Stress-testing European banks for climate-related losses

Significant credit losses likely for vulnerable banks

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The growing economic and social impacts of climate change are expected to significantly slow global economic growth. For European banks, this will result in increased credit risk across retail, corporate and sovereign lending portfolios due to both physical and transition risks.

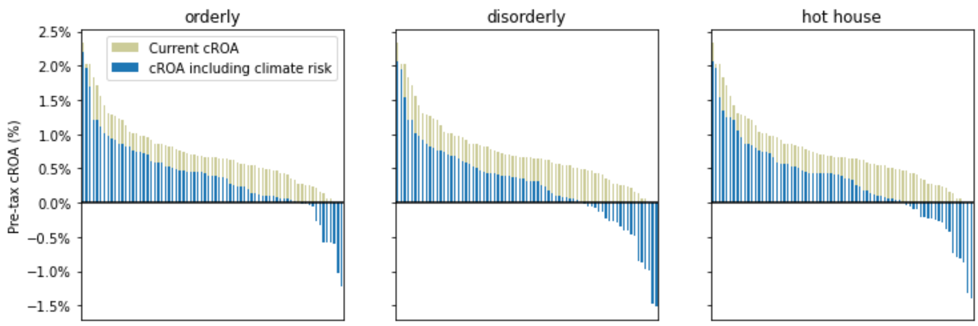
Physical risks encompass chronic effects (rising temperatures, sea level rise) and acute risks (floods and wildfires). Transition risks stem from policy shifts towards a low-carbon economy. To understand how these risks could seep into the financial system, we analysed potential credit losses for 73 banks operating in the European Economic Area under several scenarios.

Using the climate scenarios outlined by the Network of Central Banks and Supervisors for Greening the Financial System (NFGS) and based on current pre-provision profitability, banks face substantial potential credit losses. Large European banks (with assets above EUR 500bn) could see their pre-tax credit portfolio return on assets (cROA) completely wiped out in the long run.

Credit losses could almost triple under NGFS disorderly and hot-house scenarios. Economic shocks stemming from climate change could push portfolio returns into negative territory for 21 banks under the disorderly scenario and 19 banks in the hot-house scenario. We project that the most vulnerable banks located in Southern and Eastern Europe could face additional annual losses exceeding 250bp, mainly due to higher projected physical risk exposure.

While banks can risk-manage their balance sheets and margins, the magnitude of potential losses means they will need to develop robust transition plans to adapt to evolving circumstances and mitigate the associated risks of climate change. Our analysis supports ongoing regulatory efforts aimed at increasing banks awareness of climate-related risks, including their mapping and measurement, and indicates a need for increased climate risk management. The geographic concentration of losses needs further monitoring to prevent the building up of potential pockets of systemic risk.

Figure 1: Distribution of average pre-tax cROA 2045-2050 (%)



The NGFS orderly scenario = high short-term transition risk, lower physical risk; disorderly = medium transition and physical risk; hot house = low transition risk, high physical risk.
Physical risk covers chronic impacts (temperature changes, a rise in sea levels) and as well as acute impacts (floods, heatwaves or droughts). Transition risk encompasses the risks associated with a transition towards a low-carbon economy.
Source: NGFS, EBA, Scope Ratings

Introduction

Climate change is a structural challenge for economies

Climate change presents significant structural challenges for economies, which are projected to reduce growth in decades to come. Adverse economic conditions will affect financial institutions, introducing new types of risks that will have far-reaching implications for credit portfolios. These risks can generally be classified into physical risk and transition risk. Physical risk encompasses economic impacts from chronic climate changes such as rising temperatures, and acute risks arising from increases in severity and intensity of extreme weather events such as floods, wildfires, droughts, and tropical cyclones. Transition risk relates to the economic challenges associated with the shift towards a low-CO2-intensive economy.

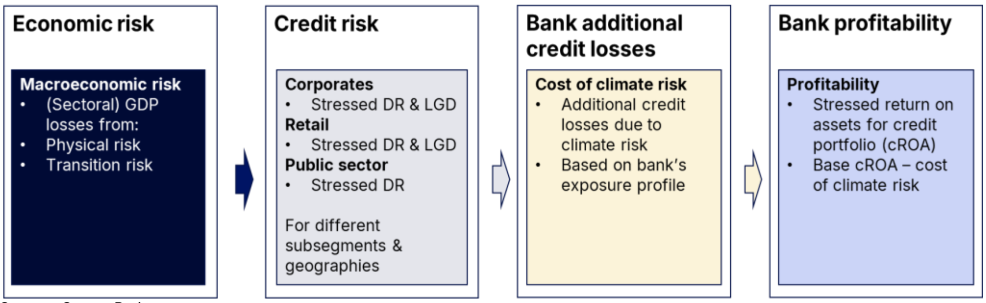
Although institutions and governments are beginning to assess the macroeconomic impacts of climate-related risks, the transmission of these risks into the financial system is not well understood. Our analysis modelled how economic shocks can translate into credit shocks across retail, government and corporate lending books for a sample of 73 European banks. We have estimated additional credit losses linked to climate risks and assessed their potential impact on banks' profitability in the short, medium and long run along three commonly adopted climate scenarios designed by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) phase V:

- **Orderly scenario**: early introduction of climate policies which front loads the cost of climate transition and the associated risk but limits physical risk in later years.
- **Disorderly scenario**: delayed introduction of climate policies, and ensuing higher long-term transition risk, because of delays or divergencies across countries and sectors. Physical risk is higher than in the orderly scenario.
- **Hot house world scenario:** no further climate policies are introduced beyond what already exists. Whereas this scenario does not imply transition risk, it results in severe physical risk in later years.

Appendix 1 provides more details on these scenarios.

Our approach to stressing banks' credit portfolio is summarised in Figure 2. Macroeconomic shocks emerge from physical and transition risk. Shocks to GDP translate into increased credit risks for corporate, retail and public-sector exposures. Due to the lack of detailed data on banks' financial institution counterparties, we did not estimate in detail their exposure to climate risk. Instead, we assumed that a bank's counterparties have similar exposures to the bank itself. Hence, we leave out financial institution exposures but assume these to be equal to the weighted average of a bank's non-financial institution exposures.

Figure 2: Schematic overview of Scope's climate stress test framework



Source: Scope Ratings

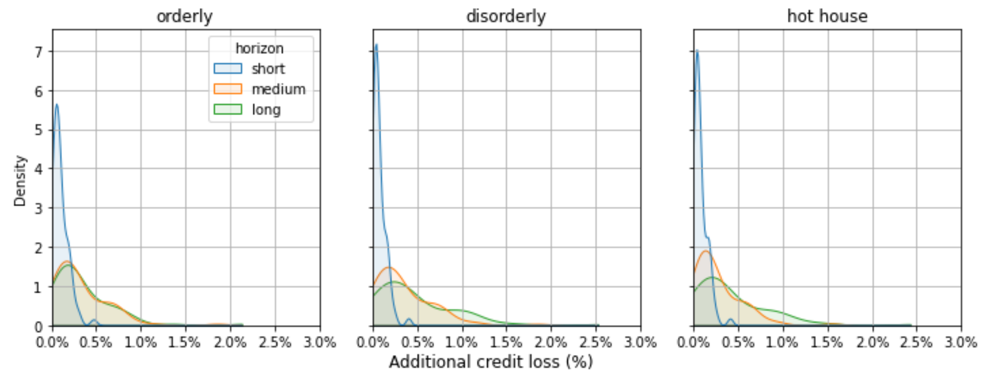
This increase in credit risk translates into higher credit losses, which in turn impacts profitability as measured by the pre-tax return on assets for banks' credit portfolios. Appendix 3 provides more detail on our stress test methodology.

Credit losses set to increase gradually but steadily

The longer the time horizon, the bigger the losses

Figure 3 shows the distribution of annual additional credit losses across the short, medium and long term[1]. In the short term, the impact is relatively benign, and most banks suffer losses of less than 50bp irrespective of the scenario. At longer time horizons, median losses increase. The impacts also become more heterogeneous, and have a long tail, particularly in the hot-house scenario.

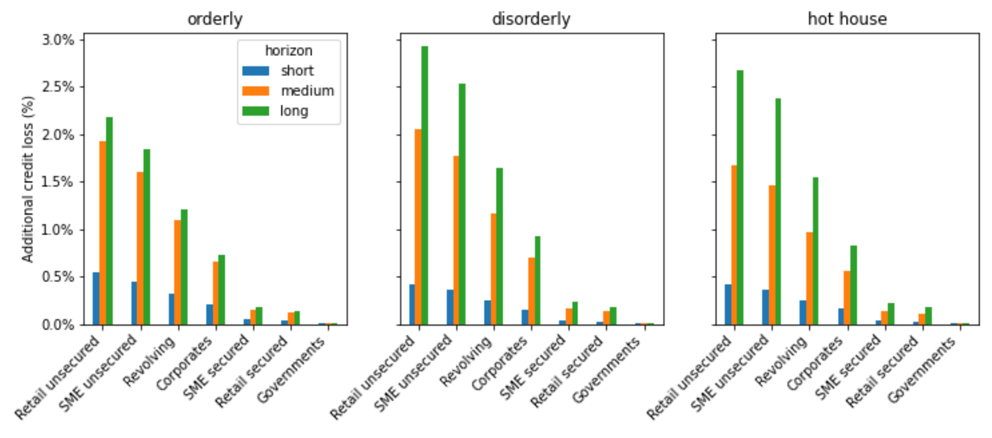
Figure 3: Annual percentual additional credit losses (pACL) by time horizon (% of interest-bearing assets)



Source: NGFS, EBA, Scope Ratings

The magnitude of losses is different for the segments analysed, reflecting their different sensitivities to GDP shocks. Figure 4 shows the average additional annual losses for different segments. Unsecured retail and SMEs have the highest additional expected losses, followed by qualifying retail and corporate revolving credit facilities. Secured loans and lending to governments have relatively small additional expected credit losses.

Figure 4: Average additional annual climate losses per segment for different scenarios and time horizons (% of interest-bearing assets)



Source: NGFS, EBA, Scope Ratings

[1] See Appendix 2 for definitions

Credit losses for a large European bank could triple by 2050

Synthetic credit profile to assess impact of climate change

To assess the potential impact of climate risk on large European banks, we constructed a synthetic profile based on the geographic and segment distribution of the credit exposures of banks with total assets above EUR 500bn participating in the European Banking Authority's (EBA) transparency exercise. This profile is described in Table 1. Most exposures are focused on Europe, though North America comprises a non-negligible proportion of exposures. In terms of lending segments, the portfolio is evenly split between corporates, government/public sector, and retail.

Table 1: Geographic and segment split of a large European bank

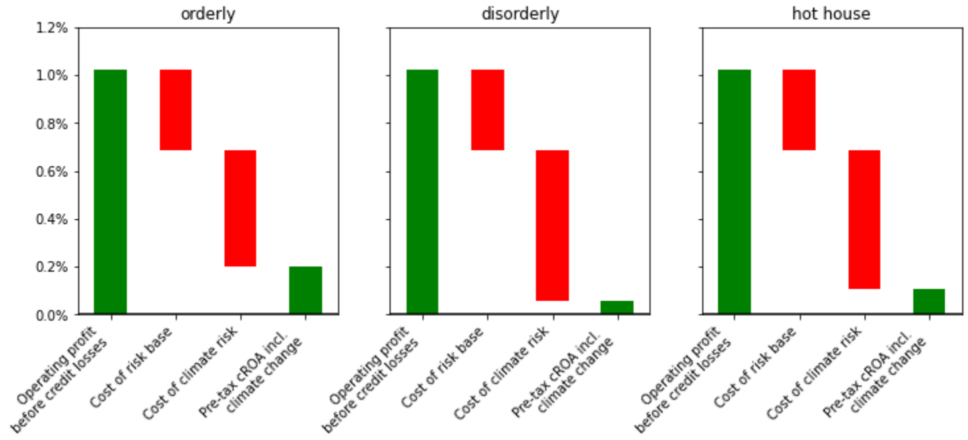
Geography	Exposure (%)
Western Europe	53%
Southern Europe	19%
North America	12%
Northern Europe	8%
Eastern Europe	3%
South & Central America	2%
Rest of the world	3%

Segment	Exposure (%)
Corporates	35%
Government & public sector	29%
Retail secured	23%
Retail unsecured	6%
SME unsecured	3%
SME secured	2%
Revolving credit facilities	1%

Source: EBA Transparency exercise 2023

The results for our synthetic bank are shown in Figure 5. Pre-provision profitability lies at 102bp of interest-bearing assets, whereas the cost of risk before considering climate risk amounts to 34bp, leaving the bank with a baseline pre-tax cROA of 68bp.

Figure 5: Average profitability of a synthetic large European bank for the period 2045-2050 (% of interest-bearing assets)



Source: NGFS, EBA, Scope Ratings

However, when we add additional losses from climate-change risks, cROA further decreases. In the orderly scenario, we expect an additional 51bp of annual credit losses in the long run. In the disorderly and hot house scenario, credit losses could almost triple, with an additional 63bp and 58bp of credit losses each year in 2045-2050 respectively, almost wiping out the bank's profitability.

Drivers of climate related additional credit losses

Physical risks outweigh transition risks in the medium-to-long run

Orderly transition leads to largest additional losses from transition risk in the short term

Refining our analysis, we delve into the drivers of climate related credit losses at the individual bank level. The objective is not necessarily to single out individual institutions but to identify the key drivers of these additional losses.

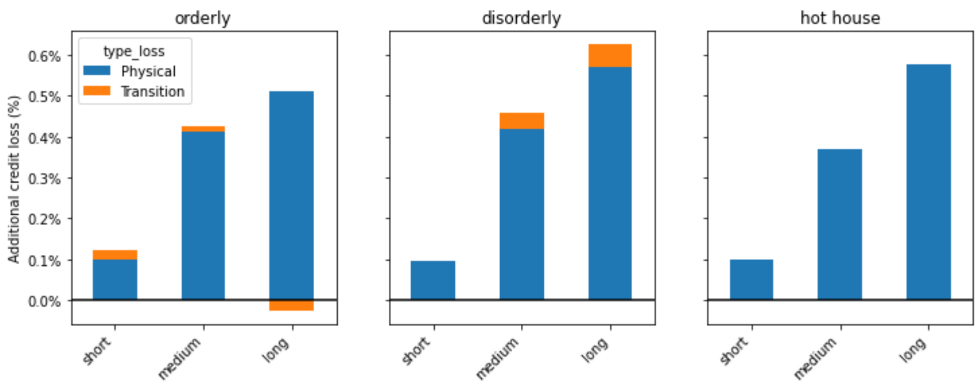
First, we attribute credit losses among transitional and physical risk. To highlight risks more specifically, Figure 6 shows how the climate credit losses of our synthetic large bank outlined in the previous section are distributed. The analysis shows that physical risks account for the majority of losses while transition risks appear to be a relatively minor driver.

In the short term, the orderly transition scenario leads to the largest additional losses due to transition risk, but these diminish as the shock from the transition fades and physical risks remain contained. In the long term, transition risk turns slightly negative reducing additional credit losses. This happens as the transition towards a carbon-neutral economy does not only have GDP-reducing effects such as carbon taxation, but also effects that can spur additional growth (e.g. increased investments). Moreover, our analysis only considers the impact of GDP shocks. Transition risk can also affect bank's credit books through other channels, such as increases in stranded assets.

The hot-house scenario assumes no further climate policy beyond what already exists, so does not have transition risk. Potentially counterintuitive, under the hot house scenario, physical risk losses in the medium term are lower than those of the other scenarios, which can happen due to projected weather interactions and their relation to economic growth.[2] Moreover, the NGFS modelling of physical GDP impacts does not directly consider the impact of extreme weather events. As intensity and frequency of extreme weather events is set to increase the most in the hot-house scenario, there may be an under-estimation of physical risk under the hot-house scenario compared to the other scenarios.

However, under the hot-house scenario, physical risk becomes larger than in the other scenarios in the long term. In between, the disorderly transition scenario assumes delayed climate action, resulting in higher overall losses in the medium and long run.

Figure 6: Additional pACL for synthetic large bank by type of climate risk (% of interest-bearing assets)



Source: NGFS, EBA, Scope Ratings

[2] The NGFS damage function depends on several variables, including average annual temperature, daily temperature variability, total annual precipitation, number of wet days, and extreme daily rainfall https://www.ngfs.net/system/files/import/ngfs/medias/documents/ngfs_scenarios_main_presentation.pdf

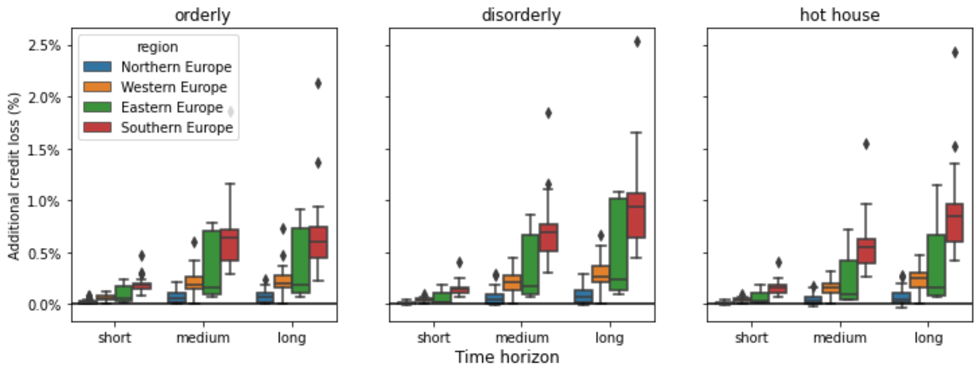
Southern European banks most exposed to climate risks

Climate risks dependent on region

Results vary across regions, as climate change and in particular acute physical risks affect weather patterns differently depending on the location. To better capture the geographical dimension of the risks involved, we looked at banks by the location of their National Supervisory Authority (NSA), grouped into four larger regions (see Appendix 2).

Figure 7 provides an overview of how additional credit losses are distributed for these regions. The median loss is highest for banks in Southern Europe, followed by Eastern European banks. In the long run, median annual additional credit losses range up to 6bp for Northern European, 27bp for Western European, 24bp for Eastern European and 94bp for Southern European banks. The largest losses exceed 250bp.

Figure 7: Distribution of additional pACL by geographical region (% of interest-bearing assets)



Source: NGFS, EBA, Scope Ratings

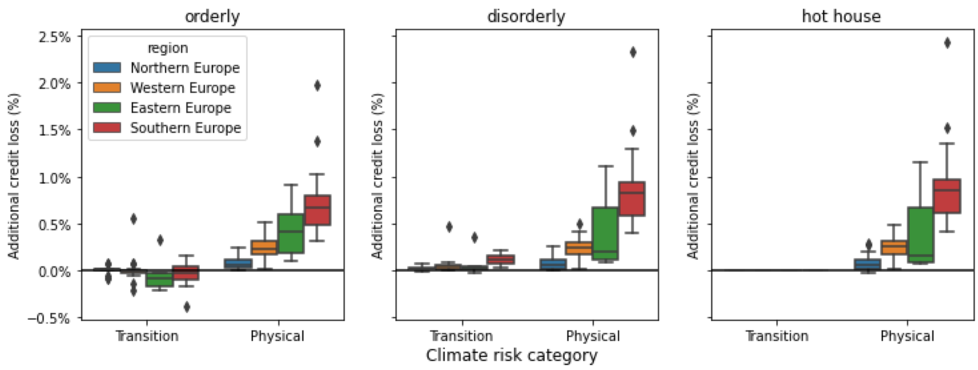
To appreciate the results, it is important to understand the non-linearity of several forms of physical risk[3]. Warmer countries in Southern and Southeast Europe are more exposed to the effects of climate change, which would result in greater GDP shortfalls and therefore higher credit losses. Banks in Southern and Eastern Europe also display the largest dispersion, with some banks moderately affected and others facing significant potential additional credit risks.

The large variations in Southern Europe are the result of geographical differences, which can be significant, as banks often operate beyond their home market, and their lending books can comprise different segments. The relatively large divergence in Eastern European climate losses is also driven by underlying geographical differences, as some countries border Northern Europe (e.g. the Baltic states), whereas others border Southern Europe (Slovenia), as well as a smaller sample size.

The breakdown of ACLs by sources of risk across different geographical areas confirms these findings. While transition risk does not show a significant location bias, acute manifestations of physical risk are significantly higher for Southern and Eastern European banks (Figure 8).

[3] https://www.sciencedirect.com/science/article/pii/S0095069620300838

Figure 8: distribution of average additional pACL by climate risk type (2045-2050, % of interest-bearing assets)

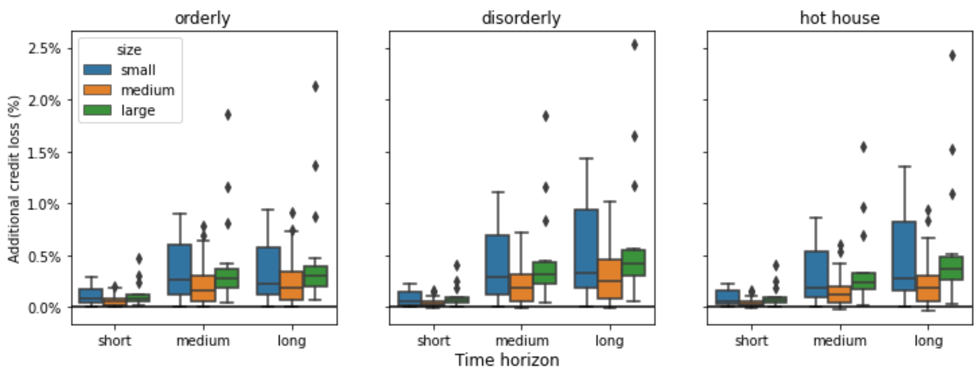


Source: NGFS, EBA, Scope Ratings

We also investigate whether bank size is a key driver of results. Smaller banks (total assets below EUR 100bn) have the highest median additional credit losses, as well as the greatest dispersion of results. The distribution depends on the time horizon and scenario. In the short term, most banks are expected to have annual additional losses between 0bp and 50bp across scenarios.

In the orderly scenario, this range remains relatively stable over time when outliers are excluded. However, in the disorderly and hot-house scenario, the range increases considerably, especially for smaller banks. We believe this increase in dispersion reflects the fact that smaller banks have less diversified business models, and some focus on the most climate-sensitive product segments (SMEs, Corporates) or geographies with higher climate risks (Southern Europe).

Figure 9: Distribution of additional pACL by size (% of interest-bearing assets)



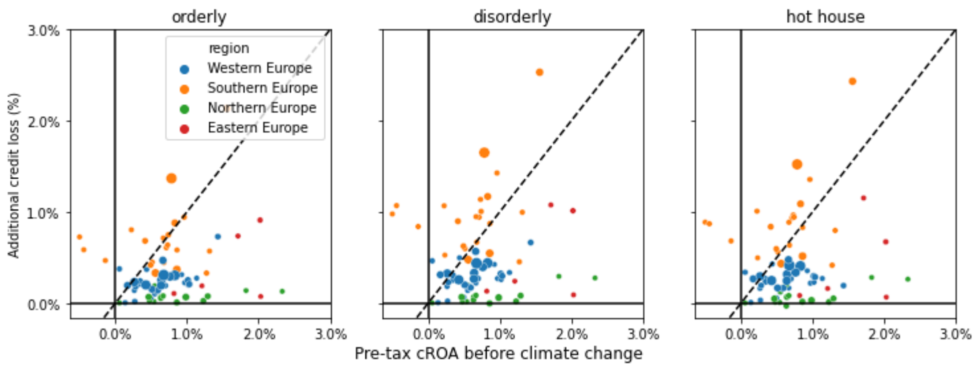
Source: NGFS, EBA, Scope Ratings

Additional credit losses to significantly impact profitability in the long run

As a final step, we simulate the impact of the estimated climate-related additional credit losses on banks' profitability in the short, medium, and long run. Figure 10 illustrates long term pre-tax cROA before including any climate losses (x-axis) with climate losses (y axis). A 45° line is also included for visibility. Distance to the line is important, as banks under the line currently have a pre-tax cROA larger than modelled climate losses. The larger the distance, the larger the buffer. Banks above the line may incur additional credit losses larger than current pre-tax cROA (the further from the line, the larger the shortfall).

We observe that in both the orderly and disorderly scenario, only a small number of banks would incur losses larger than current cROA. These banks are mostly small and medium-sized. In the hot-house scenario, a few larger banks might also incur losses larger than current cROA. However, in the hot-house scenario too, most banks incurring a shortfall are small and medium-sized, highlighting the benefits of diversification in the larger banks.

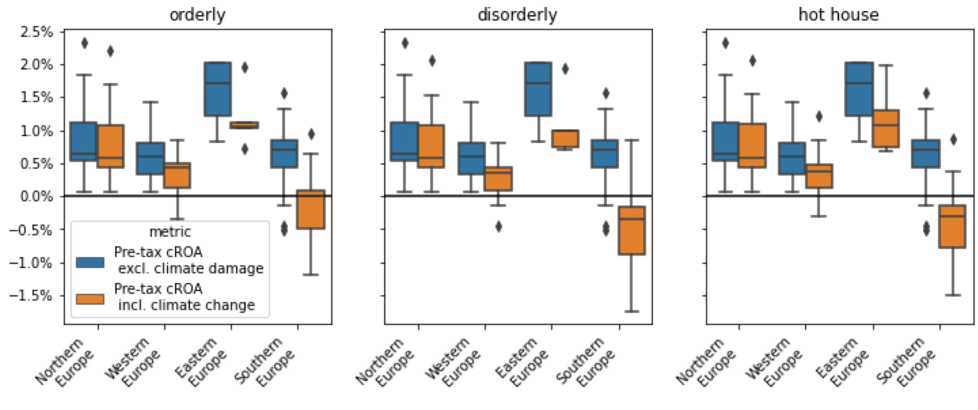
Figure 10: Comparison of pre-climate change profits with additional climate risk cost (% of interest-bearing assets, average for 2045-2050)



Source: NGFS, EBA, Scope Ratings

When analysing the geographical components, we observe that in the orderly scenario, the cROA distribution for Western and Northern Europe is shifted slightly downwards compared to a no-climate-change scenario but shows a larger shift for Eastern and Southern Europe. This trend is seen even more strongly in the disorderly and hot-house scenarios, where the median cROA including climate damage is below zero for Southern Europe. Some of the banks in other regions also have negative cROA. At individual bank level, the composition of the lending books and baseline profitability determine which banks remain resilient even in the most adverse scenarios. (Figure 11).

Figure 11: Comparison of pre-climate change and including climate damage cROA (%, average for 2045-2050)



Source: NGFS, EBA, Scope Ratings

Transition management and mitigation will become essential

Our analysis comes with some important caveats. First, we assume a constant portfolio throughout the whole period. Whereas this is a plausible assumption for short-term stresses, it is too stringent in the medium and long term, as during these time horizons portfolios have a certain degree of dynamism in terms of the client segments serviced by banks. Further, our default rates stresses are calibrated based on historical macroeconomic relationships, though banks can manage default rates by reducing exposures to riskier clients within each segment in a timely manner.

However, despite the relatively short average maturity of exposures compared to the relevant time horizon of additional credit losses, it would be naïve to assume that all banks can simply exit riskier segments without consequences. A sudden withdrawal could turn into a severe credit crunch for affected borrowers and precipitate an asset-quality crisis. Therefore, mitigation and transition management, and credible climate-change risk-management plans are thus not nice-to-haves for the distant future but must be prioritised now.

Another key assumption is that recent pre-provision profitability is a reasonable baseline for the upcoming 25 years. This implies that bank management boards and regulators sit and watch while higher climate-driven losses gradually erode profitability. In reality, an expected hit to cROA due to higher credit losses can at least partially be mitigated, for example by active portfolio management or by adjusting pricing. This requires lending standards or pricing decisions to be integrated with climate-change risk analysis.

Banks can proactively engage with clients to reduce their credit risk, for example by adjusting pricing depending on clients achieving certain transition metrics. Likewise, banks could try to engage with customers on physical risks, for example by stimulating investments in resilient infrastructure or real estate.

Our analysis focuses on the impact of physical risk and transition risk through the GDP transmission channel. Whereas the NGFS phase V methodology for estimating physical risk considers some variables correlated to acute physical risks, it does not contain direct indicators measuring these risks so probably under-estimates the GDP impact from these types of risks. The NGFS damage modelling also does not account for the effects of climate tipping points or compound risks.

Finally, physical and transmission risk can affect a bank's credit risk through channels other than GDP losses alone. One area where this is of particular relevance is damage to real estate collateral values due to extreme weather events, and its impact on loss given defaults. Whereas this risk potentially overlaps to some extent with acute physical risk impacts on GDP, it is a distinct risk unlikely to be completely covered by this macroeconomic stress. Another important channel consists of the impact of transition risk on collateral, as policy shifts could lead to stranded high-carbon assets. Including these effects could lead to even larger losses and highlight the urgency of climate change risk management.

Our exercise rests on several other assumptions, which are detailed in Appendices 1-3.

Appendix 1: Scenario narratives

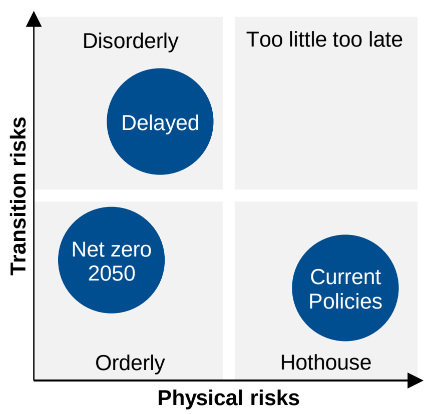
NGFS Scenarios

We analyse climate risks based on three NGFS scenarios. These scenarios are designed to provide a common basis for analysing climate risks for the economy and financial system. with a consistent set of variables and assumptions for analysing climate risks. The NGFS defines the three scenarios as follows[4]:

- **Orderly** scenarios assume climate policies are introduced early and become gradually more stringent. Both physical and transition risks are relatively subdued. Within this category we adopt the Net Zero 2050 scenario.
- **Disorderly** scenarios explore higher transition risk due to policies being delayed or divergent across countries and sectors. For example, carbon prices are typically higher for a given temperature outcome. Within this category, we adopt the Delayed Transition scenario.
- **Hot house** scenarios assume that climate policies are implemented in some jurisdictions, but global efforts are insufficient to halt significant global warming. The scenarios result in severe physical risk including irreversible impacts like sea-level rise. Within this category, we adopt the Current Policies scenario.

Figure 12: NGFS scenarios at a glance

Scenario	Physical risk	Transition risk			
	Global warming	Policy reaction	Technological change	Carbon dioxide removal	Regional policy variation
Orderly	1.4°C	Immediate and smooth	Fast change	Medium-high use	Medium variation
Disorderly	1.6°C	Delayed	Slow then very fast change	Low-medium use	High variation
Hot House	3°C+	No ramp up in policies	Slow change	Low use	Low variation



Note: The cells in the table are coloured based on associated macroeconomic risks as determined by the NGFS with lower (green), moderate (yellow), and higher (red) risks.
Source: NGFS

[4] Network for Greening the Financial System (2022), NGFS Scenarios for central banks and supervisors.

Appendix 2: Time horizon, region and size definitions

Time horizon

To provide an idea of how the risks associated with climate change may materialise over time, we look at three distinct time horizons and consider the average impact across the years in the sample to balance out potential idiosyncratic events in NGFS modelling. Table 2 shows the time horizons considered and the associated periods, whereas Table 3 and Table 4 show our geographic regions and size definitions respectively.

Table 2 : Time horizons considered

Horizon	Years considered
Short	2024-2029
Medium	2035-2040
Long	2045-2050

Source: NGFS, EBA, Scope Ratings

Table 3 : Regional segmentation

Region	National supervisory authority	Number of banks
Eastern Europe & Baltics	Slovenia, Hungary, Estonia, Latvia, Lithuania	5
Northern Europe	Ireland, Denmark, Sweden, Finland, Norway, Iceland	15
Southern Europe	Spain, Italy, Portugal, Greece, Cyprus	22
Western Europe	Belgium, the Netherlands, France, Germany, Austria	31

Source: NGFS, EBA, Scope Ratings

Table 4 : Size segmentation

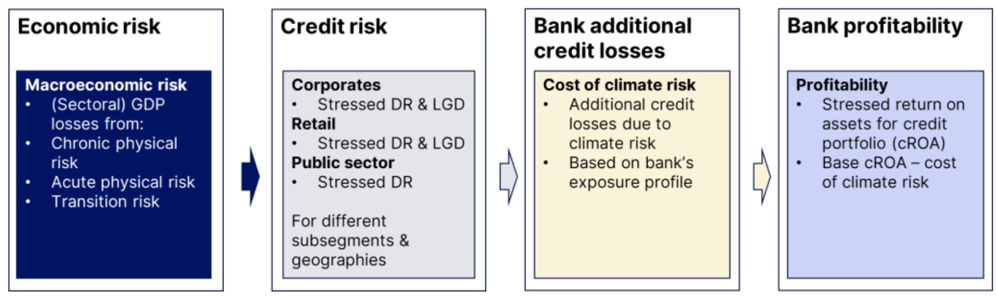
Size	Size of total assets	Number of banks
Small	< 100bn EUR	33
Medium	≥100bn EUR & <500bn EUR	24
Large	≥500bn EUR	16

Source: NGFS, EBA, Scope Ratings

Appendix 3: computing climate-related credit loss and stressed cROA

Our approach to stressing banks' credit portfolios is summarised in Figure 13. Starting from physical and transition risk, macroeconomic shocks emerge. In this study, we focus on the GDP impacts of climate risks. Shocks to GDP translate into increased credit risk for the segments under study. The resulting increase in credit risk affects banks through an increase in credit losses, which also affects profitability as measured by the return on assets of the credit portfolio.

Figure 13: Schematic representation of Scope's climate stress test framework



Source: Scope Ratings

The remainder of this appendix details our approach on defining the climate stresses.

3.1 GDP losses

The NGFS version 5 data contain projections of GDP trajectories and output losses due to chronic physical risk and transition risk for each of the scenarios, as well as a no-climate change counterfactual, which models how respective GDPs would evolve in absence of shocks stemming from climate risks. Table 5 describes the climate risk shocks to GDP we consider:

Table 5: Climate-related shocks to GDP

Risk category
GDP shocks from physical risk
GDP shocks from transition risk

The no-climate change counterfactual can be interpreted as a potential GDP outcome, whereas additional GDP losses from chronic physical risk and transition risk provide a shock to this potential GDP baseline. By dividing by potential GDP, we obtain a measure comparable to an output gap, which we can project for the period to 2050:

$$output\ gap_{i,t} = \frac{GDP_{no\ cc,t} - GDP_{i,t}}{GDP_{no\ cc,t}} = \frac{chronic\ GDP\ loss_{i,t} + transition\ GDP\ loss_{i,t}}{GDP_{no\ climate\ change,t}}$$

For scenario i and time t. In the case of corporate borrowers, we also refine this overall GDP output gap to sectoral output gaps. To this end, we make use of Scope ESG Analysis' Macroeconomic Climate Stress Test (MCST), which provides projections of value added per sector along the NGFS GDP projections. We thus define the sectoral output gap for sector s at time t under scenario i as:

$$sectoral\ output\ gap_{i,t} = \frac{sectoral\ value\ added_{no\ cc,s,t} - sectoral\ value\ added_{i,s,t}}{sectoral\ value\ added_{no\ cc,s,t}}$$

3.2 Credit losses

This appendix describes how we translate economic losses into credit losses for corporate, retail and public-sector borrowers. Based on the output gaps per country and sector, we obtain stressed credit losses for different segments: corporates, retail and public sector. Financial institution exposures are not modelled explicitly.

3.2.1 Corporates and retail

We start by calibrating the historic relation between output gaps and annual default rates (ADR) and loss given default (LGD) by estimating a sensitivity of default rates to sectoral output gap shocks. (GVA sensitivity)

This allows us to define a stressed ADR and LGD in function of sectorial output gaps:

$$Stressed\ ADR_{i,j,s,t} = Base\ ADR_{i,j}\ x\ \left(1 + sectorial\ output\ gap_{i,j,s,t}\ x\ ADR\ Sensitivity\right)$$

$$Stressed\ LGD_{i,j,s,t} = Base\ LGD_{i,j}\ x\ (1 + sectorial\ output\ gap_{i,j,s,t}\ x\ LGD\ Sensitivity)$$

For scenario s, country i, sector j and year t. The stresses on ADR and LGD for retail are similar as those to corporates, with the difference that we only look at the overall GDP output gap instead of sectoral output gaps, and that we consider different retail segments (secured & unsecured):

$$Stressed\ ADR_{i,k,s,t} = Base\ ADR_{i,k}\ x\ \left(1 + output\ gap_{i,s,t}\ x\ ADR\ Sensitivity_k\right)$$

$$Stressed\ LGD_{i,k,s,t} = Base\ LGD_{i,k}\ x\ (1 + output\ gap_{i,s,t}\ x\ LGD\ Sensitivity_k)$$

For scenario s, country i, segment k and year t.

Sensitivities to shocks in output gaps are based on panel regressions using DRs and LGDs respectively as reported in the EBA’s risk dashboard and output gaps from the IMF’s World Economic Outlook for a panel of 39 countries for different segments of corporates and retail borrowers.

We set the corporate ADR sensitivity at 20, based on our empirical research of the relation between bankruptcy rates and output gaps in the context of CLOs. For SMEs, we use the same ADR sensitivity as corporates for unsecured loans, whereas for secured SME loans we use the same ADR sensitivity as secured retail loans. The retail ADR sensitivities are shown in table 6. For LGD sensitivities, we estimated results for corporates, SME unsecured loans, and secured and unsecured retail. As for the ADRs, we use the secured retail LGD sensitivities for secured SME loans. The fact that LGDs reported in the EBA’s risk dashboard already contain a downturn adjustment may present a possible bias in our estimated LGD sensitivity to economic shocks.

The base ADR & LGD per country is based on average default rates and LGDs for the respective segment from the period 2020-2024 reported in the EBA’s risk dashboard. The relatively low bankruptcy rates in the period 2020-2024 present a possible bias, as default rates may have been lower than normal due to the Covid-19 pandemic and associated support measures.

Table 6: Sensitivity coefficients for ADR

Dependent Variable	Retail – Other Retail	Retail – Secured on Real Estate Property
GVA Sensitivity coefficient	17 (***)	7 (**)
Country Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes

Where (***) means significance at the 1% level, (**) at the 5% level, and (*) at the 10% level respectively.
Source: NGFS, EBA, Scope Ratings

Table 7: Sensitivity coefficients for LGD

Dependent Variable	Corporates	Corporates - Of Which: SME	Retail – Other Retail	Retail – Secured on Real Estate Property
GVA Sensitivity coefficient	-0.03	-3.64 (***)	-3.4 (***)	-3.2 (***)
Country Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes

Where (***) means significance at the 1% level, (**) at the 5% level, and (*) at the 10% level respectively.
Source: NGFS, EBA, Scope Ratings

Based on these stressed ADR and LGD, we compute the additional annual percentage credit losses (pACL) due to climate change risk in function of the additional ADR and LGD:

$$Additional\ pACL_{i,j,s,t} = \ Stressed\ ADR_{i,j,s,t} * Stressed\ LGD_{i,j,s,t} \ - Base\ ADR_{i,j} * Base\ LGD_{ij}$$

3.2.2 Public sector

Our approach to estimating sovereign and public sector losses is different than for retail and corporate portfolios. We start from Scope Group's Sovereign Rating Methodology, and stress a number of variables from the Sovereign Quantitative Model (SQM), (GDP per capita (PPP), Nominal GDP, Real GDP Growth, Inflation Rate, Primary Balance / GDP, Gross debt / GDP) by adding the shocks coming from the NGFS projections in the short, medium and long term, on GDP and inflation to the SQM baseline.

The result is a stressed sovereign rating for each of the scenarios and time horizons, and we then translate this stressed rating into a notch impact by comparing the stressed sovereign ratings with their baseline rating. By using Scope's idealised expected loss and default probability, we then convert the notch impact into an additional default rate (ADR) for different maturities:

$$Additional\ ADR_{i,m,s,t} \ = f_m(base\ rating_{i,t} + \Delta\ notch_{i,s,t}) - \ f_m(base\ rating_{i,t})$$

For country i, maturity m, scenario s and time t. f_m is the function converting a rating X to an m-year default probability based on Scope's idealised default probability tables. Based on this additional ADR, we again compute an additional pACL:

$$Additional\ pACL_{i,m,s,t} = \ Additional\ ADR_{i,m,s,t} \ * \ (1 - RR)$$

Where we set RR at 91%, in line with average recoveries for European sovereign, central banks and municipality defaults.

3.2.3 Financial institutions

As the EBA transparency data does not allow us to split financial institutions by counterparty, we assume that a bank's financial institution counterparties in each geography have a similar exposure to climate-related risks as the bank itself. Therefore we do not model financial institution credit losses explicitly but consider them as a weighted average of the other segments in each geography.

3.3 Characterising a bank's credit exposures

To understand how banks are exposed to losses in the retail, corporate and public sectors, we characterise banks' lending book by analysing the segments, sub-segments, and geographies they are exposed to. The basis is the EBA's transparency exercise, which provides detailed breakdowns of exposure values for corporates, retail and public sector and their sub-segments.

By multiplying the exposure values with their respective additional percentage annual credit losses (pACL), we obtain a weighted average pACL for the bank:

$$Additional\ pACL_t = \frac{\sum_{l \in L} exposure\ value_l * pACL_{l,t}}{\sum_{l \in L} exposure\ value_l}$$

As mentioned in Appendix 3.2, we do not model financial institution credit losses explicitly. We therefore exclude exposure values to financial institutions from this weighted average computation.

3.4 : cROA

We compute a profitability measure of the credit book by normalising profits by the interest-bearing assets:

$$Pretax\ cROA = \frac{Pretax\ profit}{Interest\ bearing\ assets}$$

Where:

$$Pretax\ profit = operating\ profit\ -\ cost\ of\ credit\ risk$$

We then transform our additional percentage ACL to an absolute amount by multiplying it by the interest-bearing assets:

$$Additional\ ACL_t = Additional\ pACL_t * interest\ bearing\ assets$$

As our additional ACL measure is the stress on credit books, we define our stressed pre-tax cROA as :

$$Stressed\ pretax\ cROA_t = \frac{Pretax\ profit\ -\ Additional\ ACL_t}{Interest\ bearing\ assets}$$

As ROAs can vary from one year to another, we define the baseline as the 5-year average pre-tax cROA.

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