

## CHAPTER 10

### SUSTAINABILITY AND ECONOMIC GROWTH: DO GREEN POLICIES STIMULATE OR HINDER ECONOMIC EXPANSION?

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*This paper aims to investigate the opportunities and challenges of applying artificial intelligence (AI) in modern agriculture, with a specific focus on its contribution to the green economy. Methodologically, the research is based on a desk analysis (review of relevant literature), including scientific papers, reports from international organizations, and practical examples. Through the analysis of secondary sources, key AI tools applied in agriculture were identified, such as algorithms for predictive yield analysis, drones for crop monitoring, machine learning for irrigation optimization, and sensor systems for crop nutrition optimization. Examples of countries that have implemented AI to increase productivity while reducing the negative environmental impact were also highlighted.*

*The results showed that artificial intelligence has enormous potential in transforming agriculture towards sustainability, but also that institutional support, digital infrastructure, and farmer education are essential for its successful implementation. The SWOT analysis indicated that Serbia has a solid strategic and institutional framework for the application of artificial intelligence in agriculture, but that digital literacy, infrastructural unevenness, and access to technologies are still key obstacles to its wider application. Special emphasis is placed on the role of national digitalization strategies, as well as the need for intersectoral cooperation, to ensure long-term sustainability and the inclusive application of smart solutions in rural areas. The contribution of this paper lies in the integration of existing knowledge and the identification of key areas for further research and policy development in the field of sustainable agriculture.*

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**Keywords:** *artificial intelligence (AI), agriculture, green economy, sustainable development, digital transformation.*

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## INTRODUCTION

Since the second half of the 20th century, the issue of economic sustainability has attracted significant attention in academic and political circles. Concerns over climate change and the depletion of natural resources have led to the widespread adoption of green policies worldwide (Du Pisani, 2006). These policies include the promotion of renewable energy sources, regulation of carbon dioxide emissions, and incentives for environmentally sustainable production (Mastini et al., 2021). While some economists argue that green policies drive innovation and long-term competitiveness (e.g., Stern, 2015), others warn about their potential negative effects on economic growth and development (Lomborg, 2020).

Climate change, resource depletion, and rising carbon dioxide emissions have posed a challenge to economies worldwide: how to achieve sustainable growth without jeopardizing ecosystems.

International institutions such as the United Nations, the World Bank, and the International Monetary Fund emphasize the importance of implementing Sustainable Development Goals (SDGs) as a foundation for long-term economic development (United Nations, 2024; International Monetary Fund, 2023). Through the European Green Deal, the European Union has set ambitious targets for reducing greenhouse gas emissions, further encouraging both member states and candidate countries to align their policies with global environmental standards (United Nations, 2024). However, the impact of environmental regulations on economic growth varies significantly across different countries and remains a subject of intense debate (De Santis, 2012). This ambiguity highlights the need for a deeper analysis of how green policies affect economies at different levels of development.

The aim of this paper is to examine whether green policies stimulate or hinder economic expansion through a comparative analysis of developed and developing countries. The research focuses on four key indicators of economic growth: Gross Domestic Product (GDP), investment levels, productivity rates, and employment rates. According to Hallegatte, Fay, and Vogt-Schilb (2013), developed countries possess a greater capacity to absorb the costs of green transitions due to their well-established institutions and flexible markets. In contrast, developing countries often

face the so-called “green paradox”, where environmental requirements impose constraints on their economic development.

The study contributes to the existing literature by systematizing the impact of green measures on macroeconomic performance in different contexts, offering policy recommendations that balance environmental and economic priorities.

The paper is structured into five key sections.

The first section provides a literature review, focusing on theoretical models that link green policies with economic growth while analyzing conflicting perspectives. Special attention is given to theories that discuss the long-term benefits of transitioning to renewable energy sources and the potential short-term economic costs.

The second section outlines the methodological framework. The research includes an analysis of 11 transition economies from 2000 to 2023, but due to historical limitations, data before 2000 is unavailable. The study focuses on greenhouse gas emissions, GDP per capita, and total factor productivity (TFP), comparing these indicators to the EU27 average and global trends.

The third section presents the results of the empirical analysis, indicating a positive correlation between the implementation of green policies and economic expansion in developed countries. In contrast, developing economies face challenges in attracting investments, mainly due to high initial costs and limited institutional capacity. The findings reveal a clear relationship between economic growth and greenhouse gas emissions in transition economies. Data analysis shows that countries with higher GDP per capita tend to have higher CO<sub>2</sub> emissions, while in some countries, such as Ukraine and North Macedonia, this correlation was significantly weaker.

The fourth section discusses the practical implications of the findings. The discussion emphasizes the importance of tailoring policies to each country’s specific conditions, taking into account institutional capacity, technological readiness, and market structure.

The fifth and final section summarizes the key research findings, provides recommendations for effectively integrating environmental and economic strategies, and suggests future research directions in this field.

## LITERATURE REVIEW

Sustainable economic growth and green policies have become central topics in economic literature, especially in the context of global efforts to reduce CO<sub>2</sub> emissions and transition to renewable energy sources. This section reviews relevant studies that explore the relationship between economic growth and environmental sustainability, as well as the theoretical models that explain these processes. Additionally, research gaps and potential directions for further studies are identified.

One of the central debates in academic literature concerns the impact of economic growth on CO<sub>2</sub> emissions. Traditional economic models suggest that an increase in GDP leads to higher energy consumption and greater emissions (Dinda, 2004). However, some researchers emphasize that technological advancements and the transition to cleaner energy sources can mitigate this negative effect (Grossman & Krueger, 1995; Copeland & Taylor, 2004).

Empirical studies show varying results depending on the methodological approach and the countries examined. For instance, Sadorsky (2009) found that economic growth in developing countries has a positive effect on CO<sub>2</sub> emissions, whereas developed countries reduce emissions through investments in renewable energy and resource efficiency.

In the context of environmental policy, high economic uncertainty can delay or redirect investments in green technologies and sustainable industrial practices. The findings of Živkov et al. (2023a) indicate that countries highly dependent on exports and imports, such as the Czech Republic and Hungary, experience the strongest impact of economic policy uncertainties (EPUs). This could imply greater vulnerability to supply chain and energy market disruptions. Such volatility is particularly relevant to CO<sub>2</sub> emissions analysis, as fluctuations in industrial production can lead to variability in emissions and short-term economic cycles, rather than long-term decarbonization strategies.

A study by Yan et al. (2022) explains the dual effect of economic growth on environmental pollution in China. When the economy is in a moderate growth regime, there is a positive correlation between SO<sub>2</sub> emission growth rates and GDP. However, under conditions of high and low growth, economic expansion can reduce pollution emissions under specific circumstances. The authors conclude that local factors and conditions play a crucial role in determining this relationship.

Renewable energy is often viewed as a key factor in the transition to a sustainable economy. Several studies confirm the positive effect of

renewable energy sources on economic growth, particularly in developed countries (Apergis & Payne, 2010). These energy sources contribute to reducing externalities associated with fossil fuels and can have multiplicative effects through innovation and employment in the green energy sector (Hepburn & Bowen, 2013).

However, in some fossil fuel-dependent economies, the transition to renewable energy may generate significant transition costs (Sadorsky, 2011). These differences highlight the need for more detailed research that takes into account regional specificities.

There is growing interest in exploring the economic feasibility of green investments, particularly in the context of their impact on macroeconomic factors such as employment, inflation, fiscal stability, and long-term growth. Green investments include capital expenditures directed toward renewable energy sources, energy-efficient technologies, and infrastructure projects that support the reduction of greenhouse gas emissions (Inderst et al., 2012). Through an analysis of the interaction between inflation and economic shocks, Živkov et al. (2023b) emphasize the need for long-term stable economic policies that enable a gradual transition to a sustainable economy without excessive inflationary pressures.

Empirical studies show that investments in renewable energy can contribute to long-term economic growth, but their effects depend on the institutional framework and regulatory policies (Acemoglu et al., 2012). For example, countries with stable fiscal and regulatory frameworks demonstrate greater potential for sustainable growth through green investments (Stern, 2007). In a study conducted by Falcone (2020), it was shown that countries with strong environmental incentive systems achieved greater economic benefits from green investments compared to those that did not implement adequate regulatory measures.

One of the key success factors of green investments is their potential to create new jobs. Tong et al. (2020) analyzed employment opportunities in the renewable energy sector and concluded that green investments generate more jobs per unit of capital invested compared to traditional fossil fuel-based sectors. Studying the impact of the COVID-19 pandemic on economic growth and sustainability, Zeng, Li & Magazzino (2024) concluded that investments in renewable energy, energy efficiency, and sustainable infrastructure could stimulate economic growth and create new jobs. Additionally, research suggests that transitioning to a green economy can reduce economic inequalities by ensuring a more even distribution of income and creating new economic opportunities in less developed regions (Kousar et al., 2023).

According to Barbier (2016), the effectiveness of green growth in reducing poverty and fostering economic transformation depends on its adaptation to the specific needs of developing countries. Targeted policies are required to address structural issues in resource utilization and poverty alleviation.

However, there are also concerns regarding transition costs and potential macroeconomic challenges resulting from the accelerated shift to a green economy. Research conducted by Popp, Newell & Jaffe (2010) indicates that adjustment costs can be significant in the early stages, particularly in countries with a high share of employment in the fossil fuel industry. Fiscal policy also plays a crucial role in the sustainability of green investments, as high levels of subsidies for renewable energy sources may lead to fiscal deficits if not properly balanced with revenues from environmental taxes (Carattini, Carvalho & Fankhauser, 2018).

A study published in the Review of Environmental Economics and Policy (Böhringer, 2014) suggests that green policies can negatively impact the competitiveness of energy-intensive industries, potentially leading to short-term GDP declines. Böhringer highlights that the transition costs to a green economy are particularly high for industries reliant on fossil fuels, which could result in job losses and reduced investments. This study is especially relevant for developed countries with strong industrial sectors, where the effects of green policies on employment and competitiveness are key considerations for economic policy.

Costantini & Mazzanti (2012) investigate the impact of green policies on trade and investment in the European Union. The authors conclude that green policies can positively influence economic growth by boosting exports of clean technologies and attracting foreign investments. However, they also caution that successful green policies require global coordination to avoid trade disputes and negative effects on competitiveness.

Finally, a study by Albanese, Busato & Cisco (2024) emphasizes that green policies are most effective when combined with other economic policy measures, such as subsidies for clean technologies and investments in education. This study is particularly important as it underscores that green policies cannot succeed in isolation but require a broader approach that includes other aspects of economic policy.

In the long run, green investments can reduce dependence on fossil fuel imports and enhance energy security. Additionally, there is a growing need for further research on how central banks and monetary policy can support green investments through green bonds and other financial instruments (Campiglio, 2016).

The literature on green growth presents diverse perspectives on whether economic growth and sustainability can be achieved simultaneously. Broadly speaking, three main theoretical and empirical approaches dominate academic research: the positive effects of green policies on economic growth, the limitations and negative effects of green policies on economic growth, and a critical perspective on the concept of green growth itself.

If properly implemented, green policies can bring long-term economic and environmental benefits. However, there are significant limitations and costs, especially in fossil fuel-dependent countries and those with a high Gini coefficient (Xu, Zhao & Liu, 2023). Critics argue that green growth is not a realistic goal and propose alternative approaches such as post-growth economies and the degrowth model (Johnsen, Nelund, Olaison & Meier Sørensen, 2017).

Nevertheless, the key question remains: Can the economy transform quickly enough to avoid an ecological crisis without sacrificing economic growth?

#### Theoretical Models and Concepts

The theoretical framework of this study is based on several key models and concepts that help us understand the relationship between green policies and economic growth. These models and concepts encompass economic, environmental, and institutional aspects, providing a comprehensive foundation for analysis.

The endogenous growth model (Romer, 1994) is one of the most important theoretical frameworks for understanding long-term economic growth. According to this model, economic growth is not merely the result of external factors but rather a consequence of internal processes, such as innovation and investment in research and development (R&D). Romer emphasizes that technological innovations are the key drivers of productivity and economic expansion.

In the context of green policies, the endogenous growth model suggests that investments in clean technologies and sustainable projects can stimulate long-term economic growth. For example, subsidies for renewable energy development or support for ecological innovations can lead to productivity increases and the creation of new markets. However, this model also highlights that successful green policies depend on the existence of a strong institutional framework and support for research and development (Wan et al., 2018).

The Environmental Kuznets Curve (EKC) hypothesis (Grossman & Krueger, 1995) analyzes the relationship between economic growth and environmental pollution. In the early stages of economic development,

increasing income per capita leads to higher pollution due to intensive industrialization and natural resource exploitation. However, after reaching a certain income level, pollution begins to decline because of technological advancements, changes in the economic structure, and public demand for a cleaner environment.

This concept is particularly important for understanding the differences between developed and developing countries. In developed nations, green policies are often directed toward reducing emissions and promoting sustainable practices, whereas in developing countries, the focus may be on economic growth, which can lead to increased pollution. The Environmental Kuznets Curve (EKC) suggests that green policies are most effective when adapted to specific phases of economic development (Simbi, Yao & Zhang, 2025).

The double dividend theory (Pearce, 1991) argues that environmental taxation can generate dual benefits: reducing emissions and improving economic efficiency. The first dividend refers to environmental benefits, such as pollution reduction and natural resource conservation. The second dividend pertains to economic benefits, including increased tax revenue, reduced healthcare costs, and incentives for innovation.

Chenghao et al. (2024) confirm that environmental taxes not only lower emissions but can also positively contribute to fiscal stability. However, the success of these policies depends on how revenues are distributed and the institutional capacity to implement reforms (Freire-González, 2018).

#### *Research Gaps and Future Directions*

Theoretical models and concepts provide a comprehensive foundation for understanding the relationship between green policies and economic growth. The endogenous growth model, the Environmental Kuznets Curve, and the double dividend theory suggest that green policies can positively impact economic expansion, but their effects are conditional on institutional frameworks, technological innovations, and the stage of economic development.

Despite the significant number of studies exploring the relationship between green policies and economic growth, several key research gaps limit a complete understanding of this complex relationship:

1. Lack of comparative studies - Most research focuses on either developed or developing countries, limiting general conclusions about the global impact of green policies.
2. Limited microeconomic analysis - While macroeconomic effects of green policies are well-documented, firm-level and sectoral analyses are underexplored.

3. Insufficient long-term impact studies - More research is needed on the long-term economic consequences of green policies, including their effects on productivity and employment over decades.

4. Neglect of regional and local contexts - Many studies analyze green policies at the national or international level, but local economic structures play a crucial role in determining their effectiveness.

Most existing studies focus on developed countries, while developing nations remain underrepresented in literature. This limits the ability to make general conclusions about the global impact of green policies. For example, while green policies in developed economies often lead to increased innovation and productivity, poorer nations, already facing economic challenges, may encounter major obstacles in transitioning to green growth (Resnick et al., 2012).

The lack of comparative studies examining the differences in the effects of green policies between developed and developing countries represents a significant gap in literature. Addressing this gap can contribute to a deeper understanding of the relationship between green policies and economic growth, providing a foundation for more effective policies and sustainable development strategies.

## **DATA AND METHODOLOGY**

The observed sample included 11 transition countries (Albania, Armenia, Belarus, Bosnia and Herzegovina, Georgia, Moldova, Montenegro, North Macedonia, Russia, Serbia, and Ukraine) over the period from 2000 to 2023. The common characteristic of observed countries is the lack of data because of their turbulent history (Balaban and Živkov, 2021; Balaban et al., 2019).

Tables 1-3 present greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide from all sources, including land-use change. These emissions are measured in tonnes of carbon dioxide-equivalents over a 100-year timescale. Table 4 displays GDP per capita - in international dollars at 2021 prices, while Table 5 presents the total factor productivity of the observed countries in the period from 2000 to 2023. For comparison purposes, the values of the observed variables are also presented for the EU27, as well as at the global average level.

## **GREENHOUSE GAS EMISSIONS IN TRANSITION COUNTRIES**

As can be seen from Tables 1-3, the level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry increased globally by 14.64% in the period from 2000 to 2023 (from 4.10 to 4.70 tonnes per person). The level of methane emissions remained at the same level (1.30 tonnes per person), while nitrous oxide emissions decreased by 5.13% (from 0.65 to 0.53 tonnes per person). On the other hand, Table 4 shows that the global average GDP per capita increased by 62.27% (from \$12,739 to \$20,671 international dollars in 2021 prices), while total factor productivity varied significantly over the observed period (Table 5).

In the European Union, the level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry decreased from 8.40 tonnes per person in 2000 to 5.60 tonnes per person in 2023, on average, which represents a reduction of 22.62%. Methane emissions also decreased from 1.50 tonnes per person in 2000 to 1.10 tonnes per person in 2023, on average, which is a reduction of 26.67%. Meanwhile, nitrous oxide emissions declined from 0.65 to 0.53 tonnes per person over the observed period, representing a reduction of 18.46% (Tables 1-3). On the other hand, GDP per capita increased from \$40,631 international dollars in 2021 prices in 2000 to \$50,447 international dollars in 2021 prices in 2023, on average (Table 4), representing an increase of 34.00%, while total factor productivity fluctuated significantly over the observed period (Table 5).

*Table 1: Carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry - in tonnes per person*

	ALB	ARM	BYS	BIH	GEO	MLD	MNE	NMK	RUS	SRB	UKR	EU(27) average	World average
2000	1.00	1.10	5.50	3.30	1.00	0.80	2.40	4.10	10.10	5.80	5.80	8.40	4.10
2001	1.00	1.10	5.40	3.20	0.90	0.90	2.60	4.00	10.40	6.40	6.20	8.50	4.10
2002	1.20	1.00	5.50	3.40	0.80	1.00	2.80	3.80	10.30	6.90	6.10	8.50	4.10
2003	1.40	1.10	5.60	3.40	0.90	1.10	3.00	4.10	10.50	7.40	6.40	8.70	4.30
2004	1.30	1.20	6.00	3.70	1.10	1.10	3.20	3.90	10.60	8.00	6.50	8.60	4.40
2005	1.40	1.50	6.10	3.90	1.20	1.20	2.80	4.10	10.80	6.80	6.60	8.60	4.50
2006	1.30	1.50	6.40	4.30	1.50	1.30	3.30	4.10	11.30	8.10	7.00	8.60	4.60
2007	1.30	1.70	6.30	4.40	1.60	1.30	3.20	4.30	11.30	8.00	7.20	8.50	4.70
2008	1.50	1.90	6.60	5.10	1.40	1.30	4.10	4.30	11.50	6.90	7.00	8.30	4.70
2009	1.50	1.50	6.40	5.30	1.60	1.20	2.70	4.00	10.70	6.20	6.00	7.60	4.50
2010	1.60	1.50	6.60	5.50	1.60	1.30	3.80	4.00	11.30	6.30	6.20	7.80	4.80
2011	1.80	1.70	6.50	6.40	2.00	1.40	3.80	4.30	11.70	6.60	6.70	7.50	4.90
2012	1.70	2.00	6.60	6.00	2.20	1.40	3.50	4.20	11.80	6.00	6.60	7.40	4.90
2013	1.80	1.90	6.80	6.00	2.10	1.40	3.40	3.70	11.30	6.10	6.40	7.20	4.80
2014	2.10	1.90	6.70	5.40	2.40	1.40	3.30	3.60	11.30	5.10	5.60	6.90	4.80
2015	1.60	1.90	6.20	5.20	2.60	1.50	3.60	3.40	11.30	6.10	4.90	7.00	4.70
2016	1.60	1.80	6.10	6.30	2.70	1.50	3.20	3.40	11.20	6.30	5.10	7.00	4.70
2017	1.80	1.90	6.30	6.50	2.70	1.50	3.40	3.70	11.40	6.40	4.90	7.00	4.70
2018	1.70	2.00	6.60	6.50	2.70	1.70	3.90	4.00	11.70	6.30	5.10	6.80	4.80
2019	1.70	2.20	6.60	6.20	2.90	1.80	4.00	4.00	11.60	6.40	4.90	6.50	4.80
2020	1.60	2.40	6.30	6.30	2.80	1.70	4.00	3.70	11.20	6.50	4.60	5.90	4.50
2021	1.80	2.60	6.60	6.60	2.90	1.90	4.00	3.50	11.70	6.40	4.70	6.30	4.70
2022	1.80	2.50	6.50	6.50	3.00	1.90	3.90	3.90	12.40	6.40	3.40	6.10	4.60
2023	1.80	2.60	6.20	6.30	3.10	1.90	3.70	4.10	12.50	6.30	3.60	5.60	4.70

Source: <https://ourworldindata.org/co2-and-greenhouse-gas-emissions>

A significant increase in carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry was recorded in almost all observed transition countries in the period from 2000 to 2023 (Table 1):

- Albania: 80.00% increase (from 1.00 to 1.80 tonnes per person)
- Armenia: 136.36% increase (from 1.10 to 2.60 tonnes per person)
- Belarus: 12.72% increase (from 5.50 to 6.20 tonnes per person)
- Bosnia and Herzegovina: 47.62% increase (from 3.30 to 6.30 tonnes per person)
- Georgia: 210.00% increase (from 1.00 to 3.10 tonnes per person)
- Moldova: 137.50% increase (from 0.80 to 1.90 tonnes per person)
- Montenegro: 54.17% increase (from 2.40 to 3.70 tonnes per person)
- Russia: 23.76% increase (from 10.10 to 12.50 tonnes per person)
- Serbia: 8.62% increase (from 5.80 to 6.30 tonnes per person)

The same level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry was recorded in North Macedonia (4.10 tonnes per person), while in Ukraine, the level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry decreased by 37.93% (from 5.80 to 3.60 tonnes per person) over the observed period. Ukraine is the only country where the level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry has decreased, aligning with trends observed in the European Union.

The average level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry in 2023 in the observed transition countries was 4.73 tonnes per person. Although this represents an increase compared to 2000 (3.72 tonnes per person), it remains lower than the average level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry in the European Union (5.60 tonnes per person). The average level of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry in 2023 in the observed transition countries was almost identical to the global average.

The highest levels of carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry in 2023 were recorded in:

- Russia (12.50 tonnes per person),
- Serbia (6.30 tonnes per person),
- Bosnia and Herzegovina (6.30 tonnes per person),
- Belarus (6.20 tonnes per person).

These countries had higher carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry in 2023 than the European Union average (5.60 tonnes per person), while carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry in Albania, Armenia, Georgia, Moldova, Montenegro, North Macedonia and Ukraine was below the EU average.

*Table 2: Per capita methane emissions - in tonnes of carbon dioxide-equivalents per person*

	ALB	ARM	BYS	BIH	GEO	MLD	MNE	NMK	RUS	SRB	UKR	EU(27) average	World average
2000	1.10	0.40	1.50	0.90	0.80	0.60	1.40	1.00	2.50	1.30	1.50	1.50	1.30
2001	1.10	0.40	1.50	0.90	0.80	0.60	1.40	0.90	2.60	1.20	1.50	1.40	1.30
2002	1.10	0.50	1.40	0.90	0.90	0.60	1.30	0.90	2.60	1.20	1.50	1.40	1.30
2003	1.10	0.50	1.50	1.00	0.90	0.60	1.20	0.90	2.70	1.20	1.50	1.40	1.30
2004	1.10	0.50	1.50	1.00	0.90	0.60	1.20	0.90	2.70	1.20	1.50	1.40	1.30
2005	1.10	0.50	1.50	1.00	0.90	0.60	1.10	0.90	2.80	1.10	1.50	1.30	1.30
2006	1.10	0.50	1.50	1.10	0.90	0.60	1.10	0.90	2.80	1.10	1.50	1.30	1.40
2007	1.10	0.50	1.50	1.10	0.90	0.60	1.20	0.90	2.90	1.10	1.50	1.30	1.40
2008	1.00	0.50	1.60	1.20	0.80	0.50	1.20	0.90	2.90	1.10	1.50	1.30	1.40
2009	1.00	0.50	1.60	1.20	0.80	0.50	1.10	0.90	2.80	1.10	1.50	1.30	1.30
2010	1.00	0.50	1.70	1.20	0.80	0.60	1.10	0.90	3.00	1.10	1.40	1.20	1.30
2011	1.00	0.50	1.70	1.30	0.80	0.60	1.10	1.00	3.00	1.10	1.50	1.20	1.40
2012	1.00	0.50	1.70	1.30	0.90	0.60	1.10	1.00	3.10	1.10	1.50	1.20	1.40
2013	1.00	0.50	1.70	1.30	0.90	0.60	1.10	1.00	3.10	1.10	1.60	1.20	1.30
2014	1.10	0.50	1.80	1.60	0.90	0.60	1.10	0.90	3.10	1.10	1.50	1.20	1.30
2015	1.10	0.50	1.80	1.60	0.90	0.60	1.20	0.90	3.10	1.10	1.30	1.20	1.30
2016	1.10	0.50	1.80	1.70	0.90	0.70	1.20	0.90	3.20	1.10	1.30	1.10	1.30
2017	1.10	0.50	1.80	1.80	0.80	0.70	1.20	1.00	3.30	1.10	1.20	1.10	1.30
2018	1.10	0.50	1.80	1.90	0.80	0.70	1.20	1.00	3.40	1.10	1.20	1.10	1.30
2019	1.00	0.50	1.80	1.80	0.80	0.70	1.20	0.90	3.50	1.10	1.30	1.10	1.30
2020	0.90	0.50	1.90	1.80	0.80	0.70	1.10	0.90	3.50	1.10	1.30	1.10	1.30
2021	0.90	0.50	1.90	1.70	0.80	0.70	1.10	0.90	3.60	1.10	1.20	1.10	1.30
2022	0.90	0.50	1.90	1.70	0.80	0.70	1.10	0.90	3.60	1.00	1.30	1.10	1.30
2023	0.90	0.50	1.90	1.60	0.80	0.60	1.00	0.90	3.70	1.00	1.40	1.10	1.30

Source: <https://ourworldindata.org/co2-and-greenhouse-gas-emissions#explore-data-on-co2-and-greenhouse-gas-emissions>

As can be seen from Table 2, an increase in methane emissions was recorded in:

- Armenia by 20% (from 0.50 to 0.60 tonnes per person),
- Belarus by 26.67% (from 1.50 to 1.90 tonnes per person),
- Bosnia and Herzegovina by 77.78% (from 0.90 to 1.60 tonnes per person),
- Russia by 48.00% (from 2.50 to 3.70 tonnes per person),

over the period from 2000 to 2023.

Methane emissions remained at the same level in Georgia (0.80 tonnes per person) and Moldova (0.60 tonnes per person).

On the other hand, methane emissions decreased in:

- Albania by 18.18% (from 1.10 to 0.90 tonnes per person),
- Montenegro by 28.57% (from 1.40 to 1.00 tonnes per person),
- North Macedonia by 10% (from 1.00 to 0.90 tonnes per person),
- Serbia by 23.07% (from 1.30 to 1.00 tonnes per person),
- Ukraine by 6.67% (from 1.50 to 1.40 tonnes per person),

over the observed period, which is in line with the trends in the European Union.

The average level of methane emissions in 2023 in the observed transition countries was 1.18 tonnes per person, which is slightly higher than the average level of methane emissions in the European Union (1.10 tonnes per person) significantly lower than the world average (1.30 tonnes per person).

The highest levels of methane emissions in 2023 were recorded in:

- Russia (3.70 tonnes per person),
- Belarus (1.90 tonnes per person),
- Bosnia and Herzegovina (1.60 tonnes per person),
- Ukraine (1.40 tonnes per person).

These countries had higher methane emissions in 2023 than the European Union average (1.10 tonnes per person), while methane emissions in Albania (0.90 tonnes per person), Armenia (0.50 tonnes per person), Georgia (0.80 tonnes per person), Moldova (0.60 tonnes per person), Montenegro (1.00 tonnes per person), North Macedonia (0.90 tonnes per person) and Serbia (1.00 tonnes per person) were below European Union average. What is interesting is that in 2000, among all the observed transition economies, only Russia had higher methane emissions levels than the European Union average, which at that time was 1.50 tonnes per person.

*Table 3: Per capita nitroux oxide emissions - in tonnes of carbon dioxide-equivalents per person*

	ALB	ARM	BYS	BIH	GEO	MLD	MNE	NMK	RUS	SRB	UKR	EU(27) average	World average
2000	0.38	0.16	1.44	0.24	0.45	0.18	0.27	0.32	0.46	0.43	0.43	0.65	0.39
2001	0.37	0.16	1.45	0.23	0.35	0.22	0.29	0.29	0.47	0.46	0.44	0.64	0.38
2002	0.42	0.19	1.43	0.23	0.42	0.20	0.28	0.27	0.48	0.45	0.47	0.63	0.38
2003	0.42	0.18	1.46	0.22	0.43	0.20	0.27	0.28	0.49	0.44	0.46	0.63	0.38
2004	0.41	0.20	1.49	0.26	0.44	0.21	0.31	0.30	0.46	0.55	0.45	0.63	0.39
2005	0.41	0.20	1.54	0.27	0.46	0.21	0.29	0.30	0.47	0.51	0.45	0.63	0.39
2006	0.41	0.29	1.60	0.28	0.46	0.20	0.32	0.30	0.48	0.53	0.46	0.61	0.39
2007	0.40	0.26	1.60	0.27	0.45	0.20	0.33	0.30	0.49	0.59	0.51	0.62	0.40
2008	0.38	0.25	1.66	0.31	0.44	0.21	0.30	0.29	0.51	0.52	0.54	0.58	0.39
2009	0.38	0.27	1.67	0.35	0.44	0.19	0.29	0.28	0.51	0.60	0.46	0.55	0.38
2010	0.39	0.25	1.66	0.34	0.45	0.22	0.29	0.29	0.50	0.50	0.50	0.57	0.38
2011	0.40	0.26	3.11	0.39	0.46	0.24	0.28	0.29	0.52	0.50	0.57	0.56	0.39
2012	0.40	0.32	3.12	0.41	0.48	0.24	0.28	0.28	0.51	0.59	0.55	0.56	0.39
2013	0.39	0.34	3.10	0.40	0.51	0.27	0.28	0.29	0.51	0.60	0.56	0.56	0.38
2014	0.40	0.33	3.05	0.43	0.51	0.29	0.28	0.30	0.53	0.50	0.54	0.57	0.38
2015	0.41	0.36	3.03	0.45	0.48	0.27	0.30	0.29	0.53	0.48	0.50	0.57	0.38
2016	0.42	0.53	2.95	0.42	0.48	0.31	0.30	0.31	0.53	0.53	0.55	0.57	0.37
2017	0.42	0.40	2.99	0.43	0.46	0.33	0.31	0.31	0.53	0.50	0.56	0.57	0.38
2018	0.38	0.39	2.99	0.41	0.45	0.37	0.30	0.30	0.54	0.44	0.57	0.56	0.37
2019	0.39	0.38	3.00	0.37	0.44	0.34	0.30	0.29	0.56	0.45	0.59	0.55	0.37
2020	0.36	0.39	3.07	0.41	0.48	0.32	0.28	0.31	0.56	0.56	0.59	0.55	0.37
2021	0.29	0.39	3.16	0.35	0.44	0.37	0.29	0.28	0.58	0.44	0.61	0.55	0.37
2022	0.29	0.40	3.14	0.36	0.45	0.36	0.29	0.28	0.57	0.45	0.63	0.54	0.37
2023	0.26	0.39	3.21	0.34	0.45	0.35	0.27	0.27	0.59	0.47	0.70	0.53	0.37

Source: <https://ourworldindata.org/co2-and-greenhouse-gas-emissions#explore-data-on-co2-and-greenhouse-gas-emissions>

As can be seen from Table 3, an increase in nitrous oxide emissions was recorded in most of the observed transition countries in the period from 2000 to 2023:

- Armenia: 143.75% increase (from 0.16 to 0.39 tonnes per person),
- Belarus: 122.92% increase (from 1.44 to 3.21 tonnes per person),
- Bosnia and Herzegovina: 41.67% increase (from 0.24 to 0.34 tonnes per person),
- Moldova: 94.44% increase (from 0.18 to 0.35 tonnes per person),
- Russia: 28.26% increase (from 0.46 to 0.59 tonnes per person),
- Serbia: 8.52% increase (from 0.43 to 0.47 tonnes per person),
- Ukraine: 62.79% increase (from 0.43 to 0.70 tonnes per person).

Nitrous oxide emissions remained at the same level in Georgia (0.45 tonnes per person) and Montenegro (0.27 tonnes per person), while a decrease was recorded in:

- Albania by 31.58% (from 0.38 to 0.26 tonnes per person),
  - North Macedonia by 15.62% (from 0.32 to 0.27 tonnes per person),
- over the observed period, which is in line with the trends in the EU.

The highest levels of nitrous oxide emissions in 2023 were recorded in:

- Belarus (3.21 tonnes per person),
- Ukraine (0.70 tonnes per person),
- Russia (0.59 tonnes per person),

while the lowest levels were recorded in:

- Albania (0.26 tonnes per person),
- Montenegro (0.27 tonnes per person),
- North Macedonia (0.27 tonnes per person).

The average level of nitrous oxide emissions in the observed transition countries in 2023 was 0.66 tonnes per person, which is slightly higher than the average level of nitrous oxide emissions in the European Union (0.53 tonnes per person). However, it should be noted that Belarus has exceptionally high levels of nitrous oxide emissions, which influences the higher overall average for the observed countries. Without Belarus, the average for the remaining countries is 0.41 tonnes per person, which is lower than the EU average (0.53 tonnes per person) and slightly higher than the global average (0.37 tonnes per person). Nitrous oxide emissions in Albania (0.26 tonnes per person), Armenia (0.39 tonnes per person), Bosnia and Herzegovina (0.34 tonnes per person), Georgia (0.45 tonnes per person), Moldova (0.35 tonnes per person), Montenegro (0.27 tonnes per person), North Macedonia (0.27 tonnes per person) and Serbia (0.47 tonnes per person) in 2023 were below European Union average.

## ECONOMIC PERFORMANCE OF TRANSITION COUNTRIES

As can be seen from Table 4<sup>1</sup> a significant increase in GDP per capita was recorded in all observed transition countries between 2000 and 2023:

- Albania: 176.38% increase (from \$6,601 to \$18,244 international dollars in 2021 prices)
- Armenia: 319.04% increase (from \$4,589 to \$19,230 international dollars in 2021 prices)
- Belarus: 147.88% increase (from \$11,182 to \$27,718 international dollars in 2021 prices)
- Bosnia and Herzegovina: 153.51% increase (from \$7,939 to \$20,126 international dollars in 2021 prices)
- Georgia: 295.92% increase (from \$5,706 to \$22,591 international dollars in 2021 prices)
- Moldova: 176.85% increase (from \$5,727 to \$15,855 international dollars in 2021 prices)
- Montenegro: 89.63% increase (from \$14,697 to \$27,870 international dollars in 2021 prices)
- North Macedonia: 94.74% increase (from \$12,111 to \$23,585 international dollars in 2021 prices)
- Russia: 95.74% increase (from \$20,309 to \$39,753 international dollars in 2021 prices)
- Serbia: 131.80% increase (from \$11,230 to \$26,030 international dollars in 2021 prices)
- Ukraine: 53.27% increase (from \$10,364 to \$15,885 international dollars in 2021 prices)

The highest GDP per capita in 2023 was recorded in:

- Russia (\$39,753 international dollars in 2021 prices)
- Montenegro (\$27,870 international dollars in 2021 prices)
- Belarus (\$27,718 international dollars in 2021 prices)

These values are above the global average level (\$20,671 international dollars in 2021 prices) but far below the GDP per capita level in the European Union (\$54,447 international dollars in 2021 prices).

GDP per capita in Albania (18,244 international dollars in 2021 prices), Armenia (19,230 international dollars in 2021 prices), Bosnia and Herzegovina (20,126 international dollars in 2021 prices), Moldova (15,855 international dollars in 2021 prices), and Ukraine (15,885 international dollars in 2021 prices) in 2023 were below world average.

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<sup>1</sup> This data is adjusted for inflation and for differences in living costs between countries

Table 4: GDP per capita - in international \$ in 2021 prices

	ALB	ARM	BYS	BIH	GEO	MLD	MNE	NMK	RUS	SRB	UKR	EU(27) average	World average
2000	6,601	4,589	11,182	7,939	5,706	5,727	14,697	12,111	20,309	11,230	10,364	40,631	12,739
2001	7,216	5,044	11,771	8,093	6,074	6,090	14,799	11,691	21,436	12,012	11,379	41,488	12,872
2002	7,566	5,731	12,444	8,482	6,464	6,580	15,021	11,952	22,547	12,804	12,093	41,908	13,053
2003	8,014	6,569	13,414	8,830	7,228	7,034	15,332	12,202	24,303	13,422	13,343	42,223	13,357
2004	8,491	7,299	15,052	9,474	7,694	7,574	15,982	12,814	26,158	14,353	15,021	43,238	13,863
2005	9,007	8,363	16,580	9,950	8,486	8,161	16,626	13,492	27,938	15,246	15,611	44,002	14,313
2006	9,599	9,525	18,350	10,574	9,338	8,577	18,028	14,263	30,328	15,904	16,901	45,493	14,865
2007	10,250	10,899	20,020	11,333	10,567	8,855	19,229	15,273	32,962	17,219	18,374	46,843	15,441
2008	11,104	11,727	22,138	12,149	10,856	9,564	20,582	16,203	34,692	18,185	18,884	47,102	15,671
2009	11,554	10,143	22,237	11,990	10,553	9,001	19,347	16,249	31,976	17,684	16,093	44,998	15,365
2010	12,042	10,439	24,013	12,310	11,294	9,650	19,840	16,903	33,400	18,041	16,812	45,840	15,952
2011	12,382	10,990	25,405	12,660	12,289	10,217	20,459	17,378	34,795	18,188	17,784	46,822	16,378
2012	12,578	11,794	25,879	12,801	13,194	10,158	19,885	17,366	36,104	18,195	17,849	46,404	16,674
2013	12,727	12,194	26,148	13,317	13,913	11,080	20,571	17,941	36,629	18,367	17,889	46,263	17,001
2014	12,980	12,667	26,564	13,675	14,475	11,641	20,917	18,642	36,218	18,123	16,979	46,935	17,371
2015	13,306	13,113	25,513	14,420	14,937	11,691	21,614	19,412	35,394	18,452	15,404	47,968	17,735
2016	13,770	13,193	24,847	15,083	15,443	12,377	22,247	20,029	35,362	19,101	15,857	48,823	18,098
2017	14,306	14,244	25,504	15,774	16,238	13,119	23,293	20,328	35,932	19,657	16,310	50,190	18,576
2018	14,918	15,037	26,363	16,579	17,229	13,896	24,482	21,019	36,908	20,683	16,979	51,235	19,047
2019	15,291	16,215	26,799	17,269	18,187	14,621	25,485	21,990	37,699	21,782	17,637	52,228	19,402
2020	14,869	15,053	26,731	16,983	17,031	13,559	21,609	21,187	36,746	21,720	17,093	49,260	18,662
2021	16,354	15,922	27,611	18,544	18,916	15,682	24,510	22,371	38,938	23,669	17,846	52,529	19,703
2022	17,353	17,886	26,538	19,570	20,967	15,291	26,165	23,056	38,264	24,910	13,787	54,277	20,197
2023	18,244	19,230	27,718	20,126	22,591	15,855	27,870	23,585	39,753	26,030	15,885	54,447	20,671

Source: <https://ourworldindata.org/grapher/gdp-per-capita-worldbank?tab=line&time=2000..latest&facet=none&country>

Table 5: Total factor productivity (TFP) in log difference, percent

	ALB	ARM	BYS	BIH	GEO	MLD	MNE	NMK	RUS	SRB	UKR	World median
2000	4.61	5.86	4.69		-2.02	2.11			8.92	6.55	0.77	0.99
2001	6.79	9.52	4.65	0.73	3.17	6.94		-5.15	5.47	4.41	6.77	-0.29
2002	3.28	21.06	5.40	1.55	6.20	7.57		-4.24	1.15	6.61	2.04	0.42
2003	3.68	11.45	6.90	0.01	9.97	11.90		-1.54	-0.21	3.94	2.79	0.88
2004	3.58	9.82	9.24	2.61	3.72	9.12	3.11	6.52	0.72	9.86	6.53	1.79
2005	3.79	10.57	5.58	4.01	7.00	7.09	2.95	-1.37	1.37	10.35	-0.89	0.77
2006	4.07	10.25	3.33	2.49	6.43	6.37	0.48	0.33	4.66	3.20	5.46	1.32
2007	4.06	9.24	2.60	-1.32	9.36	1.85	-1.13	2.98	3.95	0.97	5.70	1.34
2008	8.45	2.51	2.81	-1.84	4.34	5.76	1.10	-2.37	2.83	0.46	0.99	-0.65
2009	5.98	-15.57	-5.17	-2.67	-5.19	-4.03	-6.44	-5.41	0.43	0.37	-6.34	-3.21
2010	2.57	-0.63	2.91	0.61	6.46	7.56	1.54	4.30	-4.04	4.35	2.97	1.56
2011	-0.21	3.50	1.53	0.19	4.09	2.50	2.25	-0.28	2.47	4.86	2.80	0.72
2012	-1.96	5.76	-0.08	-2.52	2.72	-1.07	-5.55	-2.05	2.33	-1.59	2.85	-0.19
2013	3.13	2.57	-1.36	0.78	2.34	5.73	2.09	-2.05	0.85	-1.07	-2.80	0.15
2014	0.40	4.26	0.04	0.67	1.30	2.38	-3.77	0.61	0.31	-5.56	3.24	0.36
2015	-1.91	5.88	-4.47	1.17	-0.16	-3.21	0.70	-5.59	-0.07	-0.15	-2.20	0.34
2016	-2.19	3.76	-2.18	3.72	0.99	1.79	0.83	0.66	1.00	-2.23	0.03	0.31
2017	-0.46	5.72	2.48	-0.07	2.76	3.26	1.14	-2.73	2.38	-1.41	3.34	0.28
2018	0.55	3.58	2.44	0.88	0.96	-0.28	0.55	-0.50	2.30	2.31	2.85	0.39

Source: <https://prosperitydata360.worldbank.org/en/indicator/WB+ASPD+dtfp>

Among the observed transition countries, the country with the highest greenhouse gas emissions, was Russia. However, Russia also had the highest GDP per capita over the period from 2000 to 2023. On the other hand, Moldova and Armenia are the smallest polluters, but at the same time, they also have the lowest GDP per capita in the observed period.

The level of total factor productivity varied significantly throughout the observed period (Table 5) in the observed countries, which makes it impossible to draw a clear conclusion.

### **CORRELATION BETWEEN GREENHOUSE GAS EMISSIONS AND ECONOMIC PERFORMANCES IN TRANSITION COUNTRIES**

To determine whether there is a relationship between greenhouse gas emissions and economic performances (GDP per capita and total factor productivity) in transition countries, a correlation analysis was conducted, covering the period from 2000 to 2023. The analysis was performed for all observed countries, and the results are presented in Table 6 and Table 7. The method for interpreting the results obtained is presented in Table 8.

*Table 6: Correlation matrix  $GDP_{pc} \rightarrow$  Greenhouse gas emissions*

	$GDP_{pc} \rightarrow CO_2$	$GDP_{pc} \rightarrow CH_4$	$GDP_{pc} \rightarrow N_2O$
ALB	0.822315	-0.688243	-0.616387
ARM	0.960160	0.523244	0.857327
BYS	0.846330	0.899634	0.878103
BIH	0.889594	0.911343	0.689554
GEO	0.972456	-0.358127	0.386110
MLD	0.981181	0.632221	0.944457
MNE	0.766403	-0.562804	0.061712
NMK	0.045760	0.043760	-0.103417
RUS	0.889366	0.887431	0.853467
SRB	-0.263844	-0.859692	-0.022388
UKR	0.127587	-0.149026	0.475931
EU27	-0.875771	-0.910920	-0.837937
World	0.681892	-0.157946	-0.676867

*Source: Authors' calculation*

According to the data from Table 6, a very strong positive correlation (Guilford, 1953; Hinkle et al., 2003) between carbon dioxide ( $CO_2$ ) emissions from fossil fuels and industry and GDP per capita (GDPpc) over the period 2000 to 2023 was recorded in:

- Armenia (0.960160),
- Georgia (0.972456), and

- Moldova (0.981181).

Meanwhile, a strong positive correlation (Guilford, 1953; Hinkle et al., 2003), which is classified as very strong by Evans (1996), was recorded in:

- Albania (0.822315),
- Belarus (0.846330),
- Bosnia and Herzegovina (0.889594), and
- Russia (0.889366).

In Montenegro, a strong positive correlation (0.766403) was recorded between carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry and GDP per capita.

However, a very weak positive correlation (Guilford, 1953; Evans 1996) between carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry and GDP per capita was recorded in:

- North Macedonia (0.045760), and
- Ukraine (0.127587).

In Serbia, a very weak (Hinkle et al., 2003), or weak (Guilford, 1953; Evans 1996), negative correlation (-0.263844) between carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry and GDP per capita was observed.

In most of the observed transition countries, a strong positive correlation was recorded between carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry and GDP per capita over the period 2000 to 2023, which may suggest that economic development (measured by GDP per capita) has contributed to increased pollution during the observed period. On the contrary to that, in the European Union, a strong negative correlation was recorded between between carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry and GDP per capita, indicating that economic growth in the 27 European Union countries is not associated with an increase in CO<sub>2</sub> emissions.

At the global level, economic growth is moderately (Guilford, 1953; Hinkle et al., 2003), or strongly positively correlated (Evans, 1996) with CO<sub>2</sub> emissions, indicating that economic growth in the world could be associated with an increase in CO<sub>2</sub> emissions.

According to the data from Table 6, a very strong positive correlation (Guilford, 1953; Hinkle et al., 2003) between per capita methane emissions and GDP per capita over the period 2000 to 2023 was recorded in:

- Bosnia and Herzegovina (0.911343).

A strong (Guilford, 1953; Hinkle et al., 2003), or very strong (Evans, 1996) positive correlation between per capita methane emissions and GDP per capita was recorded in:

- Belarus (0.899634), and

- Russia (0.887431).

A strong (Guilford, 1953; Hinkle et al., 2003), or very strong (Evans, 1996) negative correlation between per capita methane emissions and GDP per capita was recorded in:

- Serbia (-0.859692).

which is consistent with the EU-27 average, where a very strong negative correlation (-0.910920) between per capita methane emissions and GDP per capita was observed.

A moderate (Guilford, 1953; Hinkle et al., 2003), or strong (Evans, 1996) negative correlation between per capita methane emissions and GDP per capita was recorded in:

- Albania (-0.688243).

while a moderate (Guilford, 1953; Hinkle et al., 2003), or strong (Evans, 1996) positive correlation between per capita methane emissions and GDP per capita was recorded in:

- Moldova (0.632221).

A moderate positive or negative correlation between per capita methane emissions and GDP per capita was recorded in:

- Armenia (0.523244), and
- Montenegro (-0.562804).

while in other countries, a weak or very weak correlation was observed between per capita methane emissions and GDP per capita in the period 2000 to 2023.

According to the data from Table 6, a very strong positive correlation (Guilford, 1953; Hinkle et al., 2003) between per capita nitrous oxide emissions and GDP per capita over the period 2000 to 2023 was recorded in:

- Moldova (0.944457).

A strong (Guilford, 1953; Hinkle et al., 2003), or very strong (Evans, 1996) positive correlation between per capita nitrous oxide emissions and GDP per capita was recorded in:

- Armenia (0.857327),
- Belarus (0.878103), and
- Russia (0.853467).

A moderate (Guilford, 1953; Hinkle et al., 2003), or strong (Evans, 1996) positive or negative correlation between per capita nitrous oxide emissions and GDP per capita was recorded in:

- Bosnia and Herzegovina (0.689554), and
- Albania (-0.616387).

A moderate (Guilford, 1953; Evans 1996), or weak (Hinkle et al., 2003) positive correlation between per capita nitrous oxide emissions and GDP per capita was recorded in:

- Ukraine (0.475931),

while in Georgia (0.386110), Montenegro (0.061712), North Macedonia (-0.103417), and Serbia (-0.022388), a weak or very weak correlation was recorded between per capita nitrous oxide emissions and GDP per capita over the period 2000 to 2023.

*Table 7: Correlation matrix TFP → Greenhouse gas emissions*

	TFP→CO <sub>2</sub>	TFP→CH <sub>4</sub>	TFP→N <sub>2</sub> O
ALB	-0.606984	-0.104759	-0.504596
ARM	-0.396502	-0.097859	-0.297104
BYS	-0.508428	-0.644848	-0.602338
BIH	-0.226502	-0.002853	-0.129330
GEO	-0.384173	0.366593	-0.188179
MLD	-0.458258	-0.020527	-0.349132
MNE	0.290690	0.298278	0.215832
NMK	0.168114	-0.102518	0.447293
RUS	-0.250513	-0.363095	-0.378505
SRB	0.489576	0.532297	-0.327783
UKR	0.279838	-0.008567	-0.072998
World	-0.001941	0.071187	0.274483

*Source: Authors' calculation*

*Table 8: Interpretation of the calculated correlation coefficients*

Interpretation of obtained results	Value of the correlation coefficient		
	Guilford, 1953	Evans, 1996	Hinkle et al., 2003
Very weak	0.00-0.20	0.00-0.20	0.00-0.30
Weak	0.21-0.40	0.21-0.40	0.31-0.50
Moderate	0.41-0.70	0.41-0.60	0.51-0.70
Strong	0.71-0.90	0.61-0.80	0.71-0.90
Very strong	0.91-1.00	0.81-1.00	0.91-1.00

*Source: <http://psihologija.ff.uns.ac.rs/viz/pirsonov-produkt-moment-koeficijent-korelacije>*

According to the data from Table 7, neither a very strong nor a strong correlation between greenhouse gas emissions and total factor productivity was recorded in any of the observed countries over the period 2000 to 2023. A moderate negative correlation between carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry and total factor productivity was observed only in Albania (-0.606984). Similarly, a moderate negative correlation between per capita methane emissions and total factor productivity was recorded only in Belarus (-0.644848).

## DISCUSSION

### Interpretation of Results and Their Significance

This study analyzes greenhouse gas emissions, GDP per capita, and total factor productivity in 11 transition economies from 2000 to 2023, comparing them with the EU27 average and global trends.

The research findings indicate that carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry have globally increased by 14.64% over the observed period. This trend can be attributed to a combination of economic, technological, demographic, and political factors. The primary driver is global GDP growth and industrial expansion. Global GDP per capita has risen by 62.27% in the same period (World Bank, 2025), directly correlating with increased energy consumption. Industrialization in developing countries (particularly in China, India, and Southeast Asia) has led to a surge in steel, cement, and petrochemical production - sectors with high CO<sub>2</sub> emissions (Li et al., 2025), confirming that global economic expansion contributes to rising CO<sub>2</sub> emissions.

According to Harris (2024), the main driver of global emissions growth is fossil fuel combustion. Specifically, the study highlights that China and India have significantly increased coal consumption since 2000, primarily for thermal power plants. Although the U.S. and EU have reduced coal dependence, they have increased reliance on natural gas, which still emits CO<sub>2</sub>, albeit at lower levels. Meanwhile, global oil consumption has risen, particularly in the transportation and aviation sectors. Additionally, Yang et al. (2024) emphasize that the expansion of global trade and air transport has significantly contributed to rising CO<sub>2</sub> emissions. According to their study, the global number of cars has doubled from 2000 to 2023, resulting in twice the oil consumption and CO<sub>2</sub> emissions from transportation, while fuel consumption in the aviation industry has increased by over 50% in the same period.

According to Li et al. (2024), the growth of global CO<sub>2</sub> emissions in urban areas is directly linked to world population growth, which has increased from 6.1 to 8 billion between 2000 and 2023. This demographic expansion has increased demand for electricity, transportation, and heating. Consequently, urbanization in developing countries has driven significant growth in cement and steel production, which are major sources of CO<sub>2</sub> emissions.

Mushtaq et al. (2024) emphasize that the energy transition requires substantial financial investments, while political decisions often delay the shift from fossil fuels to renewable energy sources. Although renewable energy sources have made significant progress, fossil fuels still accounted for 77% of global energy consumption in 2023 (International Energy Agency, 2024).

Findings by Živkov et al. (2022) suggest that countries with higher fossil fuel dependence are more vulnerable to oil price volatility, which can complicate their decarbonization efforts. Markets highly exposed to oil shocks may face greater challenges in adapting to environmental policies, as oil price volatility affects investment stability and economic growth.

Moreover, investments in green technologies in developing countries remain insufficient due to the high costs of transition. Political resistance in countries with large coal reserves (such as Russia, Saudi Arabia, and Indonesia) further slows down the global transition to clean energy sources (Martus, 2024; Wong & Dewayanti, 2024).

The studies provide additional evidence on the causes and factors explaining greenhouse gas emission trends from 2000 to 2023. This analysis confirms the complex drivers of global CO<sub>2</sub> emissions growth and the urgent need for an accelerated energy transition.

Over the past two decades, the European Union (EU) has implemented significant environmental reforms aimed at reducing carbon dioxide (CO<sub>2</sub>) emissions and transitioning to renewable energy sources. Data analyzed in this study indicate that CO<sub>2</sub> emissions in the EU decreased by 22.62% between 2000 and 2023, while GDP per capita increased by 34%. This trend confirms the possibility of achieving simultaneous economic growth and emissions reduction.

In discussing CO<sub>2</sub> reduction in the European Union, it is crucial to emphasize the role of energy policy and its impact on economic growth. The EU has successfully decoupled economic growth from emissions growth through the implementation of the Emissions Trading System (EU ETS), incentives for renewable energy investments, and strict emissions regulations.

Scientific studies confirm the effectiveness of these measures. Gołasa et al. (2024) highlight that the reform of the EU ETS system was key to achieving CO<sub>2</sub> emission reduction goals, emphasizing increased investment in renewable energy sources and reduced dependence on fossil fuels. Szczubełek & Rzeczkowski (2024) analyze how higher energy efficiency, and a greater share of renewables contributed to the EU's

economic growth, while simultaneously reducing CO<sub>2</sub> emissions through regulatory frameworks and energy diversification.

By comparing the EU and BRICS countries, Xie & Guo (2024) demonstrate that Europe has successfully established a stable green economy model, whereas BRICS nations, such as Russia and China, remain heavily reliant on fossil fuels. These studies clearly indicate that adequate policies can enable CO<sub>2</sub> emission reductions while maintaining economic growth, which has not been the case in all transition economies.

Russia, Belarus, and Bosnia and Herzegovina are among the leading CO<sub>2</sub> emitters in the region. These countries possess significant coal and oil reserves, which has resulted in a high level of dependence on fossil fuels as their primary energy source. According to Pavel et al. (2024), the energy policies in these countries are not aligned with European standards, leading to a slow implementation of emission reduction measures. Furthermore, Triarchi et al. (2024) highlight that the lack of a regulatory framework and weak enforcement of environmental taxes further contribute to the slower reduction of emissions compared to the EU.

Beyond the energy sector, political factors play a crucial role in shaping decarbonization policies. Gnjidić (2024) emphasizes that the lack of economic diversification and dependence on mining and heavy industry are the main reasons for maintaining a high level of emissions in these countries. Unlike the EU, where investments in renewable energy and energy efficiency are a priority, transition economies still favor traditional energy sources due to existing infrastructure and political frameworks.

Data analysis indicates that Albania, Moldova, and Georgia, compared to other transition economies, have relatively low levels of CO<sub>2</sub> emissions. This phenomenon can be attributed to their lower degree of industrialization and a smaller share of heavy industry in overall economic activity. Additionally, the energy mix in these countries is not predominantly based on fossil fuels but rather relies on hydropower and other low-emission sources (Siminiuc et al., 2024).

Although these countries currently have lower emissions, their future economic growth may lead to increased CO<sub>2</sub> emissions, particularly if development relies on traditional industrial sectors and unsustainable energy infrastructure. According to Gnjidić (2024), transition economies often experience a rise in emissions during early development phases, before adopting environmental standards in accordance with the principles of the Environmental Kuznets Curve (EKC).

The reduction of carbon dioxide (CO<sub>2</sub>) emissions in Ukraine over the past decades represents an exception compared to other transition

economies. While in developed economies, emission reductions are usually associated with energy transitions and effective environmental policies, in Ukraine, the key factors have been industrial recession, declining economic activity, and geopolitical conflicts. According to Han et al. (2024), the economic downturn and loss of industrial capacity have significantly contributed to lower energy consumption, which has consequently led to a decline in CO<sub>2</sub> emissions.

These differences in CO<sub>2</sub> emissions among transition economies highlight the need for tailored decarbonization strategies that would allow for emission reductions while maintaining economic stability. As shown by the research of Obwori Alwago et al. (2025), countries that implement strategic environmental taxes and support green investments are more successful in reducing emissions without negatively impacting the economy. Therefore, a successful transition requires a combination of regulatory reforms, international support, and structural changes in the energy sector.

The analysis of Total Factor Productivity (TFP) reveals significant fluctuations among the observed countries. The data show that TFP growth in transition economies was strong in the early reform period but that global crises and structural factors have significantly influenced productivity variations. While some countries have managed to sustain stable growth through institutional reforms and economic policies, others have been affected by trade dependencies and macroeconomic instabilities (Merdzan & Domazet, 2024).

The correlation analysis between Total Factor Productivity (TFP) and greenhouse gas emissions has shown different patterns of association between economic growth and environmental sustainability. It is evident that global trends do not exhibit significant correlations, suggesting that TFP growth and decarbonization do not occur synchronously on a global scale. This misalignment points to the complexity of the relationship between economic efficiency and environmental impact. Balaban et al. (2023) conclude that increased methane, nitrous oxide, and carbon dioxide emissions, as well as energy consumption, are not directly related to the value of agricultural production. However, the obtained results indicate that greenhouse gas emissions are significantly positively correlated with economic growth and development in the 11 observed transition countries.

This study also examines the correlation between economic growth and CO<sub>2</sub> emissions. The results indicate significant variations in correlation across countries and different types of gases. Most transition economies show a strong positive correlation between GDP per capita (GDPpc) and CO<sub>2</sub> emissions, suggesting that economic growth is accompanied by

increased emissions. These findings align with the research of Szczubelek & Rzeczkowski (2024), who emphasize that countries in the early stages of economic development often experience increased emissions due to their reliance on energy-intensive sectors.

Unlike transition economies, the European Union exhibits a strong negative correlation between GDP per capita (GDPpc) and emissions, specifically: CO<sub>2</sub> (-0.875), CH<sub>4</sub> (-0.910), N<sub>2</sub>O (-0.837).

These findings support the argument that the EU has successfully decoupled economic growth from emission growth. However, empirical studies only partially confirm the existence of the Environmental Kuznets Curve (EKC) for the European Union, with notable differences among countries and sectors. The latest scientific studies suggest that the relationship between economic growth and CO<sub>2</sub> emissions does not strictly follow the inverted "U" shape but rather depends on specific factors such as energy policy, renewable energy investments, and structural reforms (Frodyma et al., 2022).

This discussion of results has provided a comprehensive overview of emission trends and their relationship with economic factors, while also comparing findings with relevant scientific studies. Within the analysis, special attention has been given to variations in the correlation between economic growth and greenhouse gas emissions, highlighting the diversity of patterns that emerge in practice.

## CONCLUSION

This study analyzed the relationship between greenhouse gas emissions, total factor productivity (TFP), and economic growth in 11 transition economies, comparing the results with the European Union (EU27) average and global trends.

In most transition economies, GDP growth and CO<sub>2</sub> emissions are positively correlated, indicating a high degree of dependence on emission-intensive industrial sectors. However, significant differences in policy and economic structure influence variations between countries.

The European Union has successfully reduced emissions while maintaining economic growth, whereas most transition economies have yet to achieve this balance. This success can be attributed to a combination of effective regulatory mechanisms, increased energy efficiency, and substantial investments in renewable energy sources.

The findings confirm the complexity of the relationship between the observed variables, highlighting the need for targeted sustainable development policies.

Future research could focus on:

- Detailed sectoral analyses (industry, agriculture, transportation, and services) and their contributions to changes in TFP and emissions.
- The role of regional economic alliances in transition economies.
- The long-term effects of climate policies on economic productivity and growth.
- The socioeconomic consequences of environmental reforms on lower-income populations.

These research topics could contribute to a better understanding of the relationship between economic growth, productivity, and sustainable development, providing a foundation for effective economic and environmental policymaking in the future.

A recommendation for future research would be to examine the impact of environmentally related taxes on the reduction of GDP per capita, following the model of Balaban and Stoiljković (2023). Additionally, future studies should investigate the effect of EU accession on CO<sub>2</sub> emission reductions, drawing from the research of Stojkov Pavlović et al. (2024). This would be particularly relevant in the context of the observed transition countries, many of which have an affinity for joining the European Union in the near future.

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