

The Role of Fintech in Moderating the Impact of Green Finance on Green Innovation in Manufacturing Companies in Indonesia

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ABSTRACT

This study aims to analyze the effect of green finance on green innovation with fintech acting as a moderating variable in manufacturing companies in Indonesia. A quantitative approach was used with a causal design and panel data on 12 companies during the 2017–2024 period (96 observations). The analysis was conducted using the Random Effect Model and Moderated Regression Analysis (MRA). The results indicate that green finance does not have a significant effect on green innovation, as proxied by ISO 14001 certification. Meanwhile, fintech was found to have a positive and significant effect on green innovation; however, fintech does not act as a moderating variable in the relationship between green finance and green innovation. These findings confirm that fintech acts as a direct determinant, not as an enhancer of the green finance relationship.

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1. INTRODUCTION

Climate change and environmental degradation have evolved into increasingly urgent global challenges, including within the Indonesian context. The manufacturing sector plays a strategic role in driving national economic growth, yet it also contributes significantly to rising carbon emissions and energy consumption. Data indicates that the industrial sector's final energy consumption reached 232 million BOE [1]. Direct and indirect emissions from the industrial sector account for approximately 23% and 15.6%, respectively, of total energy-related CO₂ emissions [2]. This situation underscores the urgency of transitioning toward more sustainable industrial practices. Such efforts require the integration of environmental

strategies into corporate business models. Green innovation is a key approach to addressing these pressures [3].

Green innovation encompasses the development of environmentally friendly products, processes, and technologies to reduce emissions and improve energy efficiency [4]. The implementation of these innovations faces structural barriers in the form of high initial investment requirements and significant failure risks [5]. Financing challenges are becoming increasingly complex as companies must undertake technological transformation alongside business model adjustments that require research and training costs [6]. Traditional financial systems tend to avoid high-risk projects and have limited efficiency in supporting green innovation projects [7].

These conditions create a gap between funding needs and the availability of financing sources. These barriers have the potential to slow the transition toward a sustainable industry. These limitations demand more adaptive alternative financing solutions.

Green finance serves as a strategic instrument to bridge the funding gap for sustainable innovation [8]. Various instruments, such as green bonds and eco-friendly loans, can lower capital costs and reduce investment risks [9]. The development of green finance in Indonesia shows a significant trend, marked by an increase in green bond issuance from US\$49 million in 2017 to US\$1.8 billion in 2018 and continuing to rise to reach US\$7 billion by March 2022 [10]. This growth reflects increasing attention to sustainable financing. However, its implementation still faces various structural challenges. Limitations in definitions, information asymmetry, and the lack of green standardization in the banking sector remain key challenges. Low adoption is also evident from the fact that only 27 out of 33,923 industries had obtained green certification by 2019 [11].

The limitations of green finance in practice call for additional, more flexible, and adaptive instruments. Fintech (financial technology) [12] has emerged as a key catalyst capable of enhancing efficiency, transparency, and financial inclusion [13]. The use of technologies such as big data, artificial intelligence, and blockchain enables reduced transaction costs and improved access to financing [14], [15]. The development of the fintech industry in Indonesia shows rapid growth [16]. Data from the Financial Services Authority (OJK) indicates that loan disbursements through P2P lending platforms reached Rp1,048.64 trillion, an increase of 37.41% (year-over-year) in 2024 [17]. The rise in the number of active borrowers also reflects the expansion of digital-based financial access [18]. These conditions underscore the role of fintech as an increasingly relevant financing alternative [19]. The integration of green finance and fintech requires a conceptual framework

capable of explaining their relationship in driving sustainable innovation.

This study is grounded in Sustainable Business Theory, which emphasizes the importance of balancing economic, social, and environmental aspects to create long-term competitive advantage. Green finance and fintech are viewed as external instruments that can strengthen a company's capacity to adopt green innovation [20]. The interaction between these two variables has the potential to generate synergy in accelerating industrial transformation [21]. This approach offers a new perspective on understanding corporate sustainability strategies [22]. The relevance of this theory is particularly strong in the context of developing countries facing resource constraints [23]. Therefore, an integrative analysis is crucial.

Previous studies indicate that green finance has a positive influence on green innovation [7], [24]. Other studies reveal that digitalization and fintech can enhance the effectiveness of sustainable financing [25]. Research findings such as those by [26] and [27] confirm that external factors such as regulations and climate risks further strengthen this relationship. Research by [28] indicates that fintech can drive circular economy practices and green innovation, even when positioned as an independent variable. Study [29] treats digitalization as a moderator in the relationship between green finance and green innovation. This variation in approaches suggests a lack of consensus regarding fintech's role in empirical models. The diversity of these results opens opportunities for further exploration.

Research gaps are evident in two main aspects: geographical context and methodological approach. Most studies still focus on countries such as China and India and employ macroeconomic approaches. Empirical evidence at the level of manufacturing firms in Indonesia remains limited. The placement of fintech in research models also tends to be as an independent variable, not as a moderator [30]. In fact, fintech has great potential to strengthen the relationship between green finance and green innovation. The absence of research that

explicitly tests the moderating role of fintech indicates a significant gap. This condition serves as an important foundation for the development of further research. The need for new approaches is becoming increasingly urgent.

Based on the above discussion, this study poses the main research question regarding how green finance influences green innovation and the role of fintech in moderating this relationship within manufacturing firms in Indonesia. Other variables such as firm size, profitability, and leverage are also considered to provide a more comprehensive picture. This approach is expected to elucidate the dynamics of

financing and innovation within a sustainability context. This study aims to empirically test the effects of green finance, fintech, firm size, profitability, and leverage on green innovation. The analysis also focuses on the moderating role of fintech in strengthening the relationship between green finance and green innovation. The study's contributions are expected to enrich the literature on sustainable finance. Its practical implications include recommendations for the government, regulators, and industry players in promoting green transformation.

2. RESEARCH METHODOLOGY

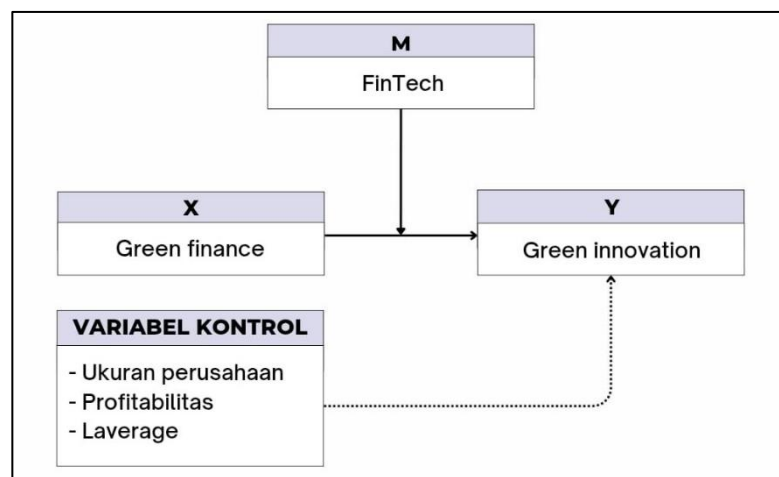


Figure 1. Research Model

This study is grounded in Sustainable Business Theory, which emphasizes the importance of integrating economic, social, and environmental aspects into corporate sustainability strategies. Within this framework, green finance is positioned as a support system that provides financial resources to fund environmentally friendly initiatives, while green innovation is viewed as a strategic output that reflects a company's success in implementing sustainable strategies.

2.1 Research Design and Data Structure

This study employs a quantitative approach with a causal-comparative design (explanatory research) to empirically test the causal relationships among variables. The quantitative approach was chosen

because it allows for the testing of hypotheses based on numerical data analyzed statistically, thereby enabling the generalization of results [31]. The explanatory nature of the study emphasizes that it not only describes phenomena but also explains the mechanisms through which green finance influences green innovation. This relationship is analyzed by including fintech as a moderating variable, along with control variables such as firm size, profitability, and leverage. This study also employs a longitudinal design using panel data. The data simultaneously captures cross-sectional and time-series dimensions, thereby enhancing estimation accuracy compared to single-approach methods. Observations were

conducted on 12 manufacturing firms over the 2017–2024 period. All data processing was performed using the EViews statistical software.

2.2 *Population, Sampling Technique, and Sample Size*

The study population includes all manufacturing companies that were ever included in the Sri-Kehati Index during the 2017–2024 period. Population selection was based on company characteristics demonstrating a commitment to sustainability and the availability of relevant data. The sampling technique employed purposive sampling with specific criteria aligned with the research objectives [31]. These criteria include companies listed in the Sri-Kehati Index during the observation period, publishing environmental costs in their Sustainability Report or Annual Report, and not experiencing delisting or an IPO during the study period. The selection results showed that out of the initial 18 companies, 4 were eliminated for failing to publish environmental costs, and 2 were excluded for not meeting data sustainability criteria. The final sample size was 12 companies. With an observation period of 8 years (2017–2024), the total observations used in this study were 96 panel data units. This data structure allows for a more robust analysis in capturing the dynamics of the relationships between variables.

2.3 *Variables and Operational Definitions*

This study categorizes variables into four main categories: independent, dependent, moderating, and control variables. Green finance, as the independent variable, is measured using total environmental investments or costs allocated by the company [26]. Green innovation, as the dependent variable, is proxied by ISO 14001 certification using a dummy variable, taking a value of 1 if the company holds the certification and 0 if it does not [32]. Fintech, as a moderating variable, is measured by the volume of P2P loans disbursed, reflecting the development of technology-based

financing [17]. Control variables consist of firm size measured by total assets, profitability proxied by Return on Assets (ROA) using the formula net profit divided by total assets, and leverage measured using the Debt to Asset Ratio (DAR) with the formula total debt divided by total assets [33]. These operational definitions are designed to ensure measurement consistency and empirical validity in the analysis [34]. Each variable is measured quantitatively to support the regression model used. This approach also allows for the replication of the research in different contexts.

2.4 *Data Analysis Technique and Econometric Model*

Data analysis was conducted using panel data regression with a Moderated Regression Analysis (MRA) approach. The selection of the panel model considered its ability to simultaneously accommodate inter-firm heterogeneity and time-varying effects. Three estimation approaches were used: the Common Effect Model (CEM), the Fixed Effect Model (FEM), and the Random Effect Model (REM). The best model was selected using the Chow test, the Lagrange Multiplier test, and the Hausman test with a significance criterion of 0.05 [35]. Descriptive analysis was conducted using the minimum, maximum, mean, and standard deviation values to provide an initial overview of the data [36]. The moderation regression model was constructed by including an interaction term between green finance and fintech. The econometric equation used is:

$$Y = \beta_0 + \beta_1 X + \beta_2 M + \beta_3 XM + \beta_4 C1 + \beta_5 C2 + \beta_6 C3 + \epsilon$$

where Y is green innovation, X is green finance, M is fintech, XM is interaction, and C1, C2, and C3 represent firm size, profitability, and leverage, respectively. Hypothesis testing was conducted using a partial test (t-test) with

a significance level of 0.05 to assess the influence of each variable [36]. A simultaneous test (F-test) was used to evaluate the overall validity of the model with the criterion $\text{Prob}(F\text{-statistic}) < 0.05$. The coefficient of determination was measured using Adjusted R^2 to avoid bias resulting from the addition of independent variables. The Adjusted R^2 value is used to assess the extent to which variations in green innovation can be explained by green finance, fintech, their interaction, and control variables. This approach ensures robust estimation results and a comprehensive interpretation of the empirical model.

3. RESULTS AND DISCUSSION

3.1 Results

The results of this study comprehensively describe the relationship between green finance, fintech, and firm characteristics on green innovation in manufacturing firms in Indonesia during the 2017–2024 period. The research focuses on the manufacturing sector due to its significant contribution to energy consumption of 232 million BOE [1] and high carbon emissions [2]. Sample selection via purposive sampling yielded 12 companies with a total of 96 observations (12 companies $\times$ 8 years), thereby forming a robust balanced panel for empirical analysis. These characteristics provide a solid foundation for testing causal relationships among the research variables.

Table 1. Descriptive Statistics

Variable	Minimum	Maximum	Mean	Standard Deviation
Y, Green Innovation	0	1	0.8958	0.3071
X, Green Finance	0	547,610,000,000	65,164,914,881	98,996,157,876
M, Fintech	2,560,000,000,000	1,048,640,000,000,000	362,287,500,000,000	360,666,284,152,276
C1, Company Size	2,443,341,000,000	471,449,000,000,000	62,834,209,737,134	102,758,944,506,734
C2, Profitability	-0.0444	0.3099	0.088	0.074
C3, Leverage	0.08301	0.6606	0.3737	0.1517

The descriptive statistics show that the green innovation variable has a minimum value of 0 and a maximum of 1, with a mean of 0.8958 and a standard deviation of 0.3071, indicating that most companies have obtained ISO 14001 certification. The green finance variable has a very wide range, from 0 to 547,610,000,000, with a mean of 65,164,914,881 and a standard deviation of 98,996,157,876, reflecting a significant gap in environmental investment among companies. The fintech variable shows an

average of 362,287,500,000,000 with a minimum value of 2,560,000,000,000 and a maximum of 1,048,640,000,000,000 and a standard deviation of 360,666,284,152,276, indicating rapid but highly volatile growth. Company size has an average of 62,834,209,737,134 with a range from 2,443,341,000,000 to 471,449,000,000,000, indicating a significant difference in scale. Profitability (ROA) ranges from -0.0444 to 0.3099 with an average of 0.088, while leverage (DAR) ranges from 0.08301 to 0.6606 with an average of 0.3737 [32].

Overall, the high variation among variables indicates strong data heterogeneity, reflecting differences in

characteristics among observation units and observation periods.

Table 2. Chow Test Results

Redundant Fixed Effects Tests
Equation: Untitled
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	15.388580	(11,78)	0.0000
Cross-section Chi-square	110.763816	11	0.0000

The results of the Chow test show a probability value of 0.0000, which is smaller than the significance level of 0.05. These results indicate that there are

significant differences in characteristics among cross-sectional units, so the Fixed Effects model is more appropriate to use than the Common Effects model.

Table 3. Hausman Test Results

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	0.000000	6	1.0000

* Cross-section test variance is invalid. Hausman statistic set to zero.

The results of the Hausman test show a probability value of 1.0000, but accompanied by invalid variance conditions, so the statistics cannot be interpreted optimally. Therefore, the

results of the Hausman test cannot be used as the primary basis for model selection and must be considered in conjunction with the results of other tests.

Table 4. Lagrange Multiplier Test Results

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	119.2592 (0.0000)	1.759599 (0.1847)	121.0188 (0.0000)

Based on the results of the Lagrange Multiplier Test, a probability value of 0.0000 was obtained for the cross-section effect. This value is smaller than the significance level of 0.05. This finding

indicates that there is variation among observation units that cannot be ignored; therefore, the Random Effects Model is more appropriate than the Common Effects Model for estimating panel data.

Based on the series of model selection tests conducted, the Random Effects model is used as the estimation model in this study. Although the Chow test indicates that the Fixed Effects model is better than the Common Effects model, the Hausman test did not produce a valid statistic and therefore cannot be used to determine the choice between Fixed

Effects and Random Effects. Meanwhile, the results of the Lagrange Multiplier Test show that the Random Effects model is more suitable than the Common Effects model. Considering these test results, the Random Effects model was selected for the panel data analysis in this study.

Table 5. Regression Results for Model 1

Dependent Variable: Y				
Method: Panel EGLS (Cross-section random effects)				
Date: 05/05/26 Time: 21:06				
Sample: 2017 2024				
Periods included: 8				
Cross-sections included: 12				
Total panel (balanced) observations: 96				
Swamy and Arora estimator of component variances				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.164806	0.184759	6.304471	0.0000
X	-2.00E-15	2.79E-13	-0.007166	0.9943
C1	5.05E-16	7.60E-16	0.664479	0.5081
C2	-1.580526	0.664739	-2.377664	0.0195
C3	-0.431966	0.353452	-1.222137	0.2248
Effects Specification			S.D.	Rho
Cross-section random			0.297357	0.7021
Idiosyncratic random			0.193678	0.2979
Weighted Statistics				
R-squared	0.064945	Mean dependent var	0.201031	
Adjusted R-squared	0.023844	S.D. dependent var	0.192967	
S.E. of regression	0.190653	Sum squared resid	3.307722	
F-statistic	1.580118	Durbin-Watson stat	1.382230	
Prob(F-statistic)	0.186311			
Unweighted Statistics				
R-squared	0.000845	Mean dependent var	0.895833	
Sum squared resid	8.950766	Durbin-Watson stat	0.510798	

The estimation results of the first model indicate that green finance has a non-significant effect on green innovation with a probability value of 0.9943. This suggests that the level of investment or environmental costs incurred by companies has not yet been able to drive a tangible increase in the adoption of

green innovation. Profitability shows a negative and significant effect with a coefficient of -1.5805 and a probability value of 0.0195 this result indicates that an increase in profitability actually tends to reduce a company's level of green innovation. Meanwhile, firm size and

leverage do not show a significant effect on green innovation.

Table 6. Regression Results for Model 2

Dependent Variable: Y				
Method: Panel EGLS (Cross-section random effects)				
Date: 05/05/26 Time: 21:12				
Sample: 2017 2024				
Periods included: 8				
Cross-sections included: 12				
Total panel (balanced) observations: 96				
Swamy and Arora estimator of component variances				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.060555	0.182528	5.810356	0.0000
X	-3.57E-13	2.94E-13	-1.214989	0.2275
M	1.87E-16	6.55E-17	2.855953	0.0053
C1	2.19E-16	7.55E-16	0.290011	0.7725
C2	-1.901386	0.645360	-2.946240	0.0041
C3	-0.148895	0.353404	-0.421317	0.6745
Effects Specification				
		S.D.	Rho	
Cross-section random		0.298130	0.7243	
Idiosyncratic random		0.183936	0.2757	
Weighted Statistics				
R-squared	0.144443	Mean dependent var	0.190919	
Adjusted R-squared	0.096912	S.D. dependent var	0.192197	
S.E. of regression	0.182647	Sum squared resid	3.002382	
F-statistic	3.038917	Durbin-Watson stat	1.545412	
Prob(F-statistic)	0.013984			
Unweighted Statistics				
R-squared	-0.058349	Mean dependent var	0.895833	
Sum squared resid	9.481039	Durbin-Watson stat	0.489389	

In the second model, fintech is shown to have a positive coefficient of 1.87E-16 with a p-value of 0.0053. These results indicate that the presence of fintech through P2P lending has a positive and significant effect on green innovation. Profitability remains significant, while green finance, firm size, and leverage

still do not have a significant effect on green innovation. Additionally, the R-squared and Adjusted R-squared values have increased compared to the first model, indicating that this model is better able to describe the dependent variable than the initial model.

Table 7. Regression Results for Model 3 (Moderation/MRA)

Dependent Variable: Y					
Method: Panel EGLS (Cross-section random effects)					
Date: 05/05/26 Time: 21:13					
Sample: 2017 2024					
Periods included: 8					
Cross-sections included: 12					
Total panel (balanced) observations: 96					
Swamy and Arora estimator of component variances					
Variable	Coefficient	Std. Error	t-Statistic	Prob.	
C	1.007513	0.200100	5.035054	0.0000	
X	-4.70E-14	5.17E-13	-0.090958	0.9277	
M	2.15E-16	7.42E-17	2.900722	0.0047	
MX	-4.47E-28	5.98E-28	-0.747842	0.4565	
C1	2.73E-16	8.01E-16	0.340320	0.7344	
C2	-1.852401	0.666202	-2.780540	0.0066	
C3	-0.063371	0.372193	-0.170264	0.8652	
Effects Specification				S.D.	Rho
Cross-section random				0.322954	0.7539
Idiosyncratic random				0.184507	0.2461
Weighted Statistics					
R-squared	0.153411	Mean dependent var		0.177366	
Adjusted R-squared	0.096337	S.D. dependent var		0.191222	
S.E. of regression	0.181778	Sum squared resid		2.940854	
F-statistic	2.687956	Durbin-Watson stat		1.568762	
Prob(F-statistic)	0.019136				
Unweighted Statistics					
R-squared	-0.060476	Mean dependent var		0.895833	
Sum squared resid	9.500095	Durbin-Watson stat		0.485627	

The results of the moderation model show that the interaction variable between green finance and fintech has no significant effect, indicating that fintech does not act as a moderating variable but rather as a direct determinant. The addition of the interaction variable increases the R-squared and adjusted R-

squared values from the two previous models. The resulting regression equation is: $Y = 1.00751266178 - 4.70023995411e-14 * X + 2.15119537584e-16 * M - 4.46994240567e-28 * MX + 2.72517104842e-16 * C1 - 1.85240082584 * C2 - 0.0633710546967 * C3 + [CX=R]$

Table 8. Goodness of Fit Table

Weighted Statistics			
R-squared	0.153411	Mean dependent var	0.177366
Adjusted R-squared	0.096337	S.D. dependent var	0.191222
S.E. of regression	0.181778	Sum squared resid	2.940854
F-statistic	2.687956	Durbin-Watson stat	1.568762
Prob(F-statistic)	0.019136		

The results of the simultaneous test show an F-statistic value of 2.687956 with a probability (p-value) of 0.019136, indicating that all independent and control variables collectively have a significant effect on green innovation. These results confirm that the model used is a good fit and suitable for explaining the phenomenon under study. The synergy between green finance, fintech, and internal company factors has proven to be a key determinant in driving green innovation.

The coefficient of determination in the main model shows an R^2 value of 0.1534, meaning that 15.3% of the variation in green innovation can be explained by green finance, fintech, and control variables. The remaining 84.7% is influenced by other factors outside the model. A low R^2 value can occur due to many factors, including human and corporate behavior that is difficult to predict accurately; thus, a value below 50% is common in empirical social science models [37]. Additionally, the variation in Green Innovation is often influenced by many factors beyond financial variables, such as investor sentiment, climate risk, or governance factors [38]. [37] explains that a low figure may occur because the primary focus of this study is to test the significance of the relationships between variables (causality test) rather than to precisely predict corporate behavior; thus, a value above 10% in social science research is considered sufficiently adequate provided the F-test is significant. Thus, the value of 15.3% is considered capable of explaining the model and empirically representing the relationships between variables well.

3.2 Discussion

a. The Effect of Green Finance on Green Innovation

Based on the statistical test results, it was found that *green finance* does not have a significant effect on *green innovation* in manufacturing companies in Indonesia. This is evidenced by a *p-value* of 0.9277,

which is greater than the significance level of 0.05. This indicates that any increase in the allocation of environmentally friendly financing does not significantly affect *green innovation* in companies. However, these results contrast with previous studies showing that environmentally friendly financing significantly drives green innovation in listed companies in China [7].

These differing findings may also be attributed to the specific characteristics of the market and regulations in Indonesia, which do not yet fully support synergy between green finance and green innovation, compared to the more mature policies in China that explicitly encourage such a relationship [26]. Meanwhile, in Indonesia, the amount of environmental investment allocated by manufacturing companies is still limited to fulfilling existing responsibilities and regulations, and has not yet reached the stage of implementing *green innovation*.

b. The Impact of Fintech on Green Innovation

Based on the results of statistical testing, it was found that Fintech has a significant impact on *Green Innovation* in manufacturing companies in Indonesia. This is indicated by the *Fintech* coefficient value of 2.15E-16 with a *p-value* of 0.0047, which is less than 0.05. These results indicate that Fintech has a positive and significant influence on *green innovation* in manufacturing companies in Indonesia [39].

Fintech, proxied as P2P Lending, shows that the larger the loans disbursed through P2P Lending, the higher the likelihood that companies will adopt *green innovation* (ISO 14001 certification) [40]. This indicates that broader access to funding via P2P lending platforms can serve as a significant catalyst for sustainable

innovation efforts in Indonesia's manufacturing sector [41]. This finding is consistent with the literature showing that fintech, including P2P lending, facilitates access to funding for manufacturing companies' supply chain partners to invest in low-carbon technologies and sustainable supply chain management practices [42], [43]. In the context of this study, the role of P2P lending in supporting sustainable supply chains can assist suppliers in securing the necessary capital to fulfill orders from companies for environmentally friendly raw materials [44].

c. The Role of Fintech as a Moderating Variable

Based on the results of statistical testing, it was found that Fintech does not have a significant effect as a moderating variable in the relationship between Green Finance and Green Innovation. This is indicated by the interaction coefficient value of MX at $-4.47\text{E-}28$ and a *p*-value of 0.4565, which is greater than 0.05.

The lack of significance of Fintech's moderating role in this study can be explained by several possibilities. First, although Fintech—particularly P2P Lending—is growing rapidly in Indonesia, its loan disbursements have not yet been specifically directed toward supporting green finance activities in manufacturing companies. Second, Green Finance and Fintech likely operate independently and separately in driving Green Innovation, as they have distinct pathways of influence, meaning their interaction does not produce a significant effect. Third, the extremely small value of the interaction coefficient MX, namely $-4.3161\text{E-}28$, indicates that the combination of Green Finance and Fintech provides almost no additional impact on the

likelihood of a company adopting ISO 14001 certification.

These findings suggest that, in the context of manufacturing companies in Indonesia, Fintech has not yet been able to serve as a bridge that strengthens the relationship between environmental funding and the implementation of green innovation. This aligns with the fact that the green fintech ecosystem in Indonesia is still in its developmental stage and has not yet been optimally integrated with the environmental financing needs of manufacturing companies [45].

d. The Effect of Firm Size on Green Innovation

Based on the results of statistical tests, it was found that company size does not have a significant influence on green innovation. This is indicated by a coefficient value of $2.73\text{E-}16$ with a *p*-value of 0.7344 (greater than 0.05). This finding indicates that the size of a company does not directly determine the level of green innovation undertaken [46]. Large companies with abundant resources and small companies with more flexible structures have equal opportunities to adopt environmentally friendly practices [47]. This suggests that green innovation in Indonesia's manufacturing sector is more determined by specific strategies and management commitment to sustainability than by the mere scale of assets held [48].

e. The Effect of Profitability (ROA) on Green Innovation

Test results show that profitability has a significant but negative effect on green innovation. The coefficient value is recorded at -1.8524 with a *p*-value of 0.0066, below 0.05. Initially, it was hypothesized that more profitable companies would have greater internal funds,

which could be allocated to research and development of green projects [49]. Companies with high profits were expected to exhibit significant green innovation as well [50]. However, we found the opposite: the level of profitability does not correlate directly with green innovation. This aligns with previous research that found short-term financial performance, particularly ROA and NPM, has a negative impact on green innovation, likely due to the high initial costs of technology adoption and compliance [51].

The transition process toward green innovation requires substantial funding to acquire environmentally friendly technologies and adapt the workforce [52]. This can directly squeeze profit margins and reduce ROA in the short term. Furthermore, regarding ISO 14001 certification, its adoption often does not yield significant direct financial benefits [53]. Meanwhile, capital-intensive companies, such as the manufacturing firms in this study's sample, tend to be profit- and short-term efficiency-oriented because they bear substantial fixed costs and asset depreciation. Referring to the arguments presented earlier, this explains how the high costs of green innovation can squeeze corporate profitability and create a significant negative relationship between green innovation and ROA.

f. The Effect of Leverage (DAR) on Green Innovation

The analysis results indicate that leverage does not have a significant effect on green innovation. This is evidenced by a coefficient value of -0.063371 and a p-value of 0.8652 (well above 0.05). Thus, leverage has no significant effect on green innovation. This finding indicates that a company's financing structure, particularly its debt level (leverage), is not a primary factor

driving or hindering environmental innovation in the manufacturing sector [54]. Companies with high or low debt levels exhibit similar behavior regarding green investment. This suggests that the decision to pursue green innovation is more a matter of strategic internal policy and compliance with environmental regulations than influenced by pressure from creditors or the company's debt levels.

4. CONCLUSION

Based on the results of the analysis using the Random Effects Model with a Moderated Regression Analysis (MRA) approach, the following conclusions can be drawn: First, green finance was not found to have a positive and significant effect on green innovation in manufacturing companies in Indonesia. This indicates that the amount of environmental investment or funds allocated by companies is still limited to fulfilling existing responsibilities and regulations, and has not yet reached the stage of implementing green innovation.

Second, fintech- s play a strategic role by directly influencing green innovation as a determinant variable, not a moderating variable. Fintech is not significant in strengthening or weakening the influence of Green Finance on Green Innovation; however, it has a substantial direct impact on Green Innovation. In this study, through a sustainable supply chain, P2P lending financing helps distributors meet capital costs so that companies can obtain more environmentally friendly raw materials, thereby fulfilling one of the ISO 14001 environmental performance evaluation criteria: a company's ability to manage environmental impacts from upstream to downstream, including through raw materials and suppliers. This indicates that advancements in financial technology can support companies in accessing financing and improving efficiency, thereby driving the implementation of green innovation [55].

Third, the results of this study show that internal financial factors, such as profitability, play a greater role than structural factors like firm size and leverage in green innovation. However, capital-intensive firms, such as the manufacturing companies

in this study's sample, tend to be profit-oriented and focused on short-term efficiency. They are also more cautious in allocating funds for green innovation, as this requires significant capital and the benefits are only realized in the long term.

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