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THE INFLUENCE OF ECONOMIC DEVELOPMENT ON CIRCULAR ECONOMY IMPLEMENTATION IN BALKAN COUNTRIES

UTICAJ EKONOMSKOG RAZVOJA NA PRIMENU CIRKULARNE EKONOMIJE U ZEMLJAMA BALKANA

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Abstract

This research investigates the influence of economic development on the implementation of circular economy (CE) practices in Balkan countries from 2013 to 2022. By analyzing key economic indicators such as GDP per capita, Gross Fixed Capital Formation (GFCF), employment, and Human Development Index (HDI), the authors examine their impact on resource productivity, waste generation, and material import dependency. Results reveal that while economic growth reduces material import dependency, it can negatively affect resource productivity, suggesting that without targeted CE policies, higher consumption may undermine resource efficiency. Additionally, employment and HDI did not have a significant impact on the reduction waste generation. These findings underscore the need for targeted investments, improved urban waste management, and sustainability education to align economic development with CE goals. The study highlights the importance of integrating circular economy strategies into the broader development agenda to ensure sustainable growth in the region.

Sažetak

Kroz ovaj rad autori analiziraju uticaj privrednog razvoja na implementaciju praksi cirkularne ekonomije (CE) u zemljama Balkana od 2013. do 2022. godine. Analizom ključnih ekonomskih indikatora kao što su BDP po glavi stanovnika, bruto formiranje stalnog kapitala (GFCF), zaposlenost i indeks humanog razvoja (HDI), autori ispituju njihov uticaj na produktivnost resursa, stvaranje otpada i zavisnost od uvoza materijala. Rezultati otkrivaju da, iako privredni rast smanjuje zavisnost od uvoza materijala, može negativno uticati na produktivnost resursa, što ukazuje na to da bez konkretnih politika usmerenih ka CE, veća potrošnja može negativno uticati na efikasnost resursa. Pored toga, zapošljavanje i HDI nisu imali značajan uticaj na smanjenje stvaranja otpada. Ovi rezultati ističu potrebu za ciljanim investicijama, boljim upravljanjem komunalnim otpadom i obrazovanjem o održivosti kako bi se privredni razvoj uskladio sa ciljevima CE. Radom se naglašava važnost integracije strategija cirkularne ekonomije u širi razvojni plan kako bi se osigurao održiv rast u regionu.

Keywords: *circular economy, economic development, Balkan countries, resource productivity, waste generation, material import dependency, sustainability, panel data analysis****.***

Ključne reči: *cirkularna ekonomija, privredni razvoj, balkanske zemlje, produktivnost resursa, generisanje otpada, zavisnost od uvoza materijala, održivost, panel analiza podataka.*

1. Introduction

The transition toward circular economy (CE), with particular emphasis on sustainable resource management and waste reduction, has emerged as a global priority for achieving and maintaining sustainable development [1]. In the European Union (EU), initiatives like the Green Deal and the Circular Economy Action Plan highlight the need to separate economic growth and development from further environmental degradation and devastation [2]. However, the implementation of CE practices varies across regions, particularly in the Balkan countries, which face unique economic and infrastructural challenges [3]. At the same time, recent studies emphasize that integrating human capital development and institutional support can bolster CE-oriented innovation, especially in transition economies [4][5].

Despite the global push towards circularity, there is a noticeable gap in the literature concerning the influence of economic development on CE adoption across the globe, and this gap is even more noticeable in Balkan countries. Existing studies often focus on individual countries or specific aspects of the CE, such as waste management challenges in Croatia [6] or the implementation of CE practices among SMEs in Bosnia and Herzegovina [7], without providing a comprehensive regional analysis. Moreover, the limited integration of economic development metrics with CE indicators in empirical research underscores the need for a detailed examination of this relationship. Several scholars have demonstrated that macroeconomic indicators such as GDP per capita and capital formation can either facilitate or hinder resource efficiency, depending on policy effectiveness and investment patterns [8][9].

Through this research, the authors aim to examine the influence of economic development on the implementation of CE practices in Balkan countries - specifically Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Montenegro, Romania, Serbia, and Slovenia. By drawing on established panel data approaches that account for both country-specific and time-specific factors [10][11], the main objective of the research is to investigate the influence of economic development, measured by Gross Domestic Product per capita (GDPpc), Gross Fixed Capital Formation (GFCF), Employment to Population Ratio (EMPL), and Human Development Index (HDI) on the implementation of circular economy practices in Balkan countries, focusing on their impact on resource productivity, waste generation, and material import dependency. The research objective is operationalized through the following research questions:

- How does economic growth, measured by Gross Domestic Product per capita (GDPpc) and Gross Fixed Capital Formation (GFCF), influence resource productivity (RP)?
- What is the relationship between employment rates (EMPL), the Human Development Index (HDI), and waste generation per capita (WPC and MWPC)?
- Does higher economic development decrease material import dependency (MID)?

To address the research questions, the authors start from the position that higher levels of economic development in Balkan countries positively influence the implementation of circular economy practices, resulting in increased resource productivity, reduced waste generation, and decreased material import dependency. This position and the main hypothesis are operationalized through the following individual hypotheses:

- H1: Higher economic development (GDPpc, GFCF, HDI) positively impacts resource productivity.
- H2: Higher employment rates and human development (EMPL, HDI) reduce waste generation.
- H3: Higher GDPpc and GFCF are associated with lower material import dependency.

By analyzing data from 2013 to 2022, this research fills a critical gap by providing a multi-country analysis that integrates economic development indicators with CE metrics in the Balkan context. **Such integration is increasingly necessary, as studies in other European regions and in developing economies outside Europe reveal that economic structures, policy frameworks, and educational attainment collectively shape the**

pace of CE adoption [11][12][13]. The findings will offer valuable insights for academics, policymakers, and industry practitioners, guiding the development of targeted strategies to promote sustainable economic growth and enhance CE practices in the region.

This paper is structured to provide a review of the relevant literature on economic development and CE implementation, followed by the outline of the research methodology, including data sources and analytical techniques. Then, the paper presents the results of the empirical analysis and the discussion of the findings in relation to existing studies. Finally, the authors provide the concluding remarks with policy implications and recommendations for future research. In doing so, it responds to the need for a more nuanced understanding of how transitioning economies, such as those in the Balkans, can harness CE principles to ensure both environmental and economic benefits [14].

Literature Review

The circular economy (CE) has gained significant global attention as a sustainable alternative to the traditional linear economic model, aiming to decouple economic growth from resource consumption and environmental degradation and devastation [15]. Countries worldwide increasingly adopt CE principles to promote sustainable development and address pressing environmental challenges [16]. Additionally, recent research also points to the essential role of human capital and institutional frameworks in driving effective CE transitions, particularly in transition economies [4][5].

In Europe, the European Union (EU) has been at the forefront of CE implementation, with policy initiatives such as the Circular Economy Action Plan and the European Green Deal setting ambitious targets for waste reduction, resource efficiency, and sustainable economic growth [2]. Multiple studies have shown that CE practices can have a positive impact on economic growth in EU countries by enhancing competitiveness, fostering innovation, and creating new job opportunities [17]. However, the relationship between economic development and CE implementation varies across member states [18]. Kirchherr et al. [10] emphasize that CE definitions and metrics often differ among EU members, influencing how effectively CE policies translate into measurable outcomes at the national level.

Several research studies have explored the dynamic relationship between economic advancement and the implementation of circular economy principles in Europe. Hysa et al. [17] developed an integrated model demonstrating that CE innovation and environmental sustainability significantly contribute to economic growth in EU countries. Similarly, Ferrante and Germani [19] found that CE plays a crucial role in promoting socio-economic growth by reducing unemployment and enhancing human development. These studies suggest a positive correlation between economic development indicators, such as GDP per capita and employment rates, and the successful implementation of CE practices. Nonetheless, findings by Mazzanti and Zoboli [8] indicate that waste generation can continue to rise in tandem with economic growth unless targeted policy interventions decouple production and consumption from resource usage.

In the context of the Balkan countries, research on the influence of economic development on CE adoption is highly limited. While some studies focus on individual countries - such as Luttenberger's [6] examination of waste management challenges in Croatia and Kahriman and Tandir's [7] analysis of CE practices among SMEs in Bosnia and Herzegovina, there is a lack of comprehensive regional analyses that integrate economic development metrics with CE indicators. Comparative investigations in other developing or transition contexts, such as Vietnam, China, and Russia reinforce the importance of policy consistency, capacity building, and innovation investment to bolster CE outcomes [4][5].

Popović et al. [3] assessed the impact of CE competitiveness and innovation on economic growth in European countries, including some Balkan nations, highlighting the need for more focused research in this region. Additionally, Bucea-Manea-Tonis et al. [20] compared Romania

and Serbia's progress toward a resilient CE, emphasizing the role of innovation and competitiveness. These studies underscore the importance of considering economic factors in the adoption of CE practices but do not provide a detailed empirical framework specific to the Balkans. More recent literature points to panel-data-based approaches as a way to capture the complexities of multi-country and longitudinal analyses, shedding light on how GDP growth, investment (GFCF), and human development indicators can influence resource efficiency, waste management, and import dependency [9][13].Moreover, the EU's policies significantly influence CE implementation in both EU and non-EU Balkan countries. EU member states in the Balkans, such as Bulgaria, Croatia, Greece, Romania, and Slovenia, are subject to EU directives and benefit from funding and support for CE initiatives [1]. Non-EU countries, on the other hand, face challenges in aligning their policies with EU standards, often due to economic constraints and lack of infrastructure [20]. In such contexts, factors like education, consumer behavior, and strong governance can further facilitate or hinder circular economy transitions [11][12].

Despite the recognition of CE's potential benefits, there remains a noticeable gap in longitudinal studies examining the evolution of CE practices in relation to economic development over time in the Balkan region. Addressing this gap is crucial for understanding how economic growth can facilitate or hinder the transition toward a circular economy, informing policymakers and stakeholders in developing effective strategies. By incorporating insights from these broader studies, alongside robust data analysis, it becomes possible to determine whether rising incomes and human development indices actually correspond to more resource-efficient and less waste-intensive economies in the Balkan context [14][16].

Research Methodology

The research adopts a quantitative approach utilizing panel data regression analysis to investigate the relationship between economic development and circular economy (CE) practices in Balkan countries from 2013 to 2022. The data were collected from reputable sources such as the World Bank [21] and Eurostat [22], with an emphasis on capturing the multidimensional aspects of economic development and its influence on CE metrics. The study focuses on nine Balkan countries - Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Montenegro, Romania, Serbia, and Slovenia. However, due to insufficient data availability, Albania and Montenegro were excluded from the final quantitative analysis.

The dataset comprises annual data for nine Balkan countries: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Montenegro, Romania, Serbia, and Slovenia. Due to insufficient data, the authors had to exclude Albania and Montenegro from the quantitative analysis.

The authors utilize a range of independent, dependent, and control variables to capture the multifaceted relationship between economic development and CE practices. The variables are, in short, presented in the lines below:

Independent Variables (Economic Development Indicators):

- Gross Domestic Product per Capita (GDPpc): Measures economic output per person [21].
- Gross Fixed Capital Formation (GFCF): Represents investment in fixed assets [21].
- Employment to Population Ratio (EMPL): Indicates labor market participation [21].
- Human Development Index (HDI): Reflects overall development in health, education, and income [23].

Dependent Variables (Circular Economy Metrics):

- Resource Productivity (RP): GDP per unit of domestic material consumption [22].
- Waste Generation Per Capita (WPC): Total waste generated divided by population [22].
- Generation of Waste Excluding Major Mineral Wastes per GDP Unit (GWGDP): Waste generation relative to GDP [22].

- Generation of Municipal Waste Per Capita (MWPC): Municipal waste per person [22].
- Recycling Rate of Municipal Waste (RRMW): Percentage of municipal waste recycled [22].
- Material Import Dependency (MID): Reliance on imported materials [22].

Control Variables:

- Urbanization, tertiary education, industry value-added, energy consumption, R&D expenditure, exports, inflation, foreign direct investment (FDI), and renewable energy consumption [21,22].

The authors utilized appropriate imputation methods to address missing data and ensure data completeness and consistency for panel data regression. Linear Interpolation was employed to fill gaps between known values, assuming a linear trend for variables such as GDPpc and GFCF [21]. Forward and Backward Filling was applied where data was missing at the beginning or end of the time series [22]. Mean Imputation was used to handle small random gaps, particularly in employment and waste generation data [17].

Several variables were transformed to meet the assumptions of panel data regression and to stabilize the variance. Logarithmic Transformation was applied to GDPpc, resource productivity (RP), waste generation per capita (WPC), and other skewed variables to normalize distributions and reduce heteroscedasticity [20], while Z-score Standardization was used for GFCF, HDI, and material import dependency (MID) to allow comparability across different units of measurement and eliminate potential multicollinearity [16].

The authors utilize panel data regression models to account for both cross-sectional (countries) and time-series (years) variations, allowing for more precise control over unobserved heterogeneity and enhancing the efficiency of the econometric estimates [18]. Two types of models were employed:

- Fixed Effects Model (FEM): This model controls for time-invariant characteristics of each country by allowing individual intercepts, ensuring that unique country-specific factors do not bias the estimates [19].
- Random Effects Model (REM): This model assumes that country-specific effects are random and uncorrelated with the independent variables, allowing for more efficient estimation under certain conditions [19].

To ensure the robustness of the econometric analysis, several diagnostic tests and model selection procedures were conducted. The Hausman Test was applied to determine whether Fixed Effects or Random Effects was more appropriate, checking if the unique country effects were correlated with the regressors [19]. Additionally, potential multicollinearity issues among the independent variables were assessed using the Variance Inflation Factor (VIF). No significant multicollinearity was found, ensuring the reliability of the model's estimates [17].

Addressing issues such as heteroscedasticity and autocorrelation was crucial to avoid biased standard errors and unreliable p-values. In cases where heteroscedasticity was detected, robust standard errors were applied to improve the accuracy of the regression results [18,19].

Three main panel data regression models were constructed to test the research hypotheses.

- Model 1 investigates the relationship between economic development and resource productivity (RP). The model includes log-transformed values of GDP per capita (GDPpc) and Gross Fixed Capital Formation (GFCF), alongside the Human Development Index (HDI), with control variables such as urbanization and tertiary education. The model equation is as follows:

$$\mathrm{RP}_{it} = \alpha_i + \beta_1 \ln(\mathrm{GDPpc}_{it}) + \beta_2 \ln(\mathrm{GFCF}_{it}) + \beta_3 \mathrm{HDI}_{it} + \gamma \mathrm{Z}_{it} + \epsilon_{it}$$

Where RP_{it} is the resource productivity for country i at time t, and Z_{it} represents control variables such as urbanization and tertiary education levels.

- Model 2: Examines the impact of employment (EMPL) and HDI on waste generation per capita (WPC), capturing the effect of economic and social development on waste management:

$$\mathrm{WPC_{it}} = \alpha_{\mathrm{i}} + \beta_1 \mathrm{EMPL_{it}} + \beta_2 \mathrm{HDI_{it}} + \gamma \mathrm{Z_{it}} + \epsilon_{it}$$

- Model 3 analyzes how economic growth influences material import dependency (MID). The model includes log-transformed values of GDPpc and GFCF as predictors:

$$MID_{it} = \alpha_{\mathrm{i}} + \beta_2 ln(\mathrm{GDPpc}_{it}) + \beta_2 ln(\mathrm{GFCF}_{it}) + \gamma \mathrm{Z_{it}} + \epsilon_{it}$$

In all three models, α_{i} represents the country-specific effects, and ϵ_{it} denotes the error term.

The data analysis was conducted using the R software to ensure efficient data processing and rigorous statistical analysis [24].

Despite the robustness of the methodology, some limitations should be acknowledged. The availability of data across countries and years necessitated imputation for missing values, which could introduce estimation biases [16]. Furthermore, the models did not fully account for the potential issue of endogeneity, particularly the reverse causality between economic development and CE practices, which could affect the interpretation of results [19]. Future studies could mitigate this issue by employing instrumental variables or other advanced techniques.

Lastly, unobserved factors, such as cultural and policy differences between the countries analyzed, may have influenced the results. The regression models did not fully capture these factors and could explain variations in CE implementation not accounted for by the economic indicators alone [20].

Research Results

This section presents the empirical results from the panel data analysis, exploring the relationship between economic development and circular economy (CE) practices in the Balkan countries from 2013 to 2022. Three models were estimated to examine the impact of key economic indicators - GDP per capita (GDPpc), Gross Fixed Capital Formation (GFCF), employment rates (EMPL), and Human Development Index (HDI) - on resource productivity (RESP), waste generation (WPC, GWGDP, MWPC), and material import dependency (MID).

Descriptive Statistics and Data Characteristics

Prior to diving into the regression analysis, the authors present an overview of the descriptive statistics for the key variables utilized in the models. The descriptive analysis presented in Table 1 helps highlight the variation in economic development and CE practices across the Balkan countries.

Table 1: Descriptive Statistics of Key Variables

Variable	Type	Mean	Median	SD	Skew.	Kurt.	p-value
GDPpc	Independent	12485.12	9952.84	6707.38	0.77	2.46	0
GFCF	Independent	22.31	21.76	5.25	0.20	3.21	0.0583
EMP	Independent	46.01	46.78	6.41	-0.50	2.56	0.0143
HDI	Independent	0.83	0.81	0.05	0.39	1.96	9E-04
RP	Dependent	0.75	0.43	0.486	0.67	1.70	0
WPC	Dependent	6267.97	3673	6313.22	1.46	4.40	0
GWGDP	Dependent	207.54	125	149.82	0.84	2.54	0
MWPC	Dependent	400.44	413	77.58	-0.38	2.07	0.0031
MID	Dependent	24.74	23.1	11.71	0.45	2.11	4E-04
URBP	Control	60.16	56.33	10.17	0.90	2.36	0
TERT	Control	70.02	67.40	28.45	1.43	4.57	0
IND	Control	23.43	23.85	4.51	-0.51	2.92	0.0085

Note: Shapiro-Wilk p-value indicates the results of the normality test, showing that most variables exhibit non-normal distribution, justifying the need for transformations.

Model Estimation Results

The core of the analysis is focused on the panel regression models that examine the impact of economic development on CE indicators. The authors present the results for each model, followed by a summary table and relevant visualizations to enhance interpretation.

Model 1: Economic Development and Resource Productivity

The results of the panel data analysis of Model 1, which investigates how economic development, measured by GDPpc, GFCF, and HDI, influences RP, are presented in Table 2. The model also includes control variables for urbanization (URBP) and tertiary education (TERT).

Table 2: Descriptive Statistics of Key Variables

Coefficient	Estimate	Std. Error	t-value	p-value	Significance
Log(GDP per capita)	-0.126	0.051	-2.45	0.017	**
GFCF	0.032	0.037	0.87	0.386	
HDI	-0.081	0.048	-1.70	0.093	*
Log(Urbanization)	1.080	0.212	5.10	0.000	***
Log(Tertiary Ed.)	0.118	0.096	1.23	0.223	

Significance codes: *** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Dependent Variable in this model is Resource Productivity (RP):

- log_GDPpc: The results show a negative significant relationship between GDP per capita and resource productivity (β=-0.126, p=0.017), suggesting that higher economic development in Balkan countries, as measured by GDP per capita, may lead to less efficient resource use. This finding possibly reflects a shift toward more consumption-driven economies as income levels rise.
- GFCF: The coefficient for GFCF is positive but not statistically significant (β=0.032, p=0.386), indicating that investment in fixed assets may not directly improve resource productivity.
- HDI: There is a weak negative association between HDI and resource productivity (β=-0.081, p=0.093), suggesting that a higher human development index does not necessarily lead to more efficient resource use.
- Control Variables: Urbanization (log_URBP) positively influences resource productivity (β=1.080, p<0.001), indicating that more urbanized regions tend to use resources more efficiently, likely due to better infrastructure and technological advancements.

Model 2: Employment, HDI, and Waste Generation

The results of the panel data analysis of Model 2 which explores the relationship between employment (EMPL), HDI, and waste generation per capita (WPC), controlling for urbanization and tertiary education.

Table 3: Model 2 Regression Results (Waste Generation Per Capita)

Coefficient	Estimate	Std. Error	t-value	p-value	Significance
Intercept	-4.85e-16	0.300	-1.62e-15	1.000	
Square(Employment)	0.132	0.173	0.76	0.447	
HDI	-0.006	0.216	-0.03	0.979	
Log(Urbanization)	0.530	0.261	2.03	0.046	**
Log(Tertiary Ed.)	-0.305	0.405	-0.75	0.454	

Significance codes: *** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Dependent Variable: Waste Generation per Capita (WPC)

- sq_EMP: Employment shows no significant impact on waste generation (β=0.133, p=0.447), implying that employment levels alone do not explain variations in waste generation practices.
- HDI: Similarly, HDI is not a significant predictor of waste generation (β=-0.006, p=0.979), suggesting that human development does not directly correlate with lower waste generation.
- Control Variables: Urbanization (log_URBP) is a significant positive predictor of waste generation (β=0.530, p=0.046), indicating that more urbanized regions generate more waste per capita. This aligns with previous research showing that urban areas tend to have higher consumption rates and, consequently, higher waste generation [4].

Model 3: Economic Growth and Material Import Dependency

Model 3 focuses on the relationship between GDP per capita (GDPpc), GFCF, and material import dependency (MID), with control variables.

Table 4: Model 3 Regression Results (Material Import Dependency)

Coefficient	Estimate	Std. Error	t-value	p-value	Significance
Log(GDP per capita)	-0.265	0.103	-2.57	0.012	**
GFCF	0.023	0.066	0.35	0.729	
Log(Urbanization)	1.585	0.659	2.41	0.019	**
Log(Tertiary Ed.)	0.669	0.216	3.10	0.003	***

Significance codes: *** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Dependent Variable: Material Import Dependency (MID)

- log_GDPpc: The results show a significant negative relationship between GDP per capita and material import dependency (β=-0.265, p=0.012), suggesting that economically developed countries in the Balkans are less dependent on material imports. This may indicate that higher economic development allows countries to produce more materials domestically, reducing their reliance on imports.
- GFCF: Investment in fixed assets (GFCF) does not have a significant effect on material import dependency (β=0.023, p=0.729).
- Control Variables: Urbanization (log_URBP) significantly increases material import dependency (β=1.585, p=0.019), which could be linked to the growing resource needs of expanding urban populations and industries.

Diagnostic Tests and Model Validation

To ensure the robustness and reliability of the panel regression models used in this study, several diagnostic tests were conducted. These tests assess potential econometric issues, such as heteroscedasticity, autocorrelation, and multicollinearity, which can bias standard errors and lead to incorrect inferences if not properly addressed.

The Breusch-Pagan test was used to detect heteroscedasticity, which occurs when the variance of the error terms is not constant across observations. Heteroscedasticity can lead to inefficient estimates and biased standard errors, affecting the reliability of p-values and hypothesis testing.

In all three models, the Breusch-Pagan test indicated significant heteroscedasticity ($p < 0.05$: Model 1: $\chi^2=17.28$, $p=0.004$; Model 2: $\chi^2=18.98$, $p=0.0008$; Model 3: $\chi^2=17.75$, $p=0.0014$). This suggests that the variance of the residuals is not constant across countries and years, which can be common in panel data due to differing economic conditions across the Balkan countries.

The presence of heteroscedasticity in all models suggests that the variability of errors changes with the level of the independent variables, possibly due to economic disparities between countries.

Autocorrelation occurs when the error terms in different time periods are correlated, which can lead to underestimated standard errors and overly optimistic statistical significance. The Wooldridge test was employed to check for the presence of autocorrelation in the panel data models.

The Wooldridge test indicated the presence of first-order autocorrelation in all three models ($p<0.05$: Model 1: $F=20.57$, $p=0.024$; Model 2: $F=33.00$, $p=0.00027$; Model 3: $F=23.20$, $p=0.010$).

Autocorrelation was detected in all models, indicating that the errors from one year are correlated with those from previous years, which is expected in time-series panel data. This violation of the classical regression assumptions can lead to inefficient estimates. To mitigate this, robust standard errors were used to correct for both heteroscedasticity and autocorrelation.

Finally, multicollinearity occurs when two or more independent variables in the model are highly correlated, which can make it difficult to determine each variable's individual effect. The Variance Inflation Factor (VIF) was used to assess the presence of multicollinearity among the independent variables in each model.

The VIF values for all models were below the commonly accepted threshold of 5 (Model 1: The VIF values for all variables were between 1.2 and 3.5; Model 2: The VIF values ranged between 1.1 and 2.4; Model 3: The VIF values ranged between 1.3 and 3.0), indicating no severe multicollinearity among the independent variables.

The absence of multicollinearity suggests that the independent variables (e.g., GDPpc, GFCF, HDI) do not exhibit problematic correlations with one another. This ensures that the estimated coefficients reflect the individual effect of each variable on the dependent variable, enhancing the confidence in the regression results and ensuring that the models are stable and interpretable.

Given the presence of both heteroscedasticity and autocorrelation, the use of robust standard errors was essential to obtain reliable standard errors, p-values, and confidence intervals. By applying cluster-robust standard errors, the authors corrected for these issues, which ensures that the coefficient estimates remain unbiased and the statistical significance of the variables is accurately determined.

Cluster-robust standard errors were used in all models to account for both heteroscedasticity and autocorrelation. This adjustment ensures that any inefficiencies in the variance of the error terms across countries and time periods are properly accounted for, leading to more accurate statistical inferences.

The diagnostic tests revealed significant issues with heteroscedasticity and autocorrelation across all models. However, these issues were effectively addressed by applying robust standard errors. There was no evidence of multicollinearity, ensuring that the models' variables are independent of one another and provide reliable coefficient estimates. By performing these diagnostic tests and corrections, the models are now robust and provide accurate results that can be confidently interpreted in the subsequent analysis.

Discussion

This section analyzes the empirical findings from the panel data analysis in light of the research objectives, hypotheses, and existing literature on economic development and circular economy (CE) practices. The focus of the discussion is on assessing how economic development, investment, employment, and human development influence circular economy outcomes like resource productivity, waste generation, and material import dependency in the Balkan region.

Economic Development and Resource Productivity (H1)

Hypothesis H1 posited that higher economic development (measured by GDP per capita, GFCF, and HDI) would positively impact resource productivity (RP). However, the results reveal a more nuanced reality.

The analysis shows a significant negative relationship between GDP per capita and resource productivity (β=-0.126, p=0.017), indicating that wealthier economies in the Balkans tend to use resources less efficiently. This aligns with the literature suggesting that unchecked economic growth often leads to higher consumption, thus undermining resource efficiency unless targeted CE policies are implemented [16,18]. This finding emphasizes the need for policies that decouple growth from resource use, as supported by Geissdoerfer et al. [15] and the EU's Circular Economy Action Plan [1].

While GFCF has a positive coefficient, it is not statistically significant (β=0.032, p=0.386), suggesting that investment in fixed assets does not necessarily lead to resource efficiency improvements. This may reflect investments concentrated in non-sustainable sectors, as observed in other transitional economies [18].

A weak negative relationship exists between HDI and resource productivity (β=-0.081, p=0.093), implying that human development alone does not guarantee better resource use. This could be due to increased consumption patterns at higher development levels, highlighting the need for CE policies alongside human development initiatives [3][19].

Employment, HDI, and Waste Generation (H2)

The second hypothesis H2 stated that higher employment and HDI would reduce waste generation per capita. However, the results do not support this assumption.

There is no significant impact of employment on waste generation (β=0.132, p=0.447), indicating that higher employment does not necessarily lead to better waste management. Increased employment could be linked to more consumption and, consequently, more waste, consistent with Luttenberger's findings on Croatia [6].

Similarly, HDI does not significantly impact waste generation (β=-0.006, p=0.979). Higher human development, without targeted sustainability efforts, can lead to increased consumption, contributing to waste generation [15][19].

Urbanization shows a significant positive effect on waste generation (β=0.530, p=0.046), highlighting the higher waste production in more urbanized areas due to greater consumption. This finding underscores the importance of improved waste management infrastructure in growing cities, as noted by Ghisellini et al. [16].

Economic Growth and Material Import Dependency (H3)

H3 proposed that higher GDP per capita and GFCF would reduce material import dependency (MID). The results largely support this hypothesis.

A significant negative relationship exists between GDP per capita and material import dependency (β=-0.265, p=0.012), indicating that wealthier economies in the Balkans rely less on imported materials, consistent with the development of domestic industries [20]. This outcome aligns with CE principles of reducing material dependency through local production [1].

The coefficient for GFCF is insignificant (β=0.023, p=0.729), indicating that general investments do not directly reduce material imports unless they target resource-efficient sectors [18].

Insights from the Diagnostic Tests

The diagnostic tests identified issues with heteroscedasticity and autocorrelation, both of which were addressed using robust standard errors. The absence of multicollinearity ensured that the model variables were independent and provided reliable coefficient estimates.

Finally, the previous results suggest the following policy implications:

- Targeted CE Investments: Focused investments in resource-efficient sectors, particularly in urban areas, are critical.
- Sustainability Education: Promoting sustainability through education can align economic growth with CE goals.
- Urban Waste Management: Balkan countries should improve urban waste management infrastructure to handle growing urban populations.

The findings from the analysis provide valuable insights into the complex relationship between economic development and circular economy practices in the Balkan region. These results demonstrate the need for targeted policies and investments to align economic growth with sustainable resource management. The following conclusion synthesizes the key takeaways and highlights implications for future research and policy.

Conclusion

This research provides an in-depth examination of the relationship between economic development and CE practices in the Balkan region from 2013 to 2022, focusing on the influence of GDP per capita, GFCF, employment, and HDI on resource productivity, waste generation, and material import dependency.

The findings indicate that while economic growth reduces material import dependency, it can also undermine resource productivity unless complemented by specific CE strategies. The study also reveals that employment and human development do not automatically lead to better waste management, particularly in urban areas where waste generation is higher. The results underscore the need for targeted investments in green technologies, improved urban waste management systems, and sustainability education to ensure that economic growth aligns with CE principles. Policymakers must prioritize circular economy integration to promote resource efficiency and environmental sustainability alongside economic development. Future research should explore the role of policy interventions and innovations in overcoming regional challenges to achieve sustainability goals.

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