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Incorporating Nature Physical Risks Into Banks' Credit Risk Models and Insurers' Market Risk Models: Focus on Water-related Risks

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Executive Summary

- The De Nederlandsche Bank Working Paper establishes that **nature-related risks - particularly those linked to biodiversity loss and ecosystem degradation - pose material threats to macroeconomic stability and financial systems**. This recognition is aligned with positions taken by institutions such as NGFS, ECB and FSB.
- The paper highlights a **critical methodological gap**: while exposure-based analyses have demonstrated that financial institutions (FIs) are highly dependent on ecosystem services, there is **no widely accepted framework to translate nature shocks into financial losses**.
- The paper introduces a **top-down stress-testing framework** linking:
  - **Nature shocks**
  - **Macroeconomic impacts**
  - **Firm-level vulnerabilities**
  - **Financial sector losses**
- A key innovation is the **calibration of a nature shock using proxy macroeconomic scenarios**, allowing quantification of **absolute financial stability impacts**, rather than relative comparisons.
- The empirical focus is on **water-related risks**, used as a proxy for broader nature degradation.

At a Glance

Keywords: ESG Risk, Physical Risk, Stress Test, Credit Risk, Market Risk, Insurance

01

Data

Data

The analysis integrates **environmental, macroeconomic and financial supervisory datasets** to quantify vulnerabilities and financial impacts.

Nature Data	
Two main databases are used:	1. **ENCORE**: provides sector-level **dependency on ecosystem services** (integrated with with multiregional input–output data) 2. **ND-GAIN**: provides indicators of **nature degradation and vulnerability**
A **key methodological challenge** arises from **mismatched granularity**:	• ENCORE: detailed ecosystem services (e.g., water purification, flow regulation) • ND-GAIN: broader categories (e.g., water vulnerability) • To reconcile this, the authors apply **principal component analysis (PCA)**
Ecosystem services cluster into three groups:	1. Water Supply 2. Biomass Provision 3. Education & Research
This allows:	• Aggregation of ecosystem services into **representative categories** • Mapping **water-related services** to a single **water vulnerability indicator** Additionally: • **Indirect dependencies** (via supply chains) are captured using **EXIOBASE input-output tables**

Financial and Regulatory Data	
The study combines:	1. **Supervisory data**: • AnaCredit (loans) • SHS-S (securities holdings) 2. **Regulatory disclosures**: • COREP (banks) • Solvency II (insurers)
The analysis is conducted at two levels:	1. **EU level**: • Production losses • Market valuation impacts 2. **Netherlands level**: • Prudential impacts (CET1, SCR)
This dual-level approach enables:	• Macro-financial assessment • Institution-level supervisory insights

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Methodology

Methodology 1/5

This section provides the **core analytical framework**, linking nature shocks to financial stability outcomes.

Proxy Scenarios for Nature Shocks

Due to limitations in nature-to-economy modelling, the paper uses **three proxy scenarios**:

- Historical production variability
- Climate-driven temperature impacts (water-cycle linkages)
- Long-term environmental stress models (Limits to Growth framework)

These scenarios converge on a **benchmark assumption**:

10% EU-wide production loss

This serves as:

- A **calibration anchor**, not a forecast
- A **"severe but plausible" stress scenario**

A key modelling assumption:

- Markets **instantaneously price in the shock**

Methodology 2/5

Calibration of Nature Shock

Nature-related risk is defined as:

The framework applies vulnerability to **production**, consistent with ENCORE definitions.

Vulnerability to Nature

Vulnerability is defined as function of **dependence on nature** and the **size** of nature **degradation**. It incorporates:

- **Direct dependencies** (firm activity)
- **Indirect dependencies** (supply chains)

Using input-output tables, the framework computes upstream exposure ratios. This allows estimation of firm-level vulnerability at sector-country level.

Key advancement: improved measurement of **government and financial sector dependencies**, which are underestimated in ENCORE.

Key Insight

The **aggregate macro shock is distributed across firms** based on their **vulnerability profiles**, leading to **heterogeneous impacts**.

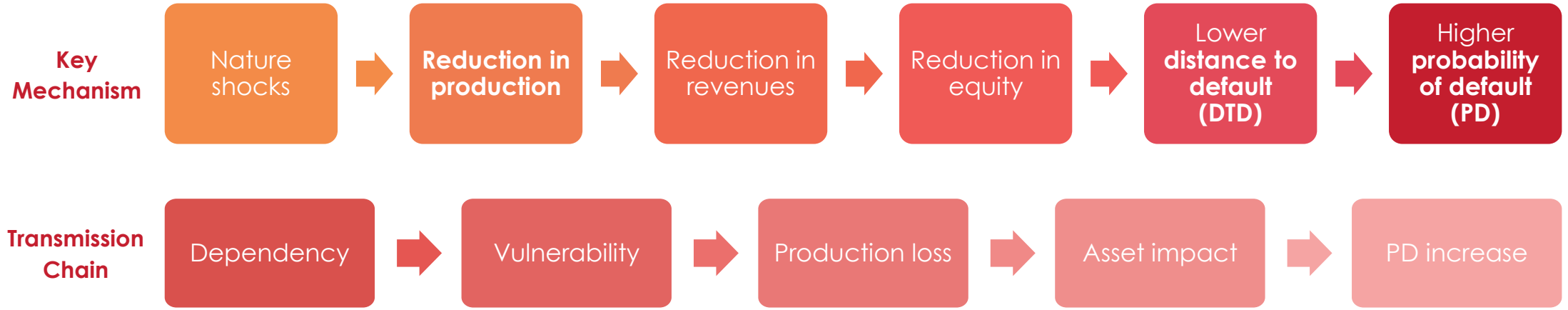
A **central innovation** is:

- Endogenous calibration of the nature shock (α) such that aggregate production loss matches the scenario (10%)

Methodology 3/5

Microeconomic Impact (Merton Model Extension)

The paper modifies the **Merton structural credit risk model** to incorporate nature shocks.



Key Innovation

Translation of **production vulnerability into asset vulnerability**, using:

- Return on revenue
- Cost of Equity

This ensures consistency between **macroeconomic shocks** and **firm-level balance sheet impacts**

Methodology 4/5

Financial Market Impact

The increase in PD drives:

Bond price declines

Bond prices decrease due to:

- **Higher PD**
- **Higher expected losses** (LGD adjustments)

Equity valuation losses

Equity is modelled as a call option on firm assets (Black-Scholes framework.

Key mechanism:

Reduced asset value + Higher PD → Lower equity prices

The framework isolates **credit spread effects**, excluding risk-free rate changes

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Prudential Impact

Banks (CET1 Ratio)

The CET1 ratio impact can be expressed as follows:

$$\Delta CET1_{ratio} = \frac{CET1 - \Delta EL}{RWA + \Delta RWA} - CET1_{ratio}$$

Where ΔEL represents the change in expected loss amounts, ΔRWA is the increase in RWA resulting from the deterioration in credit quality and $CET1_{ratio}$ stands for the bank's initial CET1 ratio prior to the shock.

Impact channels

Higher expected losses (EL) → Capital depletion

Higher risk-weighted assets (RWA) → Denominator increase

The CET1 ratio declines due to both effects.

Insurers (SCR Ratio)

Impact assessed through **revaluation of bond and equity portfolios.**

The change in the SCR ratio can be presented as follows:

$$\Delta \text{SCR}_{\text{ratio}} = \frac{EOF - \Delta EOF}{SCR + \Delta SCR} - SCR_{ratio}$$

Where EOF is the Eligible Own Funds defined under the Solvency II, ΔEOF represents the proportion of the loss attributable to shareholders and $\Delta SCR = 0$.

Key Assumptions:

- No immediate recalibration of SCR
- **Partial offset** via **loss absorption capacity of liabilities**

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Extension to Multi-Shock Scenarios

Extension to Multi-Shock Scenarios

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The framework is extended to include:

Multiple ecosystem shocks | **Climate risks** | **Transition risks**

The overall relative **variation in production** for a given sector–country pair can be expressed as the **weighted sum of the multiple shocks** and their corresponding **sector–country vulnerabilities**. A **multi-shock** can be delineated into **four core building blocks** of risk sources:

1. **ES-related Physical Risks**
   Shocks arising from ecosystem service (ES) physical risk factors.
2. **ES-related Transition Risks**
   Shocks affecting firms exerting significant pressure on nature; the methodology aligns with that of physical ES-related shocks, replacing ENCORE dependency scores with ENCORE impact scores, and is analogous to climate-related transition risks.
3. **Climate-related Physical Risks**
   Natural hazard shocks linked to global warming that are not encompassed within the ES definition.
4. **Cross-amplification Effects**
   Interactions among shocks capturing the non-linearity of real-world systems.

As an **illustrative application** of the multi-shock, **three components** are considered:

Ecosystem-based water-supply shock	Derived from an exogenous model, yielding a 3% global aggregate production loss.
Climate-condition shock	Based on an exogenous model, associated with a 5% global aggregate production loss.
Joint shock scenario	Evaluated through a model assessing the simultaneous occurrence of both shocks, resulting in a 10% global aggregate production loss.

Reductions in firms' distance to default translate into higher default probabilities within the Merton framework, prompting a repricing of bonds and equities and weakening the prudential ratios of banks and insurers exposed through holdings or credit provision.

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Results and Key Findings

Results and Key Findings

The framework produces **granular and policy-relevant outputs**.

Macroeconomic Impacts

- EU-wide production loss: **10% (assumption)**
- **Country-level variation**:
  - Finland: ~ -6.3%
  - Netherlands: ~ -14.6%

Financial Market Impacts

- Decline in **value of debt** and **equity holdings**: ~ **-5% (EUR 500 billion)**

Banking Sector

- **CET1 ratio** impact:
  - **-5.4% to -14.4%** (with RWA effects)
  - Lower when excluding RWA channel

Insurance Sector

- **SCR ratio** impact: **-0.6% to -50.4%**

Key Insight

Losses are **highly heterogeneous**, driven by:

- ***Sectoral dependencies***
- ***Geographic exposure***
- ***Supply chain linkages***

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Conclusions & Takeaways

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Methodological Contributions

- **Calibration of nature shocks** from macro scenarios
- **Operationalization of vulnerability** (dependence × degradation)
- **Integration** into Merton-based **credit risk modelling**
- **Extension to insurers' market risk** and prudential metrics

Implications for Supervisors and Institutions

- **Stress testing** frameworks should incorporate **nature risks**
- **Sectoral** and **geographic heterogeneity** must be **explicitly considered**
- **Data gaps** (especially firm-level dependencies) remain a **key constraint**
- **Joint climate-nature risk modelling is critical** for forward-looking supervision

Policy-Relevant Insights

- **Nature degradation** can:
  - Trigger systemic financial losses
  - Affect prudential ratios significantly
- **Results** support:
  - Development of **NGFS nature scenarios**
  - Integration into **Pillar 2 supervisory expectations**

Key Takeaways

- **Nature-related risks are financially material** and can be integrated into stress-testing frameworks
- **A top-down approach linking:**
  nature ➡ economy ➡ finance
  is feasible and operational
- **Water-related risks serve as a robust proxy** for broader ecosystem degradation

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