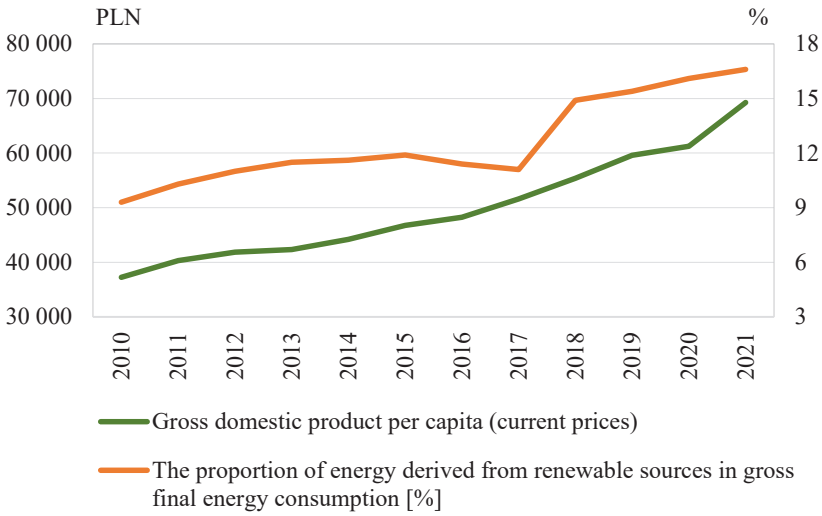

Figure 2. Trend for GDP *per capita* (current prices) and share of energy derived from renewable sources in gross final energy consumption

Source: own compilation based on the CSO data [GUS 2022]

Figure 2 depicts a clear upward trend in the share of RES in gross final electricity consumption. In 2010, the ratio was approximately 6.5%, while in 2021 it increased to approximately 17.2%. The increase in the share of renewable energy has been relatively consistent, with the exception of the 2015-2017 period, where the ratio remained at approximately 12-13%. Following 2018, there was a notable acceleration in the growth of the renewable energy share.

Figure 3 illustrates a clear downward trend in primary energy intensity of GDP. In 2010, the index was approximately 370, while in 2021 it decreased to approximately 260. The decline in energy intensity is relatively consistent, with several periods of stabilization, particularly between 2016 and 2018. The percentage of urban green areas

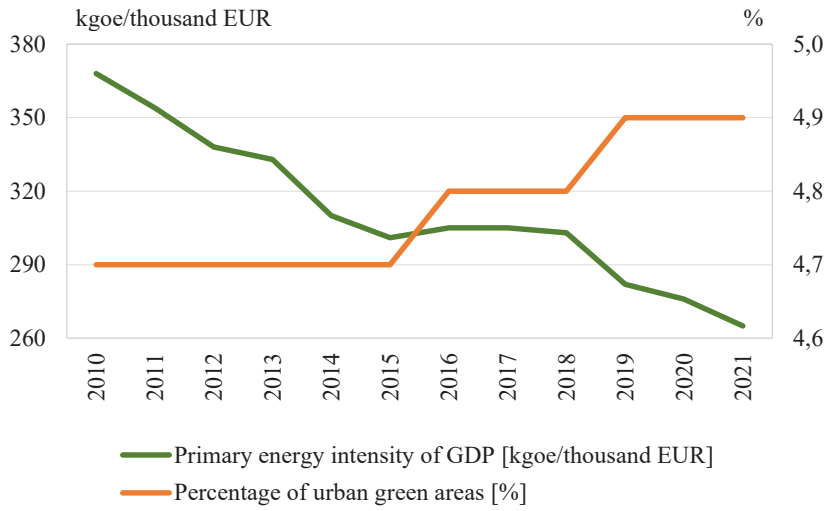

Figure 3. Trend for GDP primary energy intensity indicator [kgoe/thousand EUR] and percentage of urban green areas

Source: own compilation based on the CSO data [GUS 2022]

remained relatively stable at approximately 4.7% between 2010 and 2015. In 2016, Figure 3 increased to approximately 4.8%, before rising further to approximately 4.9% in 2019. Following this surge, the level of urban green space has since remained relatively stable at around 4.9% since 2019. A linear regression analysis was conducted for each indicator separately, followed by a multiple regression analysis incorporating all indicators (Table 1).

Table 1. Regression analysis for each indicator as independent variable and GDP *per capita* as dependent variable

Indicator	R^2	Factor	Intercept
Final energy intensity of the economy	0.876	-1.215	2,484.565
Expenditures on environmental fixed assets in relation to GDP	0.474	-0.034	68.253
Share of electricity from renewable sources in gross final consumption of electricity	0.898	0.807	-1,613.381
Primary energy intensity of GDP	0.930	-8.350	17,140.387
Percentage of urban green areas	0.841	0.022	-39.622

Source: own study

A high R^2 (0.876) indicates that the economy's final energy intensity accounts for a significant proportion of the variation in GDP *per capita*. A negative factor (-1.215) indicates that an increase in energy intensity is associated with a decrease in GDP *per capita*.

An R^2 of 0.474 was recorded for environmental fixed capital expenditures relative to GDP, suggesting a moderate relationship. A negative factor (-0.034) indicates that higher expenditures are associated with a slight decrease in GDP *per capita*.

The high R^2 (0.898) and positive factor (0.807) for the share of renewable electricity in gross final electricity consumption indicate a strong positive relationship between the share of renewable energy and GDP *per capita*.

The high R^2 (0.930) and negative factor (-8.350) indicate that higher primary energy intensity is associated with lower GDP *per capita*.

The high R^2 (0.841) and positive factor (0.022) suggest that there is a positive relationship between the percentage of green space and GDP *per capita*.

A positive factor (595.512) suggests that an increase in final energy intensity is associated with an increase in GDP *per capita*, assuming that other indicators are held constant (Table 2). Conversely, a negative factor (-6,130.281) indicates that higher expenditures are associated with a decrease in GDP *per capita*, assuming that other indicators are held constant. Finally, a positive factor (3,570.828) indicates a positive relationship between the share of renewable energy and GDP *per capita*.

A negative factor (-48.766) indicates that higher primary energy intensity is associated with lower GDP *per capita* (Table 2). A very high positive factor (71,520.237) suggests a strong positive relationship between the percentage of green space and GDP *per capita*. An R^2 of 0.950 indicates that 95% of the variation in GDP *per capita* can be explained by changes in these indicators.

Table 2. Multiple regression analysis with all indicators as independent variables and GDP *per capita* as the dependent variable

Indicator	Factor
The final energy intensity of the economy	595.512
The ratio of expenditure on environmental fixed assets to GDP	-6,130.281
The proportion of electricity generated from renewable sources in relation to the total consumption of electricity	3,570.828
The primary energy intensity of GDP	-48.766
The percentage of urban green areas	71,520.237
R^2	0.950
Intercept	-12,451.747

Source: own study

In order to gain a deeper understanding of the relationship between green economy indicators and economic growth, additional statistical analyses were conducted. These included tests of parameter significance, autocorrelation, heteroskedasticity and collinearity of explanatory variables (Table 3). The p-values in model one indicate that only the final and primary energy intensity indicators are statistically significant. In model two, none of the indicators are statistically significant, but environmental fixed capital expenditures as a proportion of GDP and the share of renewable electricity in gross final electricity consumption are close to significance at the 0.1 level. It is possible that the high p-values are due to collinearity between the variables, as confirmed by the VIF analysis. The Durbin-Watson test yielded a value of 1.909, indicating the absence of autocorrelation among the model residuals. This implies that the residuals are random and do not exhibit correlation with one another. The Breusch-Pagan test did not detect any significant heteroskedasticity in the residuals of the model. This suggests that the variance of the

Table 3. The results of statistical analyses of econometric models

Method	Values
OLS regression for single indicators	The p-values for the coefficients: – final energy intensity: 0.000; – environmental fixed capital expenditures: 0.128; – renewable electricity share in gross final electricity consumption: 0.116; – primary GDP energy intensity: 0.000; – surface area of urban green areas: 0.229
OLS regression for all indicators	The p-values for the coefficients: – final energy intensity: 0.908; – environmental fixed capital expenditures: 0.128; – renewable electricity share in gross final electricity consumption: 0.116; – primary GDP energy intensity: 0.882; – surface area of urban green areas: 0.229
Durbin-Watson test	DW = 1.909
Breusch-Pahan test	BP = 4.431; p = 0.489
VIF analysis	The VIF values for the coefficients: – final energy intensity: 86.89; – environmental fixed capital expenditures: 2.09; – renewable electricity share in gross final electricity consumption: 24.91; – primary GDP energy intensity: 146.68; – surface area of urban green areas: 9.91

Source: own study

residuals is constant, which is beneficial for the stability of the model. The VIF analysis revealed elevated values for final energy intensity and primary energy intensity, indicating a robust correlation between these variables. High collinearity may potentially impact the stability and interpretability of the regression model.

A correlation analysis was conducted using Pearson and Spearman coefficients for selected indicators. It was decided for this analysis to add an additional indicator, namely GDP in constant prices, in order to better capture the impact of changes in the green economy on the overall economy. In order to facilitate the interpretation of the Figures 1-3, the indicators have been assigned letter symbols (A – final energy intensity, B – environmental fixed capital expenditures, C – GDP *per capita*, D – GDP at constant prices, E – renewable electricity share in gross final electricity consumption, F – primary GDP energy intensity, G – surface area of urban green areas).

A – final energy intensity,
B – environmental fixed capital expenditures,
C – GDP *per capita*,
D – GDP at constant prices,
E – renewable electricity share in gross final electricity consumption,
F – primary GDP energy intensity,
G – surface area of urban green areas

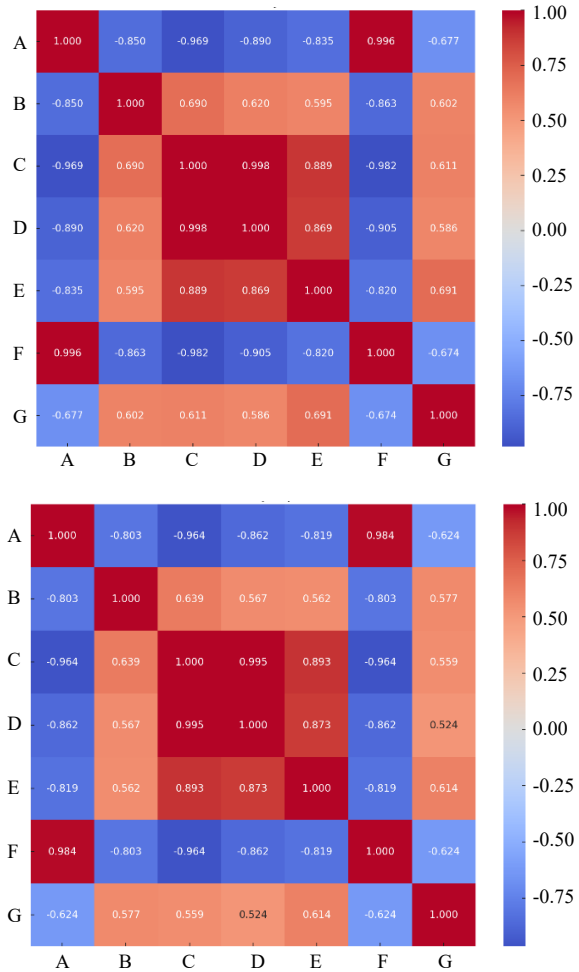

Figure 4. Pearson and Spearman correlation matrix

Source: own study

The Pearson and Spearman correlation matrices are presented in the form of a heatmap (Figure 4). The colours on the graph represent the strength and direction of the correlation between the various indicators, where red indicates a strong positive correlation and blue a strong negative correlation. Both matrices demonstrate the existence of robust correlations between certain variables, both positive and negative. The Pearson and Spearman correlations are comparable, suggesting that the relationships are both linear and monotonic. The F variable exhibits the strongest positive correlation with the A variable, indicating a robust association between their respective growth trajectories. Conversely, negative values, such as those observed between A and C, suggest a countervailing influence, whereby an increase in one variable is accompanied by a decline in the other.

CONCLUSIONS

The objective of this study was to assess the influence of selected green economy indicators on economic growth in Poland between 2010 and 2021. To this end, several analytical techniques were employed, including correlation analysis (Pearson's and Spearman's), regression analysis (linear and multivariate), and time trend analysis.

The analysis yielded several key conclusions. Firstly, improving energy efficiency is crucial for economic growth in Poland. A decrease in energy intensity is directly related to higher GDP *per capita*. Therefore, investing in energy-saving technologies and upgrading energy infrastructure should be a priority.

Secondly, investment in environmental protection, despite fluctuations, has a positive impact on the economy. Stable financing of environmental projects promotes sustainable growth. Therefore, long-term financing and support for such projects should continue and increase.

Thirdly, the expansion of renewable energy sources is a crucial factor in supporting economic growth. The promotion and support of renewable energy sources, such as wind, solar and biomass, through subsidies, tax breaks and support programmes can further increase GDP *per capita* and reduce greenhouse gas emissions.

Fourthly, the development of green urban spaces has a positive impact on the economy, supporting *per capita* GDP growth and improving residents' quality of life. Investment in green spaces, such as parks, gardens and green roofs, can enhance the health and well-being of residents, attract tourists and investors, and facilitate sustainable urban development. The above conclusions are consistent with the majority of previous studies on the subject. The World Bank document indicates that Poland has undergone a significant economic transformation since the early 1990s, moving to a market economy. This transformation has resulted in significant economic growth, and the incorporation of green economy strategies has the potential to further enhance this growth. The decarbonisation scenarios illustrate the potential macroeconomic impacts of a green transition, including the impact

on GDP *per capita*, the costs of adjustment, and the risks and trade-offs associated with the transition [WBG 2022]. The transition to a green economy presents a number of challenges for Poland, including the necessity to modernise energy infrastructure. However, it also offers numerous opportunities, such as the potential for the development of new industries and technologies that could drive economic growth [Kasztelan and Sulich 2024].

The Polish Economic Institute has also confirmed the thesis that the green economy plays a key role in shaping economic growth in Poland. Their findings indicate that investments in the green economy can accelerate GDP growth by 1.1 percentage points per year [PIE 2022]. Furthermore, Adam Juszczak and Wojciech Rabiega [2022] indicate that the transformation of the green economy has a moderately positive effect on economic growth. Moreover, countries with the highest rates of green economy development have experienced higher GDP growth compared to other EU countries.

It is also beneficial to provide additional context, as this will facilitate a more comprehensive understanding of the intricate interconnections between economic processes. Chunhua Xin, Shuangshuang Fan, William Mbanyele and Muhammad Shahbaz [2023] investigate the influence of the digital economy on inclusive green growth, demonstrating that the actual contribution of the digital economy to sustainable development is considerable. It is therefore evident that the role of innovation and industrial modernisation as an enabler of the green economy is emphasised [Albiman and Sulong 2017, Hao et al. 2023]. Conversely, Nguyen Song, Nguyen Phuong, Thai Oanh, Do Chien, Vu Phuc and Muhammad Mohsin [2021] highlight the importance of promoting sustainable development in order to effectively reduce emissions, achieve set targets and ensure continued economic growth. Consequently, the argument that the green economy represents an alternative vision of growth and development appears to be unassailable [Söderholm 2020, Chovancova et al. 2023, Dabyltayeva and Rakhymzhan 2019].

In conclusion, it can be stated that measures to enhance energy efficiency, expand the proportion of renewable energy, investments in environmental protection and the development of green urban spaces are crucial for ensuring long-term sustainable economic growth. The role of authorities at the local level should not be underestimated, as an integrated approach at this level can contribute to achieving national green economy goals [Dmuchowski et al. 2021]. The implementation of these recommendations can contribute to the improvement of the quality of life of residents, environmental protection and long-term economic development.

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ROLA ZIELONEJ GOSPODARKI W KSZTAŁTOWANIU WZROSTU GOSPODARCZEGO W POLSCE

Słowa kluczowe: zielona gospodarka, wzrost gospodarczy, energochłonność, korelacja, Polska

ABSTRAKT. Celem pracy jest zbadanie i zrozumienie wpływu różnych wskaźników zielonej gospodarki na wzrost gospodarczy w Polsce w latach 2010-2021. W badaniu uwzględniono kilka wybranych wskaźników, takich jak: energochłonność finalna gospodarki, nakłady na środki trwałe służące ochronie środowiska w relacji do PKB, udział energii elektrycznej ze źródeł odnawialnych w końcowym zużyciu energii elektrycznej brutto, energochłonność pierwotna PKB i odsetek powierzchni miejskich obszarów zielonych. Stosując metody analizy regresji, analizy szeregów czasowych i analizy korelacji zbadano związki między wskaźnikami zielonej gospodarki a wzrostem gospodarczym, wyrażonym jako PKB na jednego mieszkańca. Dane do analizy zaczerpnięto z GUS. Analiza trendów czasowych wykazała, że w analizowanym okresie energochłonność finalna gospodarki oraz udział energii odnawialnej systematycznie poprawiały się, co miało pozytywny wpływ na PKB *per capita*. Analiza korelacji potwierdziła silne negatywne związki między energochłonnością a PKB *per capita* oraz pozytywne związki między udziałem energii odnawialnej a wzrostem gospodarczym. W regresji liniowej i wielorakiej energochłonność finalna gospodarki, nakłady na środki trwałe służące ochronie środowiska oraz udział energii odnawialnej wykazały istotny wpływ na PKB *per capita*. Wnioski z badań podkreślają znaczenie kontynuacji i intensyfikacji działań na rzecz zielonej gospodarki w Polsce, co jest kluczowe dla zapewnienia długoterminowego wzrostu gospodarczego i zrównoważonego rozwoju.

AUTHOR

MARIUSZ PYRA, PHD

ORCID: 0000-0001-8246-851X
John Paul II University in Biala Podlaska, Poland
Faculty of Economic Sciences
e-mail: m.pyra@dyd.akademiabialska.pl

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