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THE ROLE OF PUBLIC DEBT IN THE TRANSITION TOWARD A REGENERATIVE ECONOMY OF SOUTHEAST EUROPEAN COUNTRIES

ABSTRACT

For decades, decision-makers at national, regional, and global levels have been adopting policies aimed at addressing environmental pollution. At the same time, the human population, global economy, and worldwide energy consumption continue to grow. Increasing investment in renewable energy sources has become imperative. In this context, the concept of a regenerative economy emerges, requiring investments in renewables, research, and innovation. The assumption is that countries with lower public debt have more fiscal space to invest in renewable energy, research, and development, while those with high public debt face limited opportunities for such endeavors. The main objective of this paper is to classify Southeast European (SEE) countries according to the level of development of their regenerative economies and to determine whether public borrowing serves as a catalyst for accelerating the transition toward a regenerative economy—or rather poses an obstacle to that path. The analysis will be conducted using indicators such as: Public Debt (% of Gross Domestic Product - GDP thereafter), Renewable Energy Share (%), CO₂ Emissions (tons per capita), R&D Expenditure (% of GDP), and Sustainable Development Goal 15 (SDG15), covering the period from 2010 to 2023. The main findings suggest that SEE countries differ significantly in terms of their regenerative economy development, and that public debt plays a substantial role in shaping their transition. These insights offer valuable guidance for policymakers in designing strategies to enhance national and regional competitiveness, attract foreign direct investment, and guide investors—especially since countries with higher R&D investment offer more favorable conditions for green investments and innovation development. Moreover, this cluster analysis can contribute to strengthening regional cooperation in SEE because it facilitates the identification of leader countries and countries that need additional support and knowledge transfer.

Keywords: Public debt, regenerative economy, transition, Southeast Europe.

JEL: O40, F64

1. INTRODUCTION

The world is facing numerous challenges. The human population, the world economy, climate change and global energy use are reaching enormous proportions. Environmental pollution has become a global problem for humanity, and its solution requires global engagement. These findings have strengthened the demands of the democratic public in different parts of the world to heed warnings and make efforts on a global scale to establish a balance between the pace of development and uncontrolled degradation of the natural environment. This degradation has reached such a level that it seriously threatens humanity's continued survival, because the environment has become the main and insurmountable limitation of life and work on this planet. As a result of the increasingly frequent public demands for increased environmental care, numerous discussions, conferences and confrontations on the nature of environmental problems have arisen. The world has had to face the fact that it is very difficult to have an ecologically stable society and an expansive economic structure. The problem of environmental preservation is one of the crucial global issues today. Over time, greater investments will be needed in technology that reduces environmental degradation or in resource management technology. The use and

investment in renewable energy sources are becoming imperative. In this context, the regenerative economy comes to the fore, which implies investments in renewable sources, research and innovation.

Regenerative economics is a relatively new branch of economics that involves a holistic approach to development challenges, analyzing them from an economic, ecological, and broader social perspective. The primary focus of regenerative economics is on improving resources and economic systems, as well as on their renewal. It incorporates the principles of responsibility, inclusion, protection of land, water, air quality, etc. The development of a regenerative economy requires adequate financial resources, or investments, and this paper considers the role and importance of public debt as one of the instruments for financing its development. Public debt is a very important financial instrument that countries often use to finance economic growth and development. It can be defined as "accumulated surplus of spending over revenues that were realized in the previous period" (Rosen & Gayer, 2010, p. 458). The amount of public debt and the way it is used are very important for each country. Questions about the size and use of public debt are often asked, but there is no single answer. Public debt can, if used wisely, be seen as an instrument for investing in future prosperity. The link between public debt and a regenerative economy is largely unexplored in academic circles. Countries that use public debt to invest in the restoration of natural and social systems, such as investments in green infrastructure, energy transition, circular economy, see public debt as an instrument or tool for increasing prosperity. However, on the other hand, excessive or inefficient borrowing can threaten the financial stability of the country, leaving little room for investment in renewable energy sources, research and development.

In recent decades, the countries of Southeast Europe have undergone significant economic reforms. Through these reforms, economic progress has been achieved (although very unevenly across countries), primarily visible in the improvement of the business environment, the attraction of foreign direct investment, and the strengthening of competitiveness. Although the reforms have led to certain economic progress, this region still faces numerous challenges, above all pronounced unemployment (in 2024, unemployment was highest in Montenegro (14.1%), North Macedonia (13.4%), Bosnia and Herzegovina (10.7%), and Albania (10.5%) (World Bank, 2025)), migration issues (some, one could say most, Southeast European countries have a negative net migration balance, particularly Bosnia and Herzegovina, Albania, and Serbia (Eurostat, 2025)), corruption, and political instability (Western Balkans Stability Monitor (2024) shows that certain Southeast European countries are still facing political tensions, with Bosnia and Herzegovina and Kosovo being the most sensitive, while Albania and Montenegro are relatively more stable). In addition, policies in the Western Balkans concerning entrepreneurship development and strengthening the resilience of the private sector "lag behind those in OECD and EU member states" (OECD, 2025). Furthermore, there are numerous problems related to infrastructure development, the energy sector, and the development of renewable energy sources. Moreover, development challenges include the implementation of development strategies as well as the continuation of structural reforms with the aim of paving the way for inclusive and sustainable economic growth. The assumption is that countries with lower public debt have more room for investment in renewable energy sources, research and development, while countries with high public debt have fewer opportunities for such endeavors. The main goal of this paper is to classify the countries of Southeastern Europe according to the level of development of the regenerative economy, and to determine whether debt is an instrument for accelerating the transition to a regenerative economy in Southeastern Europe or whether it represents an obstacle on that path?

2. THEORETICAL BACKGROUND AND PREVIOUS RESEARCH

The turn of economic science towards regenerative economics provides answers to climate challenges, pollution problems, and the promotion of social well-being. Therefore, regenerative economies are aimed at establishing "sustainable social, economic, and cultural capacity through the creation of the resources, diversity, resilience, and integrity of interconnected networks at all levels of global society" (Jain, 2021, p. 1). Regenerative economics combines the best aspects of the green economy, circular economy, and bioeconomy into a single whole. "It adds active ecosystem restoration to the green economy, situates the circular economy within a broader regeneration strategy, and grounds the bioeconomy in regenerative processes that ensure the long-term health of biological resources" (Čegar et al, 2024, p. 2). Regenerative economics involves the renewal and re-emphasis on the growth of social, economic and environmental systems. It is based on a holistic approach that balances different systems

and allows them to progress simultaneously. This implies a transition from conventional (through green, sustainable and restorative) to a regenerative economy (Figure 1).

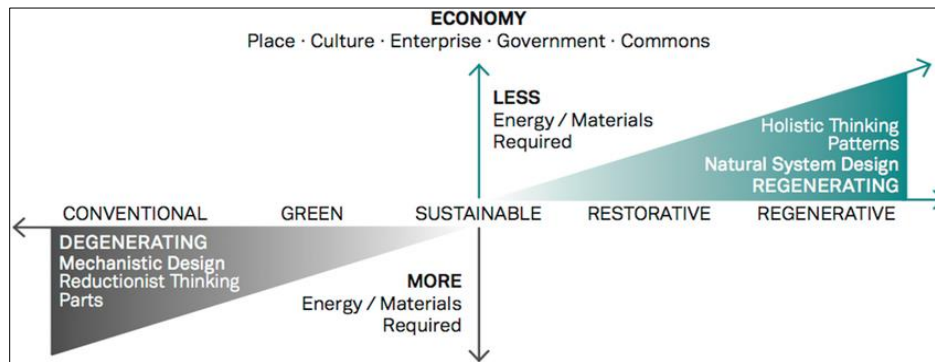


Fig 1. Stages to a regenerative economy

Source: Fullerton, J. (2015) Regenerative Capitalism; Capital Institute: Greenwich, CT, USA, p. 43.

A quantitative framework for measuring the regenerative economy was presented by Fath et al. (2019) defining 10 principles of systemic, socioeconomic health and quantitative measures of the regenerative economy. They put special emphasis on the processes of self-feeding, self-renewal and adaptive learning and conclude that a regenerative economy requires regular investments in human, social, natural and physical capital. Accordingly, the regenerative economy, and its development require adequate financial resources, i.e. financial investments. Alves et al. (2022) emphasize that monetary transformation is a key social, political and economic undertaking "which must be a global priority if we want to prevent future financial crises, reduce economic inequality and adhere to our climate agreements and sustainability goals" (Alves et al., 2022, p. 1). The authors advocate for the emergence and development of an ecological monetary economy that represents a bridge to a regenerative economy. Bolton et al. (2023) analyze the connection between climate, i.e. climate change, and debt sustainability. They focus on ways to finance climate change and instruments such as carbon credits, government bonds, green bonds, the possibility of debt forgiveness, and the like. They conclude that no instrument is universal and suggest six proposals and policies in this context, prioritizing the creation of a legal and institutional framework when it comes to mechanisms for financing climate change, i.e. the negative effects that it entails.

Yang et al. (2024) found that the impact of public debt on reducing carbon emissions is stronger in state-owned companies and companies that are large polluters. They emphasize the importance of state intervention through the use of debt in influencing corporate behavior, namely that public debt "when strategically allocated, serves as an effective tool for curbing carbon emissions, with its impact being especially pronounced in sectors where regulatory pressure to reduce emissions is higher" (Yang et al, 2024, p. 16).

Auteri et al. (2024) found a bidirectional relationship between government debt and renewable energy consumption. They point out that rising government debt hinders investment in renewable energy sources, noting that high public debt can limit government investment in green technologies. On the other hand, increasing renewable energy has a positive effect on public debt. They emphasize the importance of encouraging the use of renewable energy sources, which in the long run leads to increased fiscal benefits. Efthimiadis & Tsintzos (2023) showed that the debt default of countries with large external debt "can be combined with a policy for promoting power generation from renewable energy sources, with positive effects for economic growth and for ensuring debt sustainability" (Efthimiadis & Tsintzos, 2023, p. 1).

Kushawaha & Jain (2025) examined the impact of public debt on investment in renewable energy. They concluded that the relationship between public debt and investment in renewable energy in developing countries is inverse, that is, that public debt supports investment in renewable energy up to a certain level, after which the growth of public debt negatively affects these investments. Understanding this relationship is important because a country's ability to invest in renewable energy directly affects the development of a regenerative economy. Kantorowicz et al. (2024) found that debt financing "increases voter support for green financing by up to 10 percentage points

relative to broad-based taxes (Kantorowicz et al., 2024, p. 1). They argue that using public debt to finance green investments is politically efficient in countries with positive credit ratings and adequate access to capital markets. On the other hand Clootens & Magris (2021) analyze public debt and public spending through the use of renewable resources. They conclude that high public debt is a threat to sustainable development, that is, it negatively affects sustainable development through reduced investment and increased resource consumption.

When it comes to analyzing public debt, it is mostly associated with economic growth and there is a lot of scientific research that analyzes the nature of this relationship. However, there is less (and mostly recent) research that analyzes the relationship between public debt and the regenerative economy. Most of this research tracks investments in renewable energy sources, environmental sustainability, or the achievement of the Sustainable Development Goals (SDGs). Therefore, this research was set up in such a way that the central hypothesis is: "Public debt significantly influences the formation of clusters of SEE countries based on the development level of their regenerative economies".

The findings of this paper can help economic policy makers in designing policies and strategies to increase national and regional competitiveness, as well as attract foreign direct investment, but also investors, given that countries with higher investment in R&D offer more favorable conditions for green investments and the development of innovations. In addition, this cluster analysis can contribute to increasing regional cooperation in SEE, given that it groups countries according to the level of development of the regenerative economy, which facilitates the identification of countries that can be leaders and carriers of regional projects, but also those that need additional support and knowledge transfer.

3. RESEARCH METHODOLOGY

This study employs a quantitative comparative research design, focusing on the SEE countries for the period 2010–2023. Due to the lack of data for all years and all countries, selected SEE countries (Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, North Macedonia, Romania, Serbia and Slovenia) and the period from 2010 to 2021 were taken for research. The goal is to identify how public debt influences the transition toward a regenerative economy – a model that integrates fiscal stability, innovation capacity, and environmental sustainability.

The research relies on secondary panel data collected from internationally recognized databases, ensuring reliability and comparability across countries and years. The variables used in the analysis are: Public Debt (% of GDP) – obtained from the International Monetary Fund (2025); Renewable Energy Share (% of total final energy consumption), CO₂ Emissions (tons per capita), R&D Expenditure (% of GDP) – from World Bank (2025); Sustainable Development Goal 15 (SDG15 Index) – from Sachs et al. (2023).

These indicators were selected to capture the fiscal (Public Debt), innovation (R&D Expenditure), and ecological dimensions (Renewable Energy Share, CO₂ Emissions) of the regenerative economy. All variables were standardized prior to clustering to ensure comparability. The data were analyzed using the STATA 15 statistical software. The methodology combines several quantitative techniques: Descriptive Statistics, Pearson Correlation Analysis and Cluster Analysis (k-means). The basic clustering method is the hierarchical clustering method, and the number of clusters is additionally confirmed by a dendrogram. To check for statistically significant differences between the formed clusters, a one-way ANOVA was applied for all five variables, using the Bonferroni post-hoc test to identify pairs of clusters that differed from each other.

4. RESULTS

Descriptive statistics of the collected data are presented in Table 1. and provide a basic insight into the characteristics of the data and the interrelationships between the key variables that were selected to assess the role of public debt in the transition to a regenerative economy.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Public Debt	96	49.391	17.787	18.97	103.47
Renewable Energy Share	96	25.495	8.557	13.2	49.3
CO ₂ Emissions	96	5.667	1.212	3.88	8.38
R&D Expenditure	96	.757	.603	.1	2.56
SDG15	96	76.511	12.945	53.2	94.2

Source: Authors

The analysis of 96 observations included in the sample shows that the economic and environmental characteristics of the countries in the region are extremely heterogeneous. The average value and a standard deviation of public debt indicates significant deviations between countries and time periods. In the context of a regenerative economy, such dispersion indicates that fiscal sustainability is one of the key prerequisites for the transition to a renewable economy, as a high level of debt can limit the ability of a country to invest in green and innovative projects. However, the level of debt itself does not have to be an obstacle – what is decisive is how public debt is used: as a passive expense or as an instrument of investment in transformative processes.

The average value and the standard deviation of the share of renewable energy sources in total consumption is indicating moderate variability across countries. A higher share of renewable sources is an indicator of a structural transition of the energy system, which is necessary to reduce the carbon footprint and preserve natural resources in the long term. However, the success of this transition often depends on the fiscal support of the state, i.e. the ability to finance subsidies, infrastructure and research in the clean energy sector through public debt. The average value and relatively small standard deviation of CO₂ emissions per capita indicates a somewhat uniform level of emissions in the observed countries. These values reflect the fact that the countries of the region are still dominantly dependent on traditional energy sources, with limited progress in decarbonizing the economy. The role of public debt in this context is reflected in the state's ability to finance the modernization of industry, energy reforms and reduction of emissions through fiscal policy.

R&D Expenditure data clearly indicate a low level of investment in innovation and technological progress in most of the observed countries. Given that the regenerative economy implies innovative approaches to circularity, resource renewal and green technologies, such a low level of allocation indicates a structural obstacle to transformation. Public policy in this segment should use fiscal instruments, including public debt, to finance research programs, start-up innovations, technology centers and education.

SDG15 data shows that most countries have a moderate to high level of natural resource conservation, but there are differences in the capacity to protect ecosystems. Higher SDG15 values usually result from adequate institutional frameworks, but also from fiscal investments in the maintenance and restoration of natural capital. These results suggest that countries with better managed public finances achieve better environmental outcomes, as they can direct funds to projects that contribute to regenerative processes.

Table 2. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)
(1) Public Debt	1.000				
(2) Renewable Energy Share	-0.071	1.000			
(3) CO ₂ Emissions	-0.296*	-0.147	1.000		
(4) R&D Expenditure	0.402*	-0.217*	0.422*	1.000	
(5) SDG15	-0.361*	0.290*	0.363*	0.120	1.000

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's research

Table 2 shows the pairwise (Pearson) correlation coefficients between the five main variables analyzed in this study (correlation, not causation). The results of the correlation analysis indicate complex correlation between fiscal, innovation and environmental variables.

First of all, public debt shows significant correlation with most of the analyzed indicators. The negative correlation between public debt and SDG15 (-0.361*) suggests that countries with higher levels of debt generally perform worse in preserving terrestrial ecosystems and biodiversity. This is understandable given that high levels of public debt can limit the fiscal space for investments in environmental projects and sustainable resource management. On the other hand, public debt is positively and significantly associated with R&D expenditure (0.402*), which may indicate a long-term modernization strategy. The negative, but statistically insignificant, relationship with the share of renewable energy sources (-0.071) shows that the level of public debt does not in itself determine the energy mix, suggesting the importance of the regulatory and institutional framework.

The share of renewable energy sources shows a negative relationship with CO₂ emissions (-0.147), which confirms the expected pattern that greater use of renewable sources contributes to emission reduction. However, the negative correlation with R&D expenditure (-0.217*) may indicate that R&D funds are not sufficiently directed towards the energy sector, but towards other industries. The positive and significant connection between renewable sources and SDG15 (0.290*) additionally confirms the ecological importance of the energy transition, because countries with a higher proportion of renewable energy simultaneously achieve better results in ecosystem protection. CO₂ emissions exhibit a significant positive correlation with research and development expenditures ($r = 0.422$), which may suggest that advanced countries – despite emitting higher levels of greenhouse gases – possess greater resources for investing in innovation and potential decarbonization strategies. The positive association with SDG15 ($r = 0.363$) partially reflects the so-called "development paradox," wherein economically stronger nations tend to have more robust institutional mechanisms for biodiversity conservation.

Research and development spending shows a bidirectional relationship: it is positively associated with public debt and emissions, and negatively with renewables, while the link with SDG15 is relatively weak. These results suggest that innovation potential in itself is not a guarantee of environmental progress, but that the outcome depends on the direction in which R&D funds are directed – towards digitalization, energy efficiency or green technologies.

Finally, SDG15 shows a positive relationship with the share of renewables and emissions, but a negative relationship with public debt. Overall, environmental indicators in SEE countries remain largely dependent on fiscal capacity, institutional capacity and policies geared towards a green transition. These findings suggest that the transition to a regenerative economy requires a balanced approach: simultaneously fiscal stability, investment in R&D and consistent energy and environmental policies. Otherwise, high public debt may become a constraint, rather than a support, to long-term sustainability and regenerative growth.

Table 3. Summary statistics: N mean sd min max by (clusterID)

	N	mean	sd	min	max
clusterID: 1 Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Romania					
Public Debt	57	42.121	17.048	18.97	84.03
Renewable Energy Share	57	28.158	10.030	13.2	49.3
CO ₂ Emissions	57	5.623	1.183	3.88	7.46
R&D Expenditure	57	.525	0.272	.1	1.23
SDG15	57	84.114	5.775	76.6	94.2
clusterID: 2 Slovenia					
Public Debt	12	59.797	12.917	32.68	72.95
Renewable Energy Share	12	21.208	1.384	19.1	23.4
CO ₂ Emissions	12	7.261	0.557	6.38	8.38
R&D Expenditure	12	2.191	0.233	1.87	2.56
SDG15	12	83.342	0.211	83	83.6
clusterID: 3 Montenegro, Serbia					
Public Debt	27	60.114	13.199	39.46	103.47
Renewable Energy Share	27	21.778	3.412	17	29.8
CO ₂ Emissions	27	5.051	0.807	4	6.42
R&D Expenditure	27	.611	0.239	.22	.99
SDG15	27	57.426	3.736	53.2	66.2

Source: Author's research

The analysis of data grouped into three clusters, on the other hand, allows for a deeper understanding of the interrelationships between public debt and sustainable development indicators in the countries of Southeastern Europe. The focus of the research was on the role of public debt in the transition process towards a regenerative economy – a model that seeks not only to maintain existing resources, but also to renew and improve them through circular and inclusive practices. The results obtained indicate that fiscal policy, and in particular the level of public debt, can have different implications for the environmental performance and innovation capacities of countries. Table 3 presents the results of the mean values of the observed variables by clusters (hierarchical clustering using the Ward method). It can be seen that cluster 1 contains countries with moderate public debt and an ecological balance without innovative momentum; cluster 2 contains countries characterized by high public debt, strong innovation and a controlled ecological price; while cluster 3 contains countries with high public debt without environmental benefits.

The first cluster, which includes Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia and Romania, is characterized by moderate public debt and a relatively high share of renewable energy sources. These countries achieve solid results within the framework of the Sustainable Development Goal SDG15, which indicates relatively preserved natural resources and stable ecosystems. However, low investment in research and development indicates a lack of innovation potential, which is an obstacle to a deeper transformation towards a regenerative economy. In the context of public debt, this cluster shows that a moderate level of indebtedness can contribute to economic and environmental stability, but without strong development policies and investments in innovation, such stability remains passive and does not lead to systemic changes. Countries in this group retain traditional development patterns, where fiscal policy is primarily used to maintain budget balance, and not as an instrument for strategic investment in green and regenerative transformation.

The second cluster consists only of Slovenia, which clearly stands out across all indicators. With an average public debt of 59.80% and the highest investment in research and development, Slovenia demonstrates how a more developed economy can use public debt as a mechanism to support innovation and green technologies. Although it has slightly higher CO₂ emissions and a lower share of renewable sources, its high SDG15 value indicates a successful integration of environmental standards into industrial development. This result suggests that higher public debt does not necessarily have to be an obstacle to sustainable development – on the contrary, if used as an instrument for strategic investment in research, digitalization and green infrastructure, it can become a key driver of the regenerative economy. Slovenia thus stands out as an example of a country that has turned fiscal indebtedness into a tool for stimulating innovation, creating added value and ecological transformation. In its case, debt is not a "burden", but a catalyst for the transition to a regenerative economy.

The third cluster, which includes Montenegro and Serbia, shows the most unfavorable structure of indicators. These countries have the highest average public debt, but at the same time very low investments in research and development and the worst SDG15 result. This indicates a situation in which public debt is used predominantly to cover current consumption and budget deficits, instead of for development and environmental investments. Their moderate level of CO₂ emissions and medium share of renewable sources cannot compensate for the lack of a systemic approach to sustainability. In the context of a regenerative economy, these countries show that high public debt without strategic orientation leads to environmental and economic stagnation. The lack of long-term investments in innovation, circular models and nature conservation makes it impossible to turn public finances into an engine of regenerative development.

The results of the ANOVA analysis show that the formed clusters are statistically significantly different on all observed variables. In the case of public debt ($F=15.23$; $p<0.001$), cluster 1 has significantly lower values compared to clusters 2 and 3. The share of renewable energy sources ($F=7.79$; $p<0.01$) is also higher in cluster 1, while clusters 2 and 3 are similar. CO₂ emissions ($F=19.24$; $p<0.001$) are highest in cluster 2, followed by cluster 1, while cluster 3 has the lowest values. Allocations for research and development ($F=211.88$; $p<0.001$) are drastically higher in cluster 2 than in other groups. Finally, SDG15 shows the biggest differences ($F=285.33$; $p<0.001$), with clusters 1 and 2 achieving high results, while cluster 3 lags behind significantly. These findings confirm that clusters have clear structural differences in key economic, environmental, and innovation indicators.

The results clearly support the central hypothesis that the impact of public debt on the regenerative transition is not determined by its level, but by its structure and purpose. Countries that allocate borrowed funds toward innovation, research, and green infrastructure (e.g., Slovenia) achieve stronger ecological and economic outcomes, while those that use debt primarily for consumption or deficit coverage (e.g., Montenegro and Serbia) experience stagnation in both domains. This confirms that the quality of fiscal spending is a more critical factor than the mere amount of debt.

5. DISCUSSION

The descriptive analysis shows that the countries covered by the research have a moderate level of public debt, but also a low level of innovation investment. Although the average values of environmental indicators (Renewable Energy Share and SDG15) suggest some progress in sustainability, it is evident that such results are not the result of systemic fiscal policies, but primarily structural and geographical advantages. In the context of a regenerative economy, these findings confirm that public debt management has the potential to accelerate the ecological and technological transition, but only if debt is used productively, that is, to create, not consume, value.

Public debt directed at research, innovation, green infrastructure and energy transformation contributes to the long-term renewal of natural and social capital. In contrast, debt without a development purpose can exacerbate fiscal pressure and delay the process of economic regeneration. Therefore, descriptive indicators represent an important empirical basis for understanding how fiscal policy, through adequate public debt management, can become the foundation of a regenerative model of development, in which economic growth does not destroy nature, but actively restores and supports it.

The results of the correlation analysis confirm that there is a complex and bidirectional relationship between public debt, innovation and sustainability in the SEE countries. This pattern reflects the typical challenges of transition economies, which strive to simultaneously maintain fiscal stability, increase competitiveness and improve environmental performance. First, the negative correlation between public debt and SDG15 indicates that excessive borrowing can reduce the possibilities for financing projects related to the protection of terrestrial ecosystems, afforestation and sustainable land use. Countries with higher debt tend to direct funds to servicing obligations, while investments in environmental and regenerative projects are postponed or reduced. This finding supports the thesis that fiscal capacity is an important prerequisite for a green transition (e.g. according to theories of fiscal space for sustainable development).

At the same time, the positive relationship between public debt and R&D expenditure opens the possibility of a different interpretation: borrowing in some countries can be used as an instrument of transformation, if the debt is directed towards innovation and development programs. Thus, public debt, although a potential risk, can become a driver of structural change, especially if innovations are focused on energy efficiency, digitalization and the circular economy. In this sense, the findings suggest that the composition and purpose of public spending matter more than the level of debt itself. If debt is used for consumption without a development component, it worsens environmental indicators; however, if it is used for R&D and green technologies, it can have a regenerative effect.

Another important dimension concerns the relationship between innovation and sustainability. The positive correlation between CO₂ emissions and R&D expenditure may partly reflect the stage of industrial development: countries that consume more energy and pollute more often also have a greater potential for research investment. This may indicate that the transition to a low-carbon economy is not yet fully achieved, but is at an early stage in which innovation is not yet fully redirected towards decarbonisation. The positive link between renewable energy sources and SDG15, confirms that the energy transition has direct benefits for ecosystems. Countries that increase the share of renewables also achieve better results in protecting land, forests and biodiversity, which supports the concept of a "regenerative economy". At the regional level, these findings imply that SEE countries need to combine fiscal discipline with smart investments in innovation and renewables to create a sustainable growth path. Instead of the traditional approach of "fiscal austerity", the focus should be on green and inclusive investments, which simultaneously reduce debt in the long term and increase the resilience of the economy.

Cumulatively, the results of the cluster analysis clearly differentiate three development patterns of the observed SEE countries: Cluster 1 – countries with moderate debt, solid environmental performance, but low innovation investment; Cluster 2 – countries with higher debt and high investment in innovation, where debt is used productively; Cluster 3 – countries with high debt and poor environmental performance, indicating inefficient use of public funds.

The results of this study align with and expand upon several strands of existing literature. The negative correlation between public debt and SDG15 supports the conclusions of Clootens & Magris (2021), who argue that excessive public indebtedness threatens environmental sustainability by crowding out investment in natural resource preservation. Similar findings were presented by Auteri et al. (2024), who identified a bidirectional relationship between government debt and renewable energy use, showing that high debt burdens can constrain green investment capacity. Conversely, the positive relationship between public debt and R&D expenditure corresponds with the results of Yang et al. (2024) and Kantorowicz et al. (2024), who emphasize that strategically managed debt can serve as an effective tool for stimulating innovation and financing environmental reforms.

These findings suggest that debt-financed investments in technological progress may yield long-term regenerative benefits, particularly when directed toward renewable energy, digital infrastructure, and sustainable production. Moreover, the inverse U-shaped dynamic found by Kushawaha & Jain (2025) is relevant for interpreting the results of this paper – indicating that public debt supports green transition only up to a certain threshold, beyond which additional borrowing reduces fiscal and ecological efficiency. The countries in Cluster 2 exemplify this threshold effect: higher debt levels coexist with strong innovation capacity and stable environmental performance, as opposed to Cluster 3, where rising debt correlates with weaker ecological outcomes. At the same time, the positive link between renewable energy share and SDG15 reinforces the notion proposed by Efthimiadis & Tsintzos (2023) that debt-financed policies promoting renewable energy can yield mutually reinforcing benefits for both economic growth and ecosystem restoration. The SEE region thus demonstrates that fiscal discipline, when combined with targeted innovation and ecological investment, forms the foundation of a regenerative economy.

In comparison with earlier studies that primarily analyzed the nexus between public debt and economic growth, this paper extends the analytical horizon by embedding fiscal variables within a sustainability and innovation framework. The results confirm that public debt is not inherently negative, but that how it is used is crucial. Countries that have directed public resources towards research, innovation and green technologies have achieved long-term benefits and are moving towards regenerative models.

In contrast, countries that retain the traditional fiscal paradigm, which is focused on short-term budget balancing without strategic investments, are lagging behind in terms of the ecological transition. It is in this context that public policy and public debt management become key instruments of regenerative transformation. Investments financed by public debt can contribute to the restoration of ecosystems, the development of sustainable infrastructure, innovations in renewable energy sources and the creation of social values that go beyond the linear model of "take-produce-dispose". A regenerative economy requires a redefinition of fiscal responsibility: not only as cost control, but as an investment strategy for future resilience and natural renewal.

6. CONCLUSION

The research results show that public debt in SEE countries has a two-way impact on green and regenerative transition processes. On the one hand, higher levels of debt limit the fiscal space for environmental investments and the achievement of the Sustainable Development Goals (SDG15), while on the other hand, debt can have a developmental function if it is directed towards innovation and research. The findings indicate that the structure of public spending is more important than the level of indebtedness itself: when funds are used for R&D and green technologies, debt becomes an instrument of transformation, not an obstacle. The positive correlation between renewable energy sources and environmental indicators confirms the importance of the energy transition in strengthening sustainability. Overall, the transition to a regenerative economy in the region requires a balanced approach to fiscal stability, innovation and the protection of natural resources, with public debt being a driver, rather than a constraint, of sustainable development.

In addition, the cluster analysis showed that countries with balanced fiscal policies and a focus on innovation have a greater potential for the transition to a regenerative economy. The example of Slovenia confirms that public debt, if properly directed, can be transformed into a lever for regenerative development. In contrast, countries that use public debt without a clear development vision risk deepening economic dependence and degrading natural capital. Overall, the results of the cluster analysis show clear differentiation among the observed countries. While country from Cluster 2 leads in terms of economic development and innovative investments, countries from Cluster 1 achieve better environmental indicators, but with weaker economic performance. In contrast, Cluster 3 indicates countries that face challenges on both economic and environmental levels. The results of the ANOVA analysis confirm that the identified clusters are not random, but systematically differ across all key indicators of sustainable development and economic performance, and indicate the need for more balanced policies that would link economic growth with the preservation of natural resources. Therefore, the key challenge for the countries of the region remains to redirect public finances towards long-term, regenerative goals, thereby simultaneously strengthening economic resilience and preserving the natural basis of development.

The findings confirm the hypothesis that the developmental role of public debt depends on how it is managed. When directed toward innovation and sustainability-oriented investments, debt becomes a driver of regenerative transformation. Conversely, when used for short-term consumption, it turns into a burden that limits both fiscal and ecological resilience. The main limitations stem from data availability and the exclusion of qualitative variables, such as institutional quality and governance efficiency. Nevertheless, these dimensions are indirectly captured through performance in SDG15. The study is also limited to quantitative indicators, while future research may integrate qualitative case studies or policy analyses to provide a more comprehensive understanding of fiscal-ecological dynamics.

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