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RESEARCH

Enhancing Financial Resilience of Manufacturing Companies through Green Innovation and Environmental Governance

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Abstract

The transition to a green economy requires manufacturing companies to strengthen environmental strategies without sacrificing financial stability. This study aims to analyze the effect of Green Innovation and Environmental Governance on the Financial Resilience of manufacturing companies and to examine the moderating role of Regulatory Uncertainty on both relationships. Grounded in Stakeholder and Institutional Theory, the study employed a quantitative approach with 184 respondents consisting of financial, operational, production, environmental/ESG, and general managers of manufacturing companies in Indonesia. Data were collected using a five-point Likert-scale questionnaire and analyzed using PLS-SEM through SmartPLS 3, including a two-stage moderation approach. The results demonstrate that Green Innovation and Environmental Governance positively and significantly strengthen Financial Resilience, with green innovation being the dominant predictor. Regulatory Uncertainty significantly weakens the contribution of Green Innovation to Financial Resilience, but does not alter the effect of Environmental Governance, indicating that governance-based mechanisms are relatively more stable under policy volatility. Theoretically, this study extends Stakeholder Theory by positioning financial resilience as an outcome of fulfilling stakeholder environmental demands, and enriches Institutional Theory by identifying regulatory uncertainty as a contingency condition that differentiates the effectiveness of environmental strategies. Practically, the findings encourage managers to integrate green investment evaluation into financial risk management systems, strengthen environmental governance structures, and urge policymakers to establish consistent, transparent, and predictable environmental regulations to support a sustainable green transitio

Keywords: Green Innovation, Environmental Governance, Financial Resilience, Regulatory Uncertainty

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INTRODUCTION

The manufacturing industry is an economic sector that makes a significant contribution to economic growth, job creation and added-value creation, but at the same time faces increasingly complex environmental pressures. Manufacturing production activity is associated with the use of energy and natural resources, emissions, waste and various forms of pressure on environmental quality (Zafarullah, 2025). The shift in development orientation towards a green economy is encouraging manufacturing companies to view environmental issues not solely as a compliance obligation but as part of business strategy. Pressure from consumers, investors, governments, communities and business partners is also increasing the demand for firms to integrate sustainability into their value creation processes (Qamruzzaman, 2025).

Green innovation is a strategic approach that enables firms to respond to these demands by developing products, processes, technologies and organisational practices that reduce environmental impact. Green innovation can include the use of more efficient technologies, reduced energy and material consumption, the development of environmentally friendly products, and improvements to production processes that reduce waste and emissions. A firm's ability to generate innovations that simultaneously deliver economic and environmental benefits can create operational efficiencies, strengthen product differentiation, enhance reputation and open new market opportunities. Green innovation is therefore not only associated with ecological goals but also has the potential to be a source of competitive advantage and corporate sustainability (Navin, 2025).

Environmental governance is also increasingly seen as a critical element in ensuring that sustainability commitments are translated into corporate policies, oversight, decision-making and accountability. Sound environmental governance mechanisms can help firms identify ecological risks, control environmental impacts, ensure compliance and integrate environmental considerations into strategic decisions. Tsami (2025) argues that a firm's sustainability is influenced by its ability to respond to the interests of the various stakeholders that make economic, social and environmental demands. Green innovation and environmental governance can be mechanisms through which firms build legitimacy, trust and long-term relationships with stakeholders, and so support value creation and financial sustainability.

Financial resilience is becoming increasingly important as manufacturing companies operate in a business environment marked by fluctuating demand, changing input costs, competitive pressure, supply chain disruption and policy change. Financial resilience reflects a firm's ability to maintain financial stability, absorb economic pressure, meet obligations and sustain operational capacity in the face of shocks. An effective environmental strategy can contribute to this resilience through resource efficiency, reduced costs associated with environmental risk, improved access to markets and sustainability-oriented financing, and enhanced corporate reputation. The relationship between environmental strategy and financial resilience becomes increasingly relevant as firms are challenged to achieve sustainability goals without sacrificing their ability to survive in volatile economic conditions (Batool, 2025).

Regulatory uncertainty is an external factor that can shape a firm's strategic decisions in managing environmental and financial issues. Changing environmental standards, unclear policy direction,

differing enforcement intensity and shifting compliance requirements can increase the risks and costs of corporate decision-making. Gonçalves (2026) argues that organisational behaviour is influenced by institutional pressures stemming from regulations, norms and expectations in the institutional environment. Uncertainty about regulatory pressure can alter the benefits and risks arising from environmental strategy. This suggests that the influence of green innovation and environmental governance on financial resilience is not always uniform but can depend on the regulatory conditions a firm faces.

Rationale and Originality

The relationship between green innovation and corporate performance has attracted attention in sustainability research, but understanding of its contribution to financial resilience remains relatively limited. Most studies use financial performance, profitability or market performance as the outcome of green strategy, while a firm's ability to withstand and adapt to financial stress has not been a primary focus. Differences between financial performance and financial resilience indicate an important research opportunity, because firms with strong financial performance in a given period do not necessarily have the same ability to absorb shocks and maintain financial stability. The relationship between green innovation and financial resilience therefore needs to be examined more specifically to establish whether green investment and activity actually translate into greater financial resilience (Boubaker, 2024).

The role of environmental governance in financial resilience is also incompletely understood. The environmental governance literature has emphasised its influence on compliance, reputation, ecological risk reduction and sustainability performance. The mechanisms through which environmental governance translates into a firm's capacity to withstand financial stress still require further examination. Musah (2026) shows that environmental governance can strengthen a firm's relationship with stakeholders through transparency, accountability and responsiveness to sustainability demands, while the financial consequences of these mechanisms may depend on the external conditions the firm faces.

Regulatory uncertainty raises further complexity because environmental strategies are not implemented in a consistently stable institutional environment. Salman (2025) argues that organisations adapt their structures and behaviour to institutional pressures, including government regulation. When the direction and implementation of environmental regulation are difficult to predict, firms can face heightened investment risk, compliance costs and difficulty in setting long-term strategic priorities. This raises the question of whether regulatory uncertainty weakens the benefits of green innovation and environmental governance for financial resilience, or whether it drives firms with stronger environmental capability to build greater resilience.

A significant limitation in the literature lies in the small number of studies that consider regulatory uncertainty as a moderating variable in the relationship between environmental strategy and financial resilience, particularly in manufacturing. Many studies examine the direct effect of green innovation or environmental governance on various performance indicators without explicitly testing the moderating interaction that explains when and under what conditions the effect becomes stronger or weaker. This gap matters because the effectiveness of environmental strategy is shaped not only by a firm's internal capability but also by the certainty of the institutional environment. The present study addresses this gap by simultaneously examining the influence of green innovation and environmental

governance on financial resilience and the role of regulatory uncertainty in moderating both relationships (Jaiswal, 2024).

Research Objective

The study aims to analyse the direct influence of green innovation and environmental governance on the financial resilience of manufacturing companies and to examine the role of regulatory uncertainty as a moderating variable. The research model is designed to explain not only whether environmental strategy contributes to financial resilience, but also when and under what conditions that contribution changes. Empirically, the study examines four principal relationships: the influence of green innovation on financial resilience, the influence of environmental governance on financial resilience, the moderation of regulatory uncertainty on the green-innovation–financial-resilience relationship, and the moderation of regulatory uncertainty on the environmental-governance–financial-resilience relationship.

Summary of Research

To meet these objectives, the study surveyed 184 managers of manufacturing companies in Indonesia and analysed the data using PLS-SEM in SmartPLS 3, with two-stage moderation to test the interaction effects. Green innovation and environmental governance are supported as positive predictors of financial resilience, with green innovation the stronger of the two, and regulatory uncertainty significantly weakens the effect of green innovation while leaving the effect of environmental governance unchanged. The remainder of the article sets out the theoretical basis and hypotheses, the research methods, the results and their discussion, and the study's conclusions and limitations.

Theoretical Basis

Stakeholder theory holds that a firm's sustainability is influenced by its capacity to respond to the demands of the various parties with an interest in its economic, social and environmental performance. In the environmental context, stakeholder theory positions consumers, investors, governments, communities and business partners as actors whose interests need to be considered in corporate decision-making. A firm that is responsive to environmental demands can build trust, legitimacy and long-term relationships that support value creation. Institutional theory complements this perspective by arguing that firms operate within an institutional environment that shapes corporate structures, decisions and behaviour through regulatory, normative and cognitive pressures. Institutional pressures can generate incentives to adopt environmental strategies, but they can also introduce risks when the direction and implementation of regulation are difficult to predict.

Financial Resilience

Financial resilience refers to a firm's ability to maintain financial stability, absorb shocks, meet financial obligations and sustain operational continuity when faced with internal and external pressures. The concept describes not only a firm's financial condition in a given period but also its capacity to adapt to changes in the business environment, manage risks, maintain liquidity, and recover financially after periods of stress (Chen, 2026). In manufacturing, financial resilience is becoming increasingly important as firms face raw-material price volatility, changes in demand, supply chain disruption, energy costs, environmental pressure and policy change. Financial resilience can be captured through

the ability to maintain cash-flow stability, adequate liquidity, the ability to meet obligations, stable financial performance, flexibility of financing sources and recovery capacity after shocks.

Hypothesis Development

H1: Green innovation and financial resilience

Green innovation is the development or implementation of products, processes, technologies and organisational practices that generate economic benefit while reducing negative environmental impact. Innovations of this kind can include cleaner production technologies, energy and material efficiency, the reduction of waste and emissions, the use of more environmentally friendly raw materials, and the development of products with lower environmental impact. From a stakeholder perspective, firms need to respond to stakeholder demands that increasingly emphasise environmental responsibility as part of long-term value creation. Green innovation can strengthen relationships with customers, investors, governments and business partners by enhancing reputation, legitimacy and competitiveness. The resource efficiency generated by green innovation also has the potential to reduce operational costs and environmental risks, and therefore to enhance a firm's capacity to withstand financial pressure.

The positive relationship between green innovation and financial resilience can be explained by the capacity of green innovation to create efficiencies while opening new economic opportunities. Manufacturing firms able to develop more efficient technologies and production processes can reduce dependence on expensive or increasingly scarce resources. Environmentally friendly products can also expand access to market segments that prefer sustainability and increase the opportunity to obtain support from investors and financing institutions that consider environmental factors. These capabilities provide a cushion against economic shocks and increase a firm's flexibility in maintaining operations. The study therefore proposes:

H1: Green innovation has a positive effect on the financial resilience of manufacturing companies.

H2: Environmental governance and financial resilience

Environmental governance is the management and oversight mechanism that ensures environmental considerations are integrated into a firm's decision-making. Governance of this kind encompasses management commitment, environmental responsibility structures, oversight of ecological risk, regulatory compliance, transparency of environmental information and evaluation of the impact of operational activities. Stakeholder theory positions environmental governance as an instrument for accommodating the interests of stakeholders who expect firms to be accountable for the social and ecological impact of their business activity. Effective governance can increase accountability and transparency, reduce the potential for conflict with stakeholders and strengthen the firm's legitimacy. Systematic environmental management also allows firms to identify and control risks that could result in financial loss (Yang, 2025).

Strong environmental governance is expected to improve financial resilience because firms have better systems in place to anticipate environmental risk, control compliance cost and prevent loss from environmental violations or incidents. Environmental oversight integrated with corporate governance can improve the quality of decision-making and help firms allocate resources more efficiently. Environmental transparency can also strengthen stakeholder trust and mitigate

reputational risk that would otherwise affect revenue, access to financing and firm value. This capacity enables manufacturing firms to maintain financial stability when facing external pressure. The study therefore proposes:

H2: Environmental governance has a positive effect on the financial resilience of manufacturing companies.

H3a and H3b: The moderating role of regulatory uncertainty

Regulatory uncertainty describes a condition in which firms find it difficult to predict the direction, intensity, timing or consequences of regulatory change. Su (2025) argues that organisations operate within an institutional environment that shapes corporate structures, decisions and behaviour through regulatory, normative and cognitive pressures. Unpredictable changes in environmental regulation can increase the complexity of decision-making, raise investment risk and create uncertainty about the long-term benefits of environmental strategy. Firms operating in such environments require adaptability and governance systems capable of responding rapidly to institutional change.

Regulatory uncertainty can alter the relationship between environmental strategy and financial resilience because the benefits of both green innovation and environmental governance are strongly influenced by the institutional conditions in which a firm operates. High uncertainty can weaken the benefits of green innovation if the firm faces the risk of shifting standards, the costs of technological adjustment, or unclear environmental incentives. The same conditions can affect the effectiveness of environmental governance because firms must adapt policies and oversight mechanisms to changing regulation. Firms with strong environmental capabilities may still be able to maintain financial resilience because they are better prepared to anticipate policy change and adjust their strategy. The study therefore proposes:

H3a: Regulatory uncertainty moderates the effect of green innovation on the financial resilience of manufacturing companies.

H3b: Regulatory uncertainty moderates the effect of environmental governance on the financial resilience of manufacturing companies.

Conceptual Framework

The conceptual framework positions green innovation and environmental governance as independent variables predicted to influence the financial resilience of manufacturing companies. Regulatory uncertainty is positioned as a moderating variable that alters the strength of the relationship between these two environmental strategies and financial resilience. The model integrates the stakeholder perspective, which explains how a firm's response to environmental demand can generate value and financial resilience, with the institutional perspective, which explains how regulatory conditions can shape the effectiveness of that response. The full model is presented in Figure 1.

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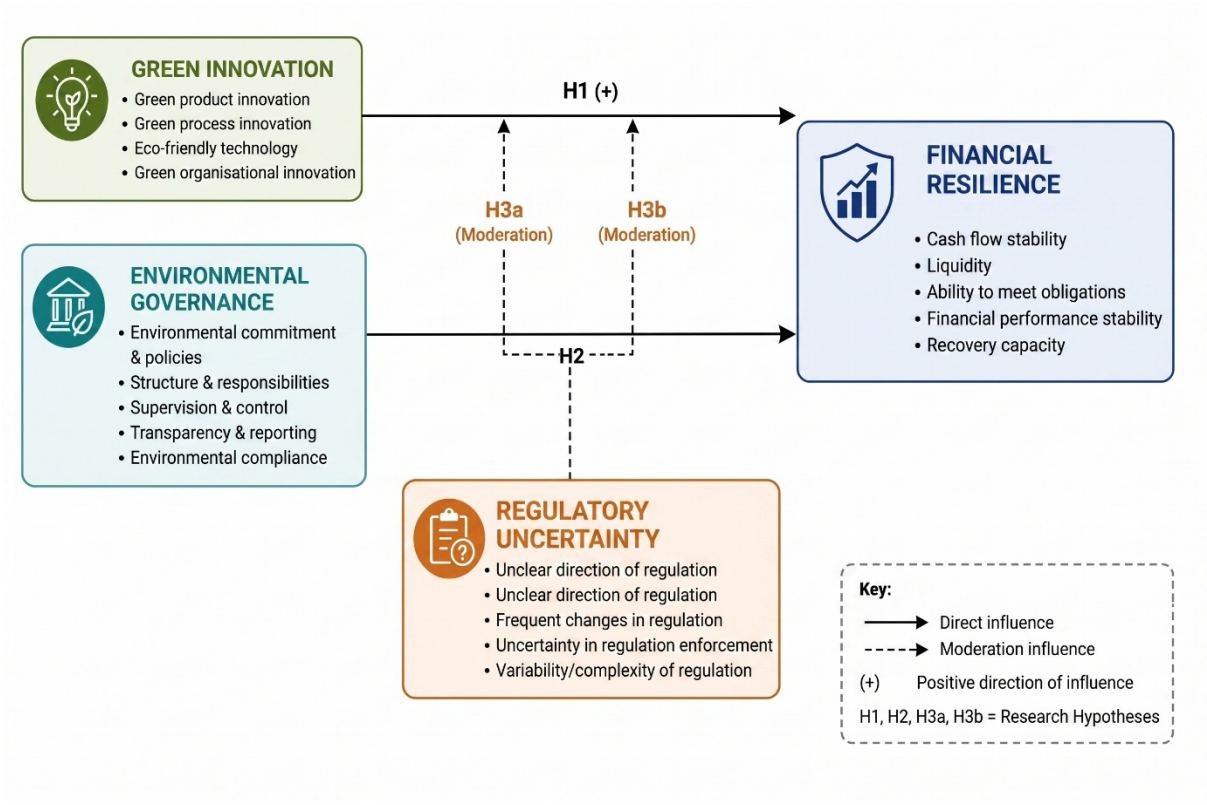

Figure 1. Conceptual framework of the research model. Source: Constructed by the author, 2026

RESEARCH METHODS

Research Design

This study uses a quantitative approach with an explanatory design to examine the causal relationships between green innovation and environmental governance on the one hand and the financial resilience of manufacturing companies on the other, and to analyse the role of regulatory uncertainty as a moderating variable. The model was estimated using partial least squares structural equation modelling (PLS-SEM) in SmartPLS 3, because the method is suited to testing predictive relationships between latent constructs and analysing the interaction effects of a moderator within a single research model.

Research Site

The study population comprised manufacturing companies registered with the Ministry of Industry of the Republic of Indonesia, and respondents were drawn from firms across nine provinces spanning Java (West Java, Central Java, East Java, Banten and DKI Jakarta) and Sumatra (North Sumatra, Riau Islands, Riau and West Sumatra) and from eight manufacturing subsectors (textiles and apparel; food and beverages; automotive and components; metal and machinery; chemicals and pharmaceuticals; plastics and rubber; paper and printing; and electronics).

Data Collection

The target respondents were financial managers, operational managers, production managers, environmental or ESG managers, and general managers with knowledge of the firm's operating conditions, environmental strategy, regulatory environment and financial condition. Sampling was

conducted using purposive sampling with the criteria that respondents held managerial positions or relevant responsibilities and had sufficient experience in corporate decision-making. The sample size was determined through an a priori power analysis in G*Power with an effect size of 0.15, a significance level of 0.05 and statistical power greater than 0.80, yielding a minimum of 184 respondents. A total of 184 completed responses was obtained.

Data were collected through a structured questionnaire using a five-point Likert scale, anchored at 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree and 5 = strongly agree. The instrument measured four constructs. Green innovation encompasses product innovation, process innovation, the use of environmentally friendly technologies and organisational practices that support environmental impact reduction (Flouri, 2025). Environmental governance includes environmental commitment and policy, responsibility structure, oversight, transparency and environmental compliance. Financial resilience covers cash-flow stability, liquidity, the ability to meet obligations, financial performance stability and recovery capacity. Regulatory uncertainty covers unclear regulatory direction, frequency of regulatory change, uncertainty of enforcement, and complexity and variability of regulation.

Data Analysis

Analysis proceeded in two stages: evaluation of the measurement (outer) model and evaluation of the structural (inner) model. The measurement model was evaluated through outer loadings, average variance extracted (AVE), Cronbach's alpha, composite reliability and the heterotrait-monotrait ratio (HTMT). The structural model was evaluated through checks for multicollinearity (VIF), the coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2) and model fit through the standardised root mean square residual (SRMR), the normed fit index (NFI) and RMS_theta. Hypothesis testing was conducted through a bootstrapping procedure to obtain path coefficients, t-statistics and p values. Moderation analysis used the two-stage approach to test the interaction between regulatory uncertainty and green innovation and between regulatory uncertainty and environmental governance in predicting financial resilience.

Data Validation

Instrument quality was evaluated against thresholds of outer loading > 0.70, AVE > 0.50, Cronbach's alpha and composite reliability > 0.70 and HTMT < 0.90, in order to ensure convergent validity, internal reliability and discriminant validity. Robustness checks were conducted through alternative model specifications and subsamples to assess the consistency of the results.

RESULTS AND DISCUSSION

Respondent Characteristics

The demographic profile of the 184 respondents is presented in Table 1.

Table 1. Demographic characteristics of respondents (n = 184)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	120	65.2
	Female	64	34.8

Characteristic	Category	Frequency (n)	Percentage (%)
Age	25–34 years	61	33.2
	35–44 years	58	31.5
	45–55 years	65	35.3
Education	Diploma	20	10.9
	Bachelor's (S1)	107	58.2
	Master's (S2)	55	29.9
	Doctoral (S3)	2	1.1
Position	Finance manager	51	27.7
	Operations manager	46	25.0
	Production manager	39	21.2
	Environmental/ESG manager	27	14.7
	General manager	21	11.4
Years of service	1–3 years	30	16.3
	4–6 years	66	35.9
	7–10 years	51	27.7
	> 10 years	37	20.1
Company size	Medium	56	30.4
	Large	128	69.6
Manufacturing subsector	Textiles and apparel	31	16.8
	Food and beverages	30	16.3
	Automotive and components	27	14.7
	Metal and machinery	26	14.1
	Chemicals and pharmaceuticals	23	12.5
	Plastics and rubber	17	9.2
	Paper and printing	16	8.7
	Electronics	14	7.6
Province	West Java	37	20.1

Characteristic	Category	Frequency (n)	Percentage (%)
	Central Java	34	18.5
	East Java	22	12.0
	Banten	20	10.9
	DKI Jakarta	19	10.3
	North Sumatra	18	9.8
	Riau Islands	13	7.1
	Riau	12	6.5
	West Sumatra	9	4.9
Total		**184**	**100.0**

Source: Primary survey data, processed by the author, 2026

Male respondents account for 120 of the sample (65.2 per cent) and female respondents for 64 (34.8 per cent). The 45–55 age band is the largest with 65 respondents (35.3 per cent), followed by 25–34 with 61 (33.2 per cent) and 35–44 with 58 (31.5 per cent). Educational attainment is dominated by bachelor's-degree holders (107 respondents; 58.2 per cent), followed by master's holders (55; 29.9 per cent), diploma holders (20; 10.9 per cent) and doctoral holders (2; 1.1 per cent). The majority of respondents therefore have a higher-education background and are in the productive to senior age range.

By position, finance managers make up the largest group with 51 respondents (27.7 per cent), followed by operations managers (46; 25.0 per cent) and production managers (39; 21.2 per cent). Respondents with 4–6 years of service number 66 (35.9 per cent), 7–10 years 51 (27.7 per cent), more than 10 years 37 (20.1 per cent) and 1–3 years 30 (16.3 per cent). Large firms dominate the sample with 128 firms (69.6 per cent), while medium-sized firms number 56 (30.4 per cent). The largest subsectors are textiles and apparel with 31 respondents (16.8 per cent) and food and beverages with 30 (16.3 per cent), and West Java is the province with the largest share, 37 respondents (20.1 per cent).

Measurement Model Assessment

Outer loadings for all indicators are reported in Table 2.

Table 2. Outer loadings of the measurement model

Construct	Indicator	Outer loading	Decision
Green innovation (X1)	GI_1	0.828	Valid
	GI_2	0.825	Valid
	GI_3	0.850	Valid

Construct	Indicator	Outer loading	Decision
	GI_4	0.845	Valid
	GI_5	0.841	Valid
Environmental governance (X2)	EG_1	0.841	Valid
	EG_2	0.845	Valid
	EG_3	0.813	Valid
	EG_4	0.834	Valid
	EG_5	0.835	Valid
Financial resilience (Y)	FR_1	0.823	Valid
	FR_2	0.830	Valid
	FR_3	0.834	Valid
	FR_4	0.854	Valid
	FR_5	0.850	Valid
Regulatory uncertainty (Z)	RU_1	0.802	Valid
	RU_2	0.853	Valid
	RU_3	0.839	Valid
	RU_4	0.851	Valid
	RU_5	0.827	Valid

Source: SmartPLS 3 output, processed by the author, 2026

The outer loadings of the green innovation indicators range from 0.825 to 0.850, and those of the environmental governance indicators from 0.813 to 0.845. The financial resilience indicators load between 0.823 and 0.854, and the regulatory uncertainty indicators between 0.802 and 0.853. The highest loading is on FR_4 at 0.854 and the lowest on RU_1 at 0.802. All indicators exceed the recommended 0.70 threshold, so no indicator was removed from the measurement model.

Construct reliability and convergent validity are reported in Table 3.

Table 3. Construct reliability and convergent validity

Construct	Cronbach's alpha	rho_A	Composite reliability	AVE
Green innovation (X1)	0.894	0.894	0.922	0.702
Environmental governance (X2)	0.890	0.891	0.919	0.695
Financial resilience (Y)	0.894	0.895	0.922	0.703

Construct	Cronbach's alpha	rho_A	Composite reliability	AVE
Regulatory uncertainty (Z)	0.892	0.900	0.920	0.697

Source: SmartPLS 3 output, processed by the author, 2026

Cronbach's alpha ranges from 0.890 to 0.894 across the four constructs, and rho_A from 0.891 to 0.900. Composite reliability ranges from 0.919 to 0.922. All values exceed the 0.70 threshold, indicating adequate internal consistency.

Convergent validity is also supported by the average variance extracted (AVE) values, all of which exceed 0.50. Green innovation returns an AVE of 0.702 and financial resilience 0.703, each explaining more than 70 per cent of the variance in its indicators. Environmental governance returns an AVE of 0.695 and regulatory uncertainty 0.697. The measurement model therefore meets the requirements of internal reliability and convergent validity and is suitable for structural model testing.

Discriminant validity was assessed using the HTMT criterion, as reported in Table 4.

Table 4. Discriminant validity based on the heterotrait-monotrait ratio (HTMT)

Construct	X1	X1 × Z	X2	X2 × Z	Y	Z
Green innovation (X1)	—					
X1 × Z	0.102	—				
Environmental governance (X2)	0.426	0.059	—			
X2 × Z	0.056	0.216	0.067	—		
Financial resilience (Y)	0.624	0.254	0.493	0.149	—	
Regulatory uncertainty (Z)	0.094	0.023	0.084	0.106	0.177	—

Source: SmartPLS 3 output, processed by the author, 2026

The HTMT value between green innovation and environmental governance is 0.426; between green innovation and financial resilience 0.624; and between environmental governance and financial resilience 0.493. The relationship between financial resilience and regulatory uncertainty returns the lowest value at 0.177. All HTMT values for the substantive constructs fall well below 0.90, and the interaction terms return acceptable values (X1 × Z with financial resilience 0.254; X2 × Z with financial resilience 0.149). Each construct can therefore be distinguished empirically from the others.

Structural Model Assessment

The coefficient of determination for the endogenous construct is reported in Table 5.

Table 5. Coefficient of determination (R^2)

Endogenous variable	R^2	R^2 adjusted	Interpretation
Financial resilience (Y)	0.434	0.418	Moderate

Source: SmartPLS 3 output, processed by the author, 2026

Financial resilience returns an R^2 of 0.434 and an adjusted R^2 of 0.418, indicating that 43.4 per cent of the variation in financial resilience is explained by the predictors in the model — green innovation, environmental governance, regulatory uncertainty and the two interaction terms — while the remaining 56.6 per cent is attributable to factors outside the model. The closeness of R^2 and adjusted R^2 indicates that the model's explanatory power is stable after adjusting for the number of predictors.

Effect sizes for each predictor are reported in Table 6.

Table 6. Effect size (f^2)

Relationship	f^2	Interpretation
Green innovation → Financial resilience	0.258	Medium
Environmental governance → Financial resilience	0.119	Small–medium
Regulatory uncertainty → Financial resilience	0.039	Small
X1 × Z → Financial resilience	0.045	Small
X2 × Z → Financial resilience	0.014	Very small

Source: SmartPLS 3 output, processed by the author, 2026

Green innovation returns an f^2 of 0.258 and is the strongest predictor in the model. Environmental governance returns an f^2 of 0.119, regulatory uncertainty 0.039, the X1 × Z interaction 0.045 and the X2 × Z interaction 0.014. The pattern indicates that green innovation has the most substantive role in explaining financial resilience, while the very small effect size for X2 × Z is consistent with the non-significant test of H3b reported below.

Collinearity, predictive relevance and model fit are reported in Table 7.

Table 7. Collinearity, predictive relevance and model fit

Indicator	Value	Criterion	Interpretation
Maximum inner VIF	1.195	< 5.00	No multicollinearity
Q^2 Financial resilience	0.295	> 0	Predictive relevance met
SRMR	0.047	< 0.08	Good fit
NFI	0.899	Approaching 1.00	Approaching good fit
RMS_theta	0.125	< 0.12	Marginal — slightly above threshold

Source: SmartPLS 3 output, processed by the author, 2026

The maximum inner VIF of 1.195 falls well below the 5.00 threshold, indicating no multicollinearity in the structural relationships tested. The Q^2 value for financial resilience of 0.295 is greater than zero, indicating predictive relevance for the endogenous construct. The SRMR of 0.047 is below the 0.08 threshold, and the NFI of 0.899 is very close to the 0.90 benchmark. RMS_theta of 0.125 falls slightly

above the 0.12 threshold, so overall model fit is reported as marginal and should be interpreted with caution.

Hypothesis Testing

Path coefficients and significance tests for the four hypotheses are reported in Table 8.

Table 8. Results of hypothesis testing

Hypothesis	Relationship	β	t-statistic	p value	Decision
H1	Green innovation → Financial resilience	0.417	6.920	< 0.001	Supported
H2	Environmental governance → Financial resilience	0.282	4.096	< 0.001	Supported
H3a	Green innovation × Regulatory uncertainty → Financial resilience	−0.162	3.060	0.002	Supported
H3b	Environmental governance × Regulatory uncertainty → Financial resilience	−0.103	1.279	0.201	Not supported

Source: SmartPLS 3 output, processed by the author, 2026

H1 records a path coefficient of 0.417 for the effect of green innovation on financial resilience ($t = 6.920$; $p < 0.001$), and H2 a coefficient of 0.282 for the effect of environmental governance ($t = 4.096$; $p < 0.001$). Both direct effects are positive, significant and in the hypothesised direction, so H1 and H2 are supported.

The moderation results follow a different pattern. The interaction between green innovation and regulatory uncertainty (H3a) returns a coefficient of −0.162 ($t = 3.060$; $p = 0.002$), supporting H3a. The negative sign indicates that as regulatory uncertainty increases, the effect of green innovation on financial resilience weakens. The interaction between environmental governance and regulatory uncertainty (H3b) returns a coefficient of −0.103 ($t = 1.279$; $p = 0.201$), which is not statistically significant, so H3b is not supported. Regulatory uncertainty therefore weakens the effect of green innovation on financial resilience, but does not alter the effect of environmental governance.

Discussion

Direct effects: green innovation and environmental governance on financial resilience

Green innovation shows a positive and significant effect on financial resilience ($\beta = 0.417$; $t = 6.920$; $p < 0.001$), indicating that a firm's capacity to develop environmentally friendly product, process, technology and organisational innovations is associated with a stronger capacity to maintain its financial condition under business pressure. Environmental governance also shows a positive and significant effect ($\beta = 0.282$; $t = 4.096$; $p < 0.001$). The model explains 43.4 per cent of the variance in financial resilience ($R^2 = 0.434$), so both environmental strategies make a substantive contribution to the financial resilience of manufacturing companies.

The larger coefficient and effect size for green innovation ($f^2 = 0.258$) than for environmental governance ($f^2 = 0.119$) indicate that green innovation is the stronger predictor in the model. The pattern suggests that the financial resilience of manufacturing companies is determined not only by the ability to generate economic performance but also by the ability to integrate environmental strategy into value creation, and that innovation-based mechanisms — which affect production

efficiency and market positioning directly — carry more weight than governance-based mechanisms in this sample.

The finding on green innovation is consistent with earlier work showing that green innovation practices influence environmental and firm performance in service and manufacturing settings, and with studies of green dynamic capabilities as a mechanism linking green innovation to performance in manufacturing SMEs. The consistency across contexts indicates that environmental innovation does not merely serve to meet ecological demand but can also be a source of competitiveness and financial performance. The result on environmental governance is consistent with work placing ESG practice and environmental governance as part of the value-creation mechanism, though the direction and strength of the effect vary in the empirical literature; the present study contributes the finding that governance has a positive effect when the outcome is defined as financial resilience rather than as accounting or market performance.

The moderating role of regulatory uncertainty

The moderating effect of regulatory uncertainty differs sharply between the two relationships. The interaction with green innovation (H3a) is negative and significant ($\beta = -0.162$; $t = 3.060$; $p = 0.002$), while the interaction with environmental governance (H3b) is not statistically significant ($\beta = -0.103$; $t = 1.279$; $p = 0.201$). Regulatory uncertainty does not therefore change every relationship between environmental strategy and financial resilience uniformly; green innovation is more sensitive to regulatory uncertainty than environmental governance.

The pattern can be read through a resource-based lens: green innovation requires a combination of resources, knowledge, technology, organisational capabilities and investments that are not easily imitated. Regulatory uncertainty can raise the risk of investment error, extend payback periods and make firms more cautious in allocating resources to innovation. Environmental governance, by contrast, works through internal procedures — accountability structures, oversight and transparency — that continue to operate even when the regulatory environment shifts. Governance therefore appears to be a relatively more stable mechanism under policy volatility (Wang, 2025).

The result on the green-innovation moderator can be contrasted with earlier evidence that environmental uncertainty may strengthen, rather than weaken, the relationship between the level of green process innovation and profitability in German manufacturing. The difference indicates that the effect of uncertainty is not universal; it depends on regulatory context, the type of innovation, industry characteristics and the time horizon of financial benefits (López-Penabad, 2025). In the present sample, regulatory uncertainty appears to raise the costs and risks of green investment more than it rewards firms with stronger environmental capabilities.

Practical and policy implications

The first implication is that manufacturing companies should treat green innovation as a strategic investment linked to financial resilience rather than a compliance cost. Innovation should be directed at activities that generate resource efficiency, waste reduction, energy efficiency, product quality improvement and competitive strengthening. Green investment evaluation should be integrated with cash-flow analysis, payback periods, regulatory-risk assessment and potential cost savings, and firms should build early-warning capacity for environmental policy change so that strategy can be adjusted before financial stress arises. Because the moderation result shows that regulatory volatility weakens

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the benefit of green innovation, technologies and processes should be selected with an eye to their flexibility under changing environmental standards.

The second implication concerns environmental governance. Its positive effect on financial resilience (β = 0.282), together with the absence of a significant interaction with regulatory uncertainty, indicates that governance-based mechanisms offer relatively more stable benefits than innovation-based ones when the regulatory environment is unpredictable. Firms should therefore invest in clarifying environmental responsibility structures, oversight mechanisms, compliance procedures, information transparency and the integration of environmental issues into financial decision-making. Environmental performance indicators can be linked to financial targets and reviewed on a regular cycle.

The third implication is directed at policymakers. A coefficient of −0.162 on the green-innovation moderator indicates that regulatory uncertainty measurably reduces the financial benefit of green investment. The finding supports policy design that improves regulatory consistency, provides clear transition periods, simplifies compliance procedures, strengthens policy communication and provides incentives for environmental innovations that deliver measurable benefits (Zhang, 2025). Recent evidence indicates that the effectiveness of environmental regulation on innovation depends on the type of instrument, enforcement credibility, sector and time horizon, so regulatory certainty is not sufficient on its own — but it appears to be a necessary supporting condition if the green-transition agenda is not to add to firms' financial pressure.

CONCLUSION

Green innovation and environmental governance both have a positive and significant effect on the financial resilience of manufacturing companies, with green innovation the stronger of the two (β = 0.417 and β = 0.282 respectively). Regulatory uncertainty produces asymmetric moderating effects: it significantly weakens the relationship between green innovation and financial resilience (β = −0.162; p = 0.002) but does not moderate the relationship between environmental governance and financial resilience (β = −0.103; p = 0.201). The conceptual contribution of the study lies in positioning regulatory uncertainty as a contingency condition that differentiates the effectiveness of environmental strategies for financial resilience, and in showing that the benefits of green strategy are not always constant under an uncertain regulatory environment. The PLS-SEM approach contributes methodologically through simultaneous testing of direct and interaction effects at the level of managerial perceptions in manufacturing companies. The study is limited by its purposive sampling, its use of perceptual data from a single respondent per firm, its coverage of the manufacturing sector alone, and its cross-sectional design, which does not capture long-term change in green strategy or in financial resilience. Further research should draw on longitudinal or panel data, expand the sectoral and regional coverage, combine perceptual data with objective financial indicators, and examine whether the type of regulatory uncertainty, firm size, emissions intensity, technological capability and government support explain variation in the relationship between environmental strategy and financial resilience.

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DECLARATION OF COMPETING INTEREST

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

In the preparation of this work, the author used no generative AI or AI-assisted technologies. The author confirms that no large language models (such as ChatGPT, GPT-4 or similar tools) were used to generate, write or substantially edit any part of the manuscript text, including the introduction, literature review, methodology, results, discussion or conclusion sections. All content in this manuscript was written and reviewed exclusively by the author, who takes full responsibility for the integrity and accuracy of the published work.

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