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SHOCK, SKILLS, OR SALES? DISENTANGLING THE DRIVERS OF GREEN ACTION IN ASEAN ENTERPRISES

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ABSTRACT

Despite increasing climate risks, manufacturing and service firms in developing economies are often slow to adopt green technologies, limiting their long-term structural resilience. This study examines the distinct roles of Physical Climate Shock (Shock), export status (Sales), and managerial quality (Skills) in shaping corporate green action. Utilizing World Bank Enterprise Surveys (2023) for four ASEAN economies (Cambodia, Indonesia, the Philippines, and Vietnam), we apply Lewbel's (2012) instrumental variables method and propensity score matching (PSM) to address endogeneity and selection bias. The models control for digital readiness to account for the twin-transition and use a continuous green index for robustness. Results reveal a clear structural hierarchy: internal managerial capability (Skills) is a stronger driver of green adaptation than direct exposure to climate damage (Shock). Regarding market pressures, we identify static GVC compliance: exporters demonstrate a higher initial baseline of green compliance but do not respond more strongly to climate shocks than domestic firms do. Furthermore, once managerial capabilities are controlled for, self-reported financial constraints become statistically insignificant. This suggests that limited access to credit primarily reflects underlying managerial gaps rather than functioning as an independent barrier to green action. Overall, the study calls for reorienting industrial and climate policies in the region. Rather than relying primarily on financial subsidies, interventions should prioritize strengthening managerial practices and enabling functional GVC upgrading to better navigate the dual demands of SDG 9 (industry and innovation) and SDG 13 (climate action).

Keywords: *Green dynamic capabilities, Climate adaptation, Global Value Chains, Innovation paradox, Management practices, ASEAN*

1. INTRODUCTION

Over the past three decades, the Association of Southeast Asian Nations (ASEAN) has experienced a profound structural transformation, moving from largely agriculture-based economies toward a central position in global manufacturing networks (Kohli et al., 2011; UNCTAD, 2024). This transition has been driven largely by integration into global value chains (GVCs) and sustained foreign direct investment (FDI) inflows (Baldwin, 2013; Gereffi, 2014; Qiang et al., 2021). However, alongside this economic expansion, the region remains highly exposed to physical climate risks, with extreme weather events threatening infrastructure, production assets, and supply chain continuity (Boehm et al., 2015; Ivanov & Das, 2020).

From the perspective of neoclassical firm theory, enterprises facing exogenous risks to business continuity should rationally reallocate resources toward adaptation and mitigation (Cassar et al., 2017). Yet evidence from developing economies shows persistent inertia in the adoption of environmental technologies and green management practices (Comin et al., 2021; Hoang-Duc et al., 2026). This gap between rising climate exposure and slow firm-level upgrading represents an adaptation paradox that requires systematic empirical investigation.

This paradox has implications beyond individual firms. Slow structural adaptation weakens competitiveness and constrains ASEAN's progress toward the Sustainable Development Goals, particularly the nexus between resilient industrial innovation under SDG 9 and urgent climate action under SDG 13 (Christ & Burritt, 2019; Shao et al., 2025; Stanković and Radukić, 2026). Understanding the micro-level mechanisms behind technological inertia is therefore essential for designing effective industrial and climate policy.

Existing research explains green technology adoption through three main theoretical lenses: exposure to exogenous climate shocks, pressure from market integration, and internal organizational capabilities. The first perspective, rooted in the attention-based view of the firm (Ocasio, 1997, 2011), treats severe weather events as environmental jolts that can redirect managerial attention toward risk mitigation (Brielmaier & Friesl, 2023; Hirschmann et al., 2025; Meyer, 1982). However, behavioral economics suggests that risk perception does not automatically translate into strategic action. Under conditions of stress and limited resources, climate shocks may trigger loss aversion, avoidance behavior, or short-term coping responses rather than long-term green investment (Carlson & Fang, 2022; Mazutis & Eckardt, 2017; Tversky & Kahneman, 1981).

The second perspective emphasizes the role of global markets. GVC participation may expose firms to international standards, advanced technologies, and buyer-driven environmental requirements (Atkin et al., 2017; DiMaggio & Powell, 1983; Kostova & Zaheer, 1999; Loecker, 2013). However, global value chain governance is often asymmetric. Lead firms may impose environmental compliance requirements on developing-country suppliers without transferring sufficient resources or technological capabilities (Dallas et al., 2019; Gereffi, 2018, 2019; Humphrey & Schmitz, 2002; Ponte, 2022). As a result, suppliers may fall into a compliance plateau, treating green standards as a contractual requirement rather than as a basis for substantive environmental upgrading (Avenyo & Tregenna, 2025; Better Factories Cambodia, 2024; De Marchi & Alford, 2022).

The third perspective focuses on firms' internal microfoundations. Building on the resource-based view and the theory of dynamic capabilities, managerial quality is increasingly understood as a core form of organizational technology (Barney, 1991; Bloom et al., 2013, 2016; Bloom & Van Reenen, 2007; Teece et al., 1997; Winter, 2003). In the environmental domain, these capabilities enable firms to sense climate-related risks, seize green investment opportunities, and reconfigure operational processes (Amui et al., 2017; Asiedu et al., 2025; Haug et al., 2025). Strong management practices can therefore help firms move beyond reactive responses to climate shocks and convert GVC compliance into genuine process innovation (Essuman et al., 2022).

This study also revisits the widespread assumption that financial constraints are the main barrier to green technology adoption in emerging markets (Ayyagari et al., 2008; Beck et al., 2015). While information asymmetries often restrict credit for high-risk green investments (Bircan &

De Haas, 2020; Myers & Majluf, 1984), the innovation paradox framework argues that reported financial obstacles may reflect deeper managerial weaknesses (Cirera & Maloney, 2017). Firms with weak organizational capabilities may struggle to design bankable projects and, therefore, misattribute technological stagnation to credit scarcity. Recent evidence on industry 4.0 adoption supports this view, showing that human capital and organizational readiness often matter more than financial barriers (Hoang-Duc et al., 2026). This paper extends that argument to environmental adaptation.

Empirically, the study uses the latest World Bank Enterprise Surveys data for 2023. The analysis combines a binary green adoption indicator with a continuous composite green index to capture both the presence and depth of environmental engagement. To address endogeneity, the study applies the heteroskedasticity-based instrumental variable approach developed by (Lewbel, 2012), exploiting cross-firm variation in managerial capabilities as the basis for identification. Propensity score matching (PSM) is also used to adjust for observable differences between exporting and non-exporting firms.

The study addresses three research questions. First, it compares the relative importance of physical climate shocks and managerial capabilities in explaining green technology adoption. Second, it tests whether GVC participation creates a state of static compliance by examining the interaction between export status and climate shocks. Third, it assesses whether financial constraints retain their explanatory power after controlling for management quality. In addition, the analysis accounts for firms' digital readiness in line with the twin-transition paradigm and considers the role of country-level institutional quality in shaping these firm-level mechanisms.

The remainder of the paper is organized as follows. Section 2 develops the theoretical framework and hypotheses. Section 3 presents the data, variables, and identification strategy. Section 4 reports the baseline estimates, interaction models and robustness checks. Section 5 discusses the mechanisms behind the empirical findings. Section 6 concludes with policy implications for industrial upgrading and climate resilience.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2. 1. PHYSICAL CLIMATE RISKS AND FIRM ADAPTATION

The first explanation of firm responses to climate risk draws on the attention-based view of the firm (Ocasio, 1997, 2011). This perspective assumes that managerial attention is limited and allocated according to organizational priorities. Under normal conditions, environmental concerns are often subordinated to short-term profitability. Extreme weather events, such as floods and hurricanes, may therefore act as environmental jolts that disrupt inertia and force firms to reconsider climate-related risks (Brielmaier & Friesl, 2023; Meyer, 1982). (Hirschmann et al., 2025) described this process through the concept of situated attention, whereby direct physical damage elevates climate risk within the managerial agenda.

However, the movement from risk awareness to structural action is not automatic. Behavioral economics shows that firms exposed to severe shocks may respond through cognitive biases such as loss aversion, framing effects, and short-term risk avoidance (Mazutis & Eckardt, 2017; Tversky & Kahneman, 1981, 1991). In developing economies, these limitations are intensified by scarce financial and organizational slack. Unlike firms in advanced economies with stronger insurance and credit markets, ASEAN firms may experience climate damage as an immediate drain on cash flow. As a result, they may prioritize repair and survival over long-term investment in green technologies (Cassar et al., 2017).

This tension suggests that climate shocks can stimulate green action, but their effect is likely to be limited. They may act as catalysts, but not as sufficient drivers of structural transformation.

H_1: experiencing physical damage from extreme weather events positively affects the probability of adopting green actions. However, this effect is bounded and is expected to be smaller than the effect of internal managerial capabilities.

2. 2. MANAGERIAL CAPITAL AND GREEN DYNAMIC CAPABILITIES

A second explanation emphasizes the internal capabilities of firms. Building on the resource-based view, Bloom and Van Reenen (2007) conceptualizes management as a technology. Core practices such as target setting, performance monitoring, and human resource management constitute intangible capital that shapes a firm's ability to absorb and implement new technologies.

In developing economies, this mechanism is central to the innovation paradox (Cirera & Maloney, 2017). According to this framework, slow technological upgrading is caused not only by shortages of physical capital but also by weak managerial capabilities. Evidence from Vietnam confirms that human capital and organizational readiness may constrain innovation more strongly than financial barriers (Comin et al., 2021; Hoang-Duc et al., 2026).

Applied to environmental adaptation, these capabilities can be understood as green dynamic capabilities. They refer to a firm's ability to identify climate risks, recognize green investment opportunities, and reconfigure operations accordingly (Asiedu et al., 2025; Haug et al., 2025; Teece et al., 1997). Strong management systems improve information processing, reduce cognitive inertia after climate shocks, and help firms transform external GVC requirements into substantive process innovation (Essuman et al., 2022). Managerial skills are therefore expected to be a primary driver of corporate greening.

H_2: Management quality has a positive, structurally dominant effect on the adoption of green practices. Its marginal effect is expected to exceed that of exogenous climate shocks.

2. 3. GVC PARTICIPATION AND ENVIRONMENTAL UPGRADING

The third mechanism concerns market integration, particularly export participation. Institutional theory suggests that firms operating in international markets face coercive pressures from buyers, regulators, and global standards (DiMaggio & Powell, 1983). Similarly, the learning-by-exporting hypothesis argues that exposure to global customers can facilitate the transfer of technologies, quality standards, and management practices (Atkin et al., 2017; Avenyo & Tregenna, 2025; Neffati and Imen Khemiri, 2025). In the environmental domain, this may lead to environmental upgrading, as suppliers adopt green practices to meet buyer requirements (De Marchi & Alford, 2022).

Yet the depth of such upgrading remains contested. Many ASEAN export industries, including garments, footwear, and electronics assembly, are embedded in buyer-driven value chains, where lead firms control standards and supplier requirements (Gereffi, 2019; Humphrey & Schmitz, 2002). These lead firms often transfer compliance risks to suppliers without providing sufficient financial or technological support (Dallas et al., 2019; Ponte, 2022).

This can create a compliance plateau. Suppliers may adopt green practices mainly to satisfy audits and preserve contracts, rather than to develop genuine environmental capabilities. Industry evidence, including (Better Factories Cambodia, 2024), suggests that buyer pressure often produces codified compliance rather than deeper upgrading. Moreover, learning-by-exporting is not automatic; without absorptive capacity, firms may remain locked into low-value-added activities with limited room for strategic adaptation (Avenyo & Tregenna, 2025).

Therefore, export participation is expected to increase the baseline probability of adopting green practices, but not necessarily to strengthen firms' responsiveness to climate shocks.

H_3: Export participation has a positive direct effect on green practice adoption by establishing a higher compliance baseline. However, export status is not expected to significantly moderate the effect of climate shocks; exporters are therefore no more responsive to natural disaster risks than domestic firms.

2. 4. RE-EVALUATING THE FINANCIAL CONSTRAINT

The final theoretical issue concerns access to finance. In development economics, credit shortages are often identified as a central barrier to technological upgrading in emerging markets (Ayyagari et al., 2008; Beck et al., 2015). This argument is based on information asymmetries: lenders may be reluctant to finance green investments because of uncertain returns, high perceived risk, and long payback periods (Bircan & De Haas, 2020; Myers & Majluf, 1984).

However, the innovation paradox questions this finance-focused explanation (Cirera & Maloney, 2017). It proposes that apparent financial constraints often stem from weaker managerial skills. Companies lacking effective internal planning might struggle to develop credible, bankable green projects or to supply trustworthy information to outside financiers. Consequently, managers may blame stagnation on a lack of credit, while the real issues relate to organizational capacity.

Evidence on Industry 4.0 adoption in Vietnam supports this interpretation, showing that human resources and organizational readiness can outweigh financial barriers (Hoang-Duc et al., 2026). This study applies the same logic to green adaptation and tests whether financial constraints remain significant after accounting for management quality.

H_4: Once management quality is controlled for, self-reported financial constraints will no longer have a statistically significant negative effect on the probability of adopting green actions.

3. DATA AND METHODOLOGY

3. 1. DATA SOURCE AND SAMPLE CONSTRUCTION

The empirical analysis uses firm-level microdata from the latest World Bank Enterprise Surveys, conducted in 2023. This survey wave is particularly suitable because it includes both the innovation and management module and the green economy module. Their combination allows direct measurement of management practices, digital readiness, and environmental behavior, reducing reliance on indirect proxies used in earlier studies.

The sample covers four ASEAN economies: Cambodia, Indonesia, the Philippines, and Vietnam. These countries provide a relevant setting because they differ in their levels of GVC integration while sharing exposure to physical climate risks. It was constructed through a structured filtering process. Observations with missing or anomalous values for key variables, including revenue, employment, and management practices, were excluded. Microenterprises with fewer than five employees were also excluded to ensure comparability with firms that have formal organizational structures.

After applying these criteria, the final cross-sectional sample consists of 2,404 formal enterprises, including 2,102 manufacturing firms and 302 service firms. The WBES uses stratified random sampling by firm size, sector, and geographic region, supporting national-level representativeness across the surveyed economies.

Table 1. Descriptive Statistics

	(1)	(2)	(3)	(4)	(5)
Variables	N	mean	sd	min	max
Green Action	2,404	0.391	0.488	0.000	1.000
Physical climate shock	2,404	0.067	0.250	0.000	1.000
Managerial Quality	2,404	0.499	0.270	0.000	1.000
Export Status	2,404	0.169	0.375	0.000	1.000
Financial Obstacles	2,404	1.047	1.103	0.000	4.000
Firm Size (Log)	2,404	3.780	1.551	0.693	9.393
Firm Age	2,404	18.895	13.660	1.000	113.000
ICT Adoption	2,404	0.592	0.492	0.000	1.000

Source: Author's calculations using Stata 18 based on World Bank Enterprise Surveys (2023)

Table 2. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
(1) Green Action	1.000							
(2) Physical climate shock	0.099***	1.000						
	(0.000)							
(3) Managerial quality	0.331***	0.030	1.000					
	(0.000)	(0.144)						
(4) Export status	0.228***	0.008	0.148***	1.000				
	(0.000)	(0.694)	(0.000)					
(5) ICT adoption	0.218***	0.070***	0.274***	0.142***	1.000			
	(0.000)	(0.001)	(0.000)	(0.000)				
(6) Financial obstacles	0.006	0.023	0.065***	0.014	0.051**	1.000		
	(0.757)	(0.252)	(0.001)	(0.487)	(0.012)			
(7) Firm size (Log)	0.424***	0.045**	0.278***	0.448***	0.355***	-0.003	1.000	
	(0.000)	(0.027)	(0.000)	(0.000)	(0.000)	(0.870)		
(8) Firm age	0.066***	0.133***	0.030	-0.016	0.121***	0.041**	0.107***	1.000
	(0.001)	(0.000)	(0.146)	(0.437)	(0.000)	(0.045)	(0.000)	

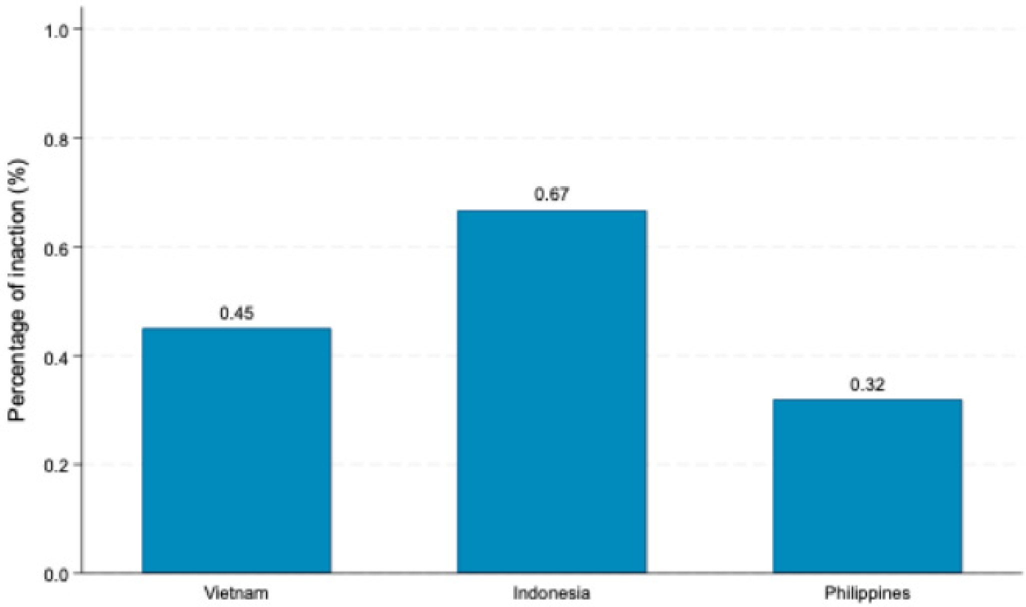
Note: *** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations using Stata 18 based on World Bank Enterprise Surveys (2023)

3. 2. OPERATIONALIZATION OF VARIABLES

The empirical analysis uses a set of firm-level indicators, with summary statistics and pairwise correlations reported in Tables 1 and 2, respectively. To capture substantive environmental behavior rather than formal compliance alone, the dependent variable, green_action, is defined as a binary indicator. Based on the WBES Green Economy Module, it takes the value 1 when a firm actively monitors energy consumption or sets specific targets to reduce energy use and carbon emissions, and 0 otherwise (Figure 1).

Figure 1. The green action gap across ASEAN-4 countries



Notes: The Green Action Gap is defined as the percentage of enterprises that reported experiencing physical damages from climate-related shocks (Shock = 1) but failed to implement any substantive green adaptation actions (e.g., energy monitoring or emission targets)

Source: Author's calculation based on the World Bank Enterprise Surveys (2023)

The explanatory framework is based on three key variables representing the study's theoretical triad of drivers. First, physical climate risk, shock, is measured as a dummy variable indicating whether the firm experienced physical damage to assets or inventory because of extreme weather events during the previous three years. Second, internal capabilities (Managerial Quality - mgt_score) are operationalized following (Bloom & Van Reenen, 2007) by aggregating the standardized Z-scores of three core management practices: performance monitoring, target setting, and employment incentives. Third, market-driven pressure, Export Status (is_exporter), is defined as a binary variable equal to 1 when direct and indirect exports account for at least 10% of the firm's total annual sales.

To isolate these effects, the baseline models include a set of firm-level control variables. Firm size, Firm Size (Log) (log_size), is calculated as the natural logarithm of the number of full-time permanent employees, while firm age, firm_age, captures the total number of years the enterprise has been in operation. To test the financial irrelevance hypothesis, H_4, the model includes a financial constraint indicator, fin_obst, which measures the self-reported severity of access-to-finance obstacles on a standard five-point scale ranging from 0 to 4.

All estimations further include country- and sector-specific fixed effects to absorb unobserved macroeconomic and industry-level heterogeneity. In addition, to account for the twin-transition mechanism linking green and digital transformation, the analysis includes a digital readiness indicator, ICT Adoption (ict_adoption). This binary variable takes the value of 1 if the enterprise has its own business website, serving as a proxy for the firm's basic technological infrastructure.

3. 3. ECONOMETRIC STRATEGY

3. 3. 1. BASELINE SPECIFICATION

To assess the relative effects of physical climate risks, H_1, managerial capabilities, H_2, and market pressures, H_3, the probability of adopting green actions is estimated using the following baseline probit model:

$$Pr\,(Y_{isc} = 1|W) = \Phi(\alpha + \beta_1 Shock_{isc} + \beta_2 Mgt\_score_{isc} + \beta_3 Exporter_{isc} + X`_{isc}\gamma + \delta_s + \eta_c + \epsilon_{isc}) \quad (1)$$

Where Y_{isc} denotes the binary green action indicator, green_action, for firm i operating in sector s and country c. $\Phi(.)$ Represents the cumulative standard normal distribution function. X_{isc} is the vector of firm-level control variables, including firm size, firm age, and financial constraints. The terms δ_s and η_c denote sector and country fixed effects, respectively, which are included to absorb unobserved industry-specific and macroeconomic heterogeneity.

3. 3. 2. MODERATION EFFECTS

To differentiate between superficial compliance and structural resilience, we augment the baseline specification with interaction terms to test for slope effects:

$$Pr\,(Y_{isc} = 1|W) = \Phi(\ldots + \theta_1(Shock_{isc} \times Exporter_{isc}) + \theta_2(Shock_{isc} \times Mgt\_Score_{isc}) + \ldots) \quad (2)$$

The parameter θ_1 tests the GVC static compliance hypothesis (H_3), which posits that exporters are not intrinsically more responsive to shocks than non-exporters. Concurrently, θ_2 captures the moderating role of managerial capabilities, testing the absorptive capacity mechanism.

3. 3. 3. ENDOGENEITY AND IDENTIFICATION STRATEGY

Cross-sectional estimates can be biased by endogeneity stemming from omitted variables and measurement errors. To enhance causal inference, we utilize (Lewbel, 2012)'s heteroskedasticity-based IV method, implemented via the Generalized Method of Moments (GMM). This approach generates internal instruments by leveraging heteroskedasticity in the first-stage regression of the endogenous variable.

$$Mgt\_Score_{isc} = Z`_{isc}\pi + \upsilon_{isc} \quad (3)$$

The generated instruments are defined mathematically as:

$$IV_{isc} = (Z_{isc} - \bar{Z})\hat{\upsilon}_{isc} \quad (4)$$

where Z_{isc} is the vector of exogenous covariates, $\bar{Z}$ is their sample mean, and $\hat{\upsilon}_{isc}$ represents the estimated first-stage residuals. Identification is achieved without relying on external instruments, provided that the Breusch-Pagan test confirms the presence of heteroskedasticity ($Cov(Z,v^2) \neq 0$).

Furthermore, to mitigate self-selection bias associated with export market entry, we deploy PSM. Using a Kernel matching algorithm to ensure covariate balance, we estimate the Average Treatment Effect on the Treated (ATT):

$$ATT = E[Y_{1i} - Y_{0i} \mid Exporter_i = 1, \rho(X_{isc})] \quad (5)$$

where $\rho(X_{isc})$ is the estimated propensity score of participating in export markets conditional on observed characteristics. Additionally, Harman's single-factor test is executed using unrotated principal component analysis to rule out Common Method Bias (CMB).

3. 3. 4. COUNTERFACTUAL SIMULATION

To translate parameter estimates into quantifiable economic magnitudes, we compute Average Marginal Effects (AMEs) and simulate counterfactual adjusted predictive margins:

$$E(Y|Shock = k) = \frac{1}{N}\sum_{i=1}^{N} \Phi(\hat{\alpha} + \hat{\beta}_1 k + \hat{\beta}_2\, Mgt\_Score_{isc} + \ldots) \quad (6)$$

This formulation yields the expected probability of green adaptation under counterfactual scenarios of capability upgrading and varying degrees of physical risk exposure, holding other covariates at their observed distributions.

4. EMPIRICAL RESULTS

This section presents the empirical findings. The analysis proceeds in three stages. First, baseline probit estimations and average marginal effects are used to assess the main drivers of green action. Second, interaction models and sectoral subsample analyses are employed to examine moderation effects and financial sensitivities. Third, robustness checks are performed using Lewbel (2012)'s instrumental-variables approach and propensity score matching (PSM) to address potential endogeneity and selection bias.

4. 1. BASELINE DETERMINANTS: THE RELATIVE IMPACTS OF SHOCK, SKILLS, AND SALES

To quantify the magnitude of the core mechanisms, Table 3 reports the baseline Probit estimates alongside the interaction models. To facilitate economic interpretation, Table 4 presents the corresponding Average Marginal Effects (AMEs).

Table 3. Determinants of green action

VARIABLES	(1) Main Probit	(2) Twin Transition	(3) Sales Interaction	(4) Skills Interaction
Physical Climate Shock	0.404***	0.404***	0.365***	0.237
	(0.115)	(0.115)	(0.124)	(0.275)
Managerial quality	1.099***	1.155***	1.100***	1.077***
	(0.126)	(0.182)	(0.126)	(0.130)
ICT Adoption	0.124*	0.177	0.125*	0.125*
	(0.068)	(0.148)	(0.068)	(0.068)
ICT Adoption × Managerial quality	-	-0.102	-	-
		(0.250)		
Export Status	0.292***	0.292***	0.273***	0.293***
	(0.090)	(0.090)	(0.092)	(0.090)
Export Status × Physical Climate Shock	-	-	0.233	-
			(0.335)	
Physical climate shock × Managerial quality	-	-	-	0.313
				(0.260)
Financial Obstacles	-0.024	-0.024	-0.024	-0.024
	(0.028)	(0.028)	(0.028)	(0.028)
Firm Size (Log)	0.263***	0.263***	0.264***	0.263***
	(0.028)	(0.028)	(0.027)	(0.028)
Firm Age	0.007***	0.007***	0.007***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	2,404	2,404	2,404	2,404
Country fixed effects	YES	YES	YES	YES
Sector fixed effects	YES	YES	YES	YES

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Cambodia and Sector Group 1 serve as the reference categories, respectively.

Source: Author's calculations using Stata 18 based on World Bank Enterprise Surveys (2023)

Table 4. Average marginal effects (AME) on green action

Variables	AME
Physical Climate Shock	0.111***
	(0.033)
Managerial quality	0.287***
	(0.032)
Export Status	0.080***
	(0.025)
ICT Adoption	0.033*
	(0.018)
Financial Obstacles	-0.006
	(0.007)
Firm Size (Log)	0.069***
	(0.007)
Firm Age	0.002***
	(0.001)
Sector group = 2	0.034
	(0.027)
Country: Vietnam	-0.588***
	(0.030)
Country: Indonesia	-0.581***
	(0.030)
Country: Philippines	-0.425***
	(0.032)
Observations	2,404

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Cambodia and Sector Group 1 serve as the reference categories, respectively

Source: Author's calculations using Stata 18 based on World Bank Enterprise Surveys (2023)

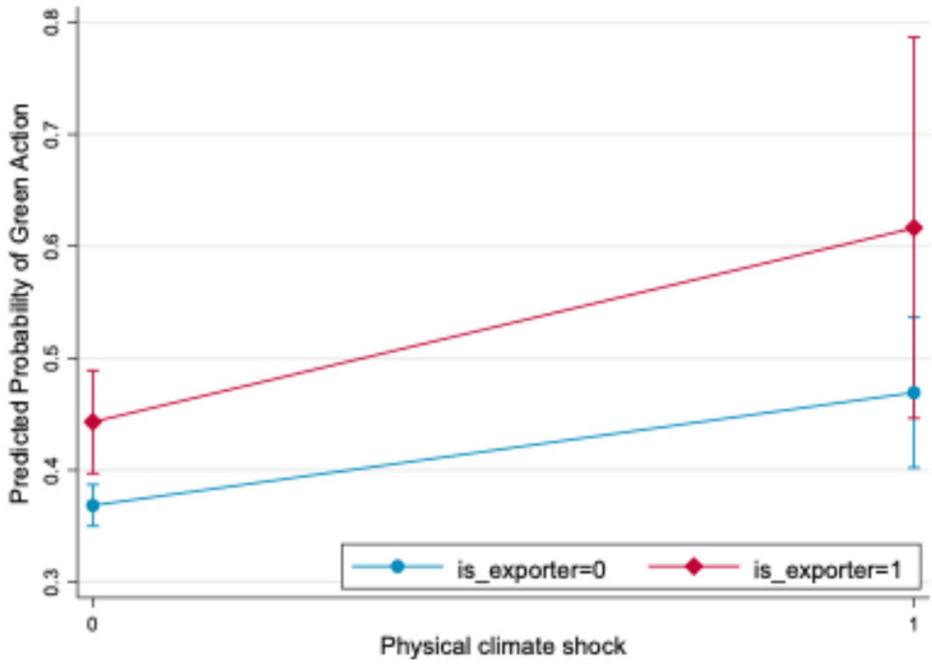
The statistical results in Table 4 show that all main independent variables are statistically significant at the 1% level, although their economic magnitudes differ considerably.

First, with respect to physical risk, H_1, firms that experienced physical damage from extreme weather events report an average marginal effect of 0.111, $p < 0.01$. This means that exposure to a climate shock is associated with an 11.1 percentage point increase in the probability of adopting green practices.

Second, regarding internal capabilities, H_2, the management quality score produces the largest marginal effect, AME = 0.287, $p < 0.01$. A one-standard-deviation increase in management quality is therefore associated with a 28.7 percentage point increase in the probability of green action. Column 2 of Table 3 further includes the interaction between management skills and digital readiness, measured through ICT adoption. While ICT adoption maintains a positive coefficient (0.177, $p > 0.10$), its interaction with the management score is not statistically significant. This confirms that the main effect of management quality remains structurally dominant.

Third, regarding market forces, H_3, Column 3 of Table 3 tests the interaction between physical shocks and export status (Export Status × Physical Climate Shock). Export status has a positive direct effect, AME = 0.080, $p < 0.01$, indicating that exporters are more likely to adopt green practices than domestic firms. However, the interaction term is not statistically significant, $p > 0.10$. This absence of a slope effect suggests that exporters do not respond more strongly to climate shocks than non-exporters. The near-parallel trajectories shown in Figure 2 visually support this interpretation.

Figure 2. The moderating effect of export status on climate shock responses



Note: The plot displays the predicted probabilities of green action with 95% confidence intervals across firms with and without physical climate shocks. The aligned, near-parallel trajectories visually represent the statistically insignificant interaction term between export status and physical climate shocks (p>0.10).

Source: Author's estimation based on the interaction model

4. 2. SECTORAL HETEROGENEITY AND THE SENSITIVITY OF FINANCIAL OBSTACLES

To empirically examine the sensitivity of financial barriers conditional on managerial capabilities (H_4), Table 5 stratifies the estimations across two structural cohorts: Manufacturing and Services.

Table 5. Sectoral heterogeneity: manufacturing vs. services

VARIABLES	(1) Manufacturing	(2) Services
Physical Climate Shock	0.369***	0.526
	(0.121)	(0.332)
Managerial quality	1.151***	0.946**
	(0.133)	(0.370)
Export Status	0.239***	1.415***
	(0.092)	(0.396)
Financial Obstacles	-0.010	-0.110
	(0.029)	(0.090)
Firm Size (Log)	0.273***	0.349***
	(0.028)	(0.088)
Firm Age	0.007***	0.001
	(0.003)	(0.008)
Constant	-0.449**	-2.316***
	(0.180)	(0.303)
Country Fixed Effects	YES	YES
Observations	2,102	302

Note: Robust standard errors in parentheses. *** p<0.01, p<0.05, * p<0.1. Country fixed effects are included in all specifications. Cambodia serves as the reference country category. In Column 2 (Services), certain country indicators may be dropped automatically by Stata due to exact collinearity within the smaller sub-sample strata.

Source: Author's calculations using Stata 18 based on World Bank Enterprise Surveys (2023)

In preliminary specifications that exclude the management score, financial obstacles show a statistically significant negative association with green adoption, although these results are not reported for brevity. However, once management quality is added to the full specification in Table 5, the coefficient on financial obstacles declines substantially and loses statistical significance in both the manufacturing subsample, -0.01, $p > 0.10$, and the services subsample, -0.110, $p > 0.10$. By contrast, the management score remains stable and statistically significant across both sectors, with coefficients of 1.151 ($p < 0.01$) and 0.946 ($p < 0.05$), respectively.

This shift in the estimated parameters provides evidence in support of H_4, suggesting that financial constraints may partly reflect underlying managerial capability gaps rather than serving as an independent structural barrier to green adoption.

4. 3. ROBUSTNESS CHECKS AND CAUSAL INFERENCE

4. 3. 1. ENDOGENEITY OF MANAGEMENT QUALITY: LEWBEL (2012) IV GMM

To mitigate potential endogeneity arising from omitted-variable bias or measurement error in the management construct, Table 6 reports GMM estimates using heteroskedasticity-based instruments (Lewbel, 2012).

Table 6. Robustness check - Lewbel IV GMM estimate

VARIABLES	IV: Management
Managerial quality	0.145
	(0.126)
Physical Climate Shock	0.138***
	(0.039)
Export Status	0.078***
	(0.027)
ICT Adoption	0.038
	(0.024)
Firm Size (Log)	0.077***
	(0.009)
Firm Age	0.003***
	(0.001)
Country: Vietnam	-0.582***
	(0.033)
Country: Indonesia	-0.564***
	(0.030)
Country: Philippines	-0.401***
	(0.035)
Constant	0.405***
	(0.061)
Sector Fixed Effects	YES
Observations	2,404
Method	Lewbel (2012) IV GMM
Instrumental variable diagnostics	
Underidentification test (p-value)	0.000
Weak ID test (Kleibergen-Paap rk Wald F-stat)	31.81
Hansen J statistic (p-value)	0.700

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Cambodia and Sector Group 1 serve as the reference categories for the country and sector dummies, respectively.

Source: Author's calculations using Stata 18 based on World Bank Enterprise Surveys (2023)

The lower panel of Table 6 supports the validity of the identification strategy. Diagnostic tests confirm the presence of heteroskedasticity, satisfying the key condition for generating Lewbel-type instruments. The economic rationale is that, in emerging ASEAN economies, management practices vary substantially across firms of different sizes and ages. This structural variation provides a suitable internal source for instrument construction.

The Kleibergen-Paap Wald F-statistic, 31.81, exceeds the Stock-Yogo 10% critical value, indicating that the instruments are sufficiently strong. In addition, the Hansen J-test, $p = 0.700$, does not reject the validity of the overidentifying restrictions, supporting the exogeneity of the instruments.

In the second-stage estimates, while the coefficient for management quality maintains its positive direction (0.145), it loses statistical significance. This shift reflects the well-known efficiency trade-off in Lewbel's approach, where generating internal instruments often inflates standard errors. Importantly, even after controlling for ICT adoption, coefficient = 0.038, $p > 0.10$, the effects of Physical Climate Shock (0.138) and Export Status (0.078) remain stable and statistically significant at the 1% level. This confirms that while the point estimate of managerial capabilities is sensitive to endogeneity controls, the positive orientation of internal capabilities and the robust impact of external drivers are sustained.

4. 3. 2. SELECTION BIAS OF EXPORTING: PSM

To address self-selection bias associated with export market entry, Table 7 reports the Average Treatment Effect on the Treated (ATT) utilizing a Kernel matching algorithm (Epanechnikov).

Table 7. Propensity Score Matching Results (Robustness Check)

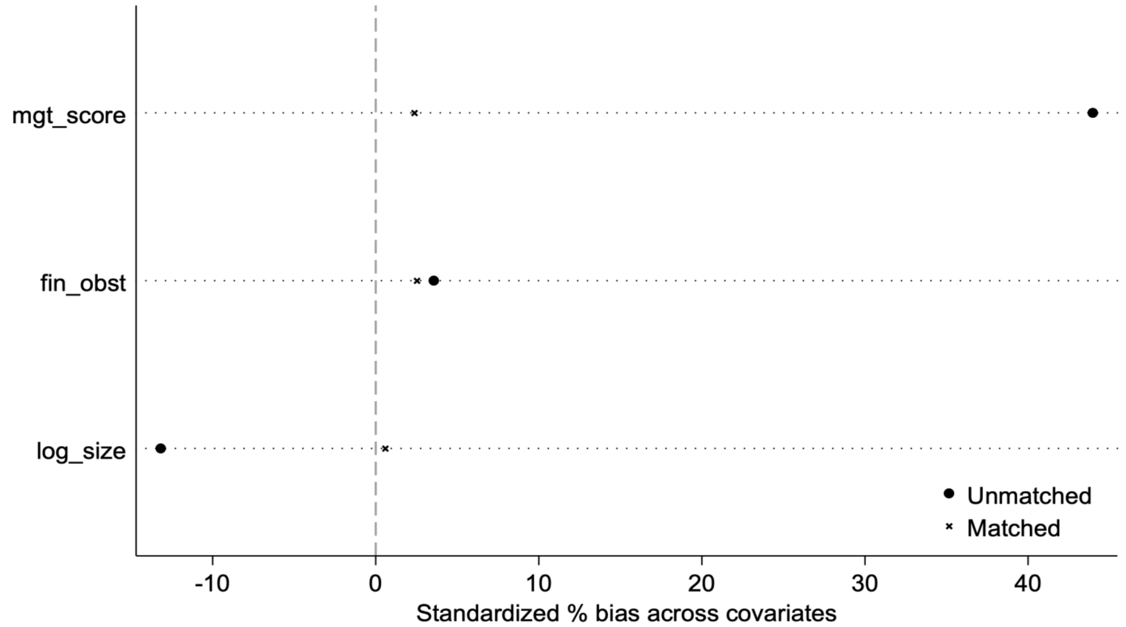
Outcome Variable	Treated	Controls	ATT	T-stat	Conclusion
Green Action	0.628	0.500	0.128***	3.84	Significant

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Method: Kernel Matching (Epanechnikov). ATT = Average Treatment Effect on the Treated. The matching protocol balances observable firm characteristics, including firm size, financial constraints, ICT adoption, as well as sector and country fixed effects

Source: Author's calculations using Stata 18 based on World Bank Enterprise Surveys (2023)

Post-matching estimates produce an average treatment effect on the treated, ATT, of 0.128, which is statistically significant at the 1% level, $t = 3.84$. This indicates that, after balancing observable firm characteristics, including firm size, financial constraints, ICT adoption, and sector-country fixed effects, exporting firms remain 12.8 percentage points more likely to adopt green actions than comparable non-exporting firms in the matched control group (Figure 3).

Figure 3. Covariate balance check for propensity score matching



Notes: The dot chart visualizes the standardized percentage bias for covariates (firm size, financial obstacles, sector, and country) between the treated (exporters) and control groups. Crosses (X) represent the matched sample, while circles (O) represent the unmatched sample. The concentration of crosses near the zero vertical line indicates a highly successful balance of covariates post-matching.

Source: Author's estimation using Kernel Matching (Epanechnikov)

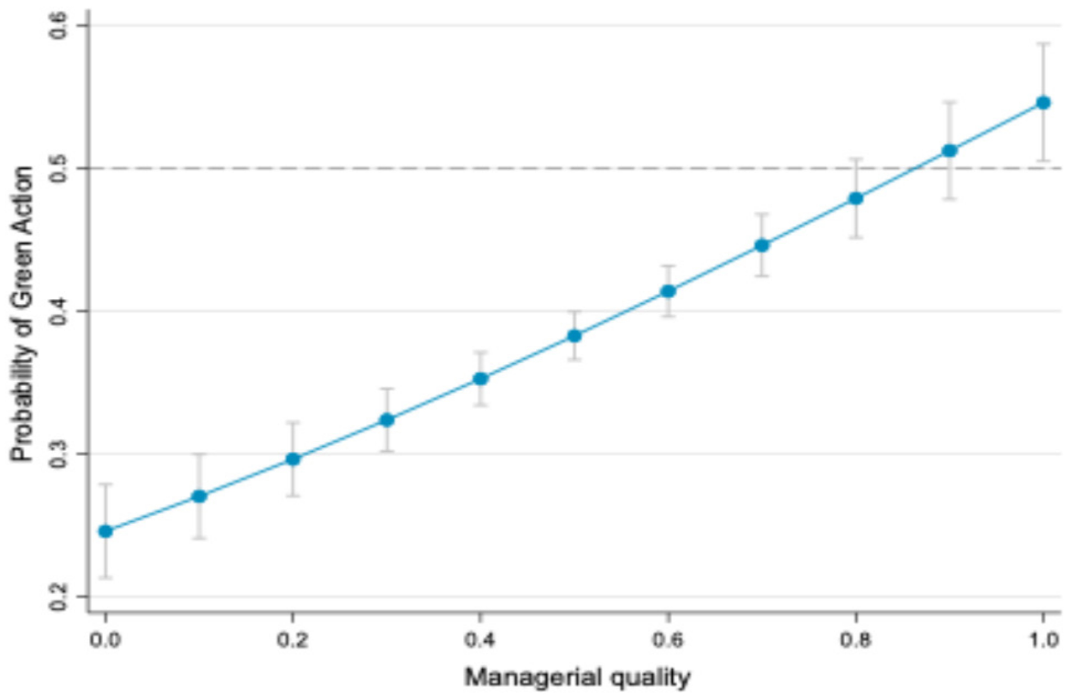
4. 4. COUNTERFACTUAL SIMULATION

To convert the econometric estimates into measurable economic effects, adjusted predictive margins are calculated to simulate the counterfactual probability of green adaptation for a representative ASEAN firm under different structural conditions. These projections are presented through the adaptation curves in Figures 4, 5 and 6.

The simulation identifies three main scenarios:

(i) Scenario A, business-as-usual: When a firm operates at the sample mean of management quality (score = 0.499) and has not experienced a physical climate shock, the predicted probability of green adaptation is approximately 37.3%.

Figure 4. Predictive Margins of Green Adaptation by Managerial Quality

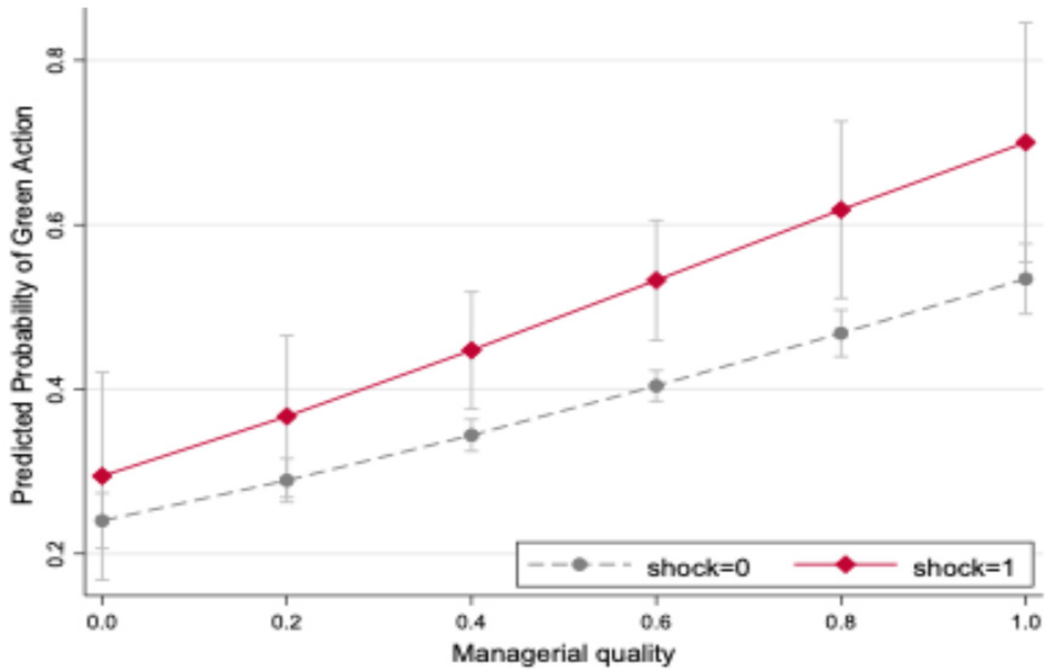


Note: The line illustrates the baseline predictive margins of corporate green actions across the full continuum of managerial quality, accompanied by 95% confidence intervals. The horizontal dashed line indicates the 0.5 probability threshold.

Source: Author's estimation based on the baseline Probit model.

(ii) Scenario B (the shock effect): Holding management quality constant at the mean, if the enterprise is subjected to a physical climate disaster (Shock = 1), the adaptation probability increases to 49.2%, yielding a net marginal gain of +11.9 percentage points.

Figure 5. The moderating effect of management quality on climate shocks



Note: This figure maps the interaction effect between physical climate shocks and managerial quality on a firm's predicted probability of green action, plotted with 95% confidence intervals.

Source: Author's estimation based on the baseline Probit model

(iii) Scenario C (the skills upgrade): In the absence of a physical shock, if the firm's management quality is elevated from the mean to an advanced level (+1.5 SD, score = 0.904), the probability surges to 50.5%, generating a net gain of +13.2 percentage points.

Comparing these counterfactuals reveals that upgrading organizational soft capabilities (Scenario C) yields an adaptation magnitude that exceeds the exogenous stimulus of a natural disaster (Scenario B). These quantified margins firmly establish internal management quality as the a powerful parameter in unlocking structural green adaptation.

5. DISCUSSION

5. 1. MANAGERIAL CAPABILITIES AND THE ADAPTATION PARADOX

The most important empirical finding of this study is that internal managerial capabilities, skills, play a stronger role than exogenous physical climate risks, shock, in explaining green adaptation. The marginal effect of management quality, AME = 0.287, is substantially larger than the effect of climate-related damage, AME = 0.111. This hierarchy helps explain the adaptation paradox in developing economies: high exposure to physical climate risks does not automatically lead to proportional investment in adaptation.

This finding can be interpreted through the attention-based view and organizational microfoundations. From the abv perspective, natural disasters act as environmental jolts that redirect managerial attention toward risk mitigation (Hirschmann et al., 2025; Ocasio, 1997). However, behavioral economics suggests that intense negative shocks may also produce cognitive freeze, avoidance behavior, or short-term coping responses when firms lack the internal capacity to act strategically.

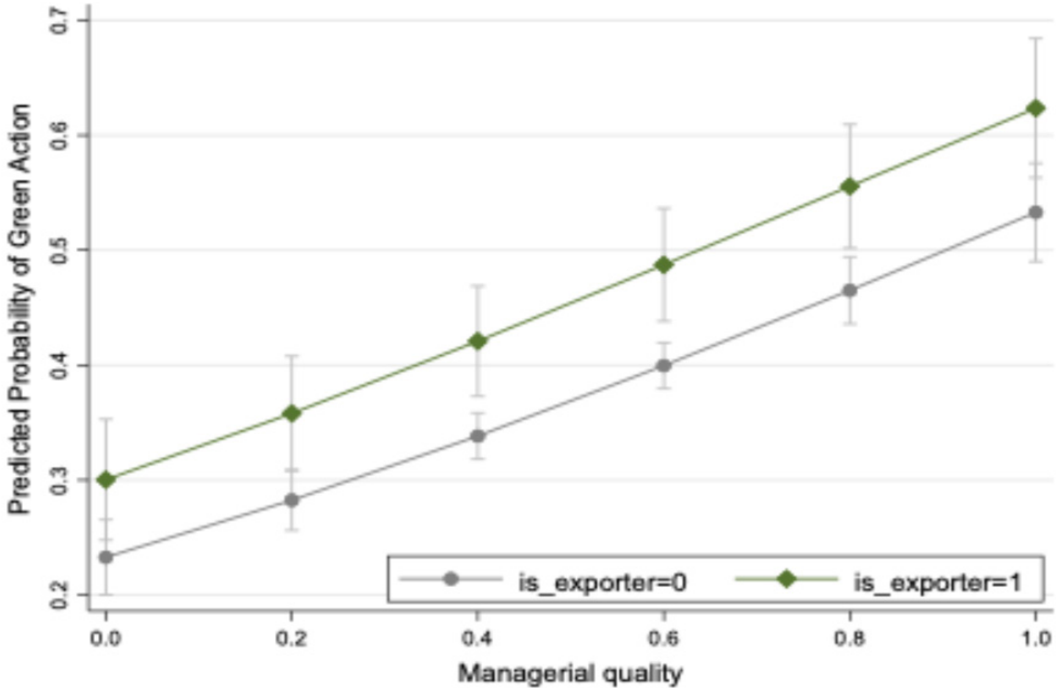
High-quality management practices help overcome this constraint. Rather than being merely an operational style, management can be understood as a core organizational technology (Bloom et al., 2013; Bloom & Van Reenen, 2007). In the environmental domain, this corresponds to green dynamic capabilities, which enable firms to identify climate risks, recognize efficiency opportunities, and reconfigure production processes (Asiedu et al., 2025; Haug et al., 2025; Teece et al., 1997). Practices such as data monitoring and target setting allow managers to assess environmental risks more objectively and move beyond reactive coping. The econometric results support micro-level evidence from Vietnam (Comin et al., 2021) and suggest that technological inertia in response to climate shocks is primarily rooted in a managerial capability gap. Accordingly, micro-managerial skills determine whether firms pursue proactive structural adaptation or remain limited to short-term responses.

5. 2. GLOBAL VALUE CHAINS AND THE STATIC COMPLIANCE

The second theoretical contribution concerns the contested role of GVC integration. The results reveal a clear distinction between level and slope effects. Export status has a positive direct effect on green actions, indicating that exporters are more likely to meet baseline environmental requirements. However, the interaction between export status and climate shocks is not statistically significant, meaning that exporters are not more dynamically responsive to physical climate risks than domestic firms. This finding provides empirical support for the phenomenon of static GVC compliance.

Traditional development literature often assumes a linear learning-by-exporting mechanism, whereby exposure to international markets strengthens absorptive capacity and supports technology transfer (Atkin et al., 2017). However, GVC governance in ASEAN is largely shaped by buyer-driven chains (Gereffi, 2019; Humphrey & Schmitz, 2002). In these asymmetric networks, lead firms from developed economies impose strict codes of conduct on suppliers, requiring them to meet basic environmental standards as a condition for maintaining market access (De Marchi & Alford, 2022; Ponte, 2022).

Figure 6. The export premium: global value chains vs. domestic market orientation



Note: The plot depicts the persistent "export premium" by contrasting the predicted green action probabilities of export status against purely domestic firms across different levels of managerial capabilities, backed by 95% confidence intervals.

Source: Author's estimation based on the baseline Probit model

Industry evidence, including Better Factories Cambodia (2024)'s compliance reviews, together with recent theoretical critiques (Avenyo & Tregenna, 2025), helps explain the behavioral pattern identified in our model. The positive level effect reflects codified compliance: a tick-box response aimed at satisfying external audits rather than embedding genuine process innovation. Since many local suppliers remain locked into low-margin assembly activities, they often lack the financial slack and strategic autonomy required to develop structural resilience. As a result, when a climate shock occurs, their adaptive capacity is not significantly stronger than that of non-exporting firms. Market integration therefore establishes an environmental floor, but it does not necessarily function as a ladder toward dynamic climate adaptation.

5. 3. FINANCIAL CONSTRAINTS AS A SYMPTOM OF MANAGERIAL DEFICIT

From a policy design perspective, the loss of statistical significance for self-reported financial constraints after controlling for managerial quality challenges the finance-centered view of green technology adoption. Although credit scarcity is often presented as the main barrier to technological upgrading in emerging markets (Ayyagari et al., 2008), our findings suggest that this perception may partly reflect managerial attribution bias.

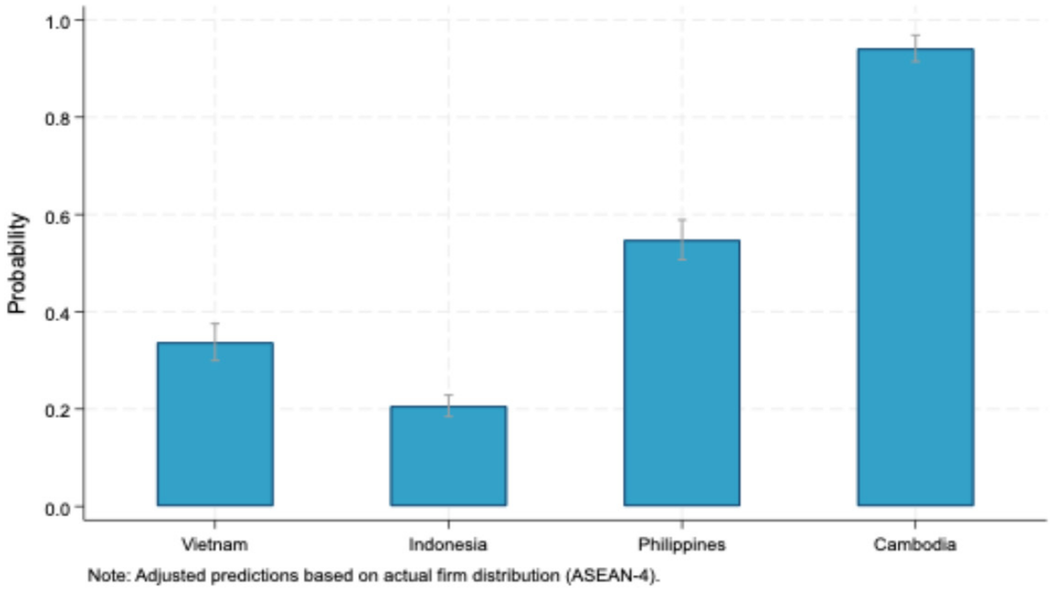
Using the innovation paradox framework (Cirera & Maloney, 2017), we interpret subjective financial constraints as a symptom rather than a root cause. Green investments are often affected by information asymmetries, leading financial institutions to require credible evidence of project viability (Bircan & De Haas, 2020; Myers & Majluf, 1984). Firms with weak managerial systems, limited performance tracking, and poor strategic forecasting may struggle to prepare bankable green projects or send reliable signals to external financiers.

As a result, managers may attribute technological stagnation to credit rationing, while the deeper obstacle lies in internal organizational capability. This interpretation is consistent with recent evidence on the adoption of fourth industrial revolution technologies in Vietnam, where human capital and organizational readiness are found to matter more than financial barriers (Hoang-Duc et al., 2026). Therefore, subsidized finance alone is unlikely to drive a substantive environmental transition unless combined with investments in intangible managerial capital.

5. 4. THE TWIN TRANSITION AND INSTITUTIONAL CONTEXT

While the econometric estimates show the average dominance of managerial skills, these mechanisms do not operate independently of broader firm and institutional conditions. Recent literature emphasizes that environmental responsiveness is increasingly linked to firms' digital readiness, a process commonly described as the twin transition between green and digital transformation (Hoang-Duc et al., 2026). Our results in Table 3 support this view. Foundational digital infrastructure, measured through ict adoption, is associated with a significantly higher baseline probability of green action. Since environmental management practices, such as energy monitoring and emissions targeting, depend heavily on data collection and processing, digital infrastructure enables firms to respond more systematically to climate-related pressures (Comin et al., 2021). However, the interaction model indicates that technology alone is not sufficient. Digital readiness contributes to green adaptation most effectively when it is combined with strong managerial capabilities. The effectiveness of GVC pressure also depends on the broader institutional environment. In many ASEAN economies, domestic environmental regulation is characterized by uneven or weak enforcement. As a result, state-based coercive pressure may be limited, leaving physical climate shocks and international buyer requirements as the main external drivers of adaptation. Institutional theory suggests that, under weak enforcement, firms may engage in isomorphic mimicry by adopting the external appearance of compliance to gain legitimacy, while separating these practices from substantive operational change (Acemoglu, 2012; North, 1990). Differences in institutional quality across ASEAN countries (Bustaman et al., 2022), therefore, shape whether market-driven environmental mandates produce resilient capabilities or remain limited to superficial checklists. Future research should explicitly examine how firm-level managerial capabilities interact with country-level institutional constraints in shaping green adaptation outcomes (Figure 7).

Figure 7. Adjusted predictive probability of green adaptation across ASEAN-4



Notes: Predictive margins with 95% CIs estimated from the baseline model, holding other firm-level covariates at their observed distributions. The varying probabilities highlight the role of country-specific institutional heterogeneity.

Source: Author's estimation based on the baseline Probit model

6. CONCLUSION AND POLICY IMPLICATIONS

This study empirically examines the microfoundations of corporate green adaptation in ASEAN economies. Using recent firm-level data and robust identification strategies, including Lewbel IV-GMM and Kernel PSM, the econometric results re-evaluate several prevailing assumptions in development economics by revealing a hierarchy among the drivers of green adaptation. First, the findings establish the central role of managerial capital. Although physical climate shocks function as environmental jolts, their marginal effect is substantially weaker than that of internal management practices. In the absence of green dynamic capabilities, exogenous shocks are more likely to generate cognitive freeze or short-term coping responses than to stimulate structural green investment (Asiedu et al., 2025; Hirschmann et al., 2025). Second, the interaction models reveal a GVC static compliance. Export participation increases the baseline probability of green action, but exporters are not more dynamically responsive to climate shocks than domestic firms. This suggests that environmental upgrading in buyer-driven chains often remains limited to codified, audit-oriented compliance rather than developing genuine absorptive capacity (Avenyo & Tregenna, 2025; De Marchi & Alford, 2022). Third, the results challenge the finance-centered explanation of green technology adoption. Once managerial quality is controlled for, self-reported financial obstacles lose statistical significance. This supports the Innovation Paradox (Cirera & Maloney, 2017), indicating that perceived capital constraints may largely reflect deeper managerial capability deficits rather than independent financial barriers (Hoang-Duc et al., 2026). The implications of these findings extend beyond Southeast Asia. They offer important lessons for the broader Global South, including Latin America and Sub-Saharan Africa, where firms are also embedded in asymmetric global supply chains and exposed to increasing climate risks. To build genuine resilience, policymakers and international development agencies should shift from merely providing capital and technology subsidies, or hardware, toward strengthening organizational capabilities, or software. Because weak green adaptation appears to stem from a capability gap rather than a purely financial gap, international financial institutions and national governments should reconsider unconditional green credit lines. Instead, industrial policy should integrate management extension services that diagnose and upgrade core firm capabilities, enabling enterprises to design credible and bankable green investment projects (Cirera & Maloney, 2017). As developed economies introduce stricter cross-border environmental regulations, including the European Union's Carbon Border Adjustment Mechanism, developing countries face the risk of functional downgrading. To transform GVC participation from coercive compliance into a source of learning, global trade policy should support functional upgrading from assembly toward original design manufacturing and original brand manufacturing. This would help local suppliers internalize green technologies rather than merely satisfy external audit requirements (Avenyo & Tregenna, 2025; Gereffi, 2019). Climate adaptation initiatives should also be closely linked to national digital transformation agendas. Data-driven management is a basic condition for green resilience. Strengthening firm-level digital readiness is therefore essential for advancing green dynamic capabilities across emerging markets (Haug et al., 2025). Ultimately, closing the managerial capability gap is not only a strategy for firm survival but also a macroeconomic condition for achieving the United Nations Sustainable Development Goals. By shifting policy attention from hardware subsidies to software capabilities, governments can better mobilize the corporate sector to advance the linked objectives of SDG 9 and SDG 13, ensuring that participation in global value chains contributes to sustainable and resilient industrialization. Although this study applies rigorous econometric methods, it has several limitations. First, it relies on cross-sectional data and behavioral proxies for green action. Because the WBES dataset captures firms at a single point in time, the findings measure static green readiness rather than a dynamic adaptation process. The estimates should therefore be interpreted as robust associations rather than strict temporal causal effects. Future research should use global panel datasets with objective environmental performance indicators, such as verified greenhouse gas emission reductions, to trace adaptation trajectories over time. Second, future studies should compare these micro-level mechanisms across different institutional environments to identify the boundary conditions of green dynamic capabilities. Finally, although Lewbel (2012)'s method provides an effective way to construct internal instruments by exploiting heteroskedasticity, its identification strategy is primarily statistical. Future research should therefore seek external instruments or quasi-natural experiments to further validate the causal mechanisms identified in this study.

Declarations

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Competing interests

The author has no relevant financial or non-financial interests to disclose.

Author contributions

Conceptualization Thi Mai Thanh Tran; methodology, Thi Mai Thanh Tran and Sy An Pham; software, Thi Mai Thanh Tran; validation, Manh Hung Nguyen, Thi Mai Thanh Tran, and Sy An Pham; formal analysis, Manh Hung Nguyen, Thi Mai Thanh Tran, and Sy An Pham; investigation, Manh Hung Nguyen; resources, Thi Mai Thanh Tran; data curation, Thi Mai Thanh Tran; writing – original draft preparation, Manh Hung Nguyen, Thi Mai Thanh Tran, and Sy An Pham; writing – review and editing, Manh Hung Nguyen, Thi Mai Thanh Tran, and Sy An Pham; visualization, Thi Mai Thanh Tran. All authors have read and agreed to the published version of the manuscript.

Use of Artificial Intelligence (AI) and AI-assisted technologies

During the preparation of this work, the author used Google Gemini and Grammarly to translate, refine academic English phrasing, and proofread the manuscript. After using these tools, the author reviewed and edited the content as needed and takes full and sole responsibility for the publication's content.

Availability of data and materials

The data supporting the findings of this study are publicly available from the World Bank Enterprise Surveys (WBES) database. The datasets can be accessed and downloaded upon free registration through the official WBES portal.

Code availability

The Stata do-files and econometric codes used for the baseline models, robustness checks, and counterfactual simulations are available from the corresponding author upon reasonable request.

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