

CIRCULAR ECONOMY AND MACROECONOMIC PERFORMANCE: A COMPARISON OF CENTRAL AND WESTERN EUROPEAN EU COUNTRIES

Marek POTKÁNY ¹✉, Jarmila SCHMIDTOVÁ ², Petra LESNÍKOVÁ ¹, Zdenka MUSOVÁ ³

¹Department of Economics, Management and Business, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Zvolen, Slovak Republic

²Department of Mathematics and Descriptive Geometry, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Zvolen, Slovak Republic

³Department of Corporate Economics and Management, Faculty of Economics, Matej Bel University in Banská Bystrica, Banská Bystrica, Slovak Republic

Article History:

- received 19 February 2026
- accepted 26 May 2026

Abstract. In the context of the growing importance of sustainable development and efficient resource utilization, the circular economy (CE) is becoming a key component of economic policy in EU countries. In the present study, the dependencies of selected CE indicators on three key macroeconomic variables were modelled across two distinct groups of European countries, specifically the Central European bloc (Slovakia, Poland, Czechia) and the Western European bloc (Austria, Switzerland, Germany). Agility captures the responsiveness of CE performance to macroeconomic conditions. To quantify these relationships, multiple linear regression was applied, enabling the assessment of the sensitivity of CE performance to macroeconomic dynamics characterized by GDP per capita, population size, and employment rate. The results provide comparative insights into how structural economic conditions influence progress toward a CE, defined by the recycling rate and the development of domestic material consumption within the examined country blocs. The findings highlight clear structural differences between the two blocs, with Western Europe demonstrating more mature and efficiency driven environmental performance, while Central Europe exhibits features of an economy in transition. The findings advance the understanding of the macroeconomic determinants of CE performance and underscore the need for policies that translate economic growth into measurable environmental efficiency gains.

Keywords: circular economy, macroeconomic variables, EU countries, multiple linear regression, comparative insight, structural changes.

JEL Classification: O44, Q01, Q56.

✉Corresponding author. E-mail: potkany@tuzvo.sk

1. Introduction

The European Union is currently facing the challenge of aligning economic growth with the principles of sustainability, particularly in the context of the European Green Deal and global resource constraints. The circular economy (CE) has emerged as a key instrument for achieving this balance, with its progress increasingly monitored through quantifiable indicators. Yet, the extent to which circular practices are statistically linked to macroeconomic performance,

such as GDP per capita or employment, remains insufficiently explored. This gap is particularly visible in comparative regional analyses. However, existing empirical studies rarely examine how these relationships differ across structurally distinct groups of economies. Most analyses either focus on single-country cases or provide EU-wide assessments that mask regional heterogeneity. As a result, the literature lacks a systematic comparison of how macroeconomic conditions shape circular-economy performance in countries at different stages of economic maturity.

Existing studies often focus on single countries or aggregated EU-wide analyses, overlooking structural differences between regions. Moreover, limited attention has been paid to the agility of circular economy systems, understood as their capacity to adjust performance in response to changing macroeconomic conditions.

This study addresses this gap by offering a comparative perspective on two contrasting blocs of EU countries: Central Europe (Slovakia, Poland, Czechia) and Western Europe (Austria, Switzerland, Germany). Comparing these two blocs provides analytical value because they differ not only in economic performance, but also in institutional capacity, innovation intensity, and historical trajectories of environmental policy. These structural contrasts allow us to observe whether macroeconomic drivers of circular-economy performance operate similarly across diverse economic contexts, or whether they follow fundamentally different patterns. Such a regional comparison is largely absent in existing empirical research, which typically treats EU member states as a homogeneous group.

The aim of the study is to identify and examine interdependencies between circular economy indicators and macroeconomic variables. The study also introduces the concept of agility, understood as the general responsiveness of CE outcomes to macroeconomic dynamics. In this study, agility serves as an interpretative lens that helps explain why CE indicators may react differently in structurally distinct country blocs. Although agility is not operationalised as an empirical variable, it provides a conceptual bridge between macroeconomic conditions and the observed patterns of CE performance.

In particular, the study seeks to test whether these relationships are statistically significant, thereby contributing to a deeper understanding of sustainable development dynamics in Europe and offering evidence-based insights for policymakers.

Based on these considerations, the study is guided by the following general research question RQ1: *To what extent are circular-economy indicators dependent on key macroeconomic variables within two structurally distinct blocs of European countries?* To address this RQ, the study formulates the following hypothesis (H1): It is assumed that within the compared blocs of European Union countries, there exists a significant dependence of selected circular economy indicators on the observed macroeconomic variables. Based on this hypothesis, we advance the thesis that differences in economic development, demographic structure, and labour-market conditions translate into divergent circular-economy outcomes between the Western and Central European blocs.

The structure of the paper is as follows. The Section 2 outlines the potential of CE and emphasizes scientific works focused on the analysis of CE indicators with their impact on the economic performance of EU countries. Section 3 provides a detailed description of the data and methodology employed and discusses their relevance for accurate data evaluation. Section 4 presents the results and compares empirical findings across two EU country blocs, with a focus on identifying potential interdependences. A brief discussion of these results is also included.

2. Theoretical background

Population growth and rising living standards are leading to more intensive use of natural resources, placing increasing pressure on traditional production and consumption models. Given the finite nature of these resources and the continued dominance of the linear economic model in global industrial systems, the need to transition toward more sustainable approaches is being increasingly emphasized (Sakthivelmurugan et al., 2022; Fura et al., 2020; Ghisellini & Ulgiati, 2019). Similar concerns regarding resource scarcity and systemic sustainability challenges have also been highlighted by Geissdoerfer et al. (2017). This shift is also being recognized within the business sector, which is becoming more engaged with sustainability issues in entrepreneurship, highlighting the importance of considering not only the economic interests of companies but also their positive impact on the social system and environmental dimensions (Khan et al., 2023). On the other hand, there are differences in the perception of selected sustainability factors among small and medium-sized enterprises in Central Europe (Petrakova & Karacsony, 2024).

Current developments reflect a growing societal and political interest in environmental issues and support the search for alternative models, among which the CE is increasingly emerging as a promising solution. CE is viewed as a systemic approach that promotes efficient resource use, waste minimization, and the reuse of materials within closed-loop cycles. In addition to its environmental benefits, its implementation is also associated with fostering innovation, creating new jobs, and advancing the sharing economy (Assemblali & Sabar, 2024; D'Adamo et al., 2024; Jacobs et al., 2022). The literature emphasizes that the successful implementation of CE principles requires a certain degree of agility, enabling systems to respond effectively to dynamic economic and regulatory conditions (Bocken et al., 2019). Consequently, the historical evolution of the CE concept and its various interpretative frameworks have been thoroughly analyzed by several authors (Baranski, 2021; Wautelet, 2018; Reike et al., 2018), who agree on its potential as a tool for achieving sustainable development. According to Strapchuk et al. (2025), structural changes and innovations aimed at addressing these challenges through cross-sectoral collaboration facilitate the transition toward a more sustainable and circular economy. The economic potential of the CE is considerable estimates by the World Economic Forum (2023) suggest that by 2030, it could represent an opportunity worth up to 4.5 trillion US dollars. In response, many countries are implementing national strategies and policy frameworks to support the circular economy, aiming not only to reduce environmental burdens but also to promote long-term sustainable economic growth.

A key tool for monitoring progress in this area is the set of CE indicators developed and managed by institutions such as Eurostat, the Ellen MacArthur Foundation, and various environmental agencies (Remeikienė et al., 2024; Özkaya, 2024; Smol, 2023). Comparable indicator-based monitoring approaches have also been discussed in broader sustainability assessment frameworks (Nazarko et al., 2022). These indicators can subsequently be used for comparative assessments of CE performance. One example is a recent study by Streimikis (2025), which applies a multi-criteria decision-making (MCDM) approach to evaluate circularity performance in the three Baltic states – Estonia, Latvia, and Lithuania. The results provide clear evidence of regional disparities operating within the shared EU policy framework. Previous research examining macroeconomic determinants of circular-economy performance highlights how GDP per capita, employment levels and demographic factors shape recycling outcomes and material-use efficiency.

Recent scientific research has primarily focused on analyzing the development of CE indicators within EU countries, comparing them across member states, and evaluating their impact on economic performance (Roleders, 2023; Mazur-Wierzbicka, 2021a; Vranjanac et al., 2023; Kozma et al., 2022). In addition, recent studies provide evidence of long-term positive links between circularity and GDP, with notable disparities between Western and Eastern European countries (Hondroyiannis et al., 2024). From a macroeconomic perspective, the ability of national economies to respond to structural changes and policy shocks is considered a key factor in long-term economic growth and sustainable development (Aghion et al., 2019). This perspective suggests the need for agility, understood as the capacity of economic systems to adjust effectively to evolving macroeconomic conditions. In this study, agility refers to the responsiveness of CE performance to changing macroeconomic conditions. This perspective draws on established concepts of adaptive efficiency and dynamic capabilities, which emphasize the capacity of economic systems to adjust to structural and policy shifts (Aghion et al., 2019; Bocken et al., 2019). Within the CE context, agility captures how rapidly indicators such as recycling rates or domestic material consumption react to developments in income, employment, or demographic dynamics. This theoretical framing provides the basis for interpreting cross-bloc differences in the sensitivity of CE performance to macroeconomic structures.

For instance, Hysa et al. (2020) proposed an integrated model that examines the relationship between CE-related innovations, environmental sustainability, and economic growth. Chen and Pao (2022) identified a causal link between CE indicators and GDP in the EU-25 countries, highlighting a bidirectional dynamic between these variables. Trica Lenuta et al. (2019) and Mattos and de Albuquerque (2018) focused on environmental factors as key determinants of CE model sustainability. More recent studies also provide empirical evidence of the positive impact of CE on economic performance. Radivojević et al. (2024) demonstrated a statistically significant correlation between resource productivity, recycling rates, and GDP per capita in EU countries. Arion et al. (2023) expanded this analysis to include social and environmental dimensions, confirming the beneficial effects of CE on social well-being and environmental performance. An interesting reverse perspective is offered by Sverko Grdic et al. (2020), who argue that higher levels of GDP support more intensive application of CE principles, particularly in the areas of municipal waste and packaging recycling.

Despite the growing interest in the circular economy and its connection to economic growth, the scope for systematic comparison between different types of economies within the European Union remains relatively underexplored. Although some attempts have been made to evaluate CE efficiency across EU member states using advanced methods such as Data Envelopment Analysis (Nazarko et al., 2022), existing research often focuses on individual countries or relies on aggregated analyses that do not account for structural differences between regions. This study offers a novel perspective through a comparative analysis of two contrasting groups of countries. Central European and Western European – with the aim of exploring interrelations between CE indicators and macroeconomic variables. In particular, the study examines whether these relationships show statistical significance, while also testing the hypothesis that higher economic performance may be accompanied by greater environmental efficiency. Such an approach enables a deeper understanding of the dynamics of sustainable development in the European context and provides valuable insights for policymakers in designing effective strategies for the transition to a circular economy.

In summary, existing research confirms the relevance of the circular economy for improving resource efficiency, while also highlighting substantial differences in its development

across countries with varying levels of economic maturity, institutional capacity and technological advancement. At the same time, comparative analyses across distinct regional groups within the EU remain limited, particularly with regard to the relationship between CE indicators and macroeconomic conditions. This study addresses this gap by providing a focused comparison of Western and Central European economies, thereby contributing to a more nuanced understanding of structural differences shaping circular-economy performance. These theoretical insights collectively suggest that macroeconomic structures may influence circular-economy outcomes differently across country groups, providing the basis for our hypothesis on the significance and heterogeneity of these relationships.

3. Methodology and data

The aim of this study is to model and examine the interdependencies between selected CE indicators and key macroeconomic variables across two blocs of EU countries, with particular attention to the statistical significance of these relationships. Building on a review of secondary sources addressing the circular economy in relation to macroeconomic indicators, the following hypothesis was formulated (H1): *It is assumed that within the compared blocs of European Union countries, there exists a significant dependence of selected circular economy indicators on the observed macroeconomic variables.*

In line with this research objective, it is essential to justify the selection of countries and indicators. The choice of countries and their subsequent grouping into specific blocs was based on the need to compare different types of economies with respect to their environmental performance, the degree of implementation of circular economy principles, and overall competitiveness. Given the nature of the correlation and regression analyses employed, only countries with comprehensive and consistent data covering the observation period 2008–2023 were included. The classification of countries into the Central European (SK_PL_CZ) and Western European (AT_CH_DE) blocs is based on analytically observable structural differences. These include disparities in GDP per capita, innovation capacity, institutional quality, and historical trajectories of environmental policy implementation, which are consistently identified in comparative CE and sustainability studies. Grouping countries according to these criteria strengthens the comparative framework by ensuring internal homogeneity within each bloc and clear structural contrast between them, allowing us to examine whether macroeconomic determinants of CE performance operate differently across distinct development contexts. Emphasis was placed on ensuring regional, economic, and legislative homogeneity within each group to maintain the comparability of results and reduce statistical deviations caused by external factors. Based on these criteria, two country blocs were established. The first includes the Slovak Republic, Poland, and the Czech Republic, representing Central European, transitioning economies with lower GDP levels (referred to in this study as the SK_PL_CZ bloc). The second bloc comprises Austria, Switzerland, and Germany, representing more advanced economies characterized by high levels of environmental responsibility and innovation capacity (referred to as the AT_CH_DE bloc).

The macroeconomic (socioeconomic) indicators used in this study were selected to accurately reflect the overall economic conditions and competitiveness analyzed blocs while incorporating relevant socio-economic dimensions. The selected indicators include:

- Population size – representing the demographic scale and potential labour force of each country.

- GDP per capita – a key indicator expressing economic performance and standard of living. Monitoring this variable in the context of the CE can reveal the extent to which economic growth correlates with a country's ability to utilize resources efficiently.
- Employment rate – an important macroeconomic factor that influences not only economic stability but also the social cohesion of society.

CE indicators capture the degree of alignment with the principles of a closed material cycle, efficient resource use, and waste minimization. The selection and interpretation of CE indicators is aligned with the EU Monitoring Framework for the Circular Economy (Eurostat, 2023). In this study, the following CE indicators were analyzed:

- Material Consumption – this captures the total amount of materials (both primary and secondary) consumed by the economy during a given period. Cross-country comparisons of this indicator offer an overview of trends in natural resource use. For the purposes of this comparative analysis, material consumption is measured per capita.
- Waste Recycling Rate – this indicates the percentage of generated waste that is recycled. It directly reflects the extent of resource reuse and waste reduction, which are core pillars of the circular economy.

In this study, the concept of agility is employed as a complementary interpretative perspective referring to the adaptive capacity of economic systems to respond to macroeconomic changes while maintaining CE performance. The concept is loosely related to broader discussions on economic resilience and adaptive capacity in sustainability transitions. However, the core focus of the study remains the empirical relationship between selected macroeconomic indicators and CE performance indicators. In this context, agility serves mainly as an interpretative lens. Due to the limited availability of harmonised indicators that directly measure agility, the empirical analysis relies on observable macroeconomic and CE indicators. Within this empirical framework, the responsiveness of CE indicators to macroeconomic dynamics can be interpreted as an indirect manifestation of systemic adaptability.

The foundation for compiling the information database of this study was the acquisition of high-quality and comprehensive data that reflect the current state and development of relevant indicators in selected European Union countries. The following primary sources were used:

- Statistical Office of the Slovak Republic – provides official statistical data related to economic, social, and environmental indicators for Slovakia.
- DATACube Online Database – an electronic database that enables access to various time series and detailed data at both national and regional levels across multiple domains.
- Eurostat Database – the official statistical portal of the EU, offering comparable data for all member states across a wide range of indicators.

This methodological framework directly addresses the identified research gap by enabling a systematic comparison between Central and Western European economies, thereby providing new insights into the relationship between circular economy indicators and macroeconomic performance.

The research design focuses on analyzing how selected CE indicators evolve in relation to macroeconomic variables. At the beginning of the analysis, the development of circular-economy indicators over the period 2008–2023 was illustrated using line charts and described for both country blocs.

To address the primary research objective, we apply multiple linear regression (MLR) as the main analytical technique to identify statistically significant relationships that explain or

predict the behaviour of CE indicators based on macroeconomic variables. The MLR model estimates how the dependent variable Y varies with several explanatory variables X_i . With three predictors, the model is defined as (Keith, 2019):

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon_i, \quad (1)$$

where Y_i is the value of CE indicator for unit i , X_{1i} , X_{2i} , X_{3i} represent macroeconomic predictors, β_0 is the intercept, β_i , $i = 1, 2, 3$ are partial-regression coefficients to be estimated, and ε_i is the random error term. The regression coefficient β_1 provides information about the average change in the dependent variable per unit change in the explanatory variable X_1 when X_2 and X_3 are held constant, etc. The coefficient of determination R^2 expresses the proportion of variability in the dependent variable explained by the model. Separate models will be estimated for each CE indicator in single blocks of countries. All statistical tests were performed using the STATISTICA 14 statistical software and were assessed using a significance level of $\alpha = 0.05$.

4. Research results and discussion

The line chart (Figure 1) illustrates the development of the recycling rate in the period 2008–2023 for two blocs of European countries. The Western European bloc (Austria, Switzerland, Germany), represented by a solid black line, maintains a consistently high recycling rate, starting at approximately 62–63% in 2008 and fluctuating moderately within the 61–68% interval. A temporary peak occurs around 2020, followed by a slight decline to around 66–67% in 2023. In contrast, the Central European bloc (Slovakia, Poland, Czechia), shown by a dashed grey line, begins from a substantially lower level of roughly 10% in 2008. This bloc demonstrates a pronounced upward trend, with a particularly strong increase between 2013 and 2015. The recycling rate continues to improve thereafter, reaching about 42–43% in 2021–2022, before dropping slightly to approximately 33–34% in 2023. Overall, the figure highlights a persistent performance gap between the two blocs, despite notable long-term convergence driven by improvements in the Central European countries. This contrast reflects findings that Western European countries sustain higher CE performance due to more mature

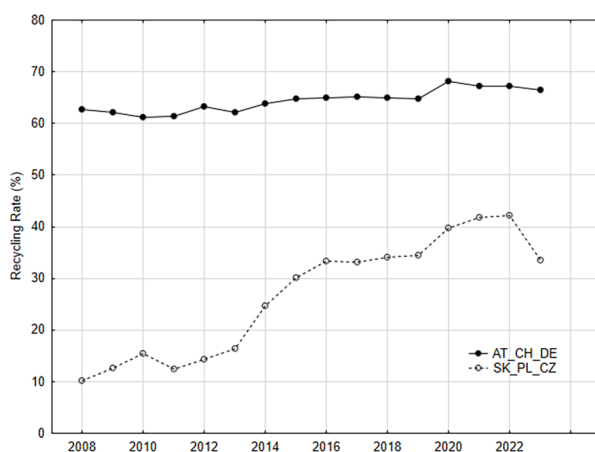


Figure 1. Line chart: Development of recycling rate in two European blocs of countries (AT_CH_DE versus SK_PL_CZ) in the period 2008 to 2023

institutional and policy structures, while Central European economies are still in a phase of accelerated convergence. These bloc-level differences align with broader evidence on uneven circular-economy development across EU regions. The temporary peak in 2020 may be linked to several exceptional factors. The early COVID-19 period temporarily increased municipal recycling rates in some Western European countries due to reduced industrial activity, higher household separation rates, and short-term regulatory adjustments in waste-management systems. At the same time, the subsequent decrease after 2021 reflects the re-normalisation of waste streams and the rebound of industrial production.

Figure 2 illustrates the development of domestic material consumption per capita (DMC) between 2008 and 2023 in the two blocs of European countries. In the Western European bloc (AT_CH_DE), DMC begins at approximately 15.8 tonnes per capita in 2008 and shows minor fluctuation between 15–16.5 tonne until 2014. After 2014 a clear downward trend becomes visible, with values declining from around 15.3 tonnes in 2016 to approximately 13 tonnes in 2023. In contrast, the Central European bloc (SK_PL_CZ) starts at a higher level of about 16.8 tonnes in 2008, and reaches a pronounced peak of roughly 19 tonnes in 2011, representing the highest value in the entire time series. Following this peak, DMC decreases and stabilizes between 16 and 17 tonnes from 2014 onward, with minor year-to-year fluctuations. Throughout the whole period, the Central European bloc consistently maintains higher material consumption levels than the Western bloc, indicating persistent structural differences in resource-use intensity. This pattern corresponds with studies showing that advanced economies gradually decouple material use from economic growth through efficiency gains and structural modernization. By contrast, higher DMC volatility in Central Europe reflects ongoing structural transitions and greater sensitivity to investment cycles. The elevated material consumption observed around 2011 in the Central European bloc corresponds to a period of intensified construction activity and investment cycles following post-crisis recovery, which tend to increase demand for primary materials. The gradual decline in the Western bloc after 2014 aligns with long-term structural trends such as increased material efficiency, adoption of cleaner technologies and shifts toward less resource-intensive industries.

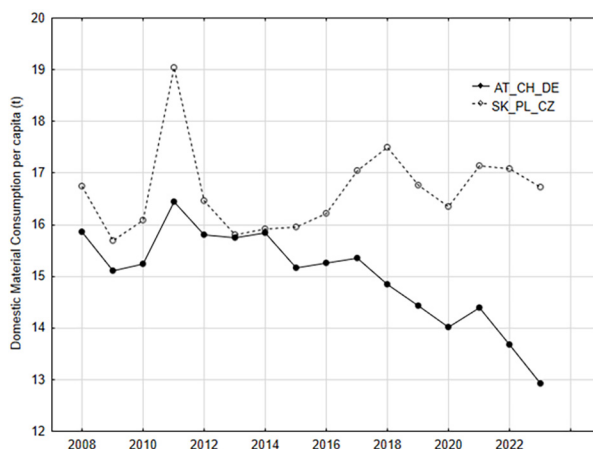


Figure 2. Line chart: Development of domestic material consumption in two European blocs of countries (AT_CH_DE versus SK_PL_CH) in the period 2008 to 2023

Table 1 presents the results of the multiple regression analysis conducted for Slovakia, Poland, and the Czech Republic over the period 2008–2023. The analysis examined whether the recycling rate is significantly associated with the selected macroeconomic variables. The overall regression model is statistically significant ($p = 0.000$), explaining 90% of the variance in the recycling rate as a function of GDP per capita, population size, and employment rate. However, among the individual predictors, only the employment rate exhibits statistical significance, showing a positive effect. This suggests that higher employment levels are associated with improved recycling performance within the SK_PL_CZ bloc, while GDP per capita and population size do not demonstrate statistically significant contributions at the 5% significance level.

Table 1. Results of multiple regression model testing: Recycling rate depending on macroeconomic indicators in Central European block (SK_PL_CZ)

Recycling rate	R = 0.65, R ² = 90%		
	F(3,12) = 36.33, p = 0.000		
	b	t-test	p-level
Intercept	−86.13	−0.38	0.707
GDP per capita	−0.0027	−2.13	0.054
Population size	−0.000002	−0.37	0.715
Employment rate	3.39	5.23	0.000

Table 2 presents the results of the multiple regression results for the Western European block of countries (AT_CH_DE).

Table 2. Results of multiple regression model testing: Recycling rate depending on macroeconomic indicators in Western European block (AT_CH_DE)

Recycling rate	R = 0.90, R ² = 81%		
	F(3,12) = 16.75, p = 0.000		
	b	t-test	p-level
Intercept	18.28	0.32	0.753
GDP per capita	0.0003	1.01	0.334
Population size	0.000001	1.98	0.071
Employment rate	−0.35	−0.49	0.634

Although none of the regression coefficients are statistically significant at the 5% significance level ($p > 0.05$), the overall model is significant ($p = 0.000$). The model explains 81% of the total variance of recycling rate depending on the explanatory variables (GDP per capita, population size, and employment rate). This result suggests that, despite the lack of significance of the individual predictors, the combined macroeconomic structure of the Western European bloc is strongly associated with recycling performance. The lack of statistically significant macroeconomic predictors within the Western European bloc can also be explained by institutional factors rather than economic variables. This interpretation is supported by Arranz and Arroyabe (2023), who showed that the performance of circular economy business

models in EU countries is strongly influenced by the effectiveness of institutional policies, regulatory stability, and the enforcement capacity of environmental frameworks. Their findings indicate that consumption- and regulation-oriented policies exert a stronger and more consistent impact on circular-economy outcomes than macroeconomic indicators such as GDP or employment. This provides a plausible explanation for the stable and high recycling performance observed in the Western European bloc, suggesting that mature institutional environments mitigate short-term macroeconomic fluctuations and help sustain long-term circular-economy progress. These findings are also aligned with the results of Nazarko et al. (2022), who showed that the efficiency of circular economy implementation across EU member states is strongly associated with their economic performance, particularly GDP per capita. Their DEA-based assessment demonstrated that countries with higher economic maturity systematically achieve higher levels of circularity efficiency, which corresponds to the stronger and more stable recycling outcomes observed in the Western European bloc. Moreover, the authors emphasize that cross-country comparative analyses remain relatively scarce in the literature, further underscoring the relevance of examining structural differences between regional clusters as undertaken in this study. The regional differentiation observed in this study also corresponds with the cluster patterns identified by Castillo-Díaz et al. (2024), who showed that EU member states group into distinct circular-economy performance clusters shaped by innovation capacity, waste-management policies, and the ability to valorize secondary materials. Their findings confirm that structural and policy-driven factors contribute substantially to cross-country disparities, reinforcing the interpretation that the higher and more stable recycling performance of the Western European bloc reflects broader systemic conditions rather than macroeconomic indicators alone.

Table 3 presents the results of the multiple regression analysis examining the relationship between domestic material consumption per capita and the selected explanatory variables within the Central European bloc (SK_PL_CZ). Neither the overall regression model nor any of the individual predictors are statistically significant at the 5% level ($p > 0.05$). The model explains only 7% of the variance in domestic material consumption, indicating that GDP per capita, population size, and employment rate do not meaningfully account for variations in material consumption within this group of countries. These findings suggest that domestic material consumption in the Central European bloc is likely influenced by other structural, technological, or sector-specific factors not captured in the present model.

Table 3. Results of multiple regression model testing: Domestic material consumption depending on macroeconomic indicators in Central European block (SK_PL_CZ)

Domestic material Consumption per capita	$R = 0.26, R^2 = 7\%$		
	$F(3,12) = 0.29, p = 0.829$		
	b	t-test	p-level
Intercept	11.19	0.22	0.826
GDP per capita	0.0002	0.58	0.573
Population size	0.0000	0.15	0.887
Employment rate	−0.06	−0.43	0.676

Table 4 presents the results of the multiple regression analysis for the Western European bloc (AT_CH_DE), examining domestic material consumption per capita as the dependent

variable. In contrast to the Central bloc, all three macroeconomic indicators exhibit a statistically significant influence at the 5% significance level. Both GDP per capita and population size show a negative correlation, suggesting that higher levels of economic performance and demographic scale are associated with lower domestic material consumption. This may reflect increased investment in resource-efficient technologies, waste management infrastructure, or more advanced circular practices in high-income Western economies. In turn, the employment rate demonstrates a positive effect, indicating that higher employment levels are linked to increased material consumption. Overall, the model explains 87% of the variability in domestic material consumption, highlighting a strong association between macroeconomic structure and material-use efficiency within the Western European bloc.

Table 4. Results of multiple regression model testing: Domestic material consumption depending on macroeconomic indicators in Western European block (AT_CH_DE)

Domestic material consumption per capita	R = 0.93, R ² = 87%		
	F(3,12) = 26.01, p = 0.000		
	b	t-test	p-level
Intercept	11.42	0.56	0.587
GDP per capita	−0.0003	−2.61	0.023
Population size	0.0000	−2.63	0.022
Employment rate	0.57	2.22	0.046

Evaluation of Hypothesis H1

The results allow for a differentiated assessment of the proposed hypothesis (H1), which assumed the existence of statistically significant relationships between selected CE indicators and the observed macroeconomic variables within both country blocs. In the case of the recycling rate, the hypothesis is only partially supported. Although the regression models were statistically significant in both blocs, the structure of significant predictors differed markedly. In the Central European bloc (SK_PL_CZ), the employment rate emerged as the only significant determinant, while GDP per capita and population size did not exhibit significant effects. Conversely, in the Western European bloc (AT_CH_DE), none of the macroeconomic variables reached statistical significance, even though the overall model was significant. This result indicates that recycling performance in more advanced economies is shaped by factors not captured by the macroeconomic structure included in this model. These structural differences between the two blocs are consistent with the findings of Hondroyiannis et al. (2024), who demonstrated on a sample of 28 European countries that higher levels of economic development are systematically associated with stronger circularity performance. Their study also shows that Western European economies consistently outperform Southern and Eastern European countries in terms of circular economy indicators, reflecting more mature institutional frameworks and long-term investments in environmental infrastructure. These results underscore the importance of regional comparative analysis and directly support the relevance of distinguishing between Western and Central European clusters in the present study. Comparable cross-country differentiation is also reported by Mazur-Wierzbicka (2021b), who found that EU member states remain unevenly advanced in circular-economy implementation, supporting the interpretation that structural maturity drives the divergence observed between the Western and Central European blocs. This expanded comparative view

confirms that Western and Central European countries consistently fall into distinct performance clusters shaped by innovation capacity and institutional maturity. Such evidence reinforces the structural explanation for the divergent recycling and material-consumption patterns observed in our analysis.

The results further suggest that in more developed economies, higher recycling rates cannot be explained solely by macroeconomic variables such as GDP per capita or employment. Instead, previous research emphasizes the importance of institutional quality, regulatory capacity, and technological readiness in shaping recycling performance, particularly in Western European countries (Smol, 2023; Sverko Grdic et al., 2020). MCDA-based studies similarly indicate that Western European countries outperform their Eastern counterparts primarily due to stronger institutional capacity, higher investment in circular technologies, and more effective resource management, rather than differences in macroeconomic conditions alone, while also highlighting the role of technological intensity and value-chain integration in material consumption patterns (D'Adamo et al., 2024). This is consistent with Bianchi and Cordella (2023), who found that while circular-economy practices can lower primary material extraction in European economies, these effects remain weaker than the pressures created by economic growth. Their results reinforce the finding that macroeconomic expansion does not automatically translate into material-use efficiency.

More broadly, the literature underscores that the development of mature circular economy systems is closely linked to innovation capacity, institutional frameworks, and the diffusion of advanced circular practices (Geissdoerfer et al., 2017; Bocken et al., 2019). This perspective aligns with findings by Calisto Friant et al. (2021), who highlight that EU circular-economy policy discourse is often more ambitious than its actual implementation, indicating that institutional design and regulatory consistency remain critical determinants of CE outcomes. At the same time, empirical evidence indicates that the CE contributes to sustainable development outcomes across economic, environmental, and social dimensions, even in contexts where direct links to macroeconomic variables such as GDP or employment are weak or heterogeneous, particularly in more developed economies (Arion et al., 2023).

For domestic material consumption (DMC), the differences between the two blocs are even more pronounced. In the Central European bloc, the hypothesis is not supported, as neither the model nor the individual predictors were statistically significant. In contrast, in the Western bloc, the hypothesis is clearly supported, with all three macroeconomic indicators significantly explaining the variability in material consumption. This suggests that, in more advanced economies, macroeconomic variables capture underlying structural characteristics of the economy that are relevant for material use. Accordingly, domestic material consumption appears to be closely linked to structural features such as material productivity and patterns of structural transformation. Empirical evidence indicates that more economically developed and structurally advanced economies tend to decouple material use from economic growth through efficiency gains and changes in production structures (Reike et al., 2018; Hondroyiannis et al., 2024), while broader circular economy assessments also point to positive environmental and social outcomes associated with higher levels of economic development (Arion et al., 2023).

Overall, the findings indicate that the hypothesis concerning the dependence of selected CE indicators on macroeconomic variables is only partially confirmed. Statistically significant relationships were identified for several indicators; however, the strength and direction of these relationships differ systematically between Western and Central European countries.

These differences reflect structural disparities in economic development, institutional capacity, and the level of implementation of CE principles. From the perspective of the agility concept introduced earlier, the results suggest that CE systems differ in their capacity to adapt to changing macroeconomic conditions. While Central European economies appear to exhibit stronger sensitivity of certain CE indicators to macroeconomic dynamics, the more stable performance observed in Western European countries may indicate a higher level of systemic adaptability supported by mature institutional and technological environments.

According to the Circularity Gap Report 2024 (Circular Economy Foundation, 2024), despite the increasing prominence of the circular economy in policy and business discourse, global circularity continues to decline, suggesting that incremental improvements are insufficient and that coordinated, systemic change is required. Building on this assessment, the Circularity Gap Report 2025 (Circular Economy Foundation, 2025) provides further evidence that global material circularity remains in decline, with production systems still heavily reliant on virgin materials, thereby reinforcing the need for deep structural transformation of production and consumption systems rather than isolated efficiency gains. Together, these findings underscore that meaningful progress toward circularity depends on systemic, technologically driven, and cross-sectoral approaches, which aligns with the differentiated patterns observed across European economies in this study.

5. Conclusions

This study examined the interdependencies between selected circular economy (CE) indicators and key macroeconomic variables across two blocs of EU countries, Central Europe (SK_PL_CZ) and Western Europe (AT_CH_DE). From a conceptual standpoint, a bloc-level analytical perspective was applied to reveal how macro-structural conditions translate differently into circular-economy outcomes in Western and Central Europe. The concept of “agility” was also formalised as a concise construct capturing the responsiveness of CE indicators to macroeconomic dynamics. Methodologically, parallel multiple linear regression models were estimated for each bloc, and a distinct pattern was identified, systematic macro-level explanatory power for domestic material consumption (DMC) in the AT_CH_DE bloc versus selective, employment-driven sensitivity of recycling in the SK_PL_CZ bloc. In this way, comparative insights were provided that are often obscured in EU-wide aggregated analyses.

The findings demonstrate that macroeconomic determinants shape CE performance in fundamentally different ways across the two blocs. For the recycling rate, the hypothesis was only partially supported: although regression models were statistically significant in both blocs, only the Central European group showed a significant predictor, namely the employment rate, while no macroeconomic variable proved significant in the Western bloc. In contrast, the analysis of domestic material consumption (DMC) revealed even more pronounced divergence. The hypothesis was not supported in the Central European bloc, where neither the model nor individual predictors were significant, while in the Western bloc all three macroeconomic variables significantly explained DMC variability. These results indicate that Hypothesis H1 is confirmed only partially, highlighting structural differences in economic maturity, institutional capacity, and the degree of circular economy implementation.

The concept of agility, understood as the responsiveness of CE performance to changes in macroeconomic condition, further clarifies these patterns. In the Western bloc, the agility of material consumption with respect to macroeconomic dynamics is strong and systematic,

whereas the agility of recycling appears muted, likely due to stable institutional frameworks. In the Central European bloc, agility manifests in the responsiveness of recycling to labor market conditions, but is weak in the case of material consumption, suggesting that sectoral composition, trade structures, and technological intensity play a stronger role.

These findings contribute to a deeper understanding of the macroeconomic determinants of circular economy performance and underline the need for policies that convert economic growth into measurable gains in environmental efficiency. The study also contributes theoretically by formalising agility as an interpretative construct that captures systemic responsiveness of CE performance to macroeconomic dynamics. The comparison of the two blocs shows that in more advanced economies, recycling performance is stabilised by institutional frameworks and is therefore less responsive to macroeconomic fluctuations, whereas transition economies display greater sensitivity to labour-market conditions. Formalising the concept of agility provides a simple link between macro-structural factors and the dynamics of circular-economy indicators, making it applicable to future cross-regional analyses. The results are particularly relevant for national and regional policymakers, ministries of economy and environment, and EU institutions responsible for cohesion and circularity strategies, offering evidence to better target investments, institutional reforms, and labour-market measures that support circular transitions.

Given the structural differences identified between the two blocs, it is important to outline policy implications that directly follow from the empirical results. The policy implications by bloc are as follows: In the AT_CH_DE bloc, reducing material intensity in labour-intensive sectors and strengthening markets for high-quality secondary materials can help maintain stable, institution-anchored recycling performance. By contrast, in the SK_PL_CZ bloc, linking labour-market policies with the development of recycling systems and accelerating investments in modern separation and sorting infrastructure can enhance both recycling outcomes and material-use efficiency.

Despite its contributions, the study has several limitations. The restricted number of countries per bloc limits the generalizability of the results, and the use of aggregated national data may obscure regional or sectoral differences. Furthermore, the application of linear modelling may not fully capture nonlinear dynamics or causal pathways, and relevant institutional or policy variables remain outside the scope of the model. Future research could expand the dataset to include additional countries to improve the robustness and comparability of the results. Further studies may also employ regional or sectoral data, which would allow for a more detailed analysis of differences in the implementation of CE principles across industries and regions. Another direction is the integration of institutional and policy-related indicators, such as environmental regulations, government support mechanisms, or innovation capacity, which may significantly influence CE performance. Moreover, future research could apply advanced econometric techniques to better capture nonlinear relationships, causal mechanisms, and dynamic interactions between macroeconomic development and CE outcomes.

Acknowledgements

The research was supported by the project VEGA 1/0111/26, VEGA 1/0204/25 and project VEGA 1/0120/25.

Author contributions

MP and JS conceived the study and were responsible for the design and development of data analysis, data collection analysis and data interpretation. PL and ZM were responsible for formal editing, manuscript review, and the development of the discussion section.

Disclosure statement

Authors declare no financial, professional, and personal interests from other parties.

References

- Aghion, P., Antonin, C., & Bunel, S. (2019). *The power of creative destruction: Economic upheaval and the wealth of nations*. Harvard University Press.
- Arranz, C. F. A., & Arroyabe, M. F. (2023). Institutional theory and circular economy business models: The case of the European Union and the role of consumption policies. *Journal of Environmental Management*, 340, Article 117906. <https://doi.org/10.1016/j.jenvman.2023.117906>
- Arion, F. H., Aleksanyan, V., Markosyan, D., & Arion, I. D. (2023). Circular pathways to sustainable development: Understanding the links between circular economy indicators, economic growth, social well-being, and environmental performance in EU-27. *Sustainability*, 15(24), Article 16883. <https://doi.org/10.3390/su152416883>
- Assemblali, S., & Sabar, M. (2024). Identification of the barriers to the adoption of circular supply chains in Moroccan companies: A combined qualitative analysis and multi-criteria decision model approach. *MATEC Web of Conferences*, 401, Article 10001. <https://doi.org/10.1051/mateconf/202440110001>
- Baranski, A. (2021). *Linear economy: Characteristics and criticism*. Profolus. <https://www.profolus.com/topics/linear-economy-characteristics-and-criticism/>
- Bianchi, M., & Cordella, M. (2023). Does circular economy mitigate the extraction of natural resources? Empirical evidence based on analysis of 28 European economies over the past decade. *Ecological Economics*, 203, Article 107607. <https://doi.org/10.1016/j.ecolecon.2022.107607>
- Bocken, N. M. P., Schuit, C. S. C., & Kraaijenhagen, C. (2019). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions*, 28, 79–95. <https://doi.org/10.1016/j.eist.2018.02.001>
- Calisto Friant, M., Vermeulen, W. J. V., & Salomone, R. (2021). Analysing European Union circular economy policies: Words versus actions. *Sustainable Production and Consumption*, 27, 337–353. <https://doi.org/10.1016/j.spc.2020.11.001>
- Castillo-Díaz, F., Belmonte-Ureña, L., Diánez-Martínez, F., & Camacho-Ferre, F. (2024). Challenges and perspectives of the circular economy in the European Union: A comparative analysis of the member states. *Ecological Economics*, 22(4), Article 108294. <https://doi.org/10.1016/j.ecolecon.2024.108294>
- Chen, C. C., & Pao, H. T. (2022). *The causal link between circular economy and economic growth in EU-25*. Research Square. <https://doi.org/10.21203/rs.3.rs-1339591/v1>
- Circular Economy Foundation. (2024). *The Circularity Gap Report 2024*. <https://reports.circularity-gap.world/cgr-global-2024-37b5f198/CGR+Global+2024+-+Report.pdf>
- Circular Economy Foundation. (2025). *The Circularity Gap Report 2025*. https://pdf.circularity-gap.world/?report=CGR_Global_2025_Report_0c90048033&page=1
- D'Adamo, I., Favari, D., Gastaldi, M., & Kirchherr, J. (2024). Towards circular economy indicators: Evidence from the European Union. *Waste Management & Research*, 42(8), 670–680. <https://doi.org/10.1177/0734242X241237171>
- Eurostat. (2023). *Revised EU Circular Economy Monitoring Framework*. <https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework>

- Fura, B., Stec, M., & Miś, T. (2020). Statistical evaluation of the level of development of circular economy in European Union member countries. *Energies*, 13(23), Article 6401. <https://doi.org/10.3390/en13236401>
- Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768. <https://doi.org/10.1016/j.jclepro.2016.12.048>
- Ghisellini, P., & Ulgiati, S. (2019). Managing the transition to the circular economy. In M. Brandão, D. Lazarevic, & G. Finnveden (Eds.), *Handbook of the circular economy* (pp. 491–544). Edward Elgar Publishing. <https://doi.org/10.4337/9781788972727.00048>
- Hysa, E., Kruja, A. D., Rehman, N. U., & Laurenti, R. (2020). Circular economy innovation and environmental sustainability impact on economic growth: An integrated model for sustainable development. *Sustainability*, 12(12), Article 4831. <https://doi.org/10.3390/su12124831>
- Hondroyannis, G., Sardanou, E., Nikou, V., Evangelinos, K., & Nikolaou, I. (2024). Circular economy and macroeconomic performance: Evidence across 28 European countries. *Ecological Economics*, 218, Article 108002. <https://doi.org/10.1016/j.ecolecon.2023.108002>
- Jacobs, C., Soulliere, K., Sawyer-Beaulieu, S., Sabzwari, A., & Tam, E. (2022). Challenges to the circular economy: Recovering wastes from simple versus complex products. *Sustainability*, 14(5), Article 2576. <https://doi.org/10.3390/su14052576>
- Keith, T. Z. (2019). *Multiple regression and beyond: An introduction to multiple regression and structural equation modeling* (3rd ed.). Routledge. <https://doi.org/10.4324/9781315162348>
- Khan, K. A., Akhtar, M. A., Vishwakarma, R., & Hoang, H. C. (2023). A sectoral perspective on the sustainable growth of SMEs: Empirical research in the V4 countries. *Journal of Business Sectors*, 1(1), 10–19. <https://doi.org/10.62222/CVFW6962>
- Kozma, D., Molnár, T., & Barna, K. (2022). The indicator-based measurement of the circular economy in the countries of the European Union. *Tér és Társadalom*, 36(2), 49–69. <https://doi.org/10.17649/TET.36.2.3374>
- Mattos, C. A., & de Albuquerque, T. (2018). Enabling factors and strategies for the transition toward a circular economy (CE). *Sustainability*, 10(12), Article 4628. <https://doi.org/10.3390/su10124628>
- Mazur-Wierzbicka, E. (2021a). Towards circular economy: A comparative analysis of the countries of the European Union. *Resources*, 10(5), Article 49. <https://doi.org/10.3390/resources10050049>
- Mazur-Wierzbicka, E. (2021b). Circular economy: Advancement of European Union countries. *Environmental Sciences Europe*, 33(1), Article 111. <https://doi.org/10.1186/s12302-021-00549-0>
- Nazarko, J., Chodakowska, E., & Nazarko, Ł. (2022). Evaluating the transition of the European Union member states towards a circular economy. *Energies*, 15(11), Article 3924. <https://doi.org/10.3390/en15113924>
- Özkaya, G. (2024). An analysis of the circular economy in Europe through comparative research employing the CRITIC-based MAUT and COPRAS methods. *Verimlilik Dergisi*, 58(3), 337–358. <https://doi.org/10.51551/verimlilik.1462098>
- Petrakova, Z., & Karacsony, P. (2024). Sustainability of SMEs and their determinants: Comparative analysis from V4 countries. *Journal of Business Sectors*, 2(2), 50–61. <https://doi.org/10.62222/KWBA5277>
- Radivojević, V., Rađenović, T., & Dimovski, J. (2024). The role of circular economy in driving economic growth: Evidence from EU countries. *SAGE Open*, 14(4). <https://doi.org/10.1177/21582440241240624>
- Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or refurbished as CE 3.0? Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling*, 135, 246–264. <https://doi.org/10.1016/j.resconrec.2017.08.027>
- Remeikienė, R., Bankauskienė, J., & Gasparėnienė, L. (2024). Evaluation of circular economy indicators in EU countries. In *XIX International May Conference on Strategic Management – IMCSM24 Proceedings* (pp. 292–300). <https://doi.org/10.5937/imcsm24029r>
- Rolenders, V. (2023). Transformation of the EU countries to the circular economy model. *Economies Horizons*, 2(24), 129–135. [https://doi.org/10.31499/2616-5236.2\(24\).2023.281264](https://doi.org/10.31499/2616-5236.2(24).2023.281264)

- Sakthivelmurugan, E., Senthilkumar, G., & Karthick, N. K. (2022). Analysis of the impact of circular economy over linear economy in the paper processing industry. *Materials Today: Proceedings*, 66(3), 1446–1452. <https://doi.org/10.1016/j.matpr.2022.05.449>
- Smol, M. (2023). Inventory and comparison of performance indicators in circular economy roadmaps of the European countries. *Circular Economy and Sustainability*, 3, 557–584. <https://doi.org/10.1007/s43615-021-00127-9>
- Strapchuk, O., Koniordos, M., Strapchuk, S., & Nitsenko, V. (2025). The role of circular economy in achieving sustainable development goals in the EU. *European Sustainability Journal*, 12(3), 45–60. <https://doi.org/10.63775/1xwx6s13>
- Streimikis, J. (2025). Comparative assessment of circular economy performance in the Baltic States using MCDM methods. *Transformations and Sustainability*, 1(1), 30–42. <https://doi.org/10.63775/pcxj8p61>
- Sverko Grdic, Z., Krstinic Nizic, M., & Rudan, E. (2020). Circular economy concept in the context of economic development in EU countries. *Sustainability*, 12(7), Article 3060. <https://doi.org/10.3390/su12073060>
- Trica Lenuta, C., Banacu, C. S., & Busu, M. (2019). Environmental factors and sustainability of the circular economy model at the European Union level. *Sustainability*, 11(4), Article 1114. <https://doi.org/10.3390/su11041114>
- Vranjanac, Ž. G., Rađenović, Ž., Rađenović, T., & Živković, S. (2023). Modelling circular economy innovation and performance indicators in the European Union: A comparative analysis of the EU-28 countries. *Environmental Science and Pollution Research*, 30, 81573–81584. <https://doi.org/10.1007/s11356-023-26431-5>
- Wautelet, T. (2018). *The concept of circular economy: Its origins and its evolution* (Working paper). <https://doi.org/10.13140/RG.2.2.17021.87523>
- World Economic Forum. (2023). *Climate governance and the circular economy: A primer for boards*. https://www3.weforum.org/docs/WEF_Climate_Governance_and_the_Circular_Economy_2023.pdf