Toward macroprudential frameworks for managing climate risk

SUERF BAFFI Bocconi e-lecture
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The ECB/ESRB Project Team on climate risk

2020: How existing data and models could be deployed for climate risk analysis

2021: Filling analytical gaps: physical risk, + longer term scenario analysis

2022: Initial macroprudential policy reflections + broadened analytical foundations

2023: Frameworks
   (i) climate risk surveillance
   (ii) macroprudential policy
   (iii) broader nature risk

2024+: Integrate frameworks into standing assessments

Workstream 1: Measurement
   Stephan Fahr (ECB)
   Thomas Allen (Banque de France)

Workstream 2: Policy mapping
   Michael Grill and Fabio Tamburini (ECB)
   Ludvine Berret (Banque de France)

Workstream 3: Environmental considerations
   Laura Parisi (ECB)
   Julja Prodani (DNB)
Climate change risks

Transition risk
- Forward looking risk and vulnerabilities (e.g. transition credit risk index, carbon risk score)

Market risk
- Equity overvaluation, climate news and sovereign spreads, Greenium

Physical risk
- Forward Lending sensitivity, protection gap physical credit risk index

Real interlinkages:
- Input-output interdependencies / spillovers

Systemic risk

Financial interlinkages:
- Financial sector contagion, risk transfer

Surveillance framework for climate-related financial stability risks

Temperature and emissions
- Geographic, institutional sectors, economic industries

Interdependencies

Natural hazards
- Chronic and acute Drought

Switches to:

Transition events
- Energy mix, households and corporates' exposures, transition: energy, corporate plans, public policies
- Weighted average carbon intensity, carbon tilt, carbon footprint, taxonomy alignment, concentration

Exposures to climate change
- Green and sustainable financing, sovereign climate financing

Physical events
- Past/current exposures, collateral, climate scenario-conditioned metrics
- Risk score, potential exposure at risk

Real economy
- Banks

Market financing
- Green and sustainable financing, sovereign climate financing

Real interlinkages:
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ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk.
Surveillance framework for climate-related financial stability risks

Temperature and emissions
- Global, country, tipping points

Climate change
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Natural hazards
- Drought, water stress, floods, wildfires

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- Transition risk
  - Transition credit risk index, carbon risk score, transition vulnerability factors
- Market risk
  - Equity overvaluation, climate news and sovereign spreads, Greenium
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Real interlinkages:
- Input-output interdependencies

Systemic risk
- Financial interlinkages:
  - Bank contagion, bank/non-banks

ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk.
It will get hot in euro area countries, in some cases markedly so.

Sources: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk. based on Copernicus Climate Change Service (C3S) Climate Data Store (CDS).

Notes: Panel (a): Projected values from Access-CM2 model. Panel (b): Projected values from Access-CM2 model. Temperature anomaly is calculated as deviation from the average observed during the period 1995-2014.
Chronic, not just acute physical risk, seems to also be accelerating

**Global sea temperature is rising**
Global sea-surface temperature anomaly in °C

**Ice extent anomaly**
Antarctic Region, (y-axis: Millions of square kilometres)

Notes: Panel (a): Temperature anomaly is computed as a difference from 1982-2011 mean. Panel (b): Sea level variation is computed with respect to 1995-2015 mean.
We are already reaching tipping point temperature ranges

**Literature-based estimates for temperature thresholds related to Global Core and Regional Impact tipping elements**

(y-axis: Temperature increase in °C, with respect to preindustrial levels)

- Greenland Ice Sheet collapse
- West Antarctic Ice Sheet collapse
- Labrador Sea ice sheet collapse
- East Antarctic Ice Sheet collapse
- Amazon Rainforest dieback
- Arctic Warm Coral die-off
- Boreal Permafrost abrupt thaw
- Barents Seas Ice Sheet collapse
- Boreal Forest [southern debasal]
- Boreal Forest [northern expansion]
- Sahel & West African Monsoon [loss]
- Mountain Glaciers [loss]


Notes: Literature-based estimates for temperature thresholds related to Global Core and Regional Impact tipping elements. Climate tipping points (CTPs) occur when change in large parts of the climate system – known as tipping elements – become self-perpetuating beyond a warming threshold. Triggering CTPs leads to significant, policy-relevant impacts, including substantial sea level rise from collapsing ice sheets, dieback of biodiverse biomes such as the Amazon rainforest or warm-water corals, and carbon release from thawing permafrost (Armstrong McKay et al., 2022). See also Dietz, S., Rising, J., Stoerk, T., and Wagner, G. (2021). Economic impacts of tipping points in the climate system (Proceedings of the National Academy of Sciences).
A stark energy transformation lies ahead, with strong country heterogeneity.

Historical and projected euro area energy mix
(y-axis: % of energy mix)

Historical and projected country-level energy mix
(y-axis: % of energy mix)


Notes: Panel (a): Projections based on the “Net Zero 2050” scenario from the NGFS. The energy mix compatible with the EU “Fit for 55” package (FF 55) is calculated based on the latest projections elaborated by the European Commission and, in particular, on the EU Reference Scenario 2020. Panel (b): Country-level projections based on the “Net Zero 2050” scenario from the NGFS.
Surveillance framework for climate-related financial stability risks

Climate change

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- Global, country, tipping points

Interdependencies

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- Drought, water stress, floods, wildfires

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Real economy
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Banks
- Weighted average carbon intensity, carbon tilt, carbon footprint, taxonomy alignment, concentration

Exposures to climate change

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- Risk score, potential exposure at risk

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- Transition credit risk index, carbon risk score, transition vulnerability factors

Market risk
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Physical risk
- Lending sensitivity, protection gap, physical credit risk index

Real interlinkages: input-output interdependencies

Systemic risk
- Bank contagion, bank/non-banks

Financial interlinkages
- ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk.

Climate physical risk hazard exposures differ markedly across regions, amid general underinsurance.

Mapping firm exposures to physical hazards

Share of insured economic losses caused by weather-related events

Sources ECB/ESRB (2021), Climate-related risk and financial stability based on AnaCredit, 427, ECB calculations. Notes: Physical risk hazard scopes reflect a 20-year horizon.

Source: EIOPA dashboard on insurance protection gap for natural catastrophes, European Environment Agency CATDAT.
Banks remain the key custodian of emissions reductions for firms

**Exposure indicators for financial institutions**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Key insights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted Average Carbon Intensity (WACI) and Bank Carbon Footprint (BCFP)</td>
<td>Assess exposure of the financial sector to high-emitting firms via loans and debt securities</td>
</tr>
<tr>
<td>Carbon-financing tilt</td>
<td>Credit-weighted emission intensity relative to a value-added-weighted emission intensity</td>
</tr>
<tr>
<td>Taxonomy alignment</td>
<td>Estimate the level of alignment of financial portfolios to the EU Taxonomy for sustainable activities</td>
</tr>
<tr>
<td>Concentrated emission exposures</td>
<td>Share of lending to certain sectors, or using a climate-weighted Herfindahl-Hirschman Index</td>
</tr>
<tr>
<td>Exposures to physical hazards: shift in return periods</td>
<td>Shift in return periods of river flooding for banks loan portfolios under different RCPs, in % of number of debtors</td>
</tr>
</tbody>
</table>

Source: ECB/ESRB (2023), *Towards macroprudential frameworks for managing climate risk*. Notes: The list of indicators covers only indicators that are newly presented in this report. For a more comprehensive list of indicators, see separate Chartbook publication.

**Euro area banks’ lending towards emission-intensive sectors**

(y-scale: percentage; right-hand scale: Kg CO2e / EUR)

![Graph showing Euro area banks' lending towards emission-intensive sectors](image)

Sources: ECB/ESRB (2023), *Towards macroprudential frameworks for managing climate risk*, based on Eurostat, ECB Consolidated Banking Data and ECB calculations.
Household mortgage carbon intensity of mortgage finance high, albeit uneven across euro area countries

From household energy expenditure to carbon emissions

Share of high emitting households in outstanding mortgage balances


Notes: Energy expenditure is calculated using HBS fuel expenditures for electricity, gas and liquid fuels (heat and transport). Solid fuels are not considered due to missing data on type (coal, wood, etc.). HBS energy expenditures are converted into emissions using national energy price data (Eurostat and European Commission) and emission factors (Sustainable Energy Authority of Ireland and European Environmental Agency). Energy and emission estimates in HFCS and EU-SILC are based on regression model coefficients using HBS data. The set of covariates are the same for every country except NL, MT, CY and HR, due to data unavailability. High emission households (panel b) are defined based on the top quartile (within each country) of the emission distribution in the HBS 2015.
**Surveillance framework for climate-related financial stability risks**

- **Temperature and emissions**
  - Global, country, tipping points

- **Climate change**
  - Interdependencies

- **Natural hazards**
  - Drought, water stress, floods, wildfires

- **Interdependencies**

- **Exposures to climate change**

- **Physical events**

- **Transition events**

  - Real economy
    - Energy mix, households, and corporates' exposures, transition: energy, corporate plans, public policies
  
  - Banks
    - Weighted average carbon intensity, carbon tilt, carbon footprint, taxonomy alignment, concentration

- **Market financing**

  - Real economy
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    - Risk score, potential exposure at risk

- **Transition risk**

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    - Transition credit risk index, carbon risk score, transition vulnerability factors

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- **Real interlinkages:**
  - Input-output interdependencies

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ECB/ESRB (2023), *Towards macroprudential frameworks for managing climate risk.*
Multiple forward looking metrics based on scenarios to understand prospective financial loss

Scenarios draw from Network for Greening the Financial System

- Scenario analyses explore trade-offs between physical and transition risk, and examine possible contours of climate transition
  - ECB (2021): Top-down climate stress test (banks)
  - SSM (2022): Bottom-up climate stress test (banks)
  - ECB (2023): Short term transition dynamics (banks)
  - ECB/ESRB (2022): System-wide considerations

➢ Results generally confirm that the path to reduced climate risk may be bumpy, with net benefits from climate action only accruing with time, amid strong distributional forces

Source: ECB.
Focusing in on near(er)-term energy transition, and with it the ability to consider standard stress test

**Interacting shocks**
Illustrative scenario options

<table>
<thead>
<tr>
<th>Shock Type</th>
<th>Scenario Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro-financial shock</td>
<td>EBA adverse scenario 2023-2025</td>
</tr>
<tr>
<td>Climate policy shock</td>
<td>NGFS Carbon price shock (NGFS Delayed transition scenario anticipated in 2023)</td>
</tr>
<tr>
<td>Climate policy shock</td>
<td>Sectoral impacts</td>
</tr>
<tr>
<td>Climate policy shock</td>
<td>Investment shock</td>
</tr>
<tr>
<td>Climate policy shock</td>
<td>Capital cost shock with higher risk premia due uncertainty</td>
</tr>
</tbody>
</table>

**Impact on euro area economic activity**
Sectoral gross value added (2027) (percentage, compared to baseline)

Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk.

Notes: The two short-term scenarios proposed include a benchmark scenario assuming that the transition happens in a context of adverse macro-financial conditions, with heterogeneous impacts across sectors and requiring massive investments from both public and private sectors, and a second variant that also factors in the impact on the financial markets of the uncertainty associated with the transition. The EBA scenarios stop in 2025. After 2025, macro-financial variables are projected forward with the NGFS Delayed transition anticipated in 2023.
**Input-output linkages amplify physical risks across the globe**
(Regional GDP losses are combined with a global Input-Output model with demand and production shocks (based on Pichler and Farmer, 2022))

S&P Global data: GDP-at-risk from climate change (country-level)

Input-output data (OECD) for 45 sectors and 71 countries

Output losses are amplified but can be mitigated by trade reallocation.
(GDP losses across world regions due to direct climate physical risk and amplified through trade interconnections (GDP changes in pp))

Notes: The amplified GDP losses through trade interconnection are simulated through an input-output model developed at the ECB. A 100% Trade Reallocation Capacity (in dark blue) implies no cost for reorganising supply chains across trading partners and 0% precludes trade reorganisation. An adverse climate scenario is considered, i.e. RCP 8.5 scenario by 2050 with no adaptation measures and where all country-specific hazards materialise simultaneously across the world.
**Systemic amplifier #2: Financial contagion**

**Concentration risk and overlapping portfolio risk**
(Systemic risk through overlaps despite individual diversification)

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**Country-hazard related portfolio similarity across sectors**
Country-hazard related portfolio similarity across financial sectors (Index; 0 - no portfolio overlap, and 1 - full portfolio similarity)

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Source: ECB/ESRB (2023), *Towards macroprudential frameworks for managing climate risk*, based on *Sources: SHSS, Moody’s, own calculations.*

Notes: LHS: A1, A2 etc. represent different assets. The lines between banks and insurers as well as country hazards represent exposures. RHS: The physical risk-weighted portfolio similarity index measures similarity in overlapping portfolios across sectors to capture joint exposures to climate-related risks. More specifically, we calculate the cosine similarity index for each sector with the other sectors and take the average to get an index for each sector. NBFI = non-bank financial intermediaries, IC = insurance corporations, IF = investment funds, PF = pension funds.
Sovereign climate-related risks and link to financial stability

Systemic amplifier #3: Risk transfer

Sovereign risk
- Contingent liabilities
- Debt sustainability risks
- Feedback loop
- Higher financing costs

Transition risk
- Policy, technology, preferences, expectations
- Inter-temporal trade-off
- Physical risk
  - Acute, chronic

Real economy
- Income losses
- Adaptation costs
- Social adjustments

Financial system
- Contagion risk
- Portfolio overlap
- Higher funding costs

Private loss insurance (protection gap)

Bank-sovereign nexus

ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk.
1. Financial stability surveillance
   - Climate shocks, exposures, risk
   - Systemic amplifiers

2. Macroprudential policy options
   - Strategy
   - Implementation

3. Broader look at nature
   - Concepts
   - Exposures

4. Summary
Why a macroprudential approach to address climate risks?

Macroprudential policy can address systemic aspects of climate risk by:

1. making the system **less prone to climate risks** by preventing the build-up of risks
2. building systemic **resilience to climate risks** by increasing loss-absorbing capacity
3. having a **system-wide perspective**, preventing the migration of risks across financial system
4. usefully **complementing supervisory efforts and microprudential measures**

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Source: ECB/ESRB (2023), **Towards macroprudential frameworks for managing climate risk**. See also ECB blog: **Climate risk, the macroprudential view** (December 2023)
Macroprudential policy as complementary to microprudential tools

Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk
Main elements of a macroprudential framework for climate-related financial risk

1. General risks
   - Lender vulnerabilities: absolute risk
   - Lender vulnerabilities: relative risk
   - Borrower vulnerabilities
   - Inability to insure climate losses
   - Informational failure

2. Main objective
   - Scale-up loss-absorption capacity / increase resilience
   - Limit risk build-up

3. Policy options
   - Capital surcharges
     - Sectoral climate buffer / sectoral Systemic Risk Buffer
     - Climate buffer / Systemic Risk Buffer activated based on a concentration measure
     - Risk weights
   - Concentration limits/thresholds
     - Concentration charges above thresholds
     - Enhanced supervisory monitoring above thresholds
   - Borrower-based measures:
     - Include climate risk features in calibration models
     - Differentiated limits
     - Exceptions
   - Insurance:
     - Address insurance protection gap
     - Ensure insurers' resilience to systemic climate risks
   - Robust (ESG) labels
   - Enhanced disclosures

Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk
Capital to cover for (additional) unexpected loss?

Historical distribution
Higher mean and variance due to climate shocks
Average

Illustration of how a systemic risk buffer could be implemented

Isolating unexpected losses due to transition risk to calibrate the climate systemic risk buffer

Why buckets?
- Buckets in multiples of 50 basis points
- Bank-level heterogeneity in projected losses
- Aligned with systemic bank capital buffers and Pillar 2 frameworks

How: transition risk losses scaled by a calibration factor
- Idea in line with other prudential capital buffer requirements
- Motivation: potential overlap of other (buffer) requirements, limitations of stress testing, transition plans
- Robustness: Examine impacts of alternative calibration factors

Illustration of how a systemic risk buffer could be implemented

Stylized systemic risk buffer design options

- **Supervisory (P2) measures**
- **General SyRB**: with different rates per risk-bucket (e.g. based on concentration measures)
- **Sectoral SyRB**: (with multiple rates)
- **General SyRB (single rate)**
- **Sectoral SyRB (single rate)**

**Scope**
- All exposures
- Targeted exposures

**Granularity**
- Highly granular
- General buffer

**ECB illustrative SyRB calibration exercise based on transition risk**

Based on second ECB top-down economy-wide climate stress test
107 euro area significant institutions, 3-year period (2023-2025)

Source: ECB/ESRB (2023), *Towards macroprudential frameworks for managing climate risk*

Projected decrease in cumulative losses caused by reducing concentration to the level of the threshold (75th percentile)

(\textit{x-axis: year; y-axis: percentage decrease in losses due to compliance})

Transmission channels of climate risk to borrow-based measures

- Transition risk
  - e.g. increase in energy price's impact on borrower's solvency, depending also on EPC of building
  - e.g. new energy efficiency requirements
  - e.g. impact of rising temperatures on production

- Physical risk
  - e.g. decrease of collateral value in highly exposed areas

Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk

Note: Sample of 100 SIs. Calculations based on the new 2023 ECB top-down. High emitting firms are defined as firms scoring above the 75th percentile of relative emissions. If the thresholds is exceeded, exposures to high emitters are pro rate redistributed to non-high emitting firms until the limit is satisfied. The change in expected losses due to diversification is then attributed to compliance with the limit.
Addressing risks in the non-banking sector

A ladder approach to catastrophe insurance

- Greenwashing can be a driver for the materialisation of several standard financial risks. Key elements to curb it:
  1. Converge towards robust standards, definitions and labels in the sustainable finance sphere
  2. Close climate data gaps; and
  3. Enhance disclosure quality

- Some ongoing European initiatives:
  1. Work of European supervisors on greenwashing
  2. Work on disclosures (financial markets and corporate)
  3. Strengthening basis for ESG ratings

Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk
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Broader look at nature
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Summary
Definitions of nature and ecosystem services

Nature encompasses multiple **natural assets** (e.g. water, biodiversity, etc), which in turn provide **ecosystem services** to the economy.

Nature consists of multiple dimensions such as...

- Ground water
- Water flow maintenance
- Water quality
- Surface water
- Water availability
- and provides numerous ecosystem services to the economy and human wellness
- Biodiversity
- Climate regulation
- Soil quality
- Pest control
- Ventilation

Source: ECB/ESRB (2023), *Towards macroprudential frameworks for managing climate risk*
Climate-nature nexus

A controlled global warming and mitigation of climate change can help preserve ecosystems.

Nature degradation can speed climate change.

Healthy nature and biodiversity are essential for limiting climate change.

- Increasing temperatures and extreme climate events can cause nature degradation.
- Policies aimed at mitigating climate change can negatively impact nature.

Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk.
Transmission channels of nature-related risks

Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk
Bank and insurance exposures highly dependent on nature

Direct and indirect dependency on ecosystem services in the euro area

a. Banks
(total dependency score, Dec. 2021)

- Direct
- Upstream

- Mass stabilisation and erosion control
- Surface water
- Ground water
- Flood and storm protection
- Climate regulation
- Bio-remediation
- Water flow maintenance
- Mediation of sensory impacts
- Water quality
- Filtration
- Fibres and other materials
- Dilution by atmosphere and ecosystems
- Soil quality
- Ventilation
- Pest control
- Disease control
- Buffering and attenuation of mass flows
- Pollination
- Genetic materials
- Animal-based energy
- Maintain nursery habitats

b. Insurers
/share of total direct investments in corporate bonds and equity, December 2022/

- Direct
- Upstream

- Surface water
- Ground water
- Flood and storm protection
- Climate regulation
- Water flow maintenance
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Source: ECB/ESRB (2023), Towards macroprudential frameworks for managing climate risk. Notes: Weighted average of the dependency scores based on relative sizes of loan portfolios.
Outline

1. Financial stability surveillance
   - Climate shocks, exposures, risk
   - Systemic amplifiers

2. Macroprudential policy options
   - Strategy
   - Implementation

3. Broader look at nature
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4. Summary
Main messages

Financial stability risk surveillance: *Unevenly distributed and path dependent, with scope for amplification*

- Climate shocks becoming increasingly salient, and vicinity of tipping points
- Financial exposures to climate are appear material albeit concentrated (regional, sectoral, and firm level), suggesting merits of a granular assessment
- Financial risk could ensue from the interplay of exposures with the evolution of financial vulnerability, with a suite of scenario analyses suggesting net benefits from an orderly transition accrue increasingly with time, with strong distributional forces at play
- Numerous systemic amplifiers could imply risk propagation and scope for financial instability, suggesting a bumpy path ahead

Macroprudential policy options: *An evidence-based approach to contain and mitigate systemic risk*

- **Rationale**: Classic market failures, and some novel ones, can motivate macroprudential policy to tackle financial risk materialisation and buildup
- **Strategy**: An encompassing approach to address risk for the banking sector (absolute and relative), borrowers and non-bank financial intermediation
- **Operationalisation**: A starting point is offered by existing macroprudential instruments, even with limited adaptation
  - Promising role of systemic risk buffer and/ or concentration limits for banks, possibly complemented by borrower-based measures
  - A ladder approach could help tackle insurance protection gaps
  - Data gaps need to continue being addressed, to tackle informational market failures

A broader look at nature: *An initial look at concepts, and exposures*

- Nature degradation risk interrelated with climate, sharing with many conceptual similarities
- Exposures suggest material dependencies on *ecosystem services* for the EU financial sector, notably water and soil related