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The Influence of Adoption Digitally-Enabled Circular Strategies on the Economic Efficiency of MSMEs in Batam City

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Abstract: This study aims to analyse the effect of digital-based circular economy strategy adoption on the economic efficiency of Micro, Small, and Medium Enterprises (MSMEs) in Batam City. Using descriptive quantitative method and multiple linear regression analysis, this study involved 311 respondents from MSMEs in Batam City. The results showed that both circular economy and digitalization have a positive and significant effect on the economic efficiency of MSMEs by 38.8%. Circular economy helps reduce waste and optimize resources, while digitalization supports operational efficiency through automation and technological innovation. The combination of these two approaches can create a sustainable business ecosystem and improve the global competitiveness of MSMEs. However, challenges such as limited digital literacy, technological infrastructure, and resistance to change remain major obstacles. This research provides important insights for the development of policies and practices that support digital transformation and circular economy in MSMEs, particularly in Batam City.
Keywords: Digitalization, Circular Economy, Economic Efficiency, UMKM, Batam City

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1. INTRODUCTION

In the midst of industrial development 4.0, digital transformation is one of the important forces in various sectors, including Micro, Small and Medium Enterprises (MSMEs). MSMEs are business activities run by individuals, households, or small-scale business entities (Sudrartono et al., 2022). Digital transformation and circular economy have great potential to improve the economic efficiency of MSMEs in Batam City, but the adoption of this strategy still faces various challenges.

Batam City has a strategic position and a developing industrial level, making it a potential hub for the implementation of a digital-based circular economy for MSMEs. According to information from the Indonesian Chamber of Commerce and Industry (KADIN) in 2022, Batam City is referred to as an industrial centre with circular economy potential due to its strategic position as a trade gateway in the ASEAN region. As a city close to international trade routes, Batam City has good access to global and regional markets. This provides advantages for business actors, including MSMEs, to connect with global supply chains and adopt circular economy practices, such as using recycled raw materials or optimizing waste into value-added products (KADIN, 2022). The number of MSMEs in Batam City, according to data from the Batam City Cooperative and Micro Business Office, is 75,064, accounting for 51% of the total MSMEs in the Riau Islands (Hariankepri.com, 2024). In 2024, the number of MSMEs going digital increased by 100 from 2023, rising from 100 MSMEs to 200 MSMEs (RRI.co.id, 2024). Based on this information, Batam City is very relevant for conducting studies related to this topic.

However, the lack of studies and research focusing on the adoption of this strategy at the local level has resulted in a limited understanding of the challenges, potential, and practical implementation in the region. Previous research conducted by (Fadhillah & Fahreza, 2023) discusses circular economy concepts in Indonesia in general, but there have been no specific policies regarding the implementation of digital-based circular strategies in Batam City. Additionally, research conducted by (Lisnawati, 2023) found that the constraints faced by MSMEs in Indonesia include limited capacity of entrepreneurs to adopt digital technology, low digital literacy, and product standardization that does not meet digital export market requirements, as well as complex regulations and licensing issues.

Data from the Indonesian Chamber of Commerce and Industry (KADIN) indicates that there are approximately 66 million MSMEs, with their contribution accounting for 61% of Indonesia's total Gross Domestic Product (GDP), equivalent to IDR 9,580 trillion (Fasa, 2021). However, only a small portion has successfully adopted sustainability strategies such as the circular economy, especially in areas with limited access to adequate digital technology.

The failure of MSMEs to leverage digital-based circular strategies can have significant impacts, both economically and environmentally. Economically, without the implementation of a circular model, MSMEs tend to rely on resources that are continuously extracted, which over time leads to increased production costs due to the scarcity and price fluctuations of raw materials (RRI.co.id, 2024). In the long term, this will reduce the competitiveness of MSMEs in both domestic and

international markets, especially given the global market trend that increasingly prioritizes sustainability.

Additionally, from an environmental perspective, the inability of MSMEs to transition to circular strategies results in high industrial waste, which directly affects the surrounding ecosystem. In Batam City, for instance, a major industrial area, the high number of MSMEs that have not managed waste efficiently has led to increased emissions and environmental pollution. Without a digital-based circular model, MSMEs cannot optimize the reuse or recycling of materials, thereby increasing the amount of solid waste and carbon emissions.

According to Masruroh et al. (2022), shifting to a circular model can offer significant opportunities, including cost savings through waste reduction, better supply chain management, lower sensitivity to resource price volatility, and longer, better relationships with customers (Masruroh et al., 2022). According to Suharso (2024) at the Green Economy Expo 2024, the circular economy has the potential to provide substantial benefits for our development, such as increasing Indonesia's GDP by approximately IDR 593 to 638 trillion, creating 4.4 million green jobs by 2030, with 75% of total jobs being held by women, reducing waste generation by 18-52% compared to business as usual by 2030, and contributing to a reduction of greenhouse gas emissions by 126 million tons of CO2 (Komunikasi LCDI, 2024).

How does the adoption of digitalization affect the economic efficiency of MSMEs in Batam City in the context of the circular economy? What challenges do MSMEs in Batam City face in integrating digitalization with circular economy strategies? In previous research, people have been able to understand the importance of circular strategies for economic and environmental efficiency. The aim of this study is to analyse the impact of digitalization on the economic efficiency of MSMEs in Batam City and to identify the challenges in integrating digitalization with circular economy strategies in Batam's MSMEs.

2. LITERATURE REVIEW

Digital Transformation Concept in MSMEs

Digital transformation refers to the process of converting information and business processes from analogy formats to digital formats, allowing for more efficient data access and process automation (Zikri, 2024). It can be understood as the integration of digital technologies into all aspects and operations of an organization, which in turn leads to changes in how the organization operates and delivers value to its customers (Feriyanto & Firdaus, 2023). To enhance productivity and efficiency in micro, small, and medium enterprises (MSMEs), digital transformation has become crucial. Digitizing business processes, utilizing management software, and employing e-commerce platforms are some examples of digital technologies. Digital technology enables MSMEs to automate manual processes, reduce operational costs, and expand market reach. This has a significant impact on the productivity of MSMEs. For instance, accounting, inventory management, and human resource management can be conducted using enterprise resource management systems (Patwa et al., 2021).

Circular Economy Concept

The Circular Economy is an economic system designed to minimize waste and optimize the use of natural resources by reintroducing unused goods and materials back into the production cycle. This concept contrasts with the linear economic model, where natural resources are extracted, processed, used, and then discarded as waste (Fasa, 2021)

The Circular Economy represents a circular economic system that maximizes the utility and value of raw materials, components, and products, thereby reducing the amount of unused waste that is sent to landfills. Its implementation can drive higher green economic growth compared to business-as-usual scenarios (Masruroh et al., 2022). The Circular Economy is widely recognized for its potential to foster economic growth by creating new businesses and job opportunities, saving material costs, dampening price volatility, enhancing supply security, and reducing environmental pressure and impact (Putri et al., 2022).

For MSMEs, adopting a circular economy model holds the potential to save costs, improve competitiveness, and add value to products. Implementing the Circular Economy in MSMEs is crucial as it can address environmental issues, such as the volume of waste generated from SME products. The Circular Economy is designed to recover and regenerate, aiming to maintain the highest utility and value of products, components, and materials (Nugraha et al., 2023).

Integration of Circular Economy and Digitalization

The integration of the circular economy and digitalization opens significant opportunities for MSMEs to create added value while reducing the environmental impact of their operations. Digitalization can greatly assist in developing sustainable circular products. Additionally, customer engagement is essential for creating innovative sustainable circular products using digitalization (Rahmiati et al., 2024).

Digitalization enables more effective implementation of circular principles, for example through digital inventory tracking, data analysis for waste management, and the use of cloud-based technology to monitor energy efficiency (Agrawal et al., 2022). While digitalization offers various benefits to MSMEs, there are a number of obstacles that often hinder the adoption of digital technology in this sector, especially in developing countries such as Indonesia. Some of the main inhibiting factors are Limited Financial Resources, Limited Digital Knowledge and Skills, Infrastructure and Technology Access Barriers, Government Regulatory and Policy Barriers, Resistance to Change (Chi et al., 2023).

According to research conducted by Friska in 2024, the findings indicate that digitalization plays a crucial role in enhancing the productivity and sustainability of MSMEs. However, challenges related to infrastructure, digital literacy, and regulation pose significant obstacles.

Previous Research

1. **Implementation of Circular Economy in the Creative Industry: Opportunities and Challenges in the Digital Era (Indonesia)**, research conducted by Irwin et al., (2024) found that the circular economy offers various opportunities for resource efficiency and product innovation. However, there

are also significant challenges, including a lack of awareness and limited infrastructure. The article concludes that the success of implementing the circular economy in the creative industry heavily depends on collaboration between the government, industry, and society to create a supportive ecosystem. In this study, the research object focuses on the creative industry, whereas the upcoming research will target MSMEs as the research object.

2. **Circular Copenhagen: Resource and Waste Management Plan (Denmark)**, this model integrates digital technology and circular economy principles to create a more sustainable city, enhance resource efficiency, and reduce the environmental impact of production activities. This initiative can also serve as inspiration for other cities around the world looking to implement a digital-based circular economy model. One of the primary goals of this program is to achieve zero waste in the coming years, where all materials can be processed and recycled back into the economic cycle, with none ending up in landfills (Djatmiko, 2023).

3. **The Austin Circular Economy Program (Australia)**, developed in Austin, Texas, supports the implementation of circular economy principles across various sectors, focusing on waste reduction, resource optimization, and the creation of local economic opportunities. This program aims to transition Austin from a linear "take, make, dispose" economic model to a more sustainable system where materials and products are continuously used in closed loops to extend their lifespan. Austin fosters the growth of businesses and start-ups focused on circular business models, such as repair, recycling, and sharing services. The city collaborates with local entrepreneurs to create opportunities for businesses that utilize waste as raw materials, enabling products that were previously discarded to re-enter the supply chain and generate new revenue streams (Friska et al., 2024).

4. **The London Circular Economy Route Map (England)**, developed by the London government, is a strategy aimed at transforming the city's economic model from a linear approach to a circular one. This Route Map is designed to help London reduce waste, improve resource efficiency, and promote sustainable business practices by targeting key sectors that have a significant impact on the city's environment and economy. The Route Map encourages business models based on shared use, such as asset sharing, reuse, and repair. In the textile sector, for example, London supports clothing-sharing models, rental services, and clothing repair providers to extend product lifespans and reduce the demand for new production (Irwin et al., 2024).

3. RESEARCH METHOD

Research Flow

This section describes the sequence of research stages to be conducted by the author in the form of a framework for the quantitative research flow using the purposive sampling method. The aim is to outline the steps the author will take. The research flow is presented in Figure 1 as follows:

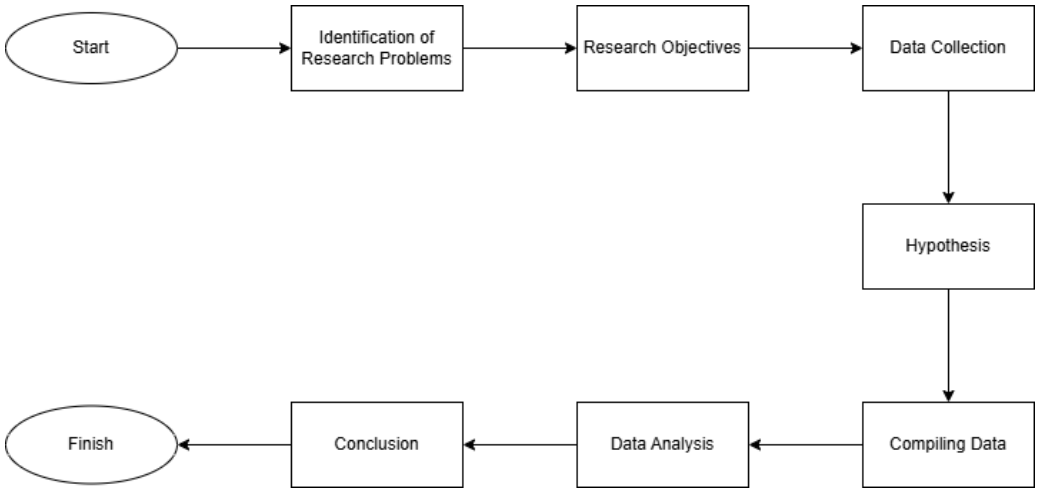

Figure 1. Research Flow

The research process begins with the identification stage, where the main focus is to identify the problem to be addressed and find solutions that can be resolved in this study. The second stage is data collection, aimed at gathering relevant information needed to achieve the research objectives. Following this, a hypothesis is formulated as a statement about the condition of the population to be tested based on the data collected from the research sample. The fourth stage involves organizing the collected information by compiling data through a questionnaire-based hypothesis. Once this is completed, the next step is to analyse the data using the purposive sampling method to present the results regarding the identified problem. After completing this analysis, conclusions can be drawn from the overall research conducted. These findings can provide valuable insights into the efforts of MSMEs in leveraging digital marketing, as well as understanding the opportunities and challenges they face in the process of digital transformation (Fasa, 2021).

Research Design

The research design is a plan for data collection, measurement, and analysis based on the research statement of the study. The type of research used in this study is descriptive quantitative. Quantitative research is a method with a research process based on the perception of a phenomenon, where the data approach generates descriptive analysis presented verbally from the research object. Through quantitative research using a survey in the form of a questionnaire, it is

possible to reveal the relationship between Digital-Based Circular Strategies and the Economic Efficiency of MSMEs in Batam City. Research has shown a positive impact of digitalization on economic efficiency. For example, a study by (Relondon, 2024) stated that in 2022, the value of Indonesia's digital economy reached IDR 714.4 trillion, growing by 27.6% compared to the previous year. This growth in the digital economy was driven by increasing internet penetration, the use of digital devices, and innovation across various economic sectors. This indicates that digitalization positively influences economic efficiency. In addition to the relationship with digitalization, Circular Strategies can serve as a strategic approach for economic efficiency by maximizing the value and utility of raw materials, components, and products, aiming to minimize environmental and social damage caused by a linear economic approach. This is also supported by the study (Djatmiko, 2023), which found that the circular strategy process has a significant positive impact on economic efficiency.

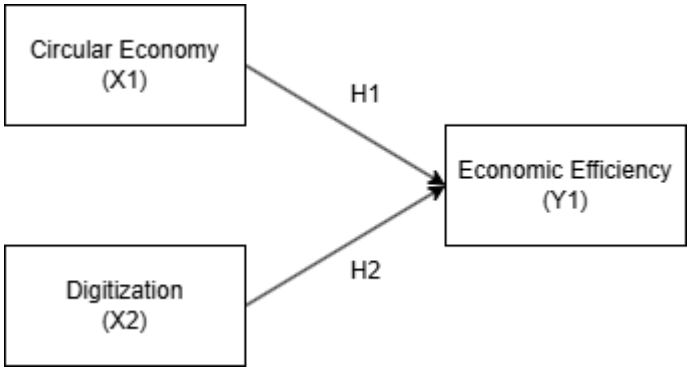

Figure 2. Research Design

Based on the research design above, it can be concluded that there are two hypotheses formulated for this study:

H1: Circular Economy has a positive effect on Economic Efficiency.
H2: Digitalization has a positive effect on Economic Efficiency.

Quantitative Data Collection

In this study, the instrument refers to a closed-ended questionnaire. A closed-ended questionnaire contains questions with predetermined answer options, such as multiple-choice or Likert scales. The author will create the questionnaire using Google Forms by designing a set of questions and distributing it to the targeted respondents. The questionnaire used in this study adopts a Likert scale model. According to Sugiyono, the Likert scale is used to explore the characteristics and opinions of an individual or group regarding a social phenomenon. The variables to be measured are broken down into indicators, which then serve as the basis for formulating the instrument items in the form of questions. Variable Indicators used in the questionnaire:

Circular Economy (X1): Waste Management, Customer Engagement and Awareness, Production Cost Reduction.

Digitization (X2): Technology Readiness, Use of Digital Platforms, Operational Efficiency Using Digitalization.
Economic Efficiency (Y): Improved Operational Efficiency, Efficient Utilization of Resources, Production Cost Reduction.

Table 1. Variable Table

Variable	Indicators	Statement	Source
Circular Economy (X1)	Waste Management	1. My MSMEs applies waste recycling in the production process 2. My MSMEs has a special program to reduce waste generated	(Feriyanto & Firdaus, 2023)
	Customer Engagement and Awareness	1. My MSMEs provides education to customers on the importance of product waste management 2. Customers are involved in my MSMEs waste management program	(Feriyanto & Firdaus, 2023)
	Production Cost Reduction	1. The implementation of circular economy helps reduce production costs in my MSMEs 2. My MSMEs has experienced a significant reduction in production costs after implementing the circular economy	(Feriyanto & Firdaus, 2023)
Digitization (X2)	Technology Readiness	1. My MSMEs has adequate technology infrastructure to support digitalization 2. Technology readiness in my MSMEs supports improved operational efficiency	(Arifin & Kohar, 2022)
	Use of Digital Platforms	1. My MSMEs uses digital platforms in its daily operations 2. The use of digital platforms helps improve the operational efficiency of my MSMEs	(Firdausya & Ompusunggu, 2023)

	Operational Efficiency Using Digitalization	1. Digitalization speeds up work processes in my MSMEs 2. My MSMEs feels more efficient after implementing digitalization	(Octavina & Rita, 2021)
Variable	**Indicators**	**Statement**	**Source**
Economic Efficiency (Y)	Improved Operational Efficiency	1. My MSMEs has seen an increase in operational efficiency after implementing circular economy or digitalization 2. My MSMEs efficiency program resulted in a reduction in working time	(Dinda & Fadillah, 2024)
	Efficient Utilization of Resources	1. My MSMEs makes efficient use of existing resources 2. Efficient resource utilization helps reduce waste in my MSMEs	(Bappenas, 2021)
	Production Cost Reduction	1. My MSMEs efficiency program has reduced production costs 2. My MSMEs experienced a significant reduction in production costs after implementing the efficiency program	(Pratamansyah, 2024)

The results of this survey are expected to provide in-depth insights into the extent to which digitalization contributes to the economic efficiency of MSMEs, while also informing policies that can support sustainable digital transformation in the MSMEs sector.

Quantitative Data Analysis Methods

In data analysis, there is a goal to be achieved, which is for the analysed data to provide the necessary information to facilitate the research activities. The results of quantitative analysis can be used to answer the hypothesis that digitalization has a positive effect on economic efficiency, and that circular strategies have a positive effect on economic efficiency. If the analysis results show a significant and positive relationship between digitalization and economic efficiency, as well as between circular strategies and economic efficiency, the proposed hypothesis can be accepted. Conversely, if no significant relationship is found, the hypothesis will be rejected. This study will use multiple linear regression data analysis with SPSS software to test the research's descriptive statistics, validity test, reliability test, classical assumption tests: normality test, heteroscedasticity test, multicollinearities test, autocorrelation test, R square test, t test, and F test.

4. RESULTS AND DISCUSSION

Descriptive Statistics of Quantitative Data

The data that has been distributed to respondents who meet the criteria in Batam City, where the data has been selected to result in data that is ready for testing, amounts to 311 respondent data. The determination of the sample size in this study uses the Slovin technique.

$$n = \frac{N}{1+ N(e)^2} \quad \text{.....(1)}$$

Through Table 2, it can be seen that the data collected from 311 respondents in Batam City shows that the majority of respondents are male (52.10%) with the dominant age group being 21-25 years old (66.90%). This data is relevant considering that the younger generation is the main driver of digital transformation and the implementation of circular economy in MSMEs. This supports the hypothesis that digitalization and the circular economy are more easily accepted by the productive age group that is adaptive to technology.

Table 2. Respondent Data by Gender

Gender	Amount	Percentage
Male	162	52.10%
Female	149	47.90%
Total	**311**	**100%**

Source: Author calculation (2025)

Through Table 3, it can be seen that the data distributed was targeted to the Millennial/Generation Y/Z in Batam City. The respondents aged 21-25 years amounted to 66.90% (208 people), followed by respondents aged over 25 years with a percentage of 33.10% (103 people). This shows that Generation Z is more dominant in the research conducted.

Table 3. Respondent Data by Age

Age	Amount	Percentage
21 – 25 Years Old	208	66.90%
Above 25 Years Old	103	33.10%
Total	**311**	**100%**

Source: Author calculation (2025)

Validity Test and Reliability Test

This validity test was conducted for 18 questions, and each of them showed that the factor value is greater than 0.05. This indicates that the questions in the questionnaire can be used as they are valid and can serve as tools to measure the research variables. The reliability test shows that the variables of Digitalization, Circular Strategies, and Economic Efficiency have Cronbach's Alpha values above 0.7, so it can be concluded that all variables are reliable.

Normality Test Results

Figure 3 is the P-P plot corresponding to the data that has been analysed. This figure shows that the points are located around the diagonal line, indicating that the residuals are distributed in a non-normal manner.

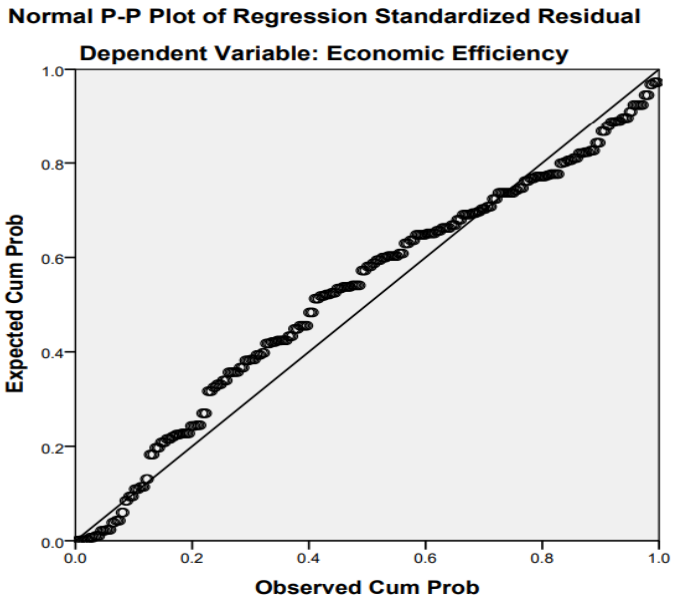

Figure 3. Normality Test Results

Based on the results of the Kolmogorov-Smirnov normality test in Table 4, it can be seen that the Asymp.Sig (2-tailed) value is 0.000, which is smaller than 0.005. Therefore, it can be concluded that the residuals are normally distributed.

Table 4. Klomogorov Smirnov test results

		Unstandardized Residual
N		311
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	2.67371180
Most Extreme Differences	Absolute	.104
	Positive	.064
	Negative	-.104
Test Statistic		.104
Asymp. Sig. (2-tailed)		.000[c]

Source: Author calculation (2025)

Heteroscedasticity Test Results

Based on Figure 4, it can be seen that the points do not form a specific pattern and are scattered above and below, to the left and right of the zero mark. Therefore, it can be concluded that, visually, the heteroscedasticity assumption is not randomly distributed.

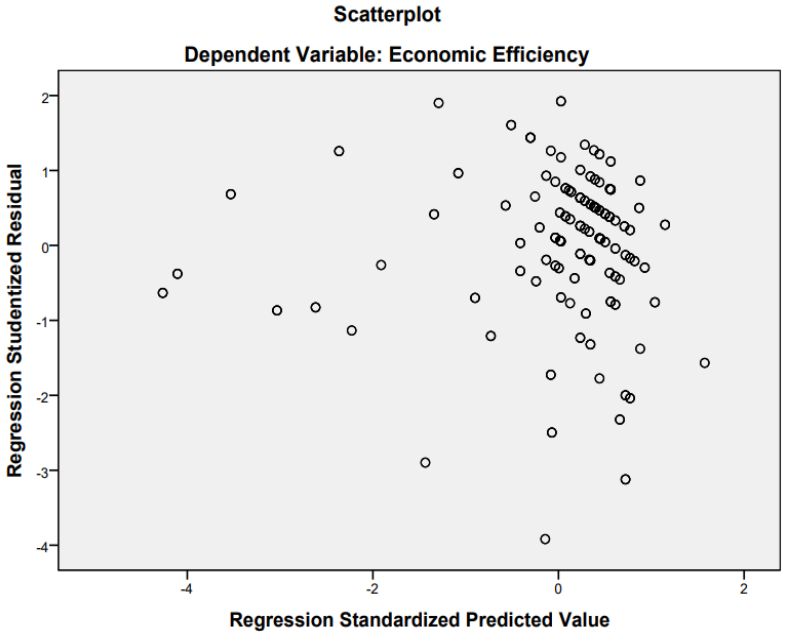

Figure 4. Heteroscedasticity Test Results

It can be concluded that the points generated are scattered irregularly, with some located above and others below the 0 line on the Y-axis, and positioned to the left and right of the 0 line on the X-axis.

Multicollinearity Test Results

Through the analysis results, Table 5 shows that the tolerance values for both variables are 0.602, which is greater than 0.10, and the VIF values are 1.662, which is smaller than 10. Therefore, it can be concluded that the variables used in this study are independent, and multicollinearity has been resolved based on these test criteria.

Table 5. Multicollinearity Test Results

Variable Independent	Collinearity Statistics		Conclusion
	Tolerance	VIF	
Circular Economy	.602	1.662	multicollinearity occurs
Digitization	.602	1.662	multicollinearity occurs

Source: Author calculation (2025)

Autocorrelation Test Results

Through the results of the autocorrelation test using the Durbin-Watson method below, the resulting Durbin-Watson value is 0.01. Therefore, the value of 2.012 is greater than the value of (du), which is 1.82019, obtained from the DW table for two independent variables with 311 data points, and it is smaller than the value of (4-du), which is 2.17981. This can be further explained as 1.82019 < 2.012 < 2.17981. Therefore, the conclusion is that the variables used in the study are free from autocorrelation and have met the requirements of this test.

Table 6. Autocorrelation Test Results

Model	Adjusted R Square	Std. Error of the Estimate	Durbin- Watson
1	.388	2.682	2.012

Source: Author calculation (2025)

R Square Test Results

From the results of the autocorrelation test, it can be explained that the adjusted R Square value is 0.388, meaning that the independent variables, namely circular economy and digitalization, can explain the dependent variable, which is economic efficiency, by 38.8%, while 62.2% is explained by other factors not included in the model. It can be concluded that MSMEs implementing circular economy and digitalization, such as posting information about the MSMEs, have a positive impact on customers, thereby increasing the economic efficiency of the MSMEs.

Table 7. R Square Test Results

Model	Adjusted R Square	Std. Error of the Estimate
1	.388	2.682

Source: Author calculation (2025)

F Test Results

Table 8 shows a value of 0.000, so it can be concluded that the Circular Economy and Digitalization have a significant impact on Economic Efficiency.

Table 8. F Test Results

Variable	Sum of Squares	df	Mean Square	F	Sig.
Regression	1428.130	2	714.065	99.242	.000[b]
Residual	2216.108	308	7.195		
Total	3644.238	310			

Source: Author calculation (2025)

Before determining F using the F table with the formula df N1 = k-1 (3-1) which is 2 and df N2 = nk (311-3) which is 308, with a probability value of 0.05 being 3.02, it can be concluded that the results of the F test above are significant with a value of 0.000 < 0.05 and the calculated F value of 99.242 > 3.02. Therefore, Ho is rejected and Ha is accepted, meaning that the Circular Economy and Digitalization have an impact on Economic Efficiency.

T Test Results

Table 9. T Test Results

Variable	Unstandardized Coefficients		t	Sig.	Hypothesis
	B	Std.Error			
(Constant)	9.910	1.010	9.816	.000	
Circular Economy	.341	.047	7.271	.000	Significant
Digitalization	.235	.049	4.773	.000	Significant

Source: Author calculation (2025)

This stage uses the formula df = n-k-1 (311-3-1) which equals 307, with a value of 0.025 resulting in approximately 1.9676. Therefore, the conclusion can be made as follows.

1. Results of the Circular Economy Test
   The Circular Economy has a significance level of 0.000 < 0.05 and a calculated t-value of 7.271 > 1.9676, so the result is that Ho is rejected and Ha is accepted. This finding supports the hypothesis that the implementation of circular economy principles, such as waste reduction and the use of recycled materials, can optimize resources and reduce production costs. Therefore, it can be interpreted that the Circular Economy has a positive impact on Economic Efficiency.
2. Results of the Digitalization Test
   Digitalization has a significance level of 0.000 < 0.05 and a calculated t-value of 4.773 > 1.9676, so the result is that Ho is rejected and Ha is accepted. This finding supports the hypothesis that the adoption of digital technologies, such as e-commerce platforms and business process automation, can increase productivity and operational efficiency. Therefore, it can be interpreted that Digitalization has a positive impact on Economic Efficiency.

Multiple Linear Regression Analysis Results

The results show the multiple linear regression analysis using the following formula:

$$Y = a + B1X1 + B2X2 + e \quad (2)$$

Here is the regression equation formulated with the following explanation:

a) The constant value of 9.910 means that if the Circular Economy and Digitalization have a value of 0, the Economic Efficiency will have a value of 9.910.
b) The regression coefficient value for the Circular Economy variable is 0.341, which means that if there is an increase in Economic Efficiency by 1 unit, it will increase by 0.341 units, assuming the other independent variables remain constant.
c) The regression coefficient value for the Digitalization variable is 0.235, which means that if there is an increase in Economic Efficiency by 1 unit, it will increase Economic Efficiency by 0.235 units, assuming the other independent variables remain constant.

Discussion

The Effect of Circular Economy on Economic Efficiency

Based on the t-test results, it can be seen that the digitalization value has a significance level of 0.000 < 0.05 and a t-value of 7.271 > 1.9676. Therefore, it can be concluded that Ho is rejected and Ha is accepted, which means that the results of this test support hypothesis H1, namely that the Circular Economy has a positive effect on Economic Efficiency.

This implies that the Circular Economy can help improve economic efficiency by reducing waste and optimizing resources. With the Circular Economy, it is possible to reduce raw material consumption, minimize waste, and also optimize

and maximize the potential of each material. It is expected to restore materials by utilizing environmentally friendly technological innovations (Raihan & Rahma, 2022). By adopting a circular economy, SMEs in Batam have the potential to reduce carbon emissions by up to 20%, aligning with the targets of the Green Economy Expo 2024. Therefore, the Circular Economy is important for Economic Efficiency.

The Effect of Digitalization on Economic Efficiency

Based on the t-test results, it can be seen that the environmental innovation value has a significance level of 0.000 < 0.05 and a t-value of 4.773 > 1.9676. Therefore, it can be concluded that Ho is rejected and Ha is accepted, which means that the results of this test support hypothesis H2, namely that digitalization has a positive effect on economic efficiency.

This implies that digitalization plays an important role in economic efficiency. Digitalization can improve productivity and economic efficiency, provide advanced technological innovations for economic efficiency, and enhance economic efficiency in a better way. Additionally, digitalization can improve the operational efficiency of MSMEs through automation and cost reduction (Zikri, 2024). This study supports LatticeMan (2023) which states that digitalization significantly enhances operational efficiency. However, our findings indicate that its impact is greater on SMEs with adequate technological infrastructure. Therefore, digitalization is crucial for economic efficiency.

Circular Economy and Digitalization Effect on Economic Efficiency

The research results indicate that the effect of the Circular Economy and Digitalization on Economic Efficiency is 38.8%, while the F-test results can be concluded as significant, with a significance level of 0.000 < 0.05 and a calculated F-value of 99.242 > 3.02. Therefore, Ho is rejected and Ha is accepted, which means that this research supports hypotheses H1 and H2, namely that the Circular Economy and Digitalization have a positive impact on Economic Efficiency.

It can be concluded that the Circular Economy and Digitalization have a significant impact on Economic Efficiency by creating business models that focus on resource optimization through environmentally friendly product innovations and the implementation of digital technologies. The Circular Economy allows for waste reduction and material reuse, while Digitalization helps expand business strategies through automation, more effective marketing, and more efficient management. By leveraging these two approaches, MSMEs can not only improve economic efficiency but also provide positive impacts for consumers and the environment.

With the challenges present in Batam City, such as the limited adoption of digital technology (Wahyuni, 2024), MSMEs in Batam are encouraged to participate in and take advantage of digitalization training programs and to support more effective waste management and the results show that the younger generation, which accounts for 66.9% of respondents, is more adaptable to digital technology. However, there is a significant challenge among the age group above 25 years, which requires further training. Local governments and MSMEs can also utilize the findings of this research to develop incentive policies that support the adoption of the Circular Economy and digital technologies. Additionally, MSMEs

can leverage digital technologies for process automation, marketing through e-commerce, and digital-based waste management. This combination can enhance operational efficiency while creating a sustainable business ecosystem.

5. CONCLUSION

Based on the analysis results of Circular Economy, Digitalization, and Economic Efficiency, from the observations and elaboration of the hypothesis tests previously, the following are the conclusions from this study:

a) Results of the Circular Economy Test
   The Circular Economy has a significance level of 0.000 < 0.05 and a t-value of 7.271 > 1.9676, resulting in Ho being rejected and Ha being accepted. This means that the Circular Economy has a positive effect on Economic Efficiency.
b) Results of the Digitalization Test
   Digitalization has a significance level of 0.000 < 0.05 and a t-value of 4.773 > 1.9676, resulting in Ho being rejected and Ha being accepted. This means that Digitalization has a positive effect on Economic Efficiency.

This study provides a new contribution by demonstrating that the combination of circular economy and digitalization can enhance the economic efficiency of SMEs by 38.8%. In conclusion, the Circular Economy and Digitalization have a significant impact on the Economic Efficiency of MSMEs in Batam City. The integration of the Circular Economy has a positive and significant effect on the economic efficiency of MSMEs, enabling waste reduction and resource optimization through recycling and reuse of raw materials. The integration of Digitalization contributes significantly to economic efficiency by automating business processes, improving productivity, and reducing operational costs.

Statistical tests indicate that the combination of the Circular Economy and Digitalization can create a more sustainable business ecosystem, enhance the global competitiveness of MSMEs, and foster innovation in resource management, this aligns with SDG 12, which emphasizes the importance of waste reduction and efficient resource management. MSMEs can participate in digital literacy training to improve their technological skills in business activities, and the government can develop specialized training programs for MSMEs to implement a digital-based Circular Economy and the government can provide tax incentives for MSMEs that adopt environmentally friendly technologies. This study is limited to respondents in Batam, so its results may not be generalized to other regions with different infrastructures and future research could explore the use of blockchain technology to enhance transparency in the circular economy of MSMEs. Thus, this study provides important insights for the development of more innovative and sustainable business practices and policies in other cities, particularly in Batam City.

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