Lesson 4.6

ASEAN Climate Vulnerability

Integrated Risk Assessment and Adaptation Finance

Module 4: Green Finance Risk Management

GREEN FINANCE micro-credential

Erasmus+ CBHE 101237817

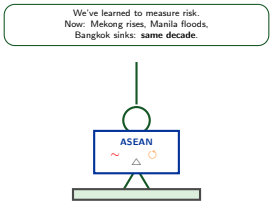
When the Mekong Rises, Manila Floods, and Bangkok Sinks

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Situation: Over five lessons you have built a complete toolkit: risk taxonomy, disclosure frameworks, scenario analysis, carbon metrics, and stress testing.
Complication: Southeast Asia faces all of these risks simultaneously: rising seas, intensifying typhoons, prolonged droughts, and coral bleaching, across 11 countries with 680 million people.

- Every Module 4 tool **converges** on ASEAN
- Physical risk dominates, but transition risk is catching up
- Adaptation finance lags everything else about **20:1**

"We've learned to measure risk. Now let's see what happens when the Mekong rises, Manila floods, and Bangkok sinks: all in the same decade."



Module 4 Capstone: every tool applied to ASEAN.

This capstone lesson integrates all Module 4 tools into ASEAN-specific applications.

From Individual Tools to Integrated Application

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Module 4 Progression

1. **L4.1, Risk Taxonomy:** Physical vs. transition vs. liability
2. **L4.2, TCFD/TNFD:** Disclosure architecture and governance
3. **L4.3, Scenarios:** NGFS pathways, IAMs, Monte Carlo
4. **L4.4, Carbon Metrics:** WACI, PCAF, CVaR, ITR
5. **L4.5, Stress Testing:** PD shocks, ΔCAR, supervisory exercises
6. **L4.6, ASEAN Application:** *Everything converges here*

Formulas You Will Need Today

- Risk equation:

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$

- Climate-adjusted default probability:

$$PD_{climate} = PD_{base} \times (1 + \Delta_{physical} + \Delta_{transition})$$

- Climate Value-at-Risk:

$$CVaR = \sum_i w_i \cdot \Delta V_i(\text{scenario})$$

- Post-stress capital adequacy:

$$\Delta CAR = \frac{\text{RWA}_{stressed} - \text{RWA}_{base}}{\text{Total Assets}}$$

Capstone Logic

Each formula was derived in isolation. Today we apply them **simultaneously** to three ASEAN countries with real hazard data, real banking sectors, and real adaptation finance gaps.

L4.6 integrates all five preceding lessons into country-level risk assessments.

Road Map: Six Sections, One Integrated Story

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Lesson Structure

1. **Introduction** (Slides 1 to 4): Bridge from L4.5, road map
2. **Context: ASEAN Climate Risk Profile** (Slides 5 to 9): Why ASEAN is the world's climate risk hotspot
3. **Challenge: Measuring & Financing Adaptation** (Slides 10 to 15): ND-GAIN decomposition, adaptation instruments, finance gap
4. **Analysis: PhD Research Methods** (Slides 16 to 24): Panel regression, GIS, DiD, IV, damage functions
5. **Resolution: Philippines Case Study** (Slides 25 to 29): Typhoon belt banking sector resilience
6. **Summary** (Slides 30 to 33): Gaps, takeaways, references

Learning Outcomes

Participants are able to:

- Apply the **Risk = H** $\times$ **E** $\times$ **V** framework to Vietnam, Thailand, and the Philippines
- Decompose the **ND-GAIN Vulnerability Index** into actionable sub-components
- Evaluate adaptation finance instruments: cat bonds, resilience bonds, parametric insurance
- Explain the **ASEAN adaptation finance gap**, why its size is contested, and which instruments address it
- Design panel regressions, DiD, and IV strategies for climate: finance research
- Conduct an **integrated stress test** for Philippine typhoon risk
- Articulate the **just transition** imperative for ASEAN economies

Six sections build from regional context through methods to a full country case study.

Why ASEAN Is the World's Climate Risk Hotspot

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Applying Risk = Hazard × Exposure × Vulnerability

Hazard: Tropical location places ASEAN in the paths of typhoons, monsoon flooding, sea-level rise, and coral bleaching simultaneously.

Exposure:

- 150,000+ km coastline across 11 countries
- Agriculture contributes 10 to 25% of GDP
- 680M people, 60% in coastal or delta zones
- Rapid urbanization in flood-prone deltas

Vulnerability:

- Income per capita $4,000 to $12,000 (most members)
- Insurance penetration 1 to 4% of GDP
- Limited early warning infrastructure
- High informality in labor markets

The combination of tropical hazard, high exposure, and low adaptive capacity makes ASEAN the region where climate risk translates most directly into **financial losses**.

ASEAN scores high on all three risk dimensions: hazard, exposure, and vulnerability.

Vietnam: Mekong Delta and Urban Flooding

[FOUNDATION]

Mekong Delta: The Rice Bowl at Risk

- **18 million** people depend on the delta
- Produces **50% of Vietnam's rice** and 60% of aquaculture
- Sea-level rise: **30 to 40 cm by 2050** (IPCC AR6 median)
- Saltwater intrusion already reaching 90 km inland
- Upstream dams (Laos, China) reduce sediment by 50%
- Land subsidence 1 to 3 cm/year from groundwater extraction

Financial Implications

- Agricultural NPLs projected to rise **3 to 5 pp** under RCP8.5
- Agribank holds 40% of rural lending: concentrated risk
- Real estate in Can Tho and My Tho faces devaluation

Ho Chi Minh City: Urban Flood Risk

- **8 million+** residents in flood-prone zones
- Land subsidence: **2 to 3 cm/year** (faster than SLR)
- 2023 floods caused **$**500M+ in damages
- 70% of industrial zones below 2m elevation
- Insurance penetration: $<$**2%** of property value

Hanoi: Riverine Flooding

- Red River flood frequency increasing: 1-in-50 $\rightarrow$ 1-in-20 year events
- Industrial corridors in Bac Ninh, Hai Phong exposed
- SBV climate risk guidelines issued 2024: enforcement pending

Vietnam's banking sector faces compound physical risk: delta, coastal, and riverine flooding converge on the same loan books.

Vietnam faces triple physical risk: Mekong salinity, HCMC subsidence, and Red River flooding.

Thailand: Subsidence, Drought, and Coral Loss

[FOUNDATION]

Bangkok: Sinking City, Rising Seas

- Land subsidence: **1.5 to 2 cm/year** in eastern suburbs
- 2011 floods: **$**46.5B damages, 2.5% GDP contraction
- Chao Phraya floodplain: 4 million residents below 1.5m
- Eastern Seaboard industrial zone: **$**200B+ asset value exposed
- BOT 2024 climate stress test: physical risk dominates

Financial Impact: 2011 as Empirical Anchor

- Manufacturing NPLs spiked **4.2 pp** within 6 months
- Thai Re insured losses: **$**12B (largest single event)
- Supply chain disruption: Honda, Toyota lost 6 months production
- Recovery took 18 to 24 months for banking sector

Northeast: Drought Intensification

- Drought frequency projected to **double by 2050** (RCP4.5)
- Isaan region: 20M people, 30% poverty rate
- Rice yields declining 8 to 15% per decade
- BAAC (agricultural bank) holds 70% of farm credit
- Drought-driven NPLs: 2 to 3 pp increase in affected provinces

Coastal Tourism: Coral Reef Loss

- **30 to 50% coral loss by 2050** (bleaching + acidification)
- Tourism: 18% of GDP, heavily coastal
- Andaman Sea and Gulf resorts: **$**50B+ asset value
- Reef-dependent fisheries: 500,000 livelihoods

Thailand's risk profile spans urban flooding, agricultural drought, and marine ecosystem collapse: three distinct transmission channels.

Thailand faces subsidence-flood, drought, and coral reef loss across three geographic zones.

Philippines: Typhoon Belt and Compound Risks

[FOUNDATION]

Typhoon Exposure: By the Numbers

- About **20 tropical cyclones/year** form in the region; **8 or 9** cross the country
- Annual disaster losses: **3.2% of GDP** (World Bank 2024)
- Typhoon Hainan/Yolanda (2013): 6,300+ deaths, **$**2.9B damages
- Typhoon Rai/Odette (2021): **$**1.0B damages, 400+ deaths
- Compound risk: volcanic, seismic, and hydrometeorological

Socioeconomic Vulnerability

- **10M+ overseas workers**: remittance-dependent coastal communities
- Informal sector: 40% of employment
- Insurance penetration: 1.8% of GDP
- Microfinance exposure: high in Visayas and Mindanao

Banking Sector Concentration

- Top 5 universal banks hold **60%+ of Visayas lending**
- BSP (Bangko Sentral ng Pilipinas) mandated climate risk disclosure 2022
- PCIP (Philippine Crop Insurance Program): covers <20% of farmers
- Post-typhoon NPL spikes: **2 to 3 pp** within 6 months
- Recovery period: 12 to 18 months (faster than Thailand)

Compound Risk Amplifiers

- Volcanic eruptions (Taal 2020) compound flood damage
- Earthquake risk in Mindanao amplifies infrastructure loss
- Sea-level rise + storm surge = non-linear coastal damage
- Manila Bay reclamation: **$**30B+ of assets at compound risk

The Philippines faces the highest disaster frequency in ASEAN, with compound hazards amplifying each individual risk.

The Philippines is the most disaster-prone ASEAN economy: about 20 tropical cyclones form in the region each year and 8 or 9 cross the country, and 3.2% GDP annual losses.

Three Countries Compared: Risk Profiles at a Glance

[FOUNDATION]

Dimension	Vietnam	Thailand	Philippines
Primary hazard	Sea-level rise, delta flooding	Subsidence-flood, drought	Typhoons (20+/year)
GDP at risk (%/yr)	1.5 to 2.5%	1.0 to 2.0%	3.0 to 3.5%
Insurance penetration	1.2% of GDP	3.8% of GDP	1.8% of GDP
Agri share of GDP	12%	9%	10%
Key banking exposure	Agribank (delta)	BAAC (drought), SCB (flood)	BDO, BPI (Visayas)
Regulatory stage	SBV guidelines 2024	BOT stress test 2024	BSP disclosure mandate 2022
Adaptation readiness	Low	Medium	Low-Medium

Vietnam is most vulnerable; Thailand is the most prepared; the Philippines is the most disaster-prone.

ND-GAIN Vulnerability Index Decomposition

[INTERMEDIATE]

Vulnerability = f(Exposure, Sensitivity, Adaptive Capacity)

The Notre Dame Global Adaptation Initiative (ND-GAIN) decomposes country vulnerability into three sub-indices across six life-supporting sectors:

- **Exposure:** Degree to which a system is exposed to climate change (SLR, temperature, precipitation)
- **Sensitivity:** Degree to which a system is affected (food, water, health, ecosystem services, infrastructure, habitat)
- **Adaptive Capacity:** Ability to adjust, moderate, or cope (institutional, economic, social capital)

Readiness = f(Economic, Governance, Social)

- Economic: business environment, credit access
- Governance: rule of law, regulatory quality
- Social: education, innovation, ICT infrastructure

Key insight: Vietnam and the Philippines score similarly on vulnerability but diverge on readiness: Thailand leads on governance and economic readiness, creating a **vulnerability-readiness gap** that defines adaptation priorities.

ND-GAIN separates vulnerability (exposure to harm) from readiness (capacity to act).

Integrated Risk Framework: Country Deep Dives

[INTERMEDIATE]

Vietnam

Mekong Delta:

- Salinity intrusion → crop failure → agricultural NPLs
- 30 to 40 cm SLR by 2050 inundates 40% of delta
- Agribank concentration: single-name risk

HCMC Urban Flooding:

- Subsidence + SLR + drainage failure
- Industrial zone losses cascade to supply chains
- Property devaluation: 15 to 30% in low-lying districts

Thailand

Chao Phraya Basin:

- 2011-scale floods now 1-in-25 year (was 1-in-50)
- Eastern Seaboard: $200B industrial assets
- BOT requires flood scenario in stress tests

Eastern Seaboard:

- Auto manufacturing hub (5% of global production)
- Sea-level rise threatens port infrastructure
- Thai Re reinsurance capacity: tested 2011

Philippines

Visayas Corridor:

- Direct typhoon path: Leyte, Cebu, Bohol
- Microfinance portfolios highly concentrated
- Post-Haiyan rebuilding: still incomplete

Metro Manila:

- 13M people, ∼one-third of GDP (NCR ∼31-36%)
- Manila Bay reclamation at compound risk
- Pasig River flooding + storm surge
- BSP headquarters itself in flood zone

Integration Point

Each country has 2 to 3 **geographic risk nodes** where physical hazard, financial exposure, and institutional vulnerability converge. Mapping these nodes is the first step toward targeted adaptation finance.

Geographic risk nodes concentrate hazard, exposure, and vulnerability in specific locations.

Why Mitigation Alone Is Insufficient for ASEAN

[INTERMEDIATE]

The Locked-In Warming Problem

- Even under Net Zero 2050, global temperatures reach **1.5°C** by 2030s
- For ASEAN: tropical amplification means **1.8 to 2.2°C** locally
- Sea-level rise continues for centuries after emissions peak
- Physical damage already in the pipeline: mitigation cannot prevent it

The Global Finance Imbalance

- Global climate finance, annual average 2021/2022: **$**1.3 trillion
- **Needs: $212B/year by 2030** for developing countries alone
- **Adaptation: $63B, under 5%** (flood defenses, drought resilience, early warning)
- ASEAN adaptation: a large gap whose size is contested, see the next section
- **Ratio: the rest of climate finance outpaces adaptation about 20:1**

The Equity Dimension

- ASEAN contributes $<$**5%** of cumulative global emissions
- But faces $>$**15%** of global physical risk losses
- Adaptation is not optional: it is a **survival imperative**
- Loss and Damage fund (COP28): insufficient at **$**700M pledged

The Banking Sector Implication

- Mitigation finance creates **green asset** opportunities
- Adaptation finance creates **resilience asset** protection
- Banks need both: green bond issuance AND flood-resilient loan books
- Without adaptation, stress test losses grow **non-linearly**

Mitigation reduces future risk. Adaptation manages risk that is already locked in. ASEAN needs both, but adaptation finance is critically under-supplied.

Adaptation drew $63B of almost $1.3T globally, under 5 percent. ASEAN's own gap is large and its published size varies with scope.

Adaptation Finance Instruments: From Cat Bonds to Green Climate Fund

[INTERMEDIATE]

Market-Based Instruments

Catastrophe Bonds (Cat Bonds):

- **Parametric trigger:** Payout when wind speed/rainfall exceeds threshold: fast, transparent, no claims adjustment
- **Indemnity trigger:** Payout based on actual losses: slower, more accurate, moral hazard risk
- ASEAN examples: Philippines parametric typhoon bond (2019, $225M), SEADRIF

Resilience Bonds:

- Green bonds earmarked for adaptation infrastructure
- Coupon linked to resilience metrics (e.g., flood defense completion)
- Nascent market: <$5B globally (2024)

Parametric Insurance:

- Index-based: payout triggered by satellite data
- Basis risk: actual loss may differ from index
- Philippines PCIP, Thailand rice insurance pilots

Public and Multilateral Instruments

Green Climate Fund (GCF):

- $10.6B announced (GCF-2 second replenishment, 2023 to 2024)
- 50/50 mitigation-adaptation mandate
- ASEAN: 15 approved projects, $800M committed

Adaptation Fund:

- CDM-levy funded, $1.1B cumulative
- Small-grant focus: community-level resilience
- ASEAN: 8 projects, $65M

Just Transition Principle:

- Adaptation must not exacerbate inequality
- Coastal communities, smallholder farmers, informal workers bear disproportionate risk
- **Inclusive adaptation:** gender, indigenous, disability lenses
- ASEAN Just Transition Finance Facility (proposed 2025)

Cat bonds provide fast parametric payouts; GCF provides concessional adaptation capital. Both are needed.

The ASEAN Adaptation Finance Gap

[INTERMEDIATE]

Quantifying the Gap

- **The gap is large and its size is contested.** Published figures differ by more than a factor of two because they differ in scope
- Check three things before repeating any headline number: is it ASEAN or Asia-wide, is it needs or the shortfall, and which years does it cover
- The most-quoted **$**40B/year figure is **ADB's Asia-wide** estimate, not an ASEAN one, and it is frequently mis-scoped in secondary sources
- Whatever the level, the direction is agreed: needs are growing faster than supply

Blended Finance: Closing the Gap

- **Concessional layer:** DFI/MDB first-loss capital (10 to 20% of deal)
- **Commercial layer:** Banks/institutional investors (70 to 80%)
- **Catalytic layer:** Technical assistance, guarantees (5 to 10%)
- Leverage ratio target: **1:5** (every **$**1 concessional mobilizes **$**5 private)
- Current ASEAN leverage: **1:2.5**, below global average

NDC Commitments:

- Vietnam: 15.8% unconditional, 43.5% conditional vs BAU
- Thailand: 30% unconditional, 40% conditional (needs **$**8B)
- Philippines: 2.7% unconditional, 72% conditional (needs **$**13B)

Key insight: The Philippines' NDC is 72% conditional on international finance: the highest conditionality in ASEAN. Without closing the adaptation finance gap, NDC targets are aspirational.

ASEAN's adaptation shortfall is wide enough that blended finance is the only realistic way to close it; the headline size depends on whose scope you adopt.

Blended Finance Negotiation: How the Capital Stack Works

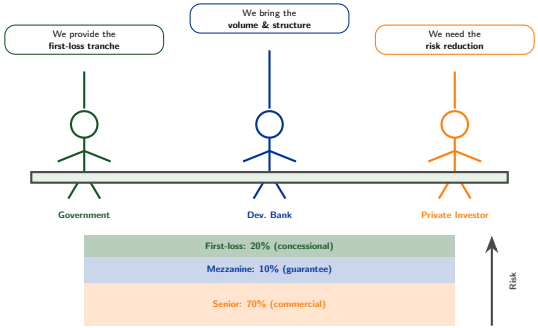
[INTERMEDIATE]

The Three-Party Deal

Blended finance works when each party takes the risk it is best positioned to bear:

1. **Government/DFI:** Provides first-loss tranche (absorbs initial losses). Accepts below-market returns for development impact.
2. **Development bank (MDB):** Brings volume and technical expertise. Structures the deal, provides guarantees.
3. **Private investor:** Seeks risk-adjusted market returns. Enters only when first-loss protection makes risk acceptable.

ASEAN example: ADB Climate Adaptation Fund: $500M facility with 20% first-loss from GCF, 80% commercial.



Blended finance uses concessional first-loss capital to de-risk private investment in adaptation.

Panel Regression: Climate Events and Non-Performing Loans

[PhD]

Research Question

Do climate-related natural disasters cause statistically significant increases in bank non-performing loans across ASEAN countries?

Panel Model Specification

$$NPL_{it} = \alpha + \beta_1 \cdot ClimateEvent_{it} + \beta_2 \cdot Controls_{it} + \gamma_i + \delta_t + \varepsilon_{it}$$

- i = country (or province), t = quarter
- $ClimateEvent_{it}$: EM-DAT count or damage (% GDP)
- $Controls_{it}$: GDP growth, interest rate, exchange rate, inflation
- γ_i: country (or province) fixed effects
- δ_t: time fixed effects (quarter dummies)
- ε_{it}: idiosyncratic error

Identification Strategy

- **Within-country variation:** FE absorb time-invariant confounders (geography, institutions, culture)
- **Expected sign:** $\beta_1 > 0$ (disasters increase NPLs)
- **Magnitude:** Cevik & Jalles (2022) find 0.5 to 1.2 pp NPL increase per major disaster event
- **Lagged effects:** Test $ClimateEvent_{i,t-k}$ for $k = 1, \ldots, 8$ quarters

Data Sources

- **EM-DAT:** International Disaster Database (1900 to present)
- **Banking data:** IMF FSI, national central banks (SBV, BOT, BSP)
- **Panel:** 10 ASEAN countries $\times$ 80 quarters (2004 to 2024)
- **Clustering:** Standard errors clustered at country level (Arellano, 1987)

Panel FE regression isolates the within-country causal effect of climate events on bank asset quality.

[PhD]

Methodology

GIS-based spatial risk models overlay three layers:

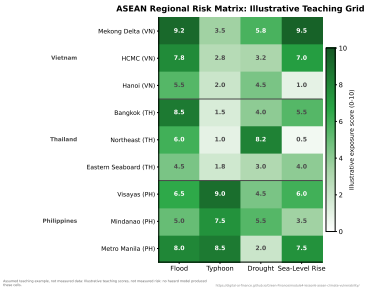
1. **Hazard layer:** Flood maps (return period), typhoon tracks, SLR projections, drought indices (SPEI)
2. **Exposure layer:** Bank branch locations, loan portfolio geocoding, asset values by district
3. **Vulnerability layer:** ND-GAIN sub-indicators, poverty rates, insurance coverage by province

Composite Risk Score:

$$R_j = \sum_h w_h \cdot H_{hj} \times E_j \times V_j$$

where j = grid cell, h = hazard type, w_h = hazard weight.

Resolution: 1 km^2 grid cells. **Tools:** QGIS, Python (geopandas, rasterio).
Validation: Historical loss data from EM-DAT.



Application: Bank regulators (SBV, BOT, BSP) can use spatial risk maps to identify loan book concentrations in high-hazard zones, converting physical science into **prudential supervision**.

PhD contribution: Link 1 km^2 hazard grids to geocoded loan-level data for granular climate-adjusted PD estimation.

GIS spatial risk modeling converts hazard maps into bank-level risk assessments at 1 km^2 resolution.

[PhD]

Hypothetical Coefficient Table

Variable	(1) Baseline	(2) + Lags	(3) + Interactions
$ClimateEvent_{it}$	0.82***	0.65**	0.71***
	(0.21)	(0.24)	(0.19)
$ClimateEvent_{i,t-1}$	n/a	0.44**	0.38*
		(0.18)	(0.20)
$ClimateEvent_{i,t-2}$	n/a	0.21	0.18
		(0.22)	(0.23)
GDP_growth_{it}	−0.35***	−0.33***	−0.31***
	(0.08)	(0.09)	(0.08)
$ClimEvent \times InsurancePen$	n/a	n/a	−0.15**
			(0.07)
Country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observations	800	780	780
R^2 (within)	0.32	0.36	0.39

Interpretation: A major climate event increases NPLs by **0.82 pp** (column 1). The effect persists one quarter ($t-1$: 0.44 pp) and dissipates by $t-2$. **Insurance penetration moderates** the impact (−0.15 interaction term): each 1 pp increase in insurance penetration reduces the NPL spike by 0.15 pp.

Robustness: Clustered SEs at country level. Results hold with Driscoll-Kraay SEs (spatial + temporal correlation). Placebo test: randomized event dates yield $\beta_1 \approx 0$.

Climate events increase NPLs by 0.8 pp on impact, with persistence. Insurance penetration is a significant moderator.

Difference-in-Differences: Evaluating Climate Disclosure Mandates

[PhD]

Research Design

Treatment: BSP mandatory climate risk disclosure (Philippines, 2022Q3).
Control: Banks in countries without mandates (at time of adoption).
DiD Estimator:

$$\hat{\delta} = (\bar{Y}_{treat,post} - \bar{Y}_{treat,pre}) - (\bar{Y}_{control,post} - \bar{Y}_{control,pre})$$

Regression specification:

$$Y_{it} = \alpha + \beta_1 \cdot Treat_i + \beta_2 \cdot Post_t + \delta \cdot (Treat_i \times Post_t) + X_{it}\theta + \varepsilon_{it}$$

- Y_{it}: risk provisioning ratio, green bond issuance, or ESG score
- δ: causal effect of disclosure mandate
- X_{it}: bank size, leverage, profitability controls

Parallel Trends Assumption

The identifying assumption: treatment and control groups would have followed **parallel trends** absent the mandate.

Testing parallel trends:

- Event study: estimate δ_k for $k = -4, \ldots, -1, 0, 1, \ldots, 4$ quarters
- Pre-treatment coefficients should be **statistically zero**
- Post-treatment coefficients capture dynamic effects

Expected Findings

- $\hat{\delta} > 0$ for risk provisioning (banks increase reserves)
- $\hat{\delta} > 0$ for green bond issuance (disclosure triggers action)
- $\hat{\delta} < 0$ for carbon-intensive lending (reallocation away from brown)
- Heterogeneity: larger banks respond faster (compliance capacity)

DiD isolates the causal effect of BSP's 2022 disclosure mandate on Philippine bank behavior.

Adaptation Finance Effectiveness: Instrumental Variable Approaches

[PhD]

The Endogeneity Problem

Naive regression of resilience outcomes on adaptation finance suffers from **reverse causality**: countries receiving more adaptation finance may be more vulnerable (selection) or may have better institutions (capacity).

$$Resilience_i = \alpha + \beta \cdot AdaptFinance_i + \varepsilon_i$$

OLS $\hat{\beta}$ is **biased**: $\text{Cov}(AdaptFinance_i, \varepsilon_i) \neq 0$.

Instrumental Variables

Candidate instruments:

- **Distance to nearest GCF National Designated Authority**: affects access but not outcomes directly
- **UN General Assembly voting alignment** with major donor countries: predicts aid allocation
- **Historical colonial ties**: affect aid flows, plausibly excludable from resilience

Validity Conditions

For IV to identify causal effects:

1. **Relevance:** $\text{Cov}(Z_i, AdaptFinance_i) \neq 0$
   Test: first-stage F-statistic > 10 (Stock & Yogo, 2005)
2. **Exclusion:** $\text{Cov}(Z_i, \varepsilon_i) = 0$
   Instrument affects resilience **only through** adaptation finance
3. **Monotonicity:** No defiers (LATE interpretation)

Two-Stage Least Squares

Stage 1: $AdaptFin_i = \pi_0 + \pi_1 Z_i + Controls + v_i$

Stage 2: $Resilience_i = \alpha + \beta \cdot \widehat{AdaptFin}_i + Controls + \varepsilon_i$

$\hat{\beta}_{2SLS}$ is the **LATE** for compliers: those whose adaptation finance receipt is affected by the instrument.

IV approaches address the endogeneity of adaptation finance allocation using geographic and political instruments.

ASEAN-Specific Damage Functions: Non-Linear Thresholds

[PhD]

Why Standard Damage Functions Fail for ASEAN

Standard integrated assessment models (DICE, PAGE) use globally calibrated damage functions:

$$D(T) = a_1 T + a_2 T^2$$

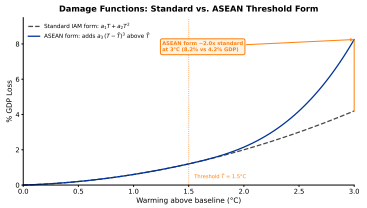
Problems for ASEAN:

- **Non-linearity:** Damage jumps at thresholds (e.g., flood walls overtopped at 1.5m, not linear from 0 to 2m)
- **Compounding:** Typhoon + flood + landslide interact multiplicatively
- **Recovery asymmetry:** Developing economies recover slower
- **Informal sector:** 30 to 40% of GDP unmeasured in standard functions

ASEAN-Calibrated Alternative

$$D_{ASEAN}(T) = a_1 T + a_2 T^2 + a_3 \cdot \mathbb{1}(T > \bar{T}) \cdot (T - \bar{T})^3$$

Threshold $\bar{T}$: tipping point (e.g., $\bar{T} = 1.5$°C for coral bleaching, $\bar{T} = 0.5$m SLR for delta inundation).



PhD research frontier: Calibrate $a_1, a_2, a_3, \bar{T}$ using ASEAN micro-data. Key challenge: separating climate signal from development trend in damage time series.

Data: EM-DAT physical damage + national accounts. Method: piecewise non-linear regression with breakpoint estimation.

Standard damage functions underestimate ASEAN losses. Threshold effects require piecewise non-linear calibration.

Cross-Border Climate Risk Transmission in ASEAN

[PhD]

Transmission Channels

1. Trade Linkages:

- Thailand 2011 floods → global auto supply chain disruption
- Honda, Toyota: 6 months lost production
- Downstream: Vietnam electronics, Philippines components affected
- Estimated global impact: $45B beyond Thailand's $46.5B direct loss

2. Financial Linkages:

- Cross-border bank lending within ASEAN: $400B+
- NPL contagion: Thai bank losses → reduced ASEAN lending
- Reinsurance networks: concentrated in Singapore, Hong Kong

3. Migration:

- Climate-driven migration: 40M+ by 2050 in ASEAN
- Remittance disruption: Philippines receives $37B/year
- Urban strain: Manila, Bangkok, HCMC receiving climate migrants

Spatial Panel Model

$$Y_{it} = \rho W Y_{it} + X_{it}\beta + WX_{it}\theta + \gamma_i + \delta_t + \varepsilon_{it}$$

- W: spatial weight matrix (trade shares, financial linkages)
- ρ: spatial autoregressive coefficient (contagion)
- WY_{it}: weighted average of neighbors' NPLs
- WX_{it}: spatial lag of explanatory variables (spillovers)

Interpretation:

- $\rho > 0$: NPL contagion exists; disasters in Thailand increase NPLs in Vietnam
- Direct effect: β (own-country climate shock)
- Indirect effect: $\rho \cdot W \cdot \beta$ (neighbor's shock through network)
- Total effect: direct + indirect

Estimation: Spatial ML or Spatial GMM (Kelejian & Prucha, 1998).
Challenge: Constructing W with time-varying trade shares.

Climate risk transmits across ASEAN through trade, finance, and migration: spatial econometrics captures these channels.

Adaptation Finance Additionality: Does Climate Finance Create New Resilience?

[PhD]

The Additionality Question

Does adaptation finance create **new** resilience, or does it replace domestic spending that would have occurred anyway?

Fungibility problem:

- Government receives **$**100M GCF grant for flood defenses
- Government reduces domestic flood defense budget by **$**80M
- **Net additional resilience:** **$**20M, not **$**100M
- Measured additionality: 20%, not 100%

Measurement Approaches

1. **Budget analysis:** Track domestic adaptation spending before/after GCF disbursement
2. **Regression:** $DomSpend_{it} = \alpha + \beta \cdot GCF_{it} + Controls + \varepsilon$
   If $\beta < 0$: crowding out. If $\beta \geq 0$: complementarity.
3. **RDD at GCF threshold:** See next column

Regression Discontinuity Design

GCF uses vulnerability scores for eligibility. Countries near the threshold provide a natural experiment:

$$Resilience_i = \alpha + \beta \cdot \mathbb{1}(Score_i \geq \bar{S}) + f(Score_i) + \varepsilon_i$$

- $\bar{S}$: GCF eligibility score threshold
- $\mathbb{1}(\cdot)$: treatment indicator (above threshold)
- $f(Score_i)$: polynomial in running variable
- β: **local average treatment effect** at cutoff

Threats to Validity

- **Manipulation:** Can countries manipulate their vulnerability score? McCrary density test
- **Bandwidth:** Narrow vs. wide bandwidth trade-off (bias vs. precision)
- **Fuzzy RD:** Not all eligible countries receive funding: use IV with eligibility as instrument

Key challenge: GCF does not publish exact scoring formulas, making threshold identification empirical.

Additionality measurement separates genuine resilience creation from fiscal substitution.

Research Frontier: Five Open Questions for PhD Scholars

[PhD]

1. **ASEAN-Calibrated Damage Functions**
   How do we estimate threshold parameters ($\bar{T}$) for ASEAN-specific tipping points? Current IAMs use global averages that underestimate tropical non-linearities. *Method:* Piecewise regression with breakpoint estimation on EM-DAT + national accounts.

2. **Cross-Border Climate Risk Transmission**
   What is the magnitude of indirect climate losses through ASEAN trade and financial networks? Thailand 2011 suggests indirect $>$ direct, but no systematic estimate exists. *Method:* Spatial panel with time-varying trade-weight matrix.

3. **Adaptation Finance Additionality**
   Does GCF/AF funding create new resilience or crowd out domestic spending? Fungibility rates are unmeasured for ASEAN recipients. *Method:* RDD at GCF eligibility thresholds + budget tracking.

4. **Catastrophe Bond Trigger Design**
   How do we optimize parametric triggers to minimize basis risk for ASEAN typhoons and floods? Current triggers over-pay some events and under-pay others. *Method:* Copula-based joint distribution of wind speed, rainfall, storm surge.

5. **Just Transition Metrics for Financial Institutions**
   How should banks measure whether their climate adaptation lending is equitable? No standardized metrics exist. *Method:* Develop composite index using distributional impact analysis + Gini decomposition.

Five open questions define the research frontier at the intersection of climate science and ASEAN finance.

Philippines: Typhoon Belt Banking Sector Resilience

[FOUNDATION]

Why the Philippines?

- **Highest disaster frequency** in ASEAN: about 20 tropical cyclones form in the region yearly, 8 or 9 crossing
- **Highest GDP losses:** 3.2% annually (World Bank 2024)
- **Most advanced regulatory response:** BSP climate risk disclosure mandate (2022)
- **Rich empirical data:** Haiyan/Yolanda (2013), Rai/Odette (2021) provide calibration anchors

Banking Sector Overview

- 47 universal and commercial banks
- Total assets: $350B (2024)
- Top 5 (BDO, BPI, Metrobank, RCBC, PNB): 55% market share
- Visayas and Mindanao branches: 35% of network, highest typhoon exposure
- Agricultural lending: 8% of portfolio, 25% of NPLs

Four-Part Assessment Framework

We apply all Module 4 tools to the Philippines in sequence:

1. **Hazard analysis:** Typhoon frequency and intensity projections under RCP4.5 and RCP8.5 (Slide 26)
2. **Exposure mapping:** Bank portfolio against typhoon tracks, NPL analysis (Slide 27)
3. **Stress testing:** Cat-5 scenario $\rightarrow$ PD shocks $\rightarrow$ ΔCAR calculation (Slide 28)
4. **Policy response:** Adaptation pathways and recommendations (Slide 29)

This mirrors the L4.1: L4.5 progression but compressed into a single country application. Each slide references specific formulas and methods from earlier lessons.

The Philippines case study demonstrates how the full Module 4 toolkit translates into actionable supervisory practice.

The Philippines case study integrates all Module 4 tools: hazard, exposure, stress testing, and policy.

Typhoon Frequency and Intensity Projections

[FOUNDATION]

Historical Baseline

- Average: **about 20 tropical cyclones/year** enter Philippine Area of Responsibility
- **8 or 9** cross the country annually
- Cat-4/5 frequency: 2 to 3 per decade (1980 to 2010)
- Trend: intensity increasing, frequency stable or slightly declining

Projections (IPCC AR6, CMIP6)

RCP4.5 (moderate):

- Total frequency: -5% to $+5\%$ (uncertain)
- Cat-4/5 intensity: **+10 to 15%** by 2050
- Rainfall per event: **+10 to 15%**
- Poleward migration: typhoon tracks shifting north

RCP8.5 (high):

- Cat-4/5 intensity: **+20 to 30%** by 2050
- Rainfall per event: **+20 to 25%**
- Rapid intensification events: **+50%** frequency
- Storm surge: amplified by SLR ($+0.3$ to 0.6m)

Reference event: Typhoon Haiyan/Yolanda (2013)

- Category 5, 315 km/h sustained winds
- Storm surge: 5 to 7 meters in Tacloban
- Deaths: 6,300+ | Damages: $2.9B
- Recovery: 5+ years for affected banking sector

Under RCP8.5, Haiyan-class events become 50% more frequent. The financial system must prepare for what was once a 1-in-100 year event to recur every 30 to 50 years.

Typhoon intensity rises 10 to 30% by 2050; Haiyan-class events become significantly more frequent.

Bank Portfolio Mapping and NPL Analysis

[INTERMEDIATE]

Exposure Mapping: BSP Branches vs. Typhoon Tracks

- **3,200+ BSP-regulated branches** in Visayas and Mindanao
- Top 5 banks hold **60%+** of Visayas lending
- Overlap: 70% of branches within 50 km of historical Cat-4+ tracks
- Agricultural portfolio: **highly concentrated** in typhoon-prone provinces (Leyte, Samar, Cebu)

Post-Disaster NPL Dynamics

- **Impact phase** (0 to 3 months): NPLs spike 2 to 3 pp
- **Peak phase** (3 to 6 months): Maximum NPL increase, forbearance programs activated
- **Recovery phase** (6 to 18 months): Gradual normalization as insurance claims, remittances, and aid arrive
- **Residual phase** (18 to 36 months): Persistent NPLs in agriculture, construction slower to recover

Philippine Crop Insurance Program (PCIP)

- Coverage: $<$**20% of farmers** enrolled
- Average payout: **$**150 per claim (insufficient for recovery)
- Claims processing: 3 to 6 months (too slow for planting season)
- **Protection gap:** 80% of agricultural losses uninsured

Concentration Risk: Top 5 Banks

Bank	Visayas Share	Agri Exposure
BDO Unibank	22%	6%
BPI	18%	5%
Metrobank	12%	8%
RCBC	5%	12%
PNB	4%	15%

PNB and RCBC face disproportionate typhoon exposure through agricultural concentration in Visayas.

Post-typhoon NPLs spike 2 to 3 pp within 6 months. PCIP covers $<$20% of farmers: 80% protection gap.

[INTERMEDIATE]

Scenario: Haiyan-Class Typhoon Hitting Cebu

Applying the L4.5 stress testing framework:

Step 1: Define scenario

- Cat-5 typhoon, 280+ km/h sustained winds
- Landfall: Central Visayas (Cebu, Bohol, Leyte)
- Storm surge: 4 to 6 meters
- Rainfall: 400+ mm in 24 hours

Step 2: $PD_{climate}$ adjustments by sector

Sector	ΔPD	Portfolio Share
Agriculture	+80%	8%
Real estate	+40%	22%
Services/tourism	+25%	18%
Manufacturing	+15%	15%
Others	+5%	37%

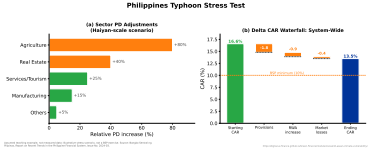
Step 3: Weighted ΔPD:

$$\Delta PD_{portfolio} = \sum_{s} w_s \cdot \Delta PD_s = 23.8\%$$

Step 4: Capital Impact (ΔCAR)

Using the L4.5 ΔCAR formula:

- Pre-stress CAR: **16.6%** (Philippine banking system, solo, Dec 2023)
- Additional provisions: 1.8% of RWA
- RWA increase: 0.9% (risk-weight migration)
- Market losses: 0.4% (sovereign spread widening)
- **Post-stress CAR: 13.5%**
- BSP minimum: 10% → **Buffer: 3.5 pp**



Result: System survives a Haiyan-class event with adequate capital buffer. But: 3 to 4 smaller banks in Visayas breach minimum CAR. **Systemic risk is concentrated, not average.**

System-wide CAR falls from 16.6% to 13.5%: adequate aggregate buffer, but some regional banks breach minimums.

Policy Implications and Adaptation Pathways

[INTERMEDIATE]

Three Priority Recommendations

1. **Mandatory Climate Stress Testing for Philippine Banks**
   - BSP should require annual climate stress tests for top 20 banks
   - Standardized scenarios: Cat-3, Cat-4, Cat-5 typhoon paths
   - Disclosure of post-stress CAR to supervisors (not public initially)
2. **Expand PCIP to Cover Agricultural Lending**
   - Current PCIP covers farmers but not their lenders
   - Proposal: portfolio-level parametric cover for Visayas agricultural books
   - Trigger: satellite-verified rainfall $>$ 300 mm in 24 hours
   - Premium: risk-based, subsidized for smallholder portfolios
3. **Blended Finance for Typhoon-Resilient Infrastructure**
   - First-loss: GCF + AIIB (20%); commercial: Philippine banks (70%), insurance (10%)
   - Target: $5B facility for Visayas resilience infrastructure

Just Transition Lens

- **Who bears the cost?** Visayas communities (poorest, most exposed) must not pay for adaptation they did not cause
- **Remittance protection:** 10M+ OFW families depend on flows: disruption cascades through consumption
- **Microfinance safeguard:** Stress testing must cover MFIs serving informal sector, not just universal banks
- **Indigenous communities:** Aeta, Mangyan, Lumad communities in typhoon paths need culturally appropriate insurance

Implementation Sequence

- **2025 to 2026:** BSP stress test pilot + PCIP expansion design
- **2027:** Mandatory stress testing + blended finance facility launch
- **2028 to 2030:** Full integration into Basel III supervisory review
- **2030+:** Cross-border ASEAN stress testing protocol

The Philippines can lead ASEAN in climate-resilient banking: the regulatory foundation (BSP 2022) already exists.

Three recommendations: mandatory stress testing, expanded crop insurance, blended adaptation finance.

Five Gaps in ASEAN Climate Risk Management

[FOUNDATION]

1. **Data Gap**
   No centralized, geocoded database linking climate hazard data to bank loan books across ASEAN. SBV, BOT, and BSP maintain separate systems. *Cost to close: $50 to 100M for regional data infrastructure.*

2. **Methodology Gap**
   Different countries use incompatible stress test methodologies. PD shocks for the same scenario vary 2 to 5× across jurisdictions. *Solution: ASEAN-wide harmonized protocol via NGFS.*

3. **Finance Gap**
   Adaptation needs outstrip supply by a wide and contested margin, and the absence of an agreed ASEAN-scope figure is itself part of the gap: what is not measured does not get managed. Blended finance leverage ratio stuck at 1:2.5 (target: 1:5). NDC conditionality is 72% in the Philippines. *Solution: Scale cat bonds, resilience bonds, GCF replenishment.*

4. **Capacity Gap**
   Central banks lack climate risk specialists. BOT has 5 FTE on climate; ECB has 150+. University programs (like this one) are essential. *Solution: GREEN FINANCE capacity building across 11 partner institutions.*

5. **Coordination Gap**
   Cross-border climate risk transmission (Thailand 2011) demands coordinated supervisory response. No ASEAN-wide climate stress test protocol exists. *Solution: ASEAN Financial Stability Board climate working group.*

Five gaps (data, methodology, finance, capacity, coordination) define the ASEAN climate risk management agenda.

[FOUNDATION]

Module 4 Capstone: Key Takeaways

1. **Risk = Hazard** $\times$ **Exposure** $\times$ **Vulnerability**: ASEAN scores high on all three dimensions, making it the world's climate risk hotspot
2. **ASEAN adaptation finance gap**: needs outstrip supply by a wide margin whose published size depends on scope, with NDC conditionality as high as 72% (Philippines)
3. **Cat bonds + parametric insurance** provide rapid post-disaster liquidity, but basis risk and coverage gaps persist (PCIP covers $<$20%)
4. **Panel regression with fixed effects** isolates within-country causal effects of climate events on NPLs ($\beta_1 \approx 0.8$ pp per major event)
5. **GIS spatial risk mapping** at 1 km^2 resolution converts hazard science into prudential supervision: the bridge between climate and banking
6. **Difference-in-differences** evaluates disclosure mandates (BSP 2022) by comparing treated vs. control banks across the policy cutoff
7. **Just transition imperative:** Adaptation finance must reach the most vulnerable (coastal communities, smallholder farmers, informal workers), not just large corporates

Seven takeaways span foundation knowledge, intermediate instruments, and PhD-level methods.

From Taxonomy to Territory: Module 4 Complete

[FOUNDATION]

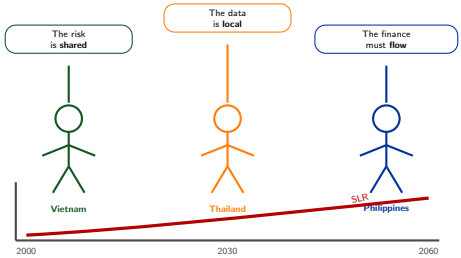
What We Built in Module 4

- **L4.1:** Named the risks (taxonomy)
- **L4.2:** Built the disclosure architecture (TCFD/TNFD)
- **L4.3:** Projected the futures (scenarios)
- **L4.4:** Measured the portfolios (carbon metrics, CVaR)
- **L4.5:** Tested the institutions (stress testing)
- **L4.6:** Applied it all to the territory (ASEAN)

Module 4 → Module 5 Bridge

Module 4 taught you to **identify, measure, and manage** climate risk. Module 5 teaches you to **report and communicate** it: ISSB S1/S2, CSRD, SFDR, and sustainability reporting standards.

Risk management without reporting is invisible. Reporting without risk management is empty.



Module 4 complete: from taxonomy to territory.

Module 4 built the toolkit. Module 5 builds the reporting framework. Together: risk management + transparency.

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References span multilateral reports, academic literature, regulatory circulars, and disaster databases.

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Use of generative AI

Generative AI was used as a writing and research assistant in preparing this module. The tool was Claude (Anthropic), versions Opus 4.8 and Opus 5, used from July 2026 to the submission of this module on 11 September 2026. Its use was confined to the following purposes:

- idea generation and brainstorming on module structure and worked examples;
- language editing of author-specified content;
- literature classification and organisation of the reading list;
- coding assistance for the chart, data-processing, and document-build scripts;
- interactive literature searching using AI-enhanced search tools.

The authors specified and reviewed the content of this module. Every cited source was checked against the original publication, and every figure states its provenance on its own face, distinguishing sourced values from derived values and from illustrative teaching assumptions. The authors remain fully responsible for the originality, accuracy, integrity, references, and conclusions of the material.

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