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The Effect of AI-Based Technology Implementation, Green Energy Sustainability, and Product Innovation on Economic Growth of the Manufacturing Industry in Indonesia

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ABSTRACT

This study investigates the effect of AI-based technology implementation, green energy sustainability, and product innovation on the economic growth of the manufacturing industry in Indonesia. Using a quantitative research approach, data were collected from 120 manufacturing firms and analyzed using Structural Equation Modeling-Partial Least Squares (SEM-PLS 3). The results show that AI-based technology has the strongest positive impact on economic growth, followed by green energy sustainability and product innovation. AI-driven technologies optimize operations, reduce costs, and enhance decision-making, contributing significantly to the economic performance of firms. Green energy sustainability promotes long-term growth by reducing operational costs and improving environmental performance. While product innovation positively influences growth, its impact is relatively weaker, indicating the need for complementary factors. These findings provide insights for policymakers and industry leaders to focus on technological advancement, sustainability, and innovation as drivers of economic growth in Indonesia's manufacturing sector.

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1. INTRODUCTION

The manufacturing industry in emerging economies like Indonesia is undergoing significant changes driven by technological advancements and sustainability concerns. The integration of AI technologies and the shift towards green energy are key to enhancing efficiency, productivity, and competitiveness. Industry 5.0 promotes human-machine collaboration, using AI to improve manufacturing processes [1]. AI, particularly generative AI and computer vision, is crucial for innovation and competitiveness in today's market [2]. Sustainable manufacturing practices, including renewable energy and advanced robotics, are essential for environmental sustainability and productivity [3]. Large-scale enterprises benefit from intelligent manufacturing by investing in environmental protection and green technology [4]. While AI and sustainable practices offer advantages, challenges like investment needs, potential job displacement, and ethical concerns must be addressed for successful implementation [3].

The integration of AI-based technologies in Indonesia's manufacturing sector offers a significant opportunity to enhance operational efficiency, reduce costs, and promote sustainability. AI can optimize production processes, improve decision-making, and align the sector with global sustainability standards, contributing to economic growth [3], [5]. In waste-to-energy conversion, AI automates waste sorting and enhances energy production forecasting, streamlining operations and reducing environmental impacts [6]. AI-driven lifecycle assessments of renewable energy systems also help manufacturers optimize resource use and minimize carbon footprints, supporting strategic decisions in renewable energy deployment [7]. Despite the benefits, the adoption of AI in manufacturing faces challenges such as the need for ongoing investment, innovation, and addressing employment displacement concerns. Future research and development are crucial to overcoming these challenges and fully realizing the potential of AI in sustainable manufacturing [5], [8].

The integration of AI-based technology, green energy sustainability, and product innovation plays a crucial role in driving economic growth within Indonesia's manufacturing sector. AI technology is pivotal in reducing carbon emissions, enabling more efficient and sustainable production processes, which enhances operational efficiency and market competitiveness [9]. Green innovation, including green product and process innovations, positively influences firm value by reducing environmental impact and complying with regulations, though its adoption in Indonesia remains low, indicating the need for greater investment in green technologies [10]. Product innovation is essential for maintaining competitiveness by developing new or improved products that meet evolving consumer needs. Sustainable product development, which integrates ecological, social, and economic considerations, presents opportunities for improvement, as its uptake in the industry is still lagging [11], [12]. These three elements not only drive efficiency and competitiveness but also serve as pillars for long-term sustainability and economic resilience. This study aims to quantitatively examine the impact of AI-based technology implementation, green energy sustainability, and product innovation on the economic growth of Indonesia’s manufacturing industry [13].

2. LITERATURE REVIEW

2.1 AI-Based Technology Implementation

AI-based technology has revolutionized various sectors, including manufacturing, by enhancing efficiency, productivity, and decision-making. AI applications in manufacturing encompass automation, predictive maintenance, quality control, and supply chain optimization. According to [14], AI-driven automation reduces human error, increases precision, and fosters smarter production processes. Moreover, AI-powered data analytics enables manufacturers to make informed decisions by analyzing large volumes of real-time data, improving operational efficiency and achieving cost savings [15]. In terms of economic growth, studies have highlighted the positive impact of AI on industrial performance. [2] argue that AI implementation boosts productivity, leading to increased economic output. In Indonesia, AI technology in manufacturing is gaining recognition as a key factor for sustaining global competitiveness. Companies adopting AI not only reduce costs but also open new business opportunities through innovation [16], [17], making this technological advancement a critical driver of economic growth in the Indonesian manufacturing industry.

2.2 Green Energy Sustainability

Green energy sustainability refers to the use of renewable energy sources, such as solar, wind, and hydropower, to reduce the environmental impact of manufacturing processes. With growing awareness of climate change and the depletion of natural resources, there is an increasing focus on integrating sustainable practices into the industrial sector. According to [18], transitioning to green energy sources is crucial for achieving long-term sustainability and reducing industries' carbon footprint. Research indicates that green energy sustainability positively impacts economic growth by lowering energy costs, promoting innovation, and attracting environmentally conscious consumers [19]. Furthermore, [20] emphasize that companies adopting sustainable energy practices are more resilient and adaptable to regulatory changes. For Indonesia's manufacturing sector, integrating green energy sustainability is both an environmental necessity and an economic opportunity [21]. By embracing renewable energy technologies, manufacturers can reduce reliance on non-renewable resources and enhance operational efficiency, driving economic growth [22]–[24].

2.3 Product Innovation

Product innovation involves the development of new or improved products that meet evolving consumer demands and boost a company's competitiveness in the market. In the manufacturing industry, such innovation is vital for maintaining relevance and driving economic growth. [25], [26] posits that innovation is the main driver of economic development, as it introduces new products and processes that enhance productivity and expand markets. Several studies confirm the strong link between product innovation and economic growth. [27], [28] asserts that firms focusing on innovation are better positioned for sustained competitive advantage, leading to greater market share and profitability. In Indonesia's manufacturing industry, product innovation has become increasingly important as companies aim to meet both domestic and international market demands [13], [29]. The introduction of innovative products allows firms to differentiate themselves from competitors, grow their customer base, and contribute to the industry's overall economic development.

2.4 Theoretical Framework

The theoretical framework of this study is based on the resource-based view (RBV) of the firm, which argues that companies can achieve sustained competitive advantage by effectively utilizing internal resources such as technology, innovation, and sustainability [30]. According to the RBV, AI-based technology, green energy sustainability, and product innovation are valuable resources that can enhance the performance and growth of manufacturing firms. Additionally, the dynamic capabilities theory suggests that firms must continuously adapt and innovate in response to changing market conditions and technological advancements [31]. By integrating AI technology, adopting green energy practices, and promoting product innovation, Indonesian manufacturing firms can strengthen their dynamic capabilities, leading to improved competitiveness and economic growth. This study applies the RBV and dynamic capabilities theory to explore the impact of these factors on the economic growth of Indonesia's manufacturing sector. Based on existing literature, the following hypotheses are developed for investigation.

H1: AI-based technology implementation positively affects the economic growth of the manufacturing industry in Indonesia.

H2: Green energy sustainability positively affects the economic growth of the manufacturing industry in Indonesia.

H3: Product innovation positively affects the economic growth of the manufacturing industry in Indonesia.

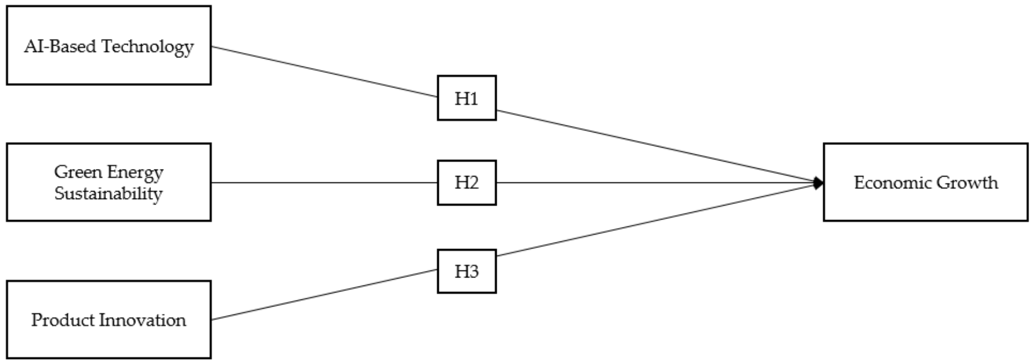

Figure 1. Conceptual Framework

3. METHODS

3.1 Research Design

This study adopts a quantitative research design to assess the relationships between AI-based technology implementation, green energy sustainability, product innovation, and the economic growth of the manufacturing industry in Indonesia. The quantitative approach allows for the empirical examination of the proposed hypotheses, enabling the identification of significant factors that contribute to economic growth in the industry. The data was gathered using a structured questionnaire, and responses were analyzed using SEM-PLS 3, a robust technique for testing complex relationships between multiple variables.

3.2 Population and Sample

The target population for this research consists of manufacturing companies operating in Indonesia, with a sample size of 120 firms selected through purposive sampling. This non-probability sampling method was used to ensure that the chosen companies had implemented AI-based technologies, adopted green energy sustainability practices, and focused on product innovation, which are the main variables of the study. The sample includes firms from various manufacturing sub-sectors, such as automotive, electronics, consumer goods, and textiles, to ensure the results are representative of Indonesia's broader manufacturing industry. Companies were selected based on specific criteria: active operations in Indonesia's manufacturing sector for at least five years, demonstrated use of AI-based technologies in production or business processes, engagement in green energy sustainability initiatives (renewable energy sources or sustainable production practices), and ongoing investment in product innovation and development.

3.3 Data Collection

The primary data for this study was collected using a structured questionnaire, designed to measure respondents' perceptions of AI-based technology implementation, green energy sustainability, product innovation, and economic growth. The questionnaire consisted of 20 items, with five items for each variable under investigation. The responses were recorded on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), where respondents indicated their level of agreement with various statements related to the study variables.

The questionnaire was distributed to managers and key decision-makers within the selected manufacturing firms, ensuring that the respondents were well-versed in the firms' technological, sustainability, and innovation strategies. Data collection was carried out over two months, and the final dataset comprised 120 valid responses.

3.4 Data Analysis

The data collected from the questionnaires was analyzed using Structural Equation Modeling-Partial Least Squares (SEM-PLS 3), a variance-based method used to model complex relationships between latent variables and their indicators. SEM-PLS is particularly suited for small to medium-sized datasets and allows researchers to test both direct and indirect relationships between multiple variables (Hair et al., 2017). SEM-PLS 3 was selected for this study due to its flexibility and ability to handle multivariate relationships between AI-based technology implementation, green energy sustainability, product innovation, and economic growth. The analysis involved two key evaluations: first, the measurement model was assessed to ensure the reliability and validity of the constructs, using Cronbach's alpha, composite reliability, and Average Variance Extracted (AVE). Constructs required a Cronbach's alpha above 0.70 and an AVE above 0.50 to demonstrate adequate reliability and validity (Hair et al., 2017). Second, the structural model was evaluated to test the hypotheses, with the significance of path coefficients examined using bootstrapping with 5000 subsamples. The model's explanatory power was determined by examining the coefficients of determination (R^2) and predictive relevance (Q^2) to assess the strength and significance of the relationships between the variables.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The descriptive statistics provide an overview of the responses from the 120 manufacturing firms, measured using a Likert scale (1-5) to assess perceptions of AI-based technology implementation, green energy sustainability, product innovation, and economic growth. The mean values for each variable were as follows: AI-based technology implementation (Mean = 4.21, SD = 0.65), green energy sustainability (Mean = 4.05, SD = 0.72), product innovation (Mean = 4.33, SD = 0.58), and economic growth (Mean = 4.15, SD = 0.67). These results indicate that respondents generally agreed with the statements regarding these factors in their firms, with the relatively high mean values suggesting that AI-based technology, green energy sustainability, and product innovation are viewed as significant drivers of economic performance in Indonesia's manufacturing industry.

The demographic composition of the respondents provides insight into the characteristics of the sample, which represents a diverse range of participants from Indonesia's manufacturing sector. In terms of gender distribution, 62.5% of the respondents were male (75 respondents), while 37.5% were female (45 respondents). The age distribution showed that 54.2% of the respondents were 30 years or older (65 respondents), and 45.8% were under 30 years (55 respondents). Regarding education level, 58.3% of respondents held undergraduate degrees (70 respondents), while 41.7% had completed postgraduate studies (50 respondents). Additionally, company size distribution indicated that 29.2% of respondents worked in small firms with fewer than 50 employees (35 respondents), and 70.8% were employed in medium-large firms with 50 or more employees (85 respondents). These demographics provide a well-rounded representation of the manufacturing industry in Indonesia.

4.2 Measurement Model

The measurement model was evaluated to ensure the reliability and validity of the constructs used in this study: AI-based technology, green energy sustainability, product innovation, and economic growth. The model's assessment focused on factor loadings, Cronbach's Alpha (CA), composite reliability (CR), and average variance extracted (AVE). These metrics are essential for establishing both the internal consistency and the validity of the constructs. Below is a detailed discussion of the measurement model for each variable.

Table 1. Validity and Reliability

Variable	Code	Loading Factor	CA	CR	AVE
AI-Based Technology	AIBT.1	0.885	0.905	0.940	0.840
	AIBT.2	0.937			
	AIBT.3	0.927			

Green Energy Sustainability	GES.1	0.875	0.766	0.857	0.749
	GES.2	0.856			
Product Innovation	PI.1	0.909	0.883	0.928	0.811
	PI.2	0.932			
	PI.3	0.859			
Economic Growth	EG.1	0.899	0.887	0.922	0.747
	EG.2	0.884			
	EG.3	0.857			
	EG.4	0.815			

The analysis of the constructs in this study demonstrates strong reliability and validity across all variables. For AI-based technology (AIBT), factor loadings for all three indicators (AIBT.1 = 0.885, AIBT.2 = 0.937, AIBT.3 = 0.927) are above the acceptable threshold of 0.7, with high Cronbach's Alpha (0.905), composite reliability (CR = 0.940), and average variance extracted (AVE = 0.840), indicating excellent internal consistency and strong convergent validity. Similarly, the green energy sustainability (GES) construct shows valid factor loadings (GES.1 = 0.875, GES.2 = 0.856), with a Cronbach's Alpha of 0.766, composite reliability of 0.857, and AVE of 0.749, confirming adequate reliability and validity. Product innovation (PI) also has high factor loadings (PI.1 = 0.909, PI.2 = 0.932, PI.3 = 0.859), a Cronbach's Alpha of 0.883, CR of 0.928, and AVE of 0.811, indicating strong measurement reliability. Lastly, economic growth (EG) has factor loadings ranging from 0.815 to 0.899, with a Cronbach's Alpha of 0.887, CR of 0.922, and AVE of 0.747, further demonstrating high reliability and substantial variance explanation in its indicators. These metrics confirm the robustness of the constructs used in this study.

4.3 Discriminant Validity

Discriminant validity refers to the extent to which a construct is truly distinct from other constructs, both in terms of how it correlates with other variables and how well it is measured. To establish discriminant validity, the correlation between constructs should be lower than the square root of the Average Variance Extracted (AVE) of each construct. The table provided below shows the diagonal elements (in bold) representing the square root of the AVE for each construct, and the off-diagonal elements representing the correlations between constructs.

Table 2. Discriminant Validity

	AI-Based Technology	Economic Growth	Green Energy Sustainability	Product Innovation
AI-Based Technology	0.817			
Economic Growth	0.708	0.864		
Green Energy Sustainability	0.749	0.686	0.866	
Product Innovation	0.565	0.576	0.689	0.891

The discriminant validity of the constructs was assessed using the Fornell-Larcker criterion, which requires that the square root of the Average Variance Extracted (AVE) for each construct be greater than its correlations with other constructs. For AI-based technology, the square root of the AVE is 0.817, exceeding its correlations with economic growth (0.708), green energy sustainability (0.749), and product innovation (0.565), indicating distinctiveness. Economic growth has a square root of AVE of 0.864, higher than its correlations with AI-based technology (0.708), green energy sustainability (0.686), and product innovation (0.576), confirming its discriminant validity. Green energy sustainability, with a square root of AVE of 0.866, surpasses its correlations with AI-based technology (0.749), economic growth (0.686), and product innovation

(0.689), establishing its uniqueness. Lastly, product innovation has a square root of AVE of 0.891, exceeding its correlations with AI-based technology (0.565), economic growth (0.576), and green energy sustainability (0.689), confirming its distinctiveness. As the square roots of the AVE values for all four constructs are higher than their correlations with other variables, the measurement model demonstrates strong discriminant validity, ensuring that each construct is conceptually and empirically distinct from the others.

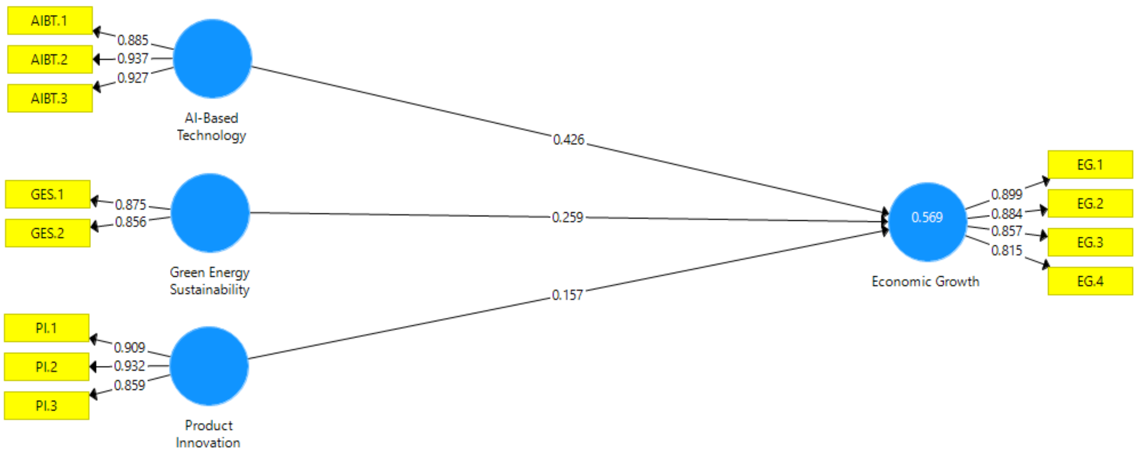

Figure 2. Internal Model

The R-Square (R^2) value for Economic Growth is 0.569, indicating that 56.9% of the variance in Economic Growth can be explained by the three independent variables: AI-based technology implementation, green energy sustainability, and product innovation. This suggests that these factors collectively account for a significant portion of the variation in economic growth within the manufacturing sector, and in the context of social sciences and business research, an R^2 value of 0.569 is considered moderately strong. However, 43.1% of the variance remains unexplained, implying the presence of other factors influencing economic growth beyond the scope of this study. The R-Square Adjusted value for Economic Growth is 0.558, slightly lower than the R^2 value, as it accounts for the number of predictors and potential overfitting. The minimal difference between R^2 (0.569) and R^2 Adjusted (0.558) indicates that the explanatory power of the model remains robust, with the independent variables (AI-based technology, green energy sustainability, and product innovation) contributing meaningfully to explaining the variance in economic growth.

4.4 Model Fit

Model fit refers to how well a hypothesized model represents the data collected. In this study, several fit indices have been provided, including the Standardized Root Mean Square Residual (SRMR), d_ULS, d_G, Chi-Square, and Normed Fit Index (NFI), which are used to evaluate the goodness-of-fit for both the Saturated Model and the Estimated Model. These indices help assess whether the proposed model is an acceptable representation of the relationships among the variables in the dataset.

Table 3. Model fit

	Saturated Model	Estimated Model
SRMR	0.079	0.079
d_ULS	0.481	0.481
d_G	0.312	0.312
Chi-Square	215.368	215.368
NFI	0.809	0.809

The model's fit was assessed using several indicators, starting with the Standardized Root Mean Square Residual (SRMR), which was 0.079 for both the saturated and estimated models. As SRMR values ≤ 0.08 indicate a good fit, the model demonstrates an acceptable fit with a small difference between observed and predicted correlations. The d_ULS (0.481) and d_G

(0.312) values, which measure the discrepancies between observed and model-implied correlations, suggest a reasonable fit with moderate and low discrepancies, respectively. The Chi-Square statistic of 215.368 is moderately high but expected due to the sample size of 120, and while it suggests some discrepancy, this result should be interpreted alongside other fit indices. The Normed Fit Index (NFI) of 0.809 indicates that 80.9% of the covariance in the data is explained by the model, which reflects an acceptable but improvable fit.

4.5 Hypothesis Testing

In this section, we evaluate the results of hypothesis testing using the path coefficients, T-statistics, and p-values derived from the Structural Equation Modeling-Partial Least Squares (SEM-PLS) analysis. The analysis tested the relationships between AI-based technology implementation, green energy sustainability, product innovation, and economic growth in the Indonesian manufacturing industry. The key metrics used to assess the significance of these relationships include the Original Sample (O), Sample Mean (M), Standard Deviation (STDEV), T-statistics, and P-values. Below is a detailed discussion of the hypothesis testing results.

Table 4. Hypothesis Test

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
AI-Based Technology -> Economic Growth	0.726	0.727	0.106	8.009	0.000
Green Energy Sustainability -> Economic Growth	0.559	0.556	0.087	5.992	0.000
Product Innovation -> Economic Growth	0.357	0.363	0.090	2.736	0.003

The analysis of the relationships between AI-based technology, green energy sustainability, product innovation, and economic growth demonstrates significant findings. The path coefficient of 0.726 for AI-based technology indicates a strong positive relationship with economic growth, supported by a T-statistic of 8.009 and a p-value of 0.000, confirming the statistical significance of this effect. This supports Hypothesis 1, indicating that AI-based technology significantly contributes to the economic growth of manufacturing firms in Indonesia. Similarly, the path coefficient of 0.559 for green energy sustainability suggests a moderately strong positive relationship with economic growth, with a T-statistic of 5.992 and a p-value of 0.000, affirming the significance of this relationship and supporting Hypothesis 2. Finally, the path coefficient of 0.357 for product innovation indicates a positive but relatively weaker relationship with economic growth, with a T-statistic of 2.736 and a p-value of 0.003, demonstrating its significance and supporting Hypothesis 3. Overall, the results suggest that AI-based technology and green energy sustainability have stronger impacts on economic growth compared to product innovation.

DISCUSSION

AI-Based Technology and Economic Growth

The findings reveal that AI-based technology implementation has the most substantial impact on economic growth, indicating that integrating AI into manufacturing processes significantly enhances productivity, efficiency, and decision-making, leading to notable economic gains. The adoption of AI technologies—such as automation, machine learning, and predictive analytics—enables firms to optimize operations, reduce production costs, and improve product quality, ultimately increasing profitability and competitiveness. These improvements contribute to the overall economic growth of the manufacturing sector. This aligns with previous research, such as [2], [14], [15], which highlighted AI-driven automation's role in improving operational efficiency by reducing human error and increasing precision in manufacturing processes. Additionally, AI's capacity to analyze large datasets in real-time allows for better decision-making, enhancing productivity and minimizing downtime. The significant impact of AI-based technology observed in this study emphasizes the importance of technological adoption as a key strategy for manufacturers to achieve growth and competitiveness in the increasingly digitized global economy.

Green Energy Sustainability and Economic Growth

Green energy sustainability plays a vital role in driving economic growth, highlighting the importance of adopting sustainable energy practices in manufacturing for long-term economic success. Utilizing renewable energy sources, energy-efficient technologies, and sustainable resource management not only lowers operational costs but also enhances a company's environmental performance. In an era of increasing environmental regulations and growing consumer demand for eco-friendly products, firms that invest in green energy sustainability are better positioned to achieve economic growth and maintain a competitive advantage. This positive relationship aligns with [18], [19], [21] findings, which suggest that sustainable practices lead to cost savings, innovation, and market differentiation. Companies that embrace green energy reduce their dependency on non-renewable resources, mitigating risks such as energy price volatility and regulatory penalties. Moreover, environmentally conscious firms are more attractive to investors, customers, and partners who prioritize sustainability. This study underscores the need for policymakers and industry leaders to promote green energy initiatives in the manufacturing sector to support sustainable economic development.

Product Innovation and Economic Growth

Product innovation was found to have a positive, though relatively weaker, impact on economic growth. This suggests that while innovation is important, its effect on growth may depend on complementary factors such as market conditions, technological infrastructure, and consumer demand. Product innovation enables firms to develop new or improved products that meet evolving market needs, helping them differentiate from competitors and seize new opportunities. However, the success of product innovation in driving growth may also hinge on a firm's ability to effectively commercialize innovations and align them with market demands. This aligns with [25]–[27] theory of competitive advantage, which identifies innovation as a key driver of economic development. Firms that invest in research and development are better positioned to adapt to market changes and sustain growth. In this study, the relatively weaker impact of product innovation on economic growth may reflect the challenges faced by Indonesian manufacturers in scaling innovations and reaching larger markets. To strengthen the role of product innovation in economic growth, firms may need to invest in marketing, distribution, and infrastructure to support the commercialization of new products.

Implications for Policy and Practice

The findings of this study offer important implications for policymakers and industry leaders in Indonesia. First, the strong impact of AI-based technology on economic growth indicates that investing in advanced technologies should be a top priority for the manufacturing sector. Policymakers can support this by creating favorable conditions for technological adoption, such as providing tax incentives for companies investing in AI and related technologies. Industry leaders, in turn, should focus on developing the necessary skills and infrastructure to maximize the benefits of AI-based technologies. Second, the significant effect of green energy sustainability on economic growth underscores the need for greater investment in renewable energy and sustainable practices. Policymakers should promote green energy adoption through regulatory frameworks and financial incentives, such as subsidies for renewable energy projects or penalties for excessive carbon emissions. This approach will not only drive economic growth but also support global climate change efforts. Lastly, while product innovation has a positive impact on economic growth, its relatively weaker effect suggests the need for enhanced innovation capacity within the manufacturing sector. Firms should prioritize research and development, while policymakers can support innovation through funding, intellectual property protection, and fostering partnerships between industry and research institutions. By cultivating a culture of innovation, Indonesia's manufacturing sector can boost competitiveness and contribute to sustained economic growth.

Limitations and Future Research Directions

While this study offers valuable insights into the factors driving economic growth in Indonesia's manufacturing sector, it has some limitations. First, the study's focus on a sample of 120 firms may limit the generalizability of the findings. Future research could expand the sample size and include firms from other sectors to gain a more comprehensive understanding of factors influencing economic growth across industries. Second, the study utilized cross-sectional data, capturing relationships between variables at a single point in time. Longitudinal studies could provide deeper insights into how AI-based technology, green energy sustainability, and product innovation affect economic growth over time. Additionally, future research could explore other factors contributing to economic growth, such as workforce skills, supply chain integration, and international trade policies.

5. CONCLUSION

This study has demonstrated that AI-based technology implementation, green energy sustainability, and product innovation significantly influence the economic growth of Indonesia's manufacturing sector. Among these, AI-based technology has the strongest impact, underscoring the transformative power of automation and data-driven decision-making in boosting productivity and competitiveness. Green energy sustainability also plays a crucial role, as firms that adopt sustainable practices not only improve efficiency but also align with global environmental standards, driving long-term growth. While product innovation is vital for maintaining competitiveness, its relatively weaker impact suggests the need for greater investment in scaling and commercializing innovations. For policymakers, these findings highlight the importance of fostering environments conducive to technological adoption, promoting green energy initiatives, and supporting innovation. Industry leaders should prioritize AI adoption, invest in renewable energy, and encourage innovation to ensure sustainable economic growth. Future research should broaden the analysis to other sectors and explore additional factors contributing to economic development in a rapidly changing global economy.

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