EUROPEAN CENTRAL BANK

EUROSYSTEM

ECB Climate stress testing

CLIFIRIUM,

École Polytechnique (Paris)

31 May 2022

Laura Parisi
ECB climate change centre

Disclaimer

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ECB economy-wide climate stress-test

Challenges and proposed solutions

Based on Alogoskoufis et al. (2021), "ECB economy-wide climate stress test: methodology and results", ECB Occasional Paper, September 2021.

Main messages from ECB economy-wide climate stress-test

Features

1. **Climate scenarios** built to account for the interplay between **transition** and **physical risk** over next **30 years** relying on the work by the NGFS
2. **Granular climate and financial information** collected for millions of corporates to which euro area banks are exposed via loans and security holdings
3. **New models** to capture climate risk transmission channels on firms' financials and on credit and market risk for banks

Results

1. **Short-term costs** of green transition always more than compensated by **long-term benefits**
2. If policies for a green transition are not introduced, **physical risks become increasingly** (and non-linearly) **higher** over time: due to the **irreversible nature** of climate change such an increase will continue over time.
3. **Impact from climate risks on average increases moderately** until 2050, it is however **concentrated** in some areas and sectors
4. For corporates and banks most at risk**, impact potentially very severe,** with possible consequences for financial stability

Challenge number 1: which stress-test approach?

Top-down
- Supervisory authority or central bank develops methodology, collects data and performs assessment
- No role for the targeted institutions

Bottom-up
- Supervisory authority or central bank provides some input/parameters (e.g. scenarios) to calibrate the exercise, however each targeted institution assesses the impact on its own portfolios
- Big role for the targeted institutions

Constrained bottom-up
- Supervisory authority or central bank provides some input/parameters (e.g. scenarios) to calibrate the exercise
- Each targeted institution assesses the impact on its own portfolios
- Supervisory authority or central bank challenges the estimates provided by the institutions with top-down models

- *EU-wide stress test (biannual)*
- *2022 supervisory climate stress test*

Challenge number 1: which stress-test approach?

Top-down

- Supervisory authority or central bank develops methodology, collects data and performs assessment
- No role for the targeted institutions

- *ECB economy-wide climate stress test*
- *Climate stress test of Eurosystem balance sheet*

✓ Less resource-intense

✓ Higher level of granularity

✓ Level playing field and comparability of results

✓ Larger sample of institutions

✗ Limited portfolios considered

✗ One-size-fit-all: no banks' views/assessment and no consideration of management actions

Top-down		Bottom-up
• DNB	• Banco de Espana	• Banque de France/ACPR (2020)
• EBA pilot sensitivity analysis	• Bundesbank sensitivity analysis	• ECB supervisory (2022, forthcoming)
• ECB economy-wide	• EIOPA sensitivity analysis	• Bank of England
• OeNB	• Banca d'Italia	

Source: ECB/ESRB, "Climate related risk and financial stability" (2021)

Challenge number 2: which time horizon?

Short (e.g. 3-5 years) — **Long (e.g. 30 years)**

- ✓ Lower **uncertainty**
- ✓ Similar to traditional stress tests: they can inform **prudential decisions** and **internal governance**
- ✓ Can assess **transition** and **acute** physical risk
- ✗ Not able to capture long-term impacts of a changing climate, i.e. chronic physical risk

- ✓ Can assess **transition** and **physical** risk
- ✓ Can assess broader **alignment** with Paris targets
- ✓ Can guide government actions/**policy proposals** and **strategic** decisions
- ✗ Higher uncertainty

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Long (e.g. 30 years)

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Policy-making perspective: comparison between the long-term costs and benefits of a green transition vs a no policy action scenario

Challenge number 3: which data?

General **lack of data availability, reliability and granularity!**

Identifying firms' **exposure to** (different types and degrees of) **natural hazards**

Lack of **disclosure of firm-level emissions**, especially for private firms and SMEs

Capturing the climate risk of firms from a **forward-looking perspective**

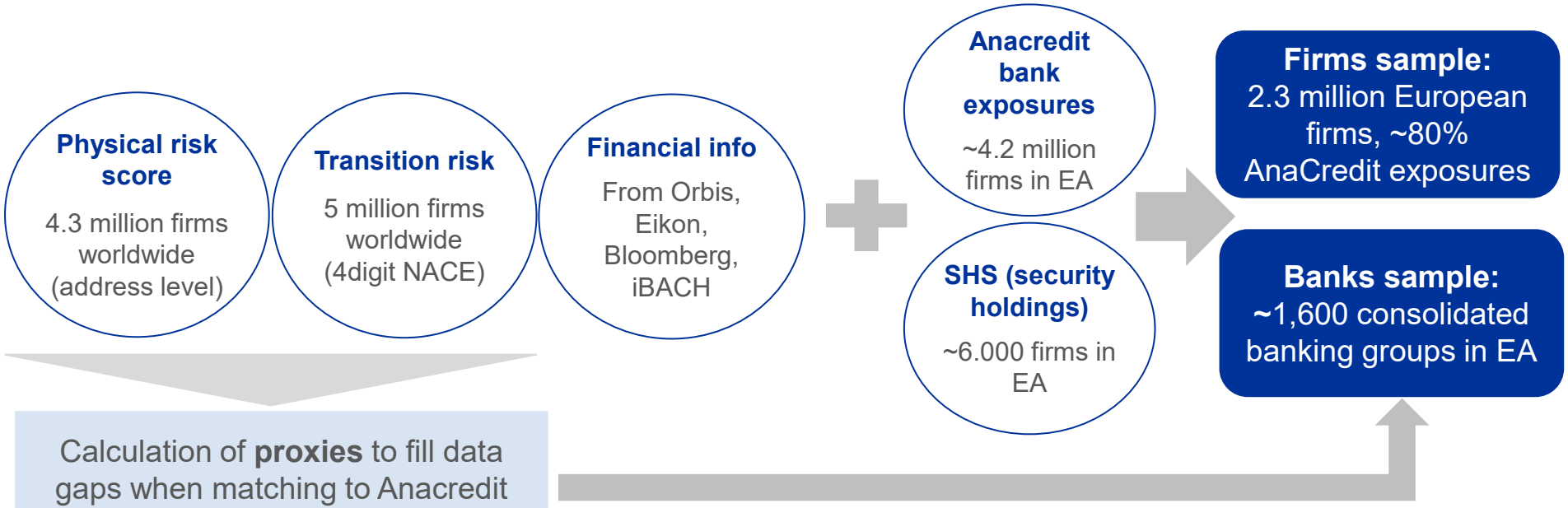
Geolocating firms and assigning physical risk scores on **address-level**

Use a **statistical estimation model** that infers firm-level emissions

Mapping NGFS scenario variables to NFCs **across the 30y horizon**

Integrated data infrastructure

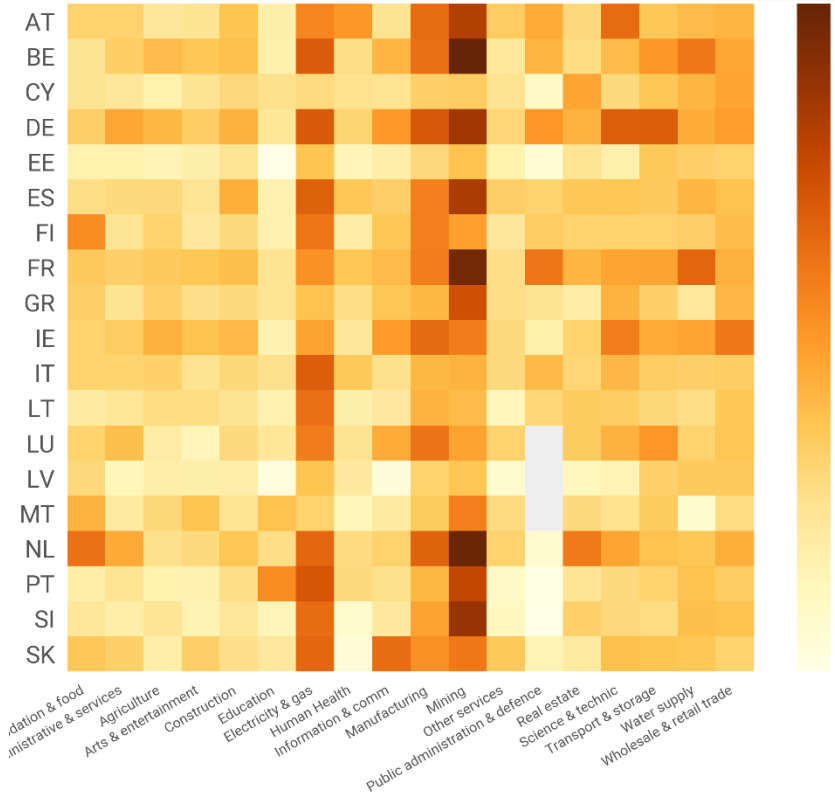
***Feature 2:** granular climate and financial information for millions of corporates*



Challenges: NACE sector, identifiers, geographical location in Anacredit (proxies based on ZIP codes)

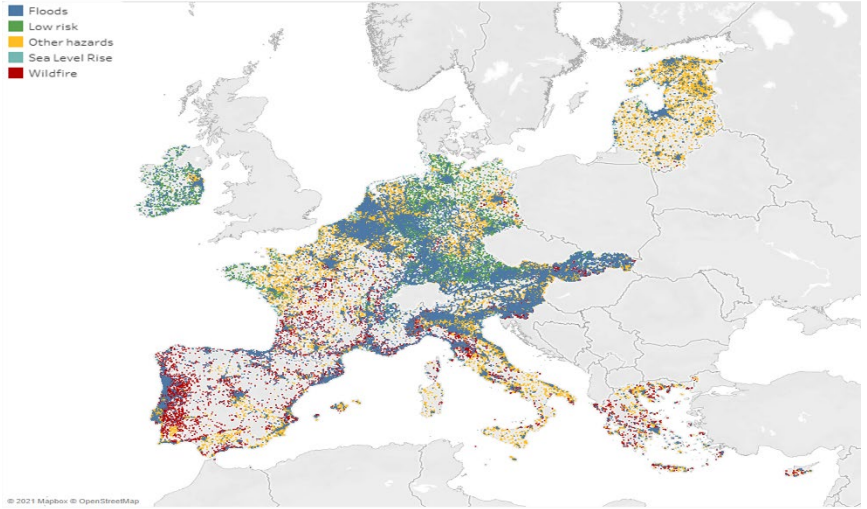
Firms' sample by transition and physical risk

Emissions by country-sector (tCO2e)



Source: ECB calculations on Urgentem data (2018). Coverage of GHG emissions in France is relatively lower due to lack of information on firms' revenues.

Physical risk intensity

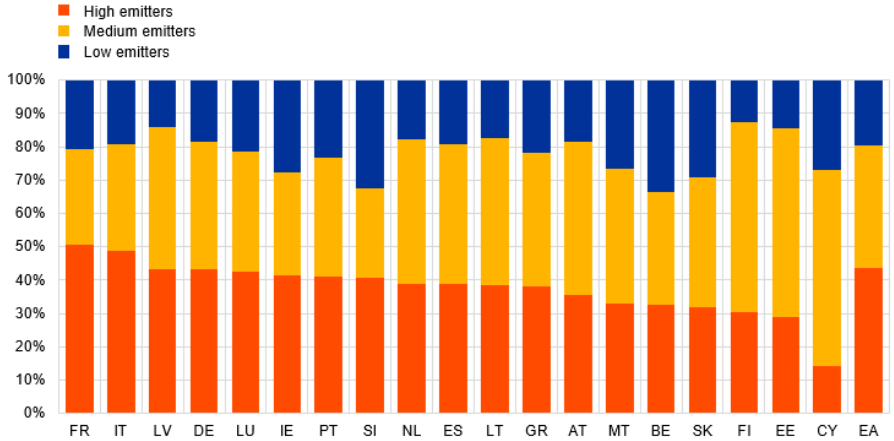


Source: ECB calculations on 427 data (physical risk scores are forward looking and reflect intensity and magnitude of natural catastrophes over a 30y horizon). Data are provided at the address level. The regional proxies are based on a sample larger than Anacredit.

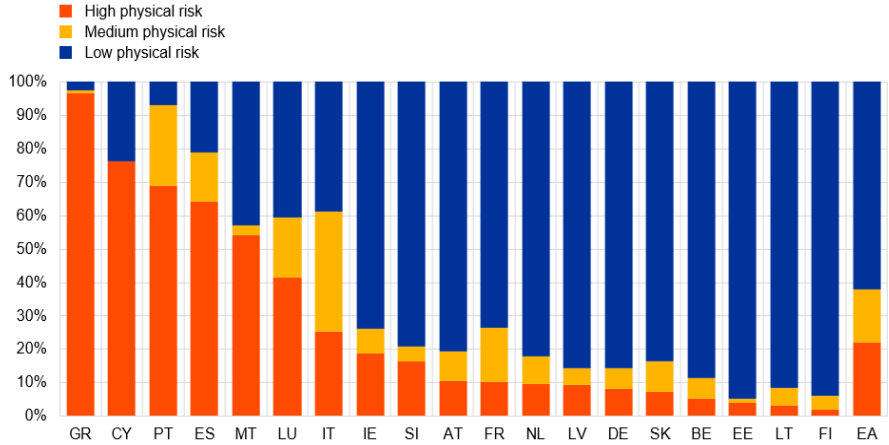
- **Highest emitting sectors:** mining, electricity, manufacturing
- Physical risk hazards **heterogeneous across countries**: south more subject to wildfire, north to flood

Banks' sample: exposures to transition and physical risk

Banks' exposure to transition risk



Banks' exposure to physical risk



Note: high emitters if total CO2 emission intensities (over revenues) > 70th percentile; low emitters if total CO2 emission intensities (over revenues) < 30th percentile. High physical risk if frequency of wildfire or sea level rise or flood >1% in 2020; low physical risk if frequency of wildfire or sea level rise or flooding for a firm <0 .1% in 2020

- **Exposure to transition risk** not too different across countries: share of exposures to **high polluting firms** in **FR and IT** slightly above euro-area average
- **Exposure to physical risk** highly divergent across countries: **bank credit portfolios** in **GR, CY, PT, and ES** most exposed to **high physical risk**

Challenge number 4: which models?

Standard stress-test methodologies do **not** account for **specific transmission channels** of climate risks!

Risk drivers

Transition risk
- Carbon costs
- Technological change and energy efficiency
- Demand for goods

Physical risk
- Damages to physical capital
- Production disruption

Revenues, costs, debt, profits, leverage, Probability of Default

Corporates (banks' counterparts)

Credit risk
Market risk

Banks
- Aggregate **default probability** of credit portfolio
- **Losses** from corporate bond repricing

Mitigants: Insurance coverage protects capital from damages

Amplifiers: Insurance costs increase in some vulnerable areas

Challenge number 4: which models?

Models' transmission channels of transition & physical risk

$$TA(t) = f(TA(t-1), GDP, inflation)$$

$$REV(t) = f(\text{REV(t−1), TA(damaged)(t) , VAT (Scope3), t})$$

$$OPEX(t) = F(\text{OPEX(t−1), TA(t), t}) + \Delta\text{cost(carbon(Scope1))} + \Delta\text{cost(energy(Scope2))} + \text{insurance} * \text{tangible}$$

$$Leverage(t) = \frac{Debt(t) + Green\ Investment(t) + Uninsured\ Physical\ Damages(t)}{Total\ Assets\ (t)}$$

$$Green\ Investment(t) = Sum(Scope1, Scope2, Scope3) * replacement\ cost$$

$$ROA(t) = \frac{REV(t) - OPEX(t)}{Total\ Assets\ (t)}$$

$$PD(t) = F(Leverage(t), ROA(t), Age, GDP)$$

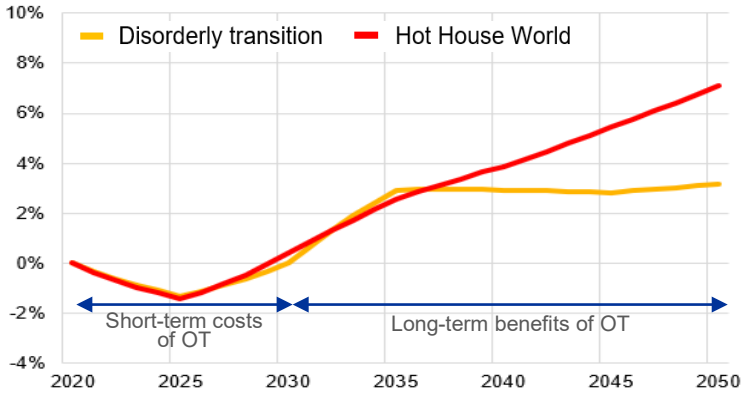
Results for banks: projected PD of corporate credit portfolio

Result 1: *short-term costs of transition always more than compensated by long-term benefits*
Result 2: *physical risks become increasingly higher over time and increase non-linearly*
Result 3: *risk for banks on average low, but concentrated in countries vulnerable to physical risk*

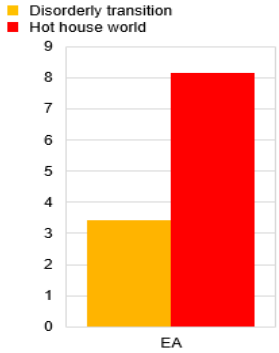
Median portfolio PD: time evolution

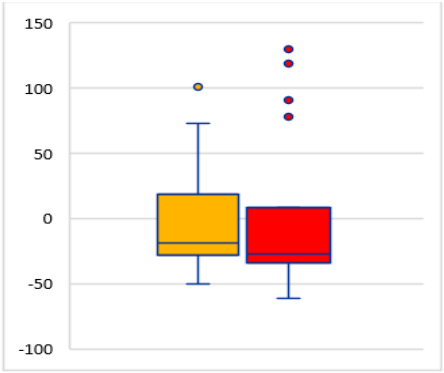
Average portfolio PD in 2050

LHS and middle panels: % differences in adverse scenarios compared to orderly transition scenarios; RHS: % difference from EA average



Note: LHS panel shows the percentage change under the adverse scenarios relative to the baseline (orderly transition) in 2050 for the corporate credit portfolio of the median bank in the sample





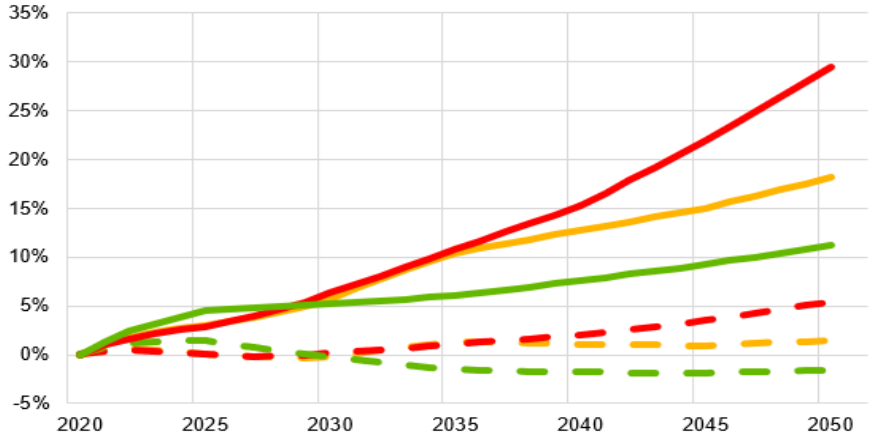
Note: Middle panel shows the Euro area average percentage changes under the adverse relative to the baseline (orderly transition) in 2050. RHS panel shows the distribution of country-level deviations from the Euro area average

Results for banks: possible financial stability implications

Result 2: *physical risks increasing over time, while transition even brings benefits in long-run*
Result 4: *impact on most vulnerable banks potentially very severe (and mostly driven by physical risk)*

Evolution of banks' credit portfolio PDs between 2020 and 2050

% differences from 2020 for the tail of banks (upper 10th percentile)



Tail banks' vulnerability

For banks **most at risk,** increase in credit portfolio PD by 30% from 2020 in HHW, **five times larger** than for other banks, and **three times larger** in HHW relative to OT in 2050

Alternative and complementary approaches

ECB supervisory climate stress test

Based on ECB (2021), "Climate risk stress test: SSM stress test 2022", October 2021.

ECB supervisory climate stress test compared to economy-wide

	Supervisory	Economy-wide
Approach	Constrained bottom-up	Top-down
Time-horizon	• Short-term: 3 years • Long-term 30 years with 10y steps • Point-in-time shock for acute physical risk	Long-term: 30 years annual
Scope	Approx. 100 supervised euro area entities: different institutions in different modules of the exercise (see next slide)	More than four million companies 1,600 EA consolidated banking groups
Risks considered	Credit, market, reputational	Credit, market
Balance-sheet	Static + dynamic	Static (dynamic extension ongoing)

ECB supervisory climate stress test: overview

Objectives

- **Joint learning exercise** with pioneering characteristics. Enhance capacity to assess climate risk, identify best practices and limitations, enhance data availability
- **Publication limited to aggregate results** with main conclusions from analysis
- **SREP integration focussing on qualitative** aspects with no direct quantitative impact

Modules

1. **Questionnaire:** Uniform and standardised assessment of banks' climate risk stress testing framework
2. **Peer benchmarks:** Uniform methodology for benchmarking banks across a common set of climate risk metrics
3. **Bottom-up stress test:** Uniform methodology for banks' bottom-up stress test projections.

ECB supervisory climate stress test: Scenarios

- **Scenarios based on NGFS Phase II** (June 2021). With respect to Phase I scenarios used in the ECB economy-wide exercise, they include expanded set of variables and country-level disaggregation
- The scenarios combine a **short-term** and **long-term** perspective

SHORT TERM

- Disorderly transition occurring in next 3 years
- Years 2031, 2032, 2033 of the NGFS disorderly transition are considered, and anticipated to 2022, 2023, 2024
- The baseline scenario is based on Eurosystem's staff projections published in December 2021

LONG TERM

- Three scenarios are chosen:
  - Hot house world
  - Disorderly transition
  - Orderly transition
- Decade-on-decade changes are given for 2030, 2040 and 2050

Applications

Metrics

Based on ECB Financial Stability Review (2022), Special Feature “Climate-related risks to financial stability”, May 2022

A new climate metric for supervisory purposes

Currently, the most **common climate metrics** is ***emissions-to-loans ratio.*** However, it has important **shortcomings** from a financial risk perspective:

- Although simple, it does **not account for the financial risk of loans**
- It can serve to identify to what extent loans finance big polluters, but **less useful for the climate/financial risk assessment** of loans

The new metric can be **used by banks and supervisors** for the combined climate and financial **risk assessment of loans**

Key elements of the new metric:

- ✓ **Simple** enough to **implement** and **analyze**
- ✓ Accounts for the **financial risk inherent in loans**
- ✓ Accounts for **firms' exposure to transition risk** and **puts it** into **perspective with financial risk**
- ✓ Can be conceptually **extended to physical risk**

Transition risk-to-credit intensity (TCI)

$$\text{TCI score}_j = \sum_i GHG\ emissions_i * Probability\ of\ default_{ij} * \frac{Loans_{ij}}{\sum_i Loans_{ij}}$$

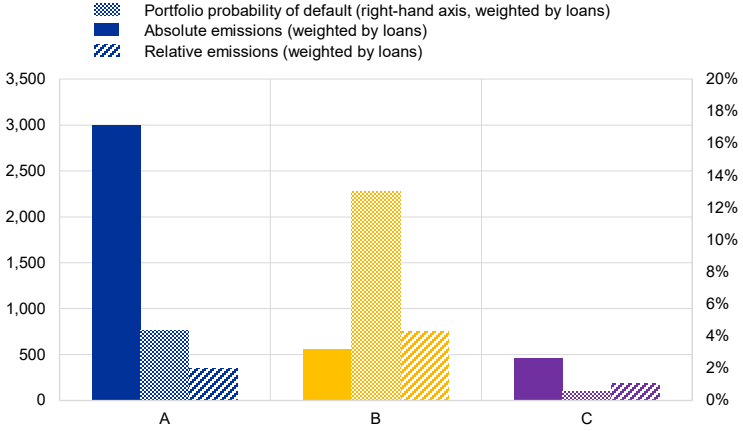
- The TCI serves as a **score** for assessing **the financial risk of a bank *j* due to the transition risk** of a firm *i* through its **loan exposures**
- Can be used with absolute emissions or emission intensities*, each capturing different types of high-risk firms:
  - Using **absolute emissions**, the TCI identifies **large and high emitting firms with the highest financial risk**
  - Using **relative emissions**, the TCI identifies firms with **high financial risk** which might be smaller but have the **highest emissions relative to their size** and are thus most sensitive to a carbon tax

* Defined as GHG emissions over revenues

TCI metric on three stylised portfolios (1/2)

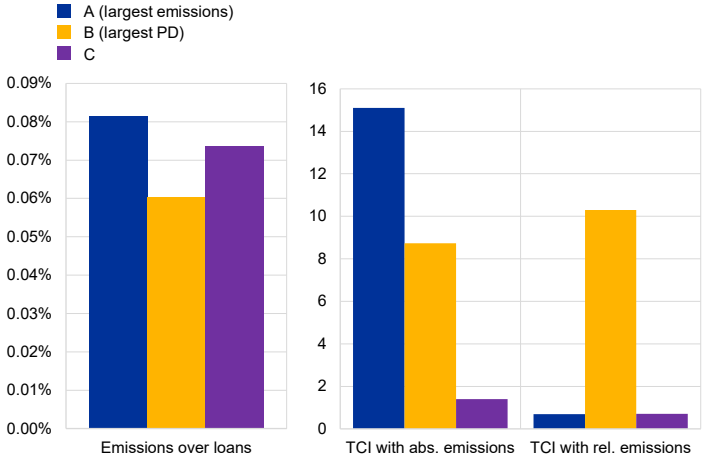
- We selected **three illustrative euro area bank portfolios from AnaCredit with real data on corporate loans**
- All portfolios have same size: **10 assets per portfolio**
- Information on **loan, provisions** and **firm IDs** are sourced from Anacredit
- We matched the assets of these portfolios with **firm-level GHG emissions from Urgentem**

Portfolio characteristics: weighted PDs and emissions of the stylized portfolios



TCI metric on three stylised portfolios (2/2)

Ranking of portfolios by different metrics*



- **Portfolio A** scores the highest in the **absolute TCI** due to large firms with large abs. emissions

→ **Reveals exposure to firms that are especially vulnerable in scenarios of climate policy changes**

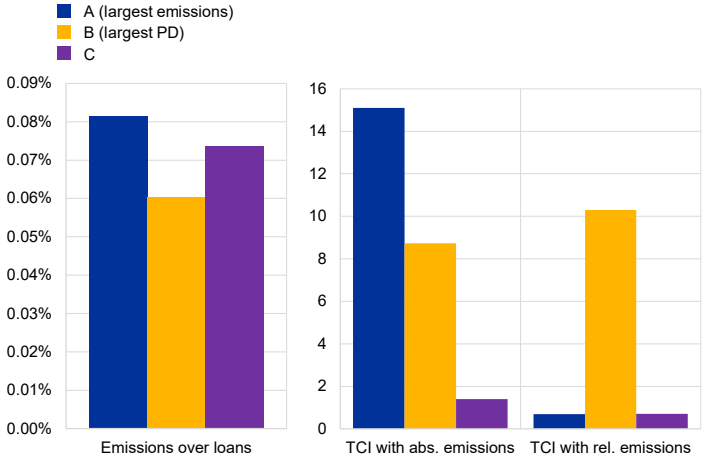
- **Portfolio B** scores highest in the **relative TCI** due to the higher relative emissions and financial risk

→ **Reveals exposure to firms with highest financial fragility and high emissions relative to their size**

* Portfolio-level metrics are the average of firm-level metrics, weighted by their loan size

Financial system exposures to transition risk have remained stable

Ranking of portfolios by different metrics*



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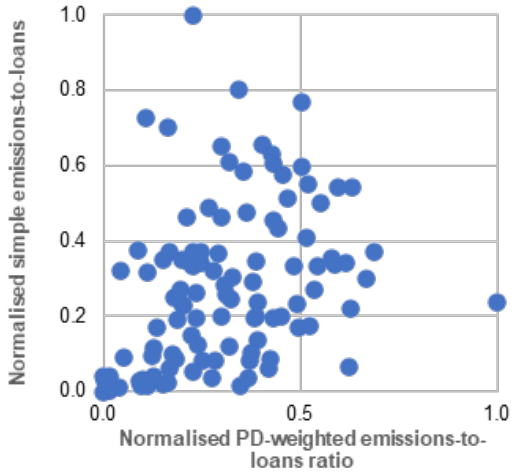
Financial system exposures to transition risk have remained stable

TCI applied to banks' credit portfolios provide complementary insights to the emissions-to-loan ratio:

- No perfect linearity, banks with large portfolios rank differently in these two metrics
- When accounting for financial risk, the ranking of sectors differs and is less pronounced for mining
- Climate risk has increased over time in the euro area banking system

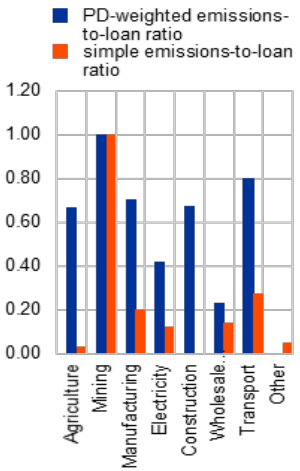
TCI versus simple emissions-to-loan ratio

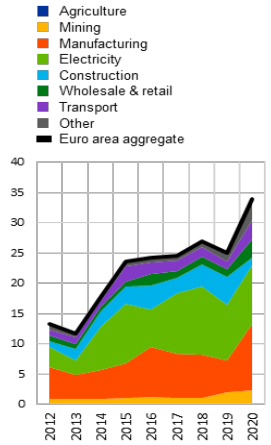
Significant Institutions



PD-weighted measures of emissions can capture the financial component of banks' climate risks

(left chart: normalized PD-weighted (TCI) and simple emissions-to-loan ratio by sector in 2019 (averages weighted by exposures); right chart: sectoral shares)





Source: ECB Financial Stability Review, Special Feature "Climate-related risks to financial stability" (2022)

Challenges ahead of us

Preliminary takeaways

Key takeaways from Phase I

- **Top-down and bottom-up** stress testing are very complementary and support each other: financial institutions' views combined with consistent top-down perspective.
    - Both exercises are learning experiences for central bankers, supervisors, supervised entities and the general public.
- **Climate risks can be material** for the financial system, with severe consequences in the long-run especially in certain economic sectors and geographical areas
- Although big milestones have been achieved over the last two years, **gaps remain** in terms of data, modelling and policy options

Next steps (1/2)

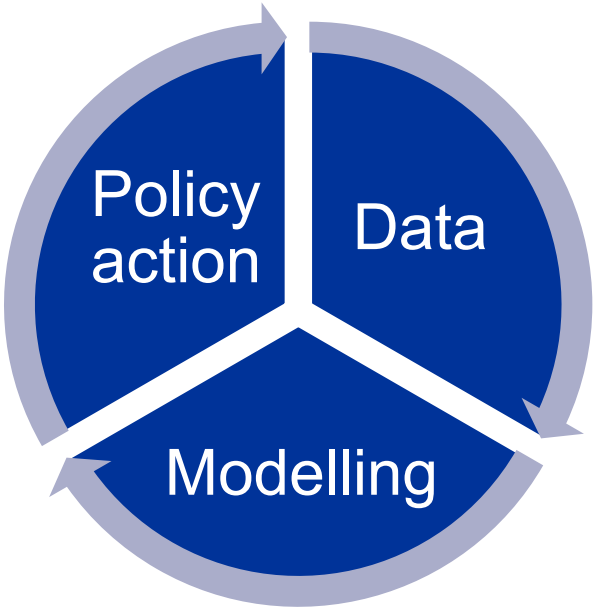
What is ongoing on climate stress test modelling

- NGFS **Phase III scenarios** (Updated figures, more granularity, additional variables)
- Extension of the modelling to **other scenarios** (Short-term Disorderly, Baseline, acute physical risk)
- Changes to the PD model from linear to **logistic** based on observed defaults instead of Expected Default Frequencies
- Improved **dynamics** of disorderly transition impact
- Introduction of **sectoral dynamics** (winning and losing sectors)
- Consideration of **distributional effects** of scenarios
- First version of a **Retail Model** for real estate loans

Next steps (2/2)

ECB approach on climate change agenda

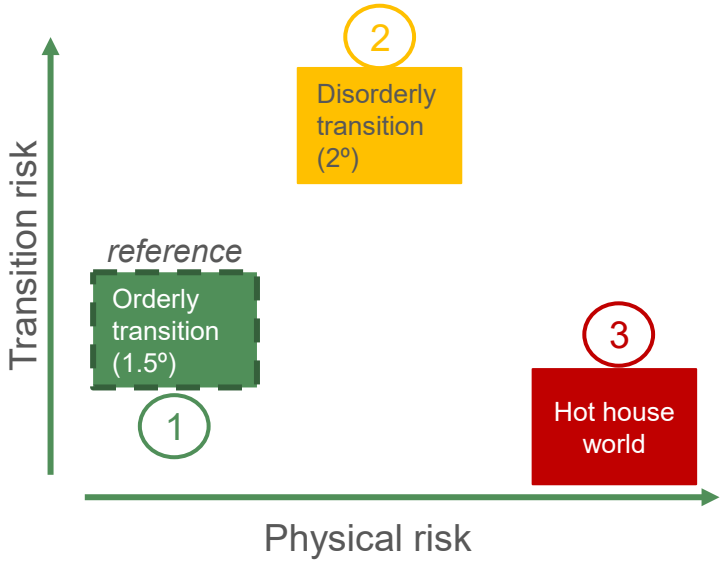
- Although climate modelling is just at the very beginning, **tackling climate change is urgent**. We cannot wait for perfect data and models
- ECB addresses the challenges of climate change in a progressive and pragmatic manner, via an **iterative and adjustable approach**
  - Increase quality and quantity of available data
  - Incorporate in analyses and modelling
  - Take policy action
  - Revise policy actions based on updated data and models
- **Regular updates** of existing exercises when new methodologies, data and scenarios become available
- **Policy application**: quantitative analyses and impact assessments to be used to understand the need and calibration of prudential instruments for the financial sector



Annex

Three climate scenarios that combine transition and physical risk

Feature 1: *climate scenarios to account for the interplay between transition and physical risk over the next 30 years*



Quantitatively, based on **NGFS scenario outputs**

Expected impact

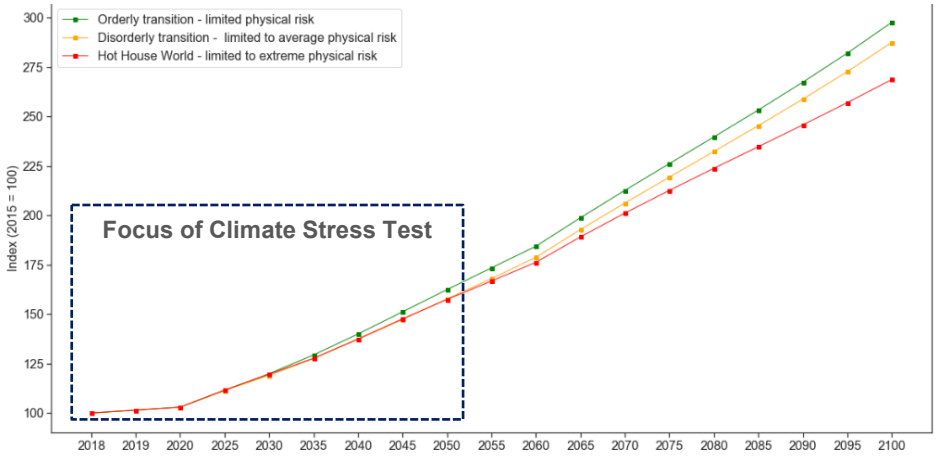
1. Orderly transition with limited physical risk
Early and effectively implemented policies
Limited costs from transition and physical risk

2. Disorderly transition with average physical risk
Delayed policies implemented
High costs from transition and average costs from physical risk

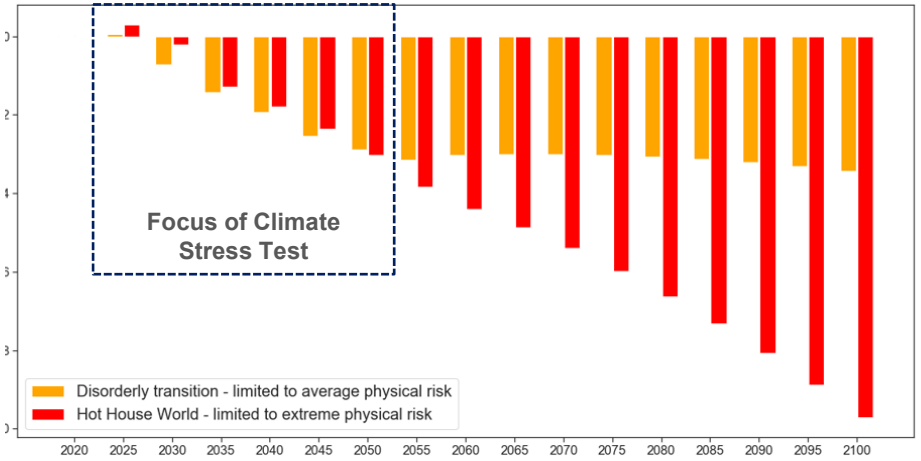
3. Hot house world with extreme physical risk
No new policies implemented (only current policies)
Very limited costs from transition but extremely high costs from physical risk

Overview of the scenarios: focus on Europe

GDP evolution (Indexed, 2005=100)



GDP deviation from orderly transition scenario (%)



Source: ECB calculations on NGFS references scenarios (2020)

- **Orderly transition** is the **first-best** option, while hot house world is the worst option especially in long run
- Disorderly transition has limited advantages with respect to policy inaction
- **Costs of the transition are more than compensated from reduced damages from physical risk in the medium-to-long run**

Modifications to the NGFS scenarios

Feature 1: *climate scenarios to account for the* ***interplay*** *between transition and physical risk over the next 30 years*

NGFS scenarios

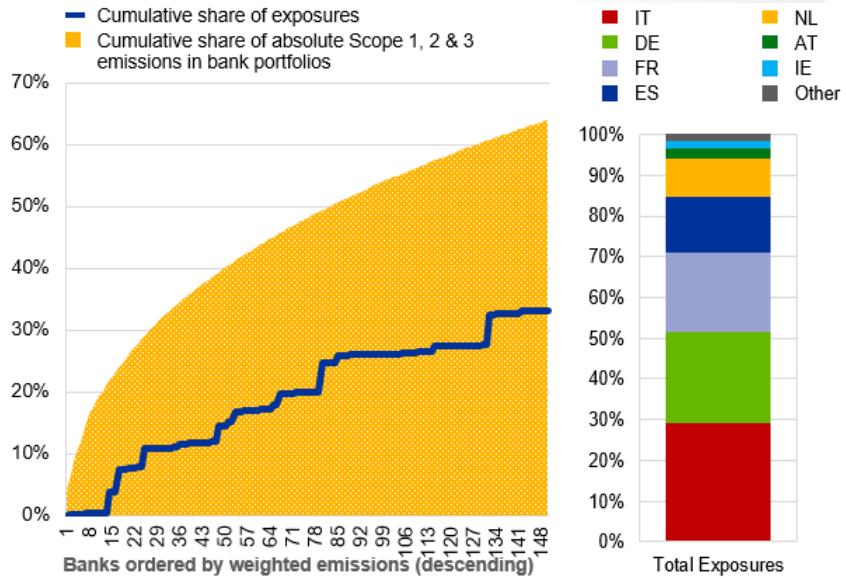
- Transition and physical risk impacts on GDP modelled and provided **separately**
- GDP impact from transition and physical risk **aggregated** in 11 macro regions worldwide

Our solution

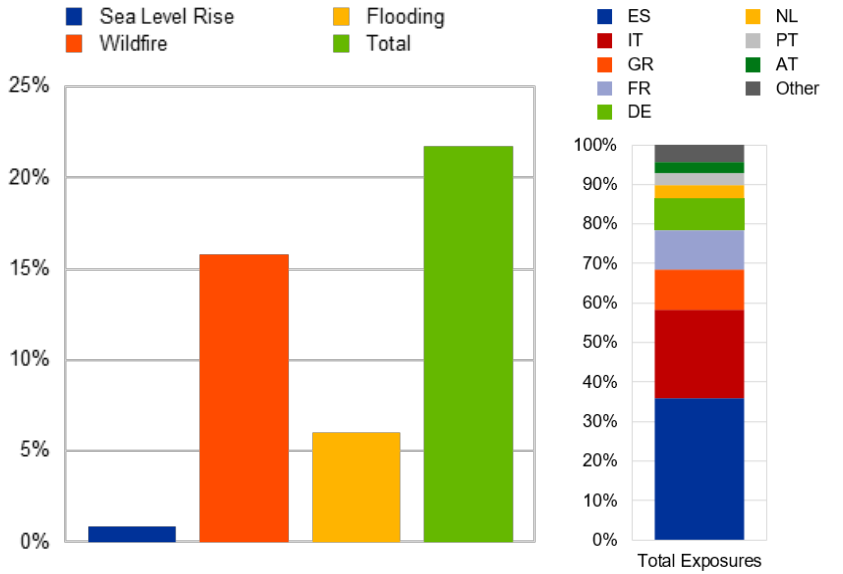
- Matrix of 3 scenarios **combining** GDP impact from transition risk with damages from physical risk
- Use granular datasets to disentangle projected emissions and damages from physical risk (for different physical hazards) at **firm-level**

Banks' sample: tail risk

Banks most exposed to transition risk



Banks most exposed to physical risk

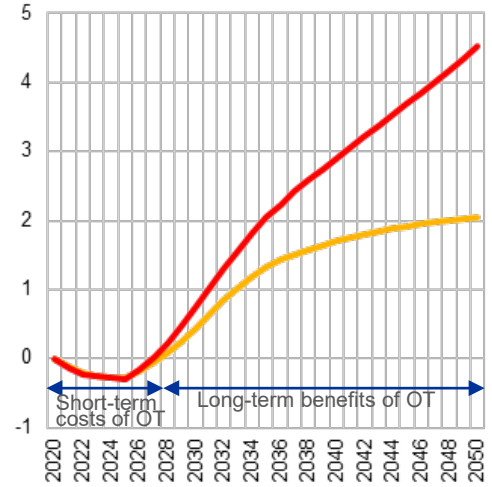


- Approx. 150 banks (<10% of total banks) account for **30% of total exposures** and **60% of overall emissions** in EA
  - of them, 65 banks already account for **20% of total exposures** and **45% of overall emissions**
- **22% of total banks' exposures** are subject to **high physical risk,** mostly driven by wildfire

Results for corporates

Result 1: *short-term costs of transition always more than compensated by long-term benefits*
Result 2: *transition more costly for carbon-intensive firms, but physical risks non-linearly increasing*

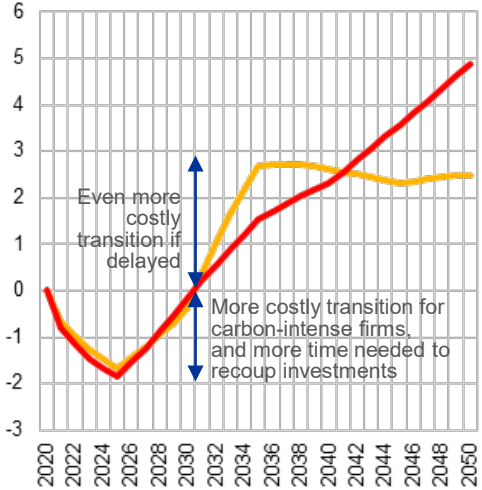
PDs: low-risk firms



- Impact of climate risks on average **limited**

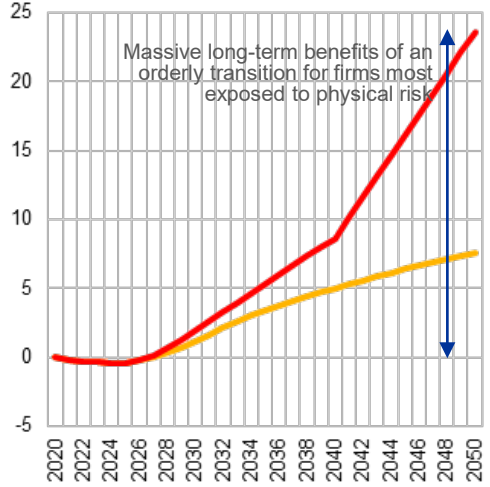
PDs: carbon intensive firms

All charts: % differences in adverse scenarios compared to orderly transition scenario



- Carbon intensive firms face **more costly transition**

PDs: high physical risk firms



- Firms vulnerable to physical risk are **at risk by 2050**

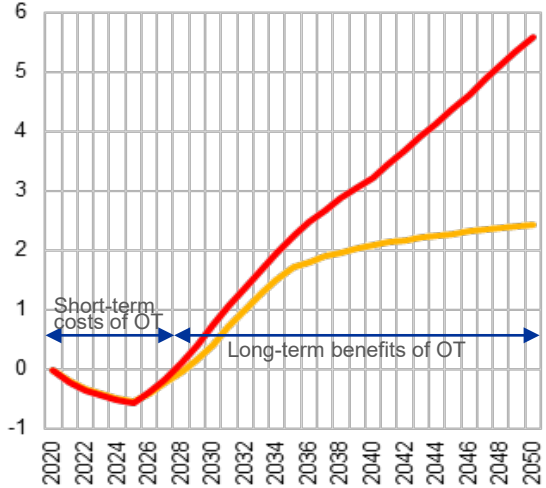
Disorderly transition Hot House World

Results for corporates

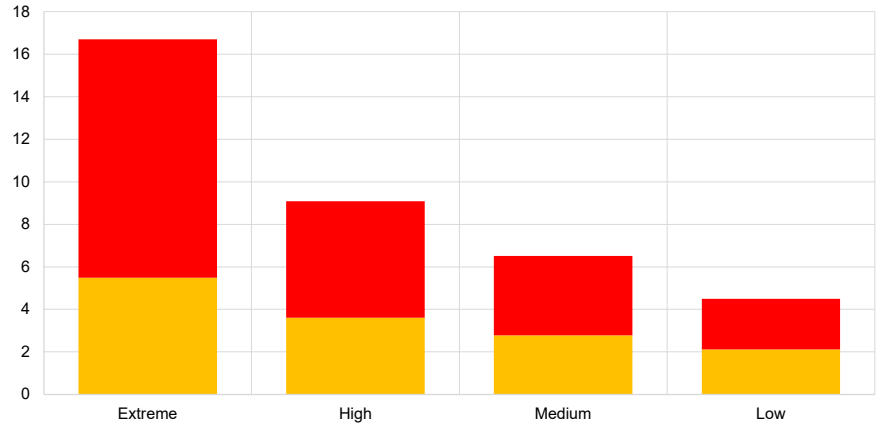
Result 1: *short-term costs of transition always more than compensated by long-term benefits*
Result 2: *physical risks become increasingly higher over time and increase non-linearly*
Result 3: *risk for corporates concentrated in some countries*

PDs of median firm

Both charts: % differences in adverse scenarios compared to orderly transition



Median PDs in 2050, country breakdown



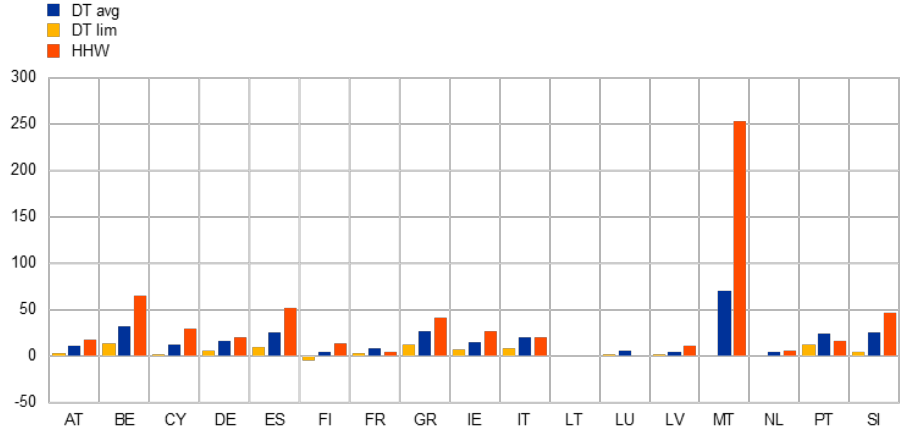
Notes: Countries are clustered in four regional clusters groups based on their level of physical risk.under the hot house world scenario. These figures are based on the average for the entire sample for each regional cluster.

Results for banks: market risk impact

Result 5: *market risk impact rather limited compared to credit risk channel (but always higher in HHW than OT*

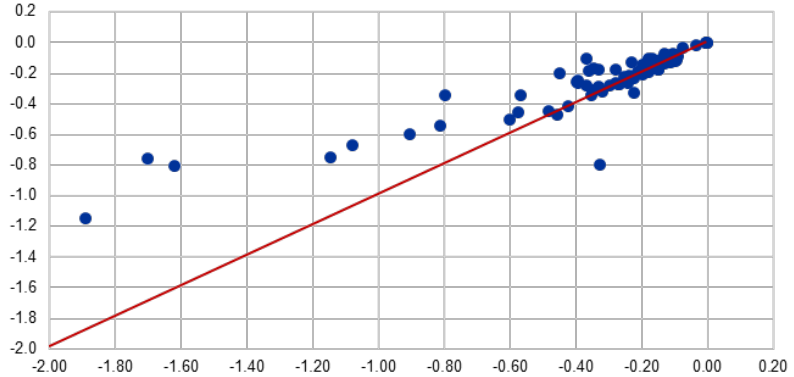
Total market losses by country

% differences in adverse scenarios compared to orderly transition



Total market losses by bank

Orderly transition (y-axis) vs hot house world (x-axis)



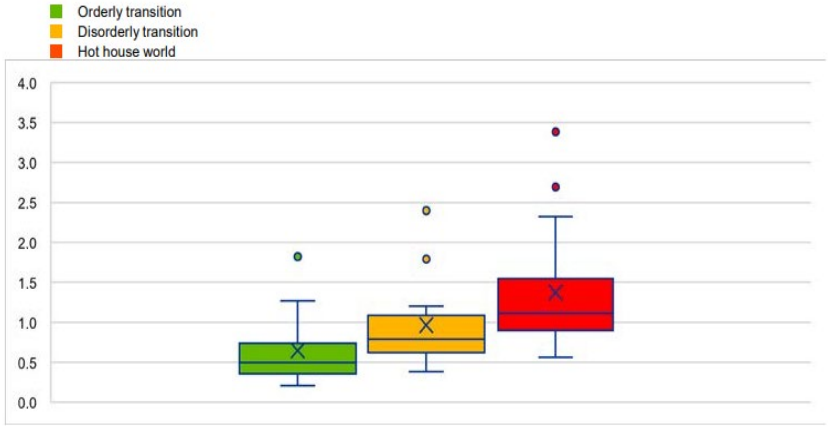
- Market losses calculated for **corporate bond portfolio** of 78 SIs (€30tn of TA and €80bn of corporate bond)
- Market losses also seem quite homogeneous across banks

Results for banks: climate adjusted LGD

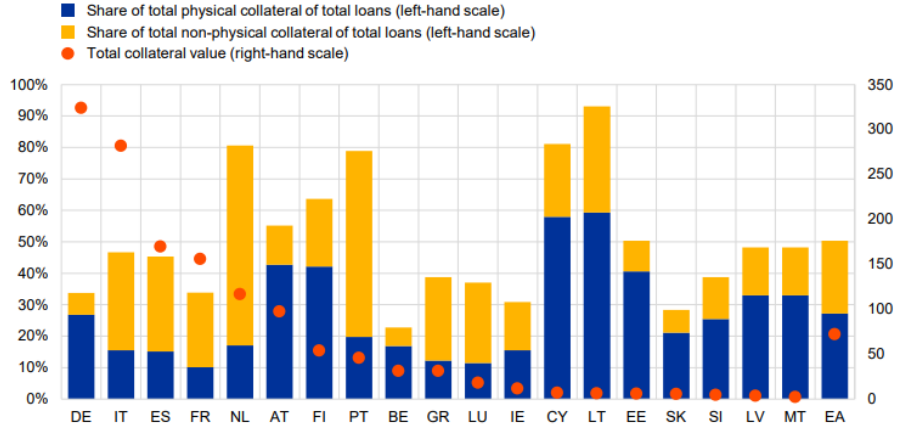
- Climate risks are assumed to impact LGDs via **two channels**
- **Macro channel** captures the sensitivity of LGDs to **macroeconomic conditions** (physical + transition risk)
- **Micro channel** captures the **depreciation** of physical collateral values from **natural hazards**

Distribution of the increase in portfolio LGDs

Difference between 2050 and 2020 LGDs (p.p.)



Share of loans protected by collaterall (split by type)



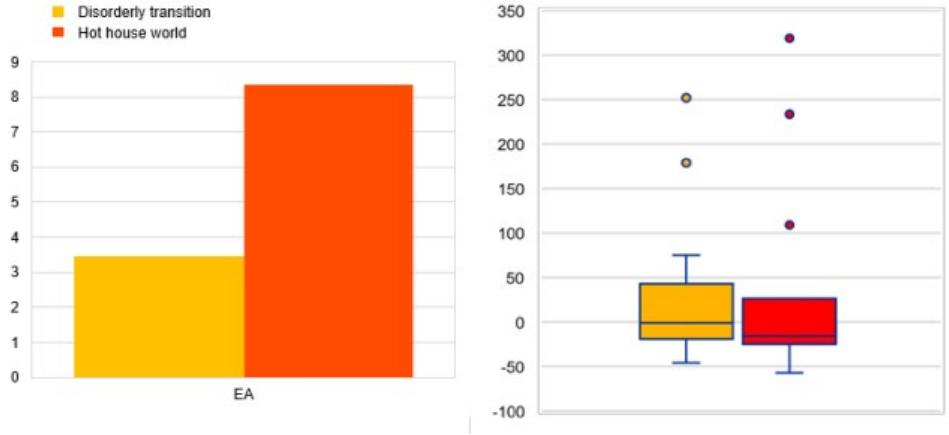
Physical risks dominate, with LGDs under the HHW scenario being most affected by **devaluation of physical collateral**

Results for banks: Expected Losses of corporate credit portfolio

Result 1: *short-term costs of transition always more than compensated by long-term benefits*
Result 2: *physical risks become increasingly higher over time and increase non-linearly*
Result 3: *risk for banks on average low, but concentrated in countries vulnerable to physical risk*

Average portfolio EL in 2050

LHS: % differences in adverse scenarios compared to orderly transition scenarios; RHS: % difference from EA average (country level)



Note: LHS panel shows the Euro area average percentage changes under the adverse relative to the baseline (orderly transition) in 2050. RHS panel shows the distribution of country-level deviations from the Euro area average