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# THE ROLE OF AI AUTOMATION IN ADVANCING RESOURCE EFFICIENCY AND CIRCULAR ECONOMY PRACTICES IN SMES

***Abstract:*** *This paper examines the relationship between artificial intelligence (AI) automation, resource efficiency, and circular economy practices in small and medium-sized enterprises (SMEs) operating in the European Union and Serbia. Data were collected through a structured online questionnaire targeting owners and senior managers of SMEs and analyzed using descriptive statistics, correlation analysis, multiple linear regression, and non-parametric group comparisons. The results indicate a strong positive relationship between sustainability-related indicators and circular economy implementation, while AI automation shows a moderate but statistically significant association with circular practices. Regression findings demonstrate that organizational resilience and the regulatory environment significantly enhance the explanatory power of models beyond AI adoption alone. Comparative analysis reveals notable differences in regulatory perceptions between EU and Serbian SMEs, whereas levels of digitalization and sustainability practices remain comparable. The findings confirm that AI-driven digital transformation supports circular economy adoption primarily when embedded within supportive organizational and institutional contexts.*

***Keywords:*** *artificial intelligence; digital transformation; resource efficiency; circular economy; SMEs*

***JEL Classification:*** *O33; Q01; Q56; L26*

## 1. Introduction

Digitalization and sustainability represent two key, but often parallel directions of development of modern economies, especially in the context of small and medium-sized enterprises (SMEs). On the one hand, the digitalization of business processes through automation, the use of artificial intelligence (AI), and advanced information systems is aimed at increasing operational efficiency, reducing costs, and speeding up decision-making. On the other hand, the concepts of circular economy (CE) and resource efficiency (RE) strive for long-term business sustainability through rational use of resources, reduction of waste, and negative environmental impacts (Guandalini 2022).

In the literature, these two processes are often viewed separately: digitalization is analyzed primarily through the prism of productivity and competitiveness, while the CE is considered within the framework of sustainable development and environmental policies (Awad et al., 2025). However, in practice, the question of their mutual connection is increasingly being raised, especially in the SME sector, which forms the backbone of national economies but at the same time has limited financial, technological, and organizational resources.

Automation of business processes in the areas of employment, logistics, production, and supply chain management brings significant operational advantages. AI systems enable faster processing of large amounts of data, more precise planning, and the reduction of operational errors. However, research indicates that the application of AI also opens a few new challenges, including algorithmic bias, a lack of transparency in decision-making, and risks in terms of compliance with regulators'

frameworks, such as the protection of personal data and the GDPR regulation. Examples of the application of AI in employment are especially highlighted, where systems like ATS (Applicant Tracking Systems) can reproduce existing social inequalities and generate legal and ethical risks (Seppälä & Małecka, 2024). In parallel, the literature on the CE emphasizes the central role of small

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and medium-sized enterprises in the transition from the linear model "take-produce-dispose" to circular models based on the reuse, recycling, and regeneration of resources. RE, energy saving, and waste reduction are recognized as key factors in the long-term competitiveness of SMEs, but their implementation often encounters obstacles in the form of a lack of knowledge, capital, and adequate tools for monitoring and measuring effect (Roberts et al., 2022).

By connecting these two streams of literature, space is opened for consideration of digitalization, and especially artificial intelligence as a potential catalyst for the implementation of the CE in SMEs. AI can enable more precise monitoring of resource flows, optimization of production and logistics processes, and better integration of sustainability into strategic decision-making (Klimecka-Tatar & Kapustka, 2025). At the same time, inadequate or fragmented application of digital technologies can lead to digitalization remaining focused solely on short-term efficiency without significant contribution to long-term sustainability.

This paper aims to examine whether and in what way the application of artificial intelligence and automated systems in small and medium-sized enterprises contributes to a faster and more efficient introduction of CE practices and improvement of resource efficiency, as well as to identify the key benefits and risks of such integration.

Although the literature regarding digital transformation and circular economy practices is already growing, the two areas are still largely studied independently of each other. The research on digitalization in SMEs primarily addresses the aspects of operational efficiency and competitiveness, whereas the research on the circular economy focuses on the results of sustainability and environmental impact (Guandalini, 2022). Most of the recent contributions also recognize the possibilities of artificial intelligence to facilitate the circular practices, but they interpret them at the operational level, e.g., at the process optimization and reverse logistics (Wilson et al., 2021).

Also, the interactions between the automation of AI and organizational and institutional dynamics remain uncommon regarding the impact they may have on the adoption of the practices of the circular economy, specifically in the case of SMEs with varying regulations. The importance of technological, organizational, and environmental dimensions is emphasized in existing studies (Badghish and Soomro, 2024), but the combined impact of the aspects has not been addressed at the empirical level in the context of the adoption of the circular economy. In addition, there is a lack of comparative understanding between developed and transitional economies.

This research study will add to the literature in a number of ways. To start with, it combines digital transformation and the study of the circular economy, focusing on how AI automation contributes to a circular practice in SMEs. Second, it expands on the existing models by including organizational resilience and regulatory environment as additional factors of explanation, which offer a more detailed perspective on the implementation of the circular economy. Third, it provides empirical data on both European Union and Serbian SMEs, hence adding to the scarce comparative study on the institutional context of developed and transitional economies. Lastly, the paper proves that the influence of AI on the implementation of a circular economy depends on the organizational and regulatory support, not just on the technological one.

## 2. Literature review

The existing literature most often views digitalization in SMEs as a means of improving operational efficiency and competitiveness. Artificial intelligence is defined as a set of technologies that enable systems to learn from data, recognize patterns, and make decisions with minimal human intervention. In the SME context, AI is applied in the areas of production planning, inventory management, logistics, recruitment, and customer relations (Dinh et al., 2025). Research indicates that AI enables precise monitoring of resource consumption – raw materials, energy, and water – in real time. These studies focus on the efficiency benefits, but mostly they present digitalization as an instrument of operation, without considering its wider strategic purpose of facilitating sustainability transitions in SMEs.

By using machine learning algorithms, companies can identify waste patterns, predict future needs, and optimize procurement processes. In this way, digitalization directly contributes to reducing costs and increasing resource efficiency, which is especially important for companies with limited resources (Arranz et al., 2023)

However, the literature also points to the limitations of AI applications in SMEs, including the lack of digital skills, dependence on external technological solutions, and risks associated with the non-transparency of algorithms. These factors can make strategic management of digital transformation difficult and reduce potential benefits.

This implies that there is a gap in the literature, with the potential of AI being greatly appreciated, yet the practical implementation of AI in SMEs is limited to organizational and capability-related variables.

### 2.1. Circular economy and resource efficiency

The circular economy is defined in the literature as an alternative model of economic development that strives to preserve the value of products, materials, and resources as long as possible. Unlike the linear model, CE implies the closure of material flows through reuse, recycling, and regeneration of resources. Research efficiency represents the central elements of this approach and refers to the achievement of greater economic output with less resource consumption. Research emphasizes that SMEs play a key role in the implementation of the circular economy due to their flexibility and proximity to local markets. At the same time, they face numerous barriers. Such as a lack of financial resources. Limited access to technologies and insufficient institutional support. (Badghish & Soomro, 2024). The results of systemic sustainability are of great priority in the study of the circular economy as opposed to internal efficiency (as found in the digitalization studies), and this represents a conceptual difference between the two literature streams.

Also, the literature is showing the synergy between artificial intelligence and the CE, where AI is identified as an enabling technology that can support the optimization of production processes, waste reduction, and more efficient management of reverse logistics. Digital tools enable production planning with the aim of extending the product life cycle and better utilization of resources (Wilson et al., 2021). In addition to operational benefits, the AI data analysis system enables SME management to assess the economic and environmental effects of implementing circular practices, including implementation costs, potential savings, and long-term benefits. In this way, sustainability is integrated into strategic decision-making and is not viewed exclusively as a regulatory and reputational requirement (Raut et al., 2025). Although these reports acknowledge the empowering position of AI in the implementation of circular practices, they largely revolve around the technical and operational applications. The effectiveness of such technologies is less focused on the impacts of organizational resilience and regulatory environments. Consequently, current studies fail to shed all the light on the reasons why comparable rates of technological adoption can have dissimilar sustainability results in firms and regions.

According to the literature, digital transformation and the practices of the circular economy are well-researched on an individual basis, but the process of their combination is under-researched, especially in a multi-dimensional approach that would incorporate the technological, organizational, and institutional components. This is where the gap lies in the foundation of the establishment of the following hypotheses:

- H1: AI automation has a positive impact on the introduction of circular economy practices to SMEs.
- H2: There is a positive correlation between organizational resilience and AI automation and the adoption of CE.
- H3: Favorable regulatory environments do not mediate the influence of AI automation on CE implementation. Such hypotheses can be tested in a systematic manner, and the interaction between the technological, organizational, and institutional factors.

## 3. Research methodology

The research was considered as an empirical study with a mixed methods research approach that enables simultaneous testing of hypotheses and a deeper understanding of contextual organizational and institutional factors that influence the relationship between the application of artificial intelligence automation of business processes and sustainable practices in small and medium size and prices (SME) (Bracio & Szarucki, 2020). The quantitative part of the research has an explanatory character with the aim of identifying statistically significant relationships between the observed variables.

Quantitative research includes micro, small, and medium enterprises from the territory of the European Union and the Republic of Serbia, where some of them are using the Small Business Act (A. Gračanac, 2012). The target population is defined in accordance with the recommendation of the European Commission 2003 / 361 / EC, according to which:

- Micro enterprises are defined as entities with less than 10 employees and the annual turnover or the balance sheet up to 2 million euros;
- Small businesses as entities with 10 to 49 employees and a turnover or balance sheet of up to 10 million euros;

- Medium-sized companies as entities with 50 to 249 employees and a turnover of up to 50 million euros or a balance sheet of up to 43 million euros; (*SME Definition*, n.d.)

The sample is formed by applying purposive sampling, where the basic criterion for inclusion in the research is that the company uses at least one form of digital or automated business technology, including but not limited to: AI tools, automated information systems, common ERP Solutions, digital platforms, or advanced analytical tools (Vrontis et al., 2022). This sampling approach enables research to be focused on organizations that have practical experience with digitalization, which is crucial for examining its relationship with sustainable business practices.

The expected sample size is between 120 and 300 valid answers, which enables the application of descriptive statistics, correlation analysis, and basic regression models, as well as conducting a comparative analysis between companies from the EU and the Republic of Serbia.

### 3.1. Research instrument

The structured questionnaire is used for primary data collection in quantitative business research (Stanley, 2021), and it was administered online to collect standardized data from owners, directors, or senior management of SMEs, considering their direct involvement in strategic decision-making, digital transformation, and defining the sustainable goals of the company (Bhuiyan et al., 2024). The questionnaire was designed to include questions about the level of application of AI and automation, types of sustainable and circular practices, perceptions of benefits and risks, as well as institutional and regulatory constraints, and consists of four thematic units:

- The first unit includes general information about the company, including size, sector, and business markets.
- The second unit measures the level of application of AI and automation in the areas of HR, logistics, production, and data management using a five-point Likert scale;
- The third unit refers to research efficiency and struggling economy, and includes questions about energy savings, ways to reduce recycling and reuse of materials, and rational water consumption;
- The fourth unit is focused on regulatory and ethical aspects of digitalization, including compliance with GDPR, transparency of AI systems, and the presence of human supervision.

The indices that were used in the study were constructed as follows:

- AI Index: Comprised of items on process automation, HR digitalization, logistics optimization, and data management.
- R Index: Calculation based on the questions regarding energy monitoring, waste reduction, and resource reuse.
- CE Index: Scale based on the items that measure the integration of principles of circularity and orientation towards strategies and sustainability.
- REG index: Based on items measuring perceptions of regulatory barriers and legal uncertainty.

Reliability of the indices was tested using the standard formula for Cronbach's alpha.

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_{yi}^{2}}{\sigma_{x}^{2}}\right)$$

Where:

K: The number of questions in the survey.

$\sigma_x^2$: The total variance of the sum of the scores for all entries.

$\sum_{i=1}^{k}\sigma_{yi}^{2}$: The sum of the variances for each item

*Table 1. Cronbach's alpha internal consistency*

| | Cronbach alpha | Reliability |
|---|---|---|
| AI index | 0.953 | Very high |
| R index | 0.778 | Good |
| CE index | 0.765 | Acceptable |
| REG index | 0.779 | Good |

(Source: Research and processing by the author)

The results indicate that all variables are showing acceptable to very high internal consistency as the alpha index is above 0.7, which confirms the measurement scales are suitable for further statistical analysis.

### 3.2. Data analysis methods

Quantitative data are analyzed using descriptive statistics, correlation analysis, and multiple linear regression to test the set hypothesis to exam-

ine the differences between SMEs in the EU and Serbia, where the t-test or the Mann–Whitney test is used depending on the distribution of the data.

Descriptives statistics were used for the basic overview and description of the collect data this method shows the average values standard deviations minimums and Max groups of key variables such as the AI automation index the research efficiency index and the circular economy index the goal is to gain inside into the structure of the sample and the general level of the development of observed practices among SMEs as well as to identify possible extreme values or deviations in the data.

Using correlation analysis, the strength and direction of the relationship between variables were examined specifically to test the connection between the level of AI automation and research efficiency. With this method, the researchers wanted to check whether the increase in the coefficient of one variable is accompanied by an increase or a decrease in another variable (Prematunga, 2012).

Multiple linear regression was used to examine the influence of several independent variables on one dependent variable. In this paper, it is applied to evaluate the effect of AI automation on the level of circular economy implementation while simultaneously controlling factors such as company size and sector of activity.

The t-test of independent samples is used to examine whether there is a statistically significant difference in the average values of the observed variables between two independent groups, in this case, SMEs from the EU and SMEs from Serbia. This method is applied when the data follow an approximately normal distribution, and when the basic statistical conditions are met, the test results enable a quantitative comparison of the level of AI automation and circular practices between regions.

The Mann–Whitney test is a non-parametric alternative to the t-test, which is used in cases where the data do not follow the normal distribution or when samples contain outliers that violate the assumptions of parametric tests. This method examined whether the distributions offer differ significantly between SMEs from the EU answer area without relying on arithmetic means. This ensures the robustness of the analysis and validity of conclusions in conditions of non-ideal data.

### 3.3. Reliability and limitations of the study

The reliability of measuring instruments is checked using Cronbach's alpha coefficient where it shows to what extent the items within the same scale measure at the same latent construct, such as the level of AI automation research efficiency or the implementation of a circular economy, limitations of the research referred to a sample size, the subjectivity of the respondents' perceptions and the impossibility of a complete cause and effect inclusion due to the cross-sectional design (Zakariya, 2022).

## 4. Results

### 4.1. Descriptive Analysis

Descriptive analysis provided basic insights into the structure of the sample and the distribution of key variables used in the re-search the total sampling includes 262 respondents from manufacturing small and medium enterprises which provides an adequate basis for further statistical analysis the geographics structure of the sample shows a relatively balanced representation of respondents from Serbia 45% the European Union 22% and companies operating in both regions 33% which enables a comparison of different institutional and regulatory contexts.

*Table 2. Descriptive analysis results*

| Variable | MD | SD | Min | Max |
|---|---|---|---|---|
| AI Index | 2.577 | 0.8 | 1.0 | 4.8 |
| R Index | 2.636 | 0.602 | 1.333 | 4.0 |
| CE Index | 2.548 | 0.728 | 1.0 | 4.5 |
| REG Index | 2.356 | 0.383 | 1.4 | 3.0 |

(Source: Research and processing by the author)

The average value of the AI index is 2.58 (SD = 0.80) as shown in Table 2, indicates a moderate level of digital transformation in the observed companies and these results suggest that AI and automation are predominantly used on a limited scale most often for basic support of business processes while more advanced forms of automation are not yet widespread (see Figure 1). The highest average value was recorded for the parameter A1_Process_Automation (M = 2.68), which indicates that the basic forms of process automation are already present, but without strategic integration of this technique.

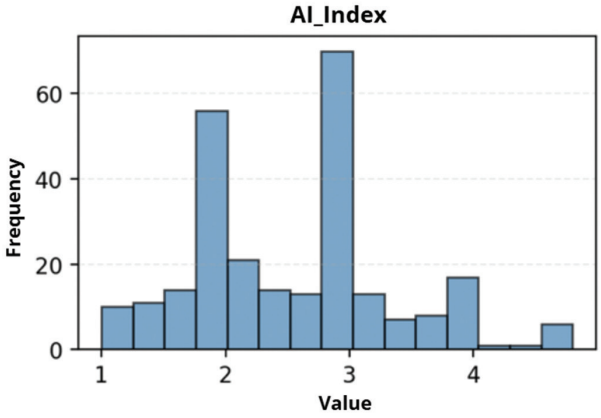


*Figure 1. Distribution of AI automation (Source: Research and processing by the author)*

The mean value of the sustainability index is 2.64 (SD = 0.60), as shown in Table 2, indicating that companies are relatively active in applying sustainable practices. The most pronounced activities are related to the waste reduction parameter (R7_Waste_Reduction; M = 2.65) and energy consumption monitoring parameter (R6_Energy_Monitoring; M = 2.63), where these findings suggest that most companies implement basic sustainability measures, primarily those that bring direct operational and cost benefits (see Figure 2).

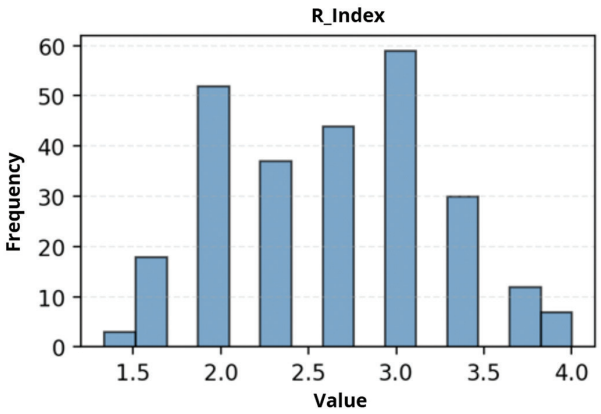


*Figure 2. Distribution of resources (Source: Research and processing by the author)*

The average value of the CE index is 2.55 (SD = 0.73) as shown in Table 2, indicates a moderate level of integration of the principles of the circular economy and similar mean values of the parameters CE9_Circular_Principles (M = 2.58) and CE10_Strategic_Direction (M = 2.52) suggest that the principles of the circular economy are partially recognized as this strategic level but that their operationalization is not yet fully developed (see Figure 3).

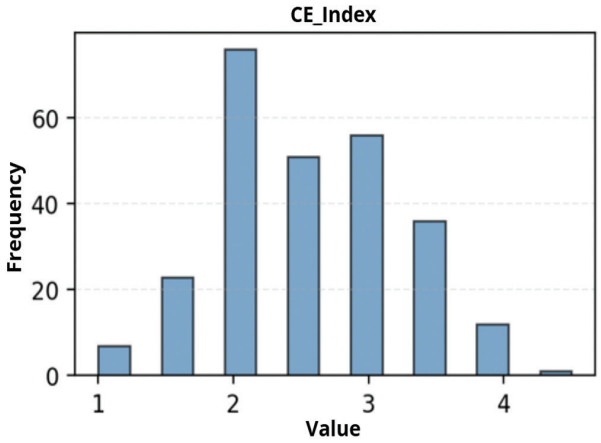


*Figure 3. Distribution of circular practices (Source: Research and processing by the author)*

The lowest average value is the regulatory index (M = 2.36; SD = 0.38), as shown in Table 2, which indicates a pronounced perception of regulatory obstacles among the respondents. The relatively higher value of the parameter REG15_Framework_Encouragement (M = 2.78) suggests that companies perceive the regulatory framework not only as limiting but also as a potential source of incentives for digital transformation and sustainable practices (see Figure 4).

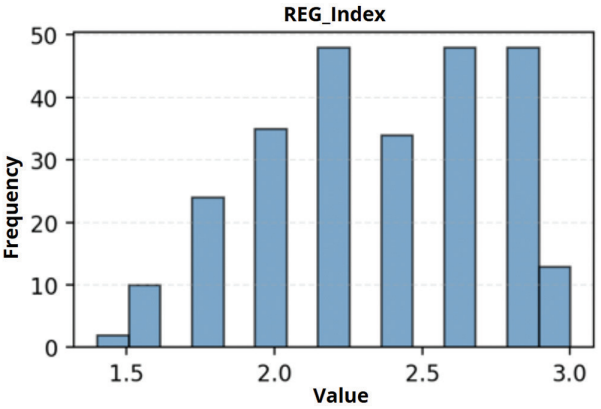


*Figure 4. Distribution of regulatory frameworks (Source: Research and processing by the author)*

## 4.2. Correlation Analysis

Correlation analysis was applied to examine mutual relations between the key indicators included in the research: AI-Index, R-Index, REG-Index, and CE-Index. The obtained correlation coefficients enable an insight into the strength and direction of the connection between the observed variables without assuming cause-and-effect relationships (see Table 3).

The highest degree of correlation was recorded between R-Index and CE-Index ($r = 0.70$, $p < 0.001$), which indicates a strong positive connection between organizational resilience and the implementation of circular economy principles.

This result is in accordance with theoretical assumptions, considering that both concepts strive to reduce waste more rational use of resources and the long-term ability of business processes. A moderate but statistically significant degree of correlation was observed between AI-Index and CE-Index ($r = 0.448$, $p < 0.001$), and this finding suggests that companies that apply artificial intelligence and digital technologies simultaneously show a higher level of circular economy implementation.

The results support the assumption that digital transformation represents an important enabling Factor for a more efficient application of CE principles, although it is not a sufficient condition by itself.

REG-Index shows a relatively weaker correlation with other indices ($r = 0.228$ with AI-Index, $r = 0.31$ with R-Index, and $r = 0.384$ with CE-Index) and these results indicate that the perception of the regulatory environment is not strongly related to the actual level of digital transformation organizational resilience or the implementation of the circular economy which may indicate discrepancy between the regulatory framework and the operational practices of companies.

*Table 3. Correlation analysis results*

| | AI-Index | R-Index | CE-Index | REG-Index |
|---|---|---|---|---|
| AI-Index | 1.0 | 0.303 | 0.448 | 0.228 |
| R-Index | 0.303 | 1.0 | 0.701 | 0.31 |
| CE-Index | 0.448 | 0.701 | 1.0 | 0.384 |
| REG-Index | 0.228 | 0.31 | 0.384 | 1.0 |

Source: Research and processing by the author

Additionally, the moderate degree of correlation between AI-Index and R-Index ($r = 0.30$) suggests that digital transformation and sustainability are not necessarily directly related processes; instead, they may be driven by different strategic priorities and motives within organizations, which further justifies their separate consideration in regression analysis.

The normality of indices was evaluated with the help of the Shapiro-Wilk test before the regression analysis was performed. The Shapiro-Wilk test indicated that all analyzed variables deviate from normality ($p < 0.05$), as shown in Table 4. However, given the relatively large sample size ($n > 200$), the test is highly sensitive and capable of detecting even minor deviations from a normal distribution.

*Table 4. Shapiro-Wilk test results*

| Variable | n | p-value |
|---|---|---|
| AI index | 262 | < 0.01 |
| RE index | 262 | < 0.01 |
| CE index | 262 | < 0.01 |
| REG index | 262 | < 0.01 |

Source: Research and processing by the author

In this regard, multiple linear regression was conducted as it is generally resistant to violations of normality in large samples. For comparisons between groups where normality assumptions were not satisfied, non-parametric methods, specifically the Mann-Whitney U test, were applied to ensure the robustness and validity of the results. The two-fold strategy was such that the statistical conclusions were sound and in line with the data distributional characteristics. This has been documented in large samples where statistical tests of normality have a tendency to reject the null hypothesis even in the case where the distribution is practically normal (Ghasemi & Zahediasl, 2012).

### 4.3. Regression Analysis

To examine the factors in financing the implementation of the circular economy, multiple linear regression analysis was applied, whereby the CE index was defined as the dependent variable, independent variables included the index of artificial intelligence (AI index), resilience (R-Index), and regulatory framework (REG-Index). The analysis was carried out through two models to see the individual and joint contributions of these factors.

Model 1 (CE ~ AI) shows that the AI index independently explains 20% of the total variance of the CE index ($R^2 = 0.20$). As a statically significant regression coefficient ($b = 0.41$, $t = 8.07$, $p < 0.001$) indicates a positive relationship between the application of AI and the level of circular economy implementation this result suggests that digital

technologies and AI can play an important role in advancing CE practices but at the same time indicates that AI is not as efficient factor to fully explain the variation in CE implementation.

Model 2 (CE ~ AI + R + REG) significantly improves the explanatory power of the model because it explains 57.3% of the variance of the dependent variable ($R^2$ = 0.57). This increase in $R^2$ indicates that the combination of technological, organizational, and institutional factors provides a much more complete explanation of the implementation of the circular economy.

The results of the second model showed that R-Index is the strongest predictor of CE-Index (b = 0.71, t = 13.19, p < 0.001), which indicates that the resilience of organizations or systems plays a key role in this successful application of CE principles. AI index remains statistically significant, b = 0.22, t = 5.47, p < 0.001, which confirms its independent contribution even when other factors are included. Also, REG-Index has a positive and significant impact (b = 0.28, t = 3.45, p = 0.001), which emphasizes the importance of the regulatory support and the institutional framework for the development of the circular economy.

Taken as a whole, the results of the regression analysis indicate that the implementation of the circular economy is not determined solely by technological factors such as AI but rather depends on their interaction with organizational resilience and the regulatory environments, whereby the lower AIC value of model 2 compared to model 1 further confirms the better fit for the comprehensive model to the observed data.

*Table 4. Regression analysis results*

| Model | $R^2$ | Adj. $R^2$ | F-statistic |
|---|---|---|---|
| **Model 1: CE ~ AI** | 0.20 | 0.197 | 65.15 |
| **Model 2 : CE ~ AI+R+REG** | 0.573 | 0.568 | 115.2 |

Source: Research and processing by the author

Even though the independent variable of AI automation is the one that explains 20 percent of the CE variance, this value remains moderate when contrasted with the impact of organizational resilience, which comes out to be the most significant predictor. This implies that without the support of sound organizational frameworks, sustainability cannot be achieved using technological tools. The regulatory framework also demonstrates a significant impact, which is the relevance of institutional support. Effect sizes show that the effect of resilience is large, AI and regulation are medium.

### 4.4. EU vs Serbia Analysis

To compare the differences between companies from the European Union and Serbia, the Mann–Whitney U test was applied, as a non-parametric method suitable for examining differences between two independent groups, while the normal distribution of data is not assumed.

The test results indicate that there are no statistically significant differences between the EU and Serbia in terms of the level of digital transformation organizational resiliency/sustainability (R-Index; U = 3009, p = 0.12) nor the implementation of circular economy principles (CE-Index; U = 3073, p = 0.13). These findings suggest that the observed levels of technological application, sustainable practices, and circular activities are largely comparable between the two regions.

In contrast, the analysis shows statistically significant differences within the regulatory dimension (REG-Index; U = 1342, p < 0.001). A closer look at individual items indicates that respondents from the European Union

perceived significantly lower regulatory barriers in areas such as legal uncertainty, data protection delays, and general regulatory barriers.

At the same time, European Union respondents assign a significantly higher score to the item REG15_Framework_Encouragement (M_EU = 4.05 compared to M-Serbia = 1.97), which indicates that the regulatory framework in the EU is perceived to a greater extent as encouraging innovation and the application of sustainable practices.

The observed differences can be interpreted because of a different level of development of regulatory systems and institutional capacities between the EU and Serbia, especially in the context of support for digital transformation and the circular economy. The practical relevance of the observed differences is confirmed by Cohen's analysis, where there is a result is (|d| > 0.8).

## 5. Discussion

The results of the paper contribute to the central idea of digital transformation and its connection with the adoption of the circular economy (CE) in SMEs by not only providing the statistical cor-

*Table 4. Results on the Mann-Whitney test of EU and Serbia*

| Variable | EU-Mean | Serbia-Mean | Mean-Diff | T-P-Value | MW-P-Value | Cohen's-d |
|---|---|---|---|---|---|---|
| **AI-Index** | 2.503448 | 2.520339 | -0.01689 | 0.893064 | 0.707963 | -0.02159 |
| **R-Index** | 2.54023 | 2.672316 | -0.13209 | 0.170015 | 0.118373 | -0.22096 |
| **CE-Index** | 2.405172 | 2.584746 | -0.17957 | 0.122065 | 0.127664 | -0.24916 |
| **REG-Index** | 1.941379 | 2.633898 | -0.69252 | 3.11E-40 | 1.69E-24 | -2.80775 |

Source: Research and processing by the author

relation of the two but also explaining the implications of such correlation. The positive correlations of sustainability indicators, organizational resilience, and the presence of a circular economy indicate that the practice of the circular economy must be understood as a systemic ability and not an individual approach to operating the business. The more sustainable orientation SMEs are observed to have, the better it appears integrated into their practices, which means the alignment of the strategic intent and the operational behavior.

The statistically significant but moderate correlation between AI automation and the practices of the circular economy suggests that digital technologies are more of facilitators than key agents of the CE transition. This correlates with the thesis that AI increases visibility, traceability, and resource efficiency, and thus, improves decision-making processes. These results agree with (Wilson et al., 2021) who highlight the importance of AI in enhancing the efficiency of operations and minimizing waste.

The current research takes this view a step further by proposing that AI influence is more effective when incorporated into a larger context of sustainability-related organizations, compared to its application as an independent technological application.

The regression findings also support the inference that AI automation not only contributes to the adoption of the circular economy at the operational level but also at the strategic level. Although AI has a significant independent effect, its highest association can be noted with the constructs of sustainability, which implies that organizational orientation is the mediator of the efficacy of digital technologies. This observation is consistent with the previous literature, like (Raut et al., 2025.), which emphasizes contextual conditions, especially the governance and compliance frameworks. Although, unlike them, they focus more on regulation as a constraint, the current study indicates that regulatory frameworks may also be an enabling condition when they are clear, have incentives, and institutional support. The comparative study of the European Union and Serbian SMEs shows that the variations in institutional environments are not always reflected in the variations in the technological adoption rates, but they affect the perceptions and the success of the implementation. The lack of major differences in the AI automation and the adoption of CE implies that technological preparedness is relatively universal. The differences in the perceived regulatory support suggest that institutional maturity is a determining factor in defining the effectiveness with which digital tools are used in the context of the circular practices. This endorses views of institutional theory where formal rules and frameworks of policies shape organizational behavior and innovation results.

On balance, the findings suggest that digital transformation is not enough to promote the uptake of the circular economy. Rather, its performance is influenced by the interplay between technological capabilities, an organizational sustainability orientation, and institutional conditions. The results of the research are showing the AI is not a tool of operational efficiency, but of strategic enabling, whose effectiveness depends on the governance frameworks and the regulatory context. Such an integrative approach can be used to understand the reason why the same degree of technological adoption can result in varying consequences in different institutional settings.

## 6. Conclusion

This study has explored the connections among the sustainability of digital transformation, the regulatory environment, and the application of the concept of the circular economy to small and medium-sized businesses. The empirical findings give reliable support that the circular economy is most closely linked with organizational resilience and sustainability, thus stating the fact that both

notions are interconnected but not independent managerial actions in terms of their structure and strategy.

The results also prove that artificial intelligence and digital technologies are significant facilitators of the implementation of the circular economy, which is mainly through enhanced access to data, increased transparency of processes, and optimization of resources. The findings show categorically that digital transformation in isolation is not a sufficient condition to have a positive impact on the sustainability practices; it is its effective supplement with a robust sustainability orientation and a favorable regulatory environment.

When the European Union and Serbian SMEs are compared as to technological capabilities and sustainability practices, it is evident that there is a general similarity in the way these areas are perceived in different regions, but there is also a significant difference in the way the regulatory frameworks are viewed and the use of the Small Business Act. This implies that the maturity of the institution and clarity of the regulator are critical in transforming the digital potential into sustainability.

In the practical sense, the study has the implication that SMEs must consider adopting an integrated strategic focus implemented by aligning digital transformation initiatives and sustainability goals instead of pursuing them as separate technological upgrades. Specifically, companies must focus on developing the resilience of the organization by using energy use, waste reduction, and resource reuse, as these operational strategies are the pillars of the successful implementation of the circular economy. The findings at the policy level, particularly in the transitional setting like Serbia, show that there is a need to have more delineate regulatory frameworks, institutional backing, and incentives that can be used to motivate the SMEs to invest in digital technologies and sustainability-oriented behaviors. Another area that should be considered by policymakers is to make the available regulatory instruments more accessible and better known to improve their practical use.

All in all, the paper finds that a successful implementation of a circular economy among SMEs needs to be coordinated so that a digital transformation is integrated into the organizational strategies and surrounded by a coherent institutional and regulatory framework.

There are various directions of this study as far as future research is concerned. Longitudinal research designs should be taken into consideration in future studies because digital transformation and methods of the circular economy are dynamic and have evolved with time. Moreover, industry-focused examinations might yield more detailed information regarding the way various industries implement and embrace AI-enabled circular approaches. The future studies might also include qualitative research, i.e., case studies, or interviews to supplement quantitative research and to gain a better insight into the organizational processes that underlie these transformations. The increase of the geographical range to other countries than the European Union and Serbia would make the results more generalizable as well as enable making wider cross-country comparisons under different institutional circumstances.

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