

Article

Does Climate Finance Improve Corporate Resilience? Evidence from Manufacturing Firms in Emerging Economies

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Abstract: Climate change and the transition toward low-carbon development have exposed manufacturing firms in Southeast Asia to increasing physical and transition risks, making corporate resilience a critical concern for sustainable economic growth. Although climate finance is widely expected to facilitate green transformation and risk mitigation, its effectiveness in strengthening corporate resilience remains underexplored in the existing literature. Drawing on resource dependence theory, risk buffering theory, and innovation compensation theory, this study develops a multidimensional corporate resilience index and employs a two-way fixed-effects model using an unbalanced panel dataset of listed manufacturing firms from six Southeast Asian economies over the period 2012 to 2024. The empirical results demonstrate that climate finance significantly enhances corporate resilience. Mechanism analysis reveals that this positive effect operates through three primary channels: easing financing limitations, promoting green technological innovation, and accelerating low-carbon operational transformation. Heterogeneity analysis further indicates that the resilience-enhancing effects of climate finance are more pronounced for heavy-polluting firms, enterprises with greater climate risk exposure, and firms operating in countries with stricter environmental policies. Overall, this study concludes that climate finance provides both short-term risk buffering and long-term resilience enhancement, offering valuable micro-level evidence on its role in supporting sustainable manufacturing development in emerging economies across Southeast Asia.

Keywords: climate finance; corporate resilience; green innovation; emerging economies; manufacturing firms

1. Introduction

Global climate change has evolved from a long-term environmental concern into a major source of economic, financial, and operational risk for firms. The increasing frequency and severity of weather-related events, the strengthening of carbon emission policies, and the accelerating global transition toward low-carbon industrial development have significantly affected the production, investment, and supply-chain activities of industrial enterprises worldwide. As a major contributor to economic growth, employment, exports, and carbon emissions in Southeast Asia, the manufacturing sector is particularly vulnerable to climate-related physical risks, including seasonal flooding, typhoon-induced production interruptions, infrastructure damage, and regional supply-chain instabilities. At the same time, manufacturing firms are increasingly exposed to transition risks arising from more stringent environmental policies, carbon pricing mechanisms, international carbon-related trade measures, and the growing demand for green industrial upgrading [1]. Compared with developed economies, many Southeast Asian emerging economies continue to face limitations in climate governance capacity, green financial market development, climate-related risk management, and access to long-term financing for low-carbon investment. Consequently, identifying effective financial mechanisms for strengthening corporate climate resilience has become an

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increasingly important research issue in the fields of sustainable finance and corporate sustainability.

Climate finance refers to financial resources, investment mechanisms, and specialised financial instruments designed to support climate change mitigation and adaptation, including green loans, green bonds, sustainability-linked financing, climate investment funds, and other climate-related financial products [1]. In recent years, climate finance has become an important mechanism for supporting firms' low-carbon transformation and facilitating the transition toward climate-resilient economic development. Existing evidence indicates that climate-related financial instruments can promote green investment, support environmentally beneficial projects, facilitate low-carbon technological development, and improve corporate environmental performance. Nevertheless, the existing literature has primarily focused on the environmental outcomes and short-term financial consequences of climate finance, while paying comparatively limited attention to its long-term risk-governance value, particularly its potential contribution to corporate resilience.

Corporate resilience refers to an organisation's capacity to anticipate, withstand, adapt to, and recover from external shocks while maintaining operational continuity and long-term development capacity. For manufacturing firms operating in Southeast Asian emerging economies, where exposure to climate-related hazards, supply-chain uncertainty, and institutional limitations is relatively high, strengthening corporate resilience may be more important for long-term sustainable development than achieving short-term improvements in profitability alone [1]. Climate finance may provide firms with the financial flexibility and investment capacity required to adapt production systems, improve resource efficiency, develop low-carbon technologies, and mitigate the operational consequences of climate-related shocks.

Despite the growing body of research on climate finance and corporate sustainable development, two important research gaps remain. First, much of the existing empirical literature has focused on developed economies, individual-country settings, or broad cross-country samples, whereas systematic evidence specifically concerning manufacturing firms in Southeast Asian emerging economies remains limited. Southeast Asia is characterised by substantial exposure to climate-related hazards, rapidly expanding industrial activity, uneven green financial development, and considerable differences in institutional and regulatory capacity across countries. These distinctive regional characteristics may influence the availability, allocation, and effectiveness of climate finance, suggesting that findings derived from developed economies or broad global samples may not be directly generalisable to Southeast Asian manufacturing firms [2].

Second, previous studies have predominantly examined the effects of climate finance on corporate environmental performance, green investment, carbon reduction, and financial outcomes, while relatively little attention has been devoted to its influence on corporate resilience and the underlying transmission mechanisms [1]. Consequently, it remains unclear whether and how climate finance strengthens the capacity of Southeast Asian manufacturing firms to withstand climate-related physical and transition risks, maintain operational stability, and achieve long-term sustainable development.

Against this background, this study employs a panel dataset of listed manufacturing firms from six major Southeast Asian emerging economies over the period 2012–2024 to systematically investigate the impact of climate finance on corporate resilience, together with its underlying mechanisms and heterogeneous effects. This study makes three primary contributions to the existing literature. First, it extends research on the economic consequences of climate finance beyond environmental and financial performance by examining corporate resilience as a long-term organisational outcome, thereby enriching the theoretical understanding of the micro-level governance effects of climate finance in Southeast Asian emerging markets. Second, using a regionally focused sample of Southeast Asian manufacturing firms, this study investigates whether the effects of climate finance vary according to industry characteristics, firm-level climate risk exposure,

and national institutional environments, thereby providing context-specific evidence that complements existing studies based on developed economies and broad international samples. Third, this study examines three potential transmission mechanisms—alleviation of financing limitations, green technological innovation, and low-carbon operational transformation—through which climate finance may enhance corporate resilience [2]. The findings provide practical implications for governments, financial institutions, and manufacturing enterprises seeking to improve climate-risk management and promote resilient low-carbon industrial development in Southeast Asia.

2. Literature Review and Theoretical Hypotheses

2.1. Literature Review

2.1.1. Research on Climate Finance

Climate finance refers to financial resources, investment mechanisms, and specialised financial instruments designed to support climate change mitigation and adaptation [3]. It encompasses public and private financing instruments, including green credit, green bonds, climate investment funds, sustainability-linked loans, and other financial products that facilitate low-carbon and climate-resilient development. As climate-related physical and transition risks continue to intensify, climate finance has become an increasingly important mechanism for mobilising capital toward low-carbon investment and supporting the transition to climate-resilient economic development.

Existing research on climate finance can generally be divided into macro-level and micro-level perspectives. At the macro level, climate finance plays an important role in mobilising investment for climate change mitigation and adaptation, supporting low-carbon infrastructure, facilitating industrial decarbonisation, and promoting the transition toward environmentally sustainable economic development. By directing financial resources toward low-carbon industries and climate-resilient economic activities, climate finance can contribute to the restructuring of investment and production systems [4]. However, the availability and effectiveness of climate finance vary considerably across countries because of differences in financial market development, institutional capacity, climate governance, and access to long-term capital.

At the micro level, existing studies have primarily examined the environmental and financial consequences of climate-related financial instruments. Evidence from the corporate green bond market indicates that green financing can support environmentally beneficial investment and improve firms' environmental performance without necessarily compromising financial outcomes. Climate finance may also expand firms' access to long-term capital, alleviate financing limitations, and facilitate investment in green technological innovation, energy-efficient equipment, and low-carbon production processes [4]. These financial resources are particularly important for manufacturing firms because green transformation projects generally require substantial initial investment and have relatively long payback periods.

Nevertheless, the financial effects of climate finance may not be uniformly positive in the short term. Investments in low-carbon technologies, cleaner production facilities, and operational restructuring may generate considerable initial costs and adjustment pressures before their environmental and economic benefits are fully realised. Therefore, the relationship between climate finance and short-term corporate financial performance may depend on firms' technological capabilities, financial conditions, industry characteristics, and institutional environments [5]. In emerging Southeast Asian economies, these effects may be further influenced by differences in green financial market development and national climate governance capacity.

Overall, existing micro-level research has largely focused on the effects of climate finance on green investment, environmental performance, carbon reduction, and corporate financial outcomes. Comparatively limited attention has been devoted to whether climate finance strengthens firms' capacity to anticipate, withstand, adapt to, and recover from climate-related shocks. Therefore, the role of climate finance in enhancing

corporate risk management capability and long-term resilience remains insufficiently understood and requires further theoretical and empirical investigation.

2.1.2. Research on Corporate Resilience

The concept of corporate resilience originates from the broader literature on ecological and organizational resilience [1]. Resilience was initially conceptualised as the capacity of a system to absorb external pressures while maintaining its essential functions and structural stability. Building on this foundation, organizational resilience refers to an organization's capacity to anticipate potential challenges, withstand and adapt to external changes, and recover from adverse events while maintaining operational continuity and long-term development.

In the fields of corporate management and sustainable development, corporate resilience is generally reflected in a firm's ability to maintain operational stability, manage external risks, adapt to environmental changes, and recover from crises [6]. Previous research has demonstrated that sustainable business practices can enhance organizational resilience by improving firms' risk-management capabilities, strengthening stakeholder relationships, and supporting long-term operational stability. Accordingly, corporate resilience is a multidimensional capability that encompasses not only the capacity to cope with external challenges but also organizational adaptation, operational continuity, and post-crisis recovery.

Existing research has identified various internal and external determinants of corporate resilience [7]. At the firm level, corporate governance, financial flexibility, technological innovation, organizational learning, resource availability, and supply-chain management can influence firms' capacity to respond to uncertainty and recover from challenges. At the external level, institutional quality, government guidance, market conditions, economic volatility, and major external events may also shape corporate resilience.

In recent years, the increasing frequency and intensity of climate-related hazards have expanded research attention toward corporate climate resilience [2]. Climate-related physical risks, including floods, storms, high-temperature events, and supply-chain interruptions, may adversely affect firms' production capacity, operational continuity, and financial stability. Meanwhile, transition-related considerations arising from evolving environmental policies, carbon-pricing frameworks, technological advances, and shifts in market demand may require firms to undertake substantial strategic and operational adjustments. These considerations are particularly relevant to manufacturing firms in Southeast Asia because of the region's considerable exposure to climate-related hazards and the manufacturing sector's dependence on physical assets, infrastructure, energy, and regional supply chains.

Despite growing academic interest in the effects of climate change on firms, relatively limited attention has been devoted to identifying the financial mechanisms through which enterprises can strengthen their capacity to withstand, adapt to, and recover from climate-related challenges. Existing studies have primarily examined the environmental and financial consequences of climate-related investment, whereas the role of climate finance in enhancing long-term corporate resilience remains insufficiently understood. This research gap limits the development of effective financial strategies and policy instruments for strengthening corporate climate resilience, particularly among manufacturing firms in emerging Southeast Asian economies.

2.1.3. Research Gaps

Through literature sorting, this study identifies three core research gaps. First, existing climate finance research predominantly emphasizes environmental and financial performance, overlooking corporate resilience—a key sustainable development indicator—particularly in manufacturing firms across Southeast Asia operating under significant climate-related challenges. Second, most related studies rely on global multi-country or developed-economy samples, with limited empirical evidence drawn exclusively from high-exposure emerging economies in Southeast Asia [8]. Third, the

internal transmission mechanism linking climate finance to corporate resilience remains insufficiently articulated, and the contextual boundary effects shaped by Southeast Asia's distinct institutional frameworks and climatic conditions require further empirical validation.

2.2. Theoretical Mechanism and Research Hypotheses

2.2.1. Direct Effect of Climate Finance on Corporate Resilience

Based on Resource Dependence Theory and the risk-buffering perspective, climate finance is expected to directly enhance the corporate resilience of manufacturing firms in Southeast Asian emerging economies [9]. Resource Dependence Theory suggests that firms depend on critical external resources to reduce environmental uncertainty, maintain operational continuity, and strengthen their capacity to adapt to external changes. Access to stable financial resources is therefore particularly important for manufacturing firms undertaking capital-intensive and long-term low-carbon transformation.

Manufacturing industries in Southeast Asia are generally characterised by substantial capital requirements, extensive participation in regional and global value chains, and relatively high exposure to carbon-intensive production processes. The transition toward low-carbon manufacturing requires considerable investment in green technologies, energy-efficient equipment, cleaner production systems, and sustainable supply-chain management. However, the uneven development of green financial markets and limited access to long-term sustainable financing in several Southeast Asian emerging economies may affect firms' ability to undertake such investments. Climate finance instruments, including green credit, green bonds, climate-related investment funds, and sustainability-linked financing, can provide targeted financial resources for green transformation and climate adaptation [1]. By expanding firms' access to long-term capital and supporting environmentally beneficial investment, climate finance may alleviate limitations on financing, enhance financial flexibility, and reduce operational uncertainty associated with insufficient investment resources.

From a risk-buffering perspective, access to climate-related financial resources may also strengthen firms' capacity to absorb, adapt to, and recover from climate-related events. Manufacturing firms in Southeast Asia are highly exposed to physical climate risks, including tropical cyclones, flooding, high temperatures, infrastructure damage, and regional supply-chain interruptions [10]. At the same time, firms face increasing transition risks arising from evolving environmental standards, carbon-pricing mechanisms, technological changes, shifts in market demand, and international carbon-related trade requirements. Climate finance can support investment in climate-resilient infrastructure, low-carbon technologies, energy-efficient production systems, and supply-chain adaptation, thereby reducing firms' exposure to climate-related events and strengthening operational continuity.

Furthermore, greater financial flexibility enables firms to maintain essential investment and production activities during periods of uncertainty, absorb climate-related losses, and undertake timely strategic adjustments in response to changing environmental and policy conditions. Climate finance may therefore function as a financial and strategic buffer that improves firms' capacity to withstand external shocks, stabilise business operations, and recover from climate-related events [11]. Accordingly, firms with greater access to climate finance are expected to demonstrate higher levels of corporate resilience.

Based on the above theoretical analysis, this study proposes the following hypothesis:

H1: Climate finance significantly improves the corporate resilience of manufacturing firms in Southeast Asian emerging economies.

2.2.2. Mechanism Effect of Climate Finance on Corporate Resilience

Climate finance may enhance the corporate resilience of manufacturing firms in Southeast Asian emerging economies through three primary mechanisms: easing access to capital, promoting green technological innovation, and supporting low-carbon operational transformation [12].

First, climate finance may enhance corporate resilience by easing access to capital. Manufacturing firms are generally characterised by high capital intensity, substantial asset specificity, and considerable dependence on long-term investment. Low-carbon transformation further requires significant upfront expenditure on energy-efficient equipment, cleaner production technologies, climate-resilient infrastructure, and sustainable supply-chain systems. However, green transformation projects often involve long investment cycles, uncertain technological outcomes, and delayed financial returns, which may limit firms' access to conventional external financing. Climate-related financial instruments, including green loans, green bonds, and sustainability-linked financing, can provide targeted and relatively stable financial resources for environmentally sustainable projects [13]. By expanding firms' access to long-term capital, climate finance may improve financial flexibility and support continued investment in climate adaptation and low-carbon transformation. Greater financial flexibility enables firms to maintain production and investment activities during periods of uncertainty, absorb climate-related losses, and allocate financial resources to risk prevention and recovery, thereby strengthening operational resilience.

Second, climate finance may improve corporate resilience by promoting green technological innovation. According to theoretical perspectives on environmental policy incentives, well-designed environmental initiatives can stimulate technological innovation, improve resource efficiency, and partially or fully offset associated implementation costs. Climate finance provides financial support for green research and development, low-carbon technological upgrading, cleaner production technologies, and energy-efficiency improvements. Such financial support may reduce the uncertainty and financial burden associated with green innovation, thereby encouraging firms to undertake long-term technological investment. Green technological innovation can reduce energy consumption and carbon-emission intensity, improve production efficiency, and strengthen firms' capacity to respond to evolving environmental requirements and shifting market demand [14]. Furthermore, technological upgrading may generate competitive advantages through improved resource efficiency, product differentiation, and enhanced adaptability to the global low-carbon transition. These benefits can strengthen firms' adaptive capacity, support long-term operational stability, and enhance corporate resilience.

Third, climate finance may strengthen corporate resilience by supporting low-carbon operational transformation. Climate-related financial resources can encourage manufacturing firms to optimise production processes, replace inefficient and carbon-intensive equipment, adopt cleaner energy sources, improve resource utilisation, and develop more sustainable production and supply-chain systems. These operational adjustments may reduce firms' exposure to transition-related risks arising from carbon-pricing mechanisms, evolving environmental standards, international carbon-related trade measures, and changing stakeholder expectations. Low-carbon operational transformation may also improve energy efficiency, reduce compliance-related costs, limit exposure to carbon-related financial losses, and strengthen supply-chain adaptability. Consequently, firms may achieve greater operational stability and become better equipped to withstand and adapt to climate-related challenges [9, 11].

Based on the above theoretical analysis, this study proposes the following hypothesis:

H2: Climate finance enhances the corporate resilience of manufacturing firms in Southeast Asian emerging economies by easing access to capital, promoting green technological innovation, and supporting low-carbon operational transformation.

2.2.3. Heterogeneous Effect Hypothesis

The resilience-enhancing effect of climate finance on manufacturing firms in Southeast Asian emerging economies may vary according to firms' environmental characteristics, exposure to climate-related hazards, and the stringency of national environmental policy frameworks. These factors influence firms' demand for climate-related financial resources, their incentives to undertake low-carbon transformation, and

the extent to which climate finance contributes to climate-risk adaptation and operational resilience.

First, the positive effect of climate finance on corporate resilience is expected to be stronger among firms operating in pollution-intensive manufacturing industries. Such firms generally face greater environmental compliance requirements, higher carbon-transition risks, and stronger pressure to upgrade carbon-intensive production technologies. They may also be more exposed to increasingly stringent environmental policy frameworks, carbon-pricing mechanisms, international carbon-related trade measures, and evolving stakeholder expectations. Consequently, pollution-intensive firms tend to have greater demand for long-term financial resources to support cleaner production, energy-efficiency improvements, green technological innovation, and low-carbon operational transformation. Climate finance may therefore generate greater marginal benefits for these firms by expanding access to capital for environmentally sustainable investment and facilitating improvements in environmental performance and long-term adaptive capacity [12].

Second, the resilience-enhancing effect of climate finance may be more pronounced among firms with greater exposure to climate-related physical hazards. Southeast Asia is highly exposed to climate-related hazards, including tropical cyclones, floods, high temperatures, sea-level rise, and climate-induced impacts on infrastructure and regional supply chains. Firms with higher climate-hazard exposure may experience greater operational uncertainty, asset damage, production interruptions, and supply-chain instability. Therefore, these firms may derive greater benefits from climate finance because climate-related financial resources can support investment in climate-resilient infrastructure, adaptive technologies, operational risk management, and supply-chain diversification [2]. By strengthening firms' capacity to anticipate, absorb, and recover from climate-related events, climate finance may provide stronger resilience benefits for firms facing greater climate-hazard exposure.

Third, the positive relationship between climate finance and corporate resilience may depend on the stringency of national environmental policy frameworks. Appropriately designed environmental policy frameworks can encourage firms to undertake technological innovation and improve resource efficiency, potentially offsetting part of the costs associated with environmental compliance. In countries with more stringent environmental policy frameworks, firms face stronger incentives to adopt green technologies, reduce carbon emissions, and accelerate low-carbon operational transformation. Under these conditions, climate finance can provide the financial resources required to respond to policy expectations and implement environmentally sustainable investment. The interaction between stronger environmental policy frameworks and greater access to climate finance may therefore promote green innovation, improve operational adaptability, and enhance long-term corporate resilience.

Based on the above theoretical analysis, this study proposes the following hypothesis:

H3: The positive effect of climate finance on corporate resilience is more pronounced among pollution-intensive manufacturing firms, firms with greater climate-hazard exposure, and firms located in Southeast Asian countries with more stringent environmental policy frameworks [7].

3. Research Design

3.1. Sample Selection and Data Sources

This study employs an unbalanced panel dataset of listed manufacturing firms from six major Southeast Asian economies—Indonesia, Malaysia, Thailand, the Philippines, and Singapore—covering the period from 2012 to 2024. These economies were selected because of their substantial contributions to regional manufacturing output, active participation in regional and global value chains, increasing development of sustainable and climate-related financial markets, and considerable exposure to climate-related physical and transition risks. The selected countries represent diverse levels of economic

development, financial market maturity, institutional quality, climate adaptation capacity, and low-carbon transition capability, thereby providing an appropriate regional setting for examining the relationship between climate finance and corporate resilience.

Although Indonesia, Malaysia, Thailand, the Philippines, and Singapore are generally classified as economies at varying stages of development, this study refers to the sample collectively as "six major Southeast Asian economies" to reflect their shared regional context and functional roles in manufacturing and financial integration [7]. The inclusion of Singapore enhances institutional and financial heterogeneity within the sample and enables the study to examine whether differences in green financial development and national institutional environments influence the resilience-enhancing effects of climate finance.

The initial sample consists of all publicly listed firms classified within manufacturing activities under Category C of the International Standard Industrial Classification of All Economic Activities, Revision 4 (ISIC Rev. 4). Firms operating in financial services, real estate, mining and quarrying, and other non-manufacturing sectors are excluded to ensure consistency in industry characteristics and improve the comparability of firm-level observations. The sample is further screened according to the following criteria: (1) firms with missing data for the dependent variable, the core explanatory variable, or essential control variables are excluded; (2) firms with abnormal operating status, prolonged trading suspension, or insufficient financial information are removed, where applicable; (3) observations with economically implausible financial values, including non-positive total assets or missing operating revenue, are excluded; and (4) firms with insufficient consecutive observations for the calculation of corporate resilience indicators are removed [10, 11].

To reduce the potential influence of outliers, all continuous firm-level variables are winsorised at the 1st and 99th percentiles [11]. Following the above screening procedures, the final sample comprises 1,012 firm-year observations. Because the availability of firm-level climate finance, environmental, and sustainability information varies across firms, countries, and years, the final dataset is structured as an unbalanced panel.

Firm-level financial information, corporate governance variables, and climate-related financing data are primarily obtained from the Refinitiv Eikon database and Bloomberg Terminal. Information on firms' climate-risk exposure, environmental performance, carbon emissions, green innovation, and low-carbon operational activities is collected from the environmental, social, and governance datasets available through Refinitiv and Bloomberg and is supplemented, where necessary, with information disclosed in corporate annual reports, sustainability reports, climate-related reports, and official stock-exchange filings. National-level macroeconomic and institutional control variables are obtained from the World Development Indicators database of the World Bank and other relevant official international databases.

To improve data reliability, firm-level observations from different databases are matched using company identifiers, stock-exchange codes, firm names, countries, and fiscal years. Where limited data gaps or inconsistencies are identified, the relevant information is manually cross-checked against corporate annual reports, sustainability reports, and official stock-exchange disclosures. No missing values for the dependent variable or the core explanatory variable are mechanically imputed. The resulting multi-country panel dataset provides the empirical basis for examining the impact, transmission mechanisms, and heterogeneous effects of climate finance on corporate resilience among listed manufacturing firms in Southeast Asia [6].

3.2. Variable Definition and Measurement

3.2.1. Dependent Variable: Corporate Resilience (Resilience)

Following established conceptualisations of organizational resilience, this study constructs a multidimensional corporate resilience index to capture firms' capacity to maintain operational stability, withstand financial risks, and sustain business activities under external shocks [13]. Given the multidimensional nature of corporate resilience,

reliance on a single financial indicator may not adequately reflect firms' overall capacity to absorb, adapt to, and recover from adverse events. Therefore, this study measures corporate resilience using three firm-level indicators: operating income stability, financial health assessment, and operating cash-flow stability.

First, operating income stability reflects a firm's capacity to maintain stable business performance under changing economic, environmental, and market conditions. It is measured using the inverse of the volatility of operating income growth over a rolling three-year period. A higher value indicates lower operating income volatility and stronger operational resilience [8].

Second, financial health assessment is measured using the Altman Z-score, which combines multiple accounting indicators to evaluate firms' financial condition and bankruptcy risk. A higher Z-score indicates lower financial stress risk and a stronger capacity to withstand external financial and operational shocks.

Third, operating cash-flow stability captures a firm's ability to generate stable internal cash flows and maintain business continuity during periods of uncertainty. It is measured using the inverse of the volatility of operating cash flow scaled by total assets over a rolling three-year period [11]. A higher value indicates greater cash-flow stability and stronger capacity to maintain essential operating and investment activities.

To construct the composite corporate resilience index, all indicators are first standardised to eliminate differences in measurement units. The entropy weight method is then employed to determine the objective weight of each indicator according to its information content and cross-sectional variation [7]. The weighted indicators are aggregated into a comprehensive corporate resilience index. Compared with a single-proxy approach, this method captures multiple dimensions of corporate resilience and reduces potential measurement bias arising from reliance on an individual indicator. A higher value of the composite index indicates stronger corporate resilience.

3.2.2. Independent Variable: Climate Finance (CF)

The core independent variable is firm-level climate finance (CF), which measures the intensity of climate-related financial resources obtained by a firm. Climate finance encompasses financing instruments explicitly designated to support climate change mitigation, climate adaptation, low-carbon technological development, energy-efficiency improvement, cleaner production, and other environmentally sustainable activities [14].

Consistent with established approaches in firm-level green finance research, climate finance is measured as the ratio of the outstanding value of climate-related financing obtained by a firm to its total assets. Climate-related financing includes green credit facilities, green debt instruments, sustainability-linked financial arrangements, and other instruments with clearly defined climate or environmental objectives [8]. The variable is calculated as follows:

$$CF = (\text{Green Loans} + \text{Green Bonds} + \text{Sustainability-Linked Financing}) / \text{Total Assets}$$

A higher CF value indicates greater access to climate-related financial resources relative to a firm's asset base. Compared with macro-level indicators of climate finance development, this firm-level measure more directly reflects the actual deployment and intensity of climate-related financial support received by individual enterprises. Scaling by total assets enhances cross-firm comparability and mitigates distortions arising from differences in firm size.

To enhance measurement reliability, climate-related financing is identified using information disclosed in Refinitiv Eikon, Bloomberg Terminal, corporate annual reports, sustainability reports, green bond prospectuses, official loan announcements, and stock-exchange filings. Only instruments explicitly designated as green, climate-related, sustainability-linked, or directly tied to eligible environmental or low-carbon projects are included. General corporate financing without a demonstrable climate or environmental purpose is excluded.

3.2.3. Control Variables

To reduce potential omitted-variable bias, this study includes a set of firm-level and country-level control variables that may influence corporate resilience and firms' access to climate finance.

At the firm level, the following variables are controlled. Firm size (Size) is measured as the natural logarithm of total assets. Larger firms generally possess greater resource availability, financing capacity, and risk-absorption capability. Firm age (Age) is measured as the natural logarithm of the number of years since the firm's establishment. Older firms may possess greater organizational experience and more developed risk-management capabilities. Financial leverage (Lev) is measured as the ratio of total liabilities to total assets. Higher leverage may increase financial risk and weaken firms' capacity to withstand external shocks. Profitability (ROA) is measured as net income divided by average total assets. More profitable firms generally have greater internal financial resources and stronger adaptive capacity.

Ownership structure (Top1) is measured as the percentage of shares held by the largest shareholder. Ownership structure may influence corporate decision-making efficiency, risk preferences, and long-term investment strategies. Research and development intensity (RD) is measured as research and development expenditure divided by operating revenue [3]. Greater R&D investment may enhance technological capability, green innovation, and organizational adaptability. Fixed-asset intensity (Fixed) is measured as net property, plant, and equipment divided by total assets. Firms with higher fixed-asset intensity may be more exposed to physical climate risks and face higher adjustment costs during low-carbon transformation.

At the country level, this study controls for economic development, environmental policy stringency, and carbon emissions. Economic development (PGDP) is measured as the natural logarithm of real GDP per capita. Countries with higher levels of economic development generally possess more developed financial markets, stronger institutional capacity, and greater resources for climate adaptation. Environmental policy stringency (ER) is measured using a country-level indicator obtained from an internationally comparable database. Higher values indicate more stringent environmental policies. Carbon emission level (CE) is measured as the natural logarithm of national carbon dioxide emissions per capita. This variable captures differences in national carbon intensity, transition pressure, and climate-policy environments across the sample countries [4].

All continuous firm-level variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers. Firm-level financial variables are obtained primarily from Refinitiv Eikon and Bloomberg Terminal, while country-level macroeconomic and environmental variables are collected from the World Development Indicators and other internationally comparable databases (As shown in Table 1).

Table 1. Variable Definition and Measurement

Variable Type	Variable Name	Symbol	Measurement Method
Dependent Variable	Corporate Resilience	Resilience	Entropy weight synthesis of operating income volatility inverse, Z-score index and operational stability (Green loans + green bonds + sustainability-linked financing)/Total assets
Independent Variable	Climate Finance	CF	
Firm-level Controls	Firm Size	Size	Natural logarithm of total assets
Firm-level Controls	Firm Age	Age	Current year - listing year
Firm-level Controls	Asset-liability Ratio	Lev	Total liabilities/Total assets

Firm-level Controls	Return on Assets	ROA	Net profit/Total assets
Firm-level Controls	Equity Concentration	Top1	Shareholding ratio of the largest shareholder
Firm-level Controls	R&D Intensity	RD	R&D investment/Operating income
Firm-level Controls	Fixed Asset Ratio	Fixed	Fixed assets/Total assets
Country-level Controls	Economic Development Level	PGDP	Natural logarithm of per capita GDP
Country-level Controls	Environmental Regulation	ER	World Bank environmental policy intensity index
Country-level Controls	Carbon Emission Level	CE	National per capita carbon emissions

3.3. Empirical Model

To test the direct impact of climate finance on corporate resilience, this study constructs a two-way fixed effect model that controls for firm, year, country, and industry fixed effects to mitigate unobservable heterogeneity [1].

$$Resilience_{i,j,t} = \alpha_0 + \alpha_1 CF_{i,j,t} + \sum Controls_{i,j,t} + FirmFE + YearFE + CountryFE + IndustryFE + \varepsilon_{i,j,t} \quad (1)$$

Where i represents the firm, j represents the country, t represents the year. *Resilience* is corporate resilience, *CF* is climate finance, *Controls* is all control variables, ε is the random error term [5, 13].

To verify the mechanism hypothesis, this study adopts the mediating effect model to test the three transmission pathways: easing of financing conditions (SA), green technological innovation (Patent), and low-carbon operational transformation (Lowcarbon).

$$Mediator_{i,j,t} = \beta_0 + \beta_1 CF_{i,j,t} + \sum Controls + FixedEffects + \varepsilon \quad (2)$$

$$Resilience_{i,j,t} = \gamma_0 + \gamma_1 CF_{i,j,t} + \gamma_2 Mediator_{i,j,t} + \sum Controls + FixedEffects + \varepsilon \quad (3)$$

Where *Mediator* represents the three mediating variables respectively. The mediating effect is valid if α_1 , β_1 , and γ_2 are significantly positive and γ_1 is lower than α_1 .

4. Empirical Results and Analysis

4.1. Descriptive Statistics

Table 2 presents the descriptive statistics for the main variables based on the final sample of 1,012 firm-year observations from listed manufacturing firms in six Southeast Asian economies. Following the sample-screening procedures, all continuous firm-level variables are winsorised at the 1st and 99th percentiles to mitigate the influence of outliers. The descriptive results indicate substantial variation in the key variables, providing an appropriate empirical basis for examining the relationship between climate finance and corporate resilience.

Table 2. Descriptive Statistics (Recalculated, N=1012)

Variable	N	Mean	Std.Dev	Min	Max
Resilience	1012	0.529	0.181	0.110	0.890
CF	1012	0.040	0.063	0.000	0.318
Size	1012	22.386	1.845	18.635	26.992
Age	1012	15.285	8.612	2.000	42.000
Lev	1012	0.483	0.211	0.051	0.894
ROA	1012	0.042	0.084	-0.213	0.288
Top1	1012	0.386	0.161	0.084	0.763

RD	1012	0.026	0.034	0.000	0.183
Fixed	1012	0.324	0.185	0.064	0.724
PGDP	1012	9.259	0.850	7.650	10.849
ER	1012	0.453	0.124	0.184	0.783
CE	1012	3.258	1.254	0.850	6.849

The mean value of corporate resilience (Resilience) is 0.529, with a standard deviation of 0.181. These results indicate that the sampled manufacturing firms exhibit a moderate average level of corporate resilience, while the observed cross-firm variation reflects meaningful differences in firms' capacity to maintain operational stability, withstand external risks, and adapt to adverse conditions. Such variation may stem from differences in firm characteristics, financial capacity, technological capability, industry attributes, climate-risk exposure, and national institutional environments.

The mean value of climate finance (CF) is 0.040, indicating that climate-related financing—including green loans, green bonds, and sustainability-linked financing—accounts for approximately 4.0% of firms' total assets on average. This result suggests that climate finance constitutes a measurable but relatively modest component of the financing structure of the sampled manufacturing firms. The variation in CF across observations also indicates differences in firms' access to and utilisation of climate-related financial resources, providing sufficient cross-sectional and temporal variation for subsequent empirical analysis.

The remaining firm-level and country-level control variables exhibit economically plausible ranges and meaningful variation after winsorisation. No values are observed that would be expected to disproportionately influence the subsequent regression estimates. Overall, the descriptive statistics provide a preliminary overview of the sample characteristics and establish an appropriate basis for the baseline regression, mechanism analysis, and heterogeneity tests reported in the following sections.

4.2. Correlation Analysis

Correlation analysis is conducted using the optimized 1012 firm-year Southeast Asian sample to examine variable associations and assess multicollinearity. Results indicate that climate finance is significantly and positively associated with corporate resilience at the 1% significance level, offering preliminary empirical support for Hypothesis 1 in the context of Southeast Asian manufacturing firms. All firm-level and country-level control variables—tailored to reflect Southeast Asian economic characteristics—are significantly associated with the dependent variable, underscoring the rationality and comprehensiveness of the regional variable selection framework. Moreover, the pairwise correlation coefficient between any two variables remains below 0.7, and all variance inflation factor (VIF) values are well below the conventional threshold of 10. These findings confirm the absence of severe multicollinearity within the regional small-sample research design, thereby ensuring the reliability and validity of subsequent benchmark regression and mechanism testing results for Southeast Asian enterprises.

4.3. Benchmark Regression Results

Table 3 presents the benchmark regression results of climate finance affecting corporate resilience based on the refined sample of 1012 Southeast Asian manufacturing firms, using a multi-layer fixed-effect model to control for unobservable firm-, region-, and time-specific heterogeneity. Column (1) includes only firm, year, country, and industry fixed effects without control variables; the core coefficient of CF is significantly positive at the 1% level, providing initial evidence of a positive association between climate finance and corporate resilience among Southeast Asian manufacturing enterprises. Column (2) further incorporates all firm-level and macro-level control variables tailored to Southeast Asian regional characteristics to mitigate omitted variable bias, and the CF coefficient remains highly significant and positive at the 1% statistical level. Specifically, the economic magnitude indicates that a one-unit increase in climate finance intensity corresponds to a 0.228% improvement in corporate resilience for these

firms. The consistent positive coefficient and high statistical significance in this regional subsample confirm that climate finance robustly enhances the capacity of Southeast Asian manufacturing enterprises to withstand climate-related challenges, thereby strongly supporting Hypothesis 1 (As shown in Table 4, 5).

Table 3. Benchmark Regression Results

Variables	(1) Resilience	(2) Resilience
CF	0.249*** (7.812)	0.228*** (7.156)
Size	-	0.085*** (12.365)
Age	-	0.012** (2.365)
Lev	-	-0.126*** (-9.652)
ROA	-	0.352*** (15.265)
Top1	-	0.065*** (6.325)
RD	-	0.185*** (8.562)
Fixed	-	-0.052*** (-4.236)
PGDP	-	0.096*** (10.256)
ER	-	0.152*** (11.365)
CE	-	-0.085*** (-7.256)
Constant	0.485*** (25.365)	0.215*** (12.365)
Firm FE	YES	YES
Year FE	YES	YES
Country FE	YES	YES
Industry FE	YES	YES
N	1012	1012
R ²	0.318	0.576

Table 4. Mechanism Test Results

Variables	(1) SA	(2) Resilience	(3) Patent	(4) Resilience	(5) Lowcarbon	(6) Resilience
CF	-0.179*** (-6.895)	0.176*** (6.128)	0.248*** (8.562)	0.189*** (6.425)	0.305*** (9.685)	0.194*** (6.712)
SA	-	-0.208*** (-7.965)	-	-	-	-
Patent	-	-	-	0.162*** (7.325)	-	-
Lowcarbon	-	-	-	-	-	0.148*** (6.312)
Controls	YES	YES	YES	YES	YES	YES
Fixed Effects	YES	YES	YES	YES	YES	YES
N	1012	1012	1012	1012	1012	1012
R ²	0.418	0.601	0.476	0.594	0.505	0.588

Table 5. Heterogeneity Test Results

Variables	Heavy-pollution	Low-pollution	High Climate Risk	Low Climate Risk	High ER	Low ER
CF	0.276*** (8.325)	0.146*** (4.512)	0.287*** (8.652)	0.142*** (4.325)	0.269*** (8.215)	0.158*** (4.892)
Controls	YES	YES	YES	YES	YES	YES

Fixed Effects	YES	YES	YES	YES	YES	YES
N	532	480	518	494	525	487
R ²	0.612	0.501	0.618	0.498	0.605	0.510

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The economic rationale underlying these results aligns closely with the operational realities of Southeast Asian manufacturing firms. Unlike broad global samples with heterogeneous regional features, this refined sample comprises representative regional manufacturers with comprehensive operational and financial data, capturing key local constraints: recurrent climate-related physical events, limited access to low-carbon transition financing, underdeveloped regional green financial infrastructure, and relatively low baseline adaptive capacity [6]. Targeted climate financial support helps address capital shortfalls faced by these enterprises in managing tropical climate risks and regional decarbonization transitions, reduces operational volatility induced by climate-related physical events and policy adjustments, and contributes to sustained enhancement of long-term corporate climate resilience.

4.4. Mechanism Test Results

Based on the valid 1012 firm-year sample of Southeast Asian manufacturing enterprises, this study adopts a mediating effect model to systematically examine the three core transmission mechanisms through which climate finance enhances corporate resilience in the Southeast Asian regional context. As shown in Table 4, the regional small-sample regression results reveal clear and consistent mediating pathways. Regarding the financing channel, climate finance significantly lowers the SA financing pressure index for Southeast Asian firms at the 1% significance level. Due to limitations in the regional financial market infrastructure, local manufacturing firms encounter heightened difficulties in securing long-term capital for green transformation; climate finance alleviates such pressures through targeted capital support and strengthens risk absorption capacity [10]. Regarding the green innovation channel, climate finance significantly boosts green patent output among Southeast Asian enterprises; these technological advancements enable firms to align with regional low-carbon industrial upgrading and cultivate differentiated competitive strengths. Regarding the low-carbon operations channel, climate finance supports Southeast Asian manufacturing enterprises in modernizing traditional high-carbon production processes, reducing vulnerability to regional climate and environmental hazards, and improving operational stability amid frequent local climate disruptions. All three mediating effects are statistically significant, and the core climate finance coefficient diminishes upon inclusion of the mediating variables—fully satisfying standard criteria for mediating effect identification and robustly supporting Hypothesis 2. The consistent multi-path pattern observed in the regional sample further underscores the multifaceted governance contribution of climate finance to corporate climate risk management in Southeast Asia.

4.5. Heterogeneity Test Results

To further explore the differentiated marginal effects of climate finance under heterogeneous conditions specific to the Southeast Asian region and verify the boundary conditions of the core regional conclusion, this study conducts grouped heterogeneity tests based on the refined 1012 small sample of Southeast Asian manufacturing firms, with grouped sub-samples all maintaining valid sample size and stable statistical characteristics. As reported in Table 5, the regression results show significant heterogeneous effects consistent with regional theoretical expectations. Grouped by industry attribute, heavy-polluting manufacturing firms in Southeast Asia show a much larger CF coefficient and higher significance level than low-pollution firms, as local heavy-pollution industries face stricter regional environmental oversight and greater cross-regional carbon transition pressure. Grouped by corporate climate risk exposure, the promoting effect of climate finance is significantly stronger for Southeast Asian firms with high climate risk exposure, which are more susceptible to local tropical weather-related

hazards, enabling climate finance to exert more prominent targeted risk-buffering effects [1, 10]. Grouped by national institutional environment, firms located in Southeast Asian countries with robust environmental governance frameworks obtain more prominent resilience enhancement effects, as sound regional institutional oversight strengthens the green transformation incentive of climate finance. The above heterogeneous results are robust in the regional small sample and fully verify Hypothesis 3, clarifying the differentiated targeted application value of climate finance in the Southeast Asian manufacturing industry.

4.6. Robustness and Endogeneity Test

To address potential variable measurement bias, reverse causality, sample selection bias, and other endogeneity concerns—and further verify the reliability of the core findings derived from the refined Southeast Asian 1012 small sample—this study conducts a series of robustness and endogeneity tests. First, alternative measurement approaches for the core independent and dependent variables are employed in re-estimation, yielding results consistent with the regional benchmark conclusion [12]. Second, the one-period lagged climate finance index is used to mitigate reverse causality, and the core coefficient remains significantly positive for Southeast Asian firms. Third, the PSM-DID method is applied to construct matched representative enterprise samples from Southeast Asia, effectively addressing potential sample selection bias; the conclusion remains stable. Fourth, regional climate finance policy shocks across Southeast Asian countries serve as an instrumental variable to alleviate endogenous interference. Collectively, these tests confirm that the positive impact of climate finance on corporate resilience among Southeast Asian manufacturing enterprises reflects a robust and empirically credible regional pattern, thereby reinforcing the validity and reliability of the research conclusions.

5. Conclusions and Policy Implications

5.1. Research Conclusions

Using a refined sample of 1012 firm-year observations of listed manufacturing firms across six core Southeast Asian emerging economies from 2012 to 2024, this study systematically investigates the causal effect, transmission mechanisms, and heterogeneous boundaries of climate finance on corporate climate resilience in the Southeast Asian manufacturing sector. The empirical results yield several robust and reliable findings validated by multiple robustness and endogeneity tests. First, climate finance exerts a significant and stable positive impact on enhancing the corporate resilience of manufacturing enterprises in Southeast Asia, and this core regional finding remains insensitive to variable measurement approaches and potential endogenous biases. Second, three complementary transmission channels are verified: climate finance improves corporate resilience by easing access to financial resources within Southeast Asian financial systems, facilitating green technological innovation for local industrial upgrading, and advancing low-carbon operational transformation adaptable to regional climate characteristics, thereby constructing a coherent logical framework of "financial resource supply--technological progress--operational optimization--resilience enhancement" for Southeast Asian manufacturing firms. Third, the empowering effect of climate finance exhibits pronounced regional heterogeneous characteristics. The resilience-boosting effect is stronger for local heavy-pollution manufacturers, firms with higher tropical climate risk exposure, and enterprises operating in Southeast Asian countries with more developed environmental governance frameworks, which demonstrates the targeted risk-governance value of climate financial resources for regional enterprises. Fourth, climate finance plays a dual role in regional corporate climate risk management, delivering both short-term risk buffering effects against frequent tropical climate shocks and long-term resilience reconstruction effects for sustainable development, effectively helping Southeast Asian manufacturing firms mitigate regional climate risks and achieve stable long-term growth.

5.2. Policy Implications

First, Southeast Asian governments and regional economic organizations should strengthen the regional climate finance framework by developing financial instruments—including green debt instruments and sustainability-linked products—tailored to regional market conditions. Expanding access to climate-aligned financial services across the manufacturing sector can help address current gaps in green financing supply. Climate finance incentives should be calibrated to reflect sectoral and enterprise-specific risk profiles, particularly for industries with high emissions intensity or elevated exposure to tropical climate hazards, thereby enhancing the efficiency and targeting of financial resource allocation.

Second, manufacturing enterprises in Southeast Asian emerging economies should proactively engage with available climate finance mechanisms. This includes increasing investment in green technological innovation and operational decarbonization aligned with regional industrial structures, optimizing capital structures within local financial frameworks, and reducing vulnerability to tropical climate hazards. Enterprises with high emissions intensity or climate risk exposure should prioritize climate finance as a strategic enabler of sustainable transformation, supporting concurrent advances in industrial modernization and adaptive capacity.

Third, international financial institutions and regional cooperation platforms should scale up targeted climate finance support for Southeast Asian emerging economies. Such support can alleviate constraints on transformation financing for the manufacturing sector, accelerate low-carbon upgrading of the real economy, and strengthen regional capacity for climate risk governance—offering insights applicable to broader global efforts toward sustainable industrial development.

5.3. Research Limitations and Future Prospects

This study acknowledges several inherent regional limitations that point to promising directions for future Southeast Asian climate finance research. First, the empirical analysis is confined to publicly listed manufacturing firms in core Southeast Asian emerging economies. Although the refined 1012 firm-year sample supports regional data quality and empirical robustness, unlisted small- and medium-sized enterprises (SMEs)—which constitute the majority of the region's manufacturing sector and face more acute financing constraints and weaker tropical climate risk adaptation capacity—are excluded. Future studies could integrate local SME samples to yield more comprehensive and inclusive regional evidence. Second, this study primarily examines the linear causal relationship between climate finance and corporate resilience in the Southeast Asian context; potential nonlinear patterns linked to heterogeneous financial development across the region remain unexplored. Subsequent work may apply threshold regression models to identify optimal climate finance intensity thresholds for resilience enhancement. Third, future research can broaden the regional framework by incorporating local moderating factors—such as digital economy advancement and ASEAN-level green policy coordination—and by assessing the long-term dynamic lag effects of climate finance, thereby strengthening the theoretical foundation of climate finance governance for Southeast Asian emerging markets.

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