EUROPEAN CENTRAL BANK

EUROSYSTEM

Towards climate-related statistical indicators

Statistics Committee of the
European System of Central Banks

January 2023

Contents

1 Introduction

Climate change poses risks to the economy and to the stability of the financial sector. At the same time, the financial sector will have to play a role in supporting the transition to a net-zero economy. In line with its mandate, the European Central Bank (ECB) is committed to addressing climate change. This includes managing climate-related risks to monetary policy and to the financial system, supporting the green transition, and enhancing transparency on climate-related matters. To do this effectively, high-quality data and aggregate indicators are needed.

In this context, and as part of the ECB's action plan[1] to include climate change considerations in its monetary policy strategy, the Governing Council made a commitment to develop statistical indicators on climate change. This task was entrusted to the Statistics Committee of the European System of Central Banks (ESCB) and was carried out under its supervision by experts from the ECB and the national central banks. The project also benefited from input from potential users of the data as well as from other stakeholders both within and outside the ESCB.

The development of climate change indicators entails a very high degree of complexity, including, among other things, matching various cross-country, micro-level datasets of different natures, developing appropriate imputation mechanisms for missing data, and inspecting data quality, taking into consideration aspects such as confidentiality, replicability and representativeness.

Where possible, existing data from the ESCB or other publicly available sources have been used to ensure that the summary indicators produced are accessible and that there is transparency on the underlying methodology. For some indicators, the use of proprietary data sources has been necessary.

Sufficient progress has been made over the last eighteen months to present an initial set of statistical indicators covering sustainable finance, carbon emissions and physical risks. However, this is still a work in progress and the use of these indicators is subject to a number of caveats. Further improvements, in some cases significant ones, are required and will be addressed in future work.

The indicators were constructed using harmonised methodologies across euro area countries.[2] The sustainable finance indicators meet the requirements for experimental statistics, and hence comply with many, but not all, quality requirements of official ECB statistics.[3] By contrast, the carbon emission and physical risk indicators are subject to more serious caveats and limitations as further

---

1 For more detail, see "ECB presents action plan to include climate change considerations in its monetary policy strategy", *press release*, ECB, 8 July 2021.

2 This means, among other things, that datasets that are only available at national level were not used.

3 A detailed description of this classification is available on the ECB's website.

explained in this report. They are therefore published as analytical indicators[4] to clearly flag the difference in quality standards.

The indicators are intended to support the analysis of climate-related issues for the financial sector. As they are a work in progress, the intention of this release is also to facilitate a public debate and allow an open exchange of views (including on methodological aspects) with the research community and other stakeholders on how to achieve further progress towards the derivation of statistical indicators.

This report provides a short description of the indicators released, presents the methodology and highlights existing caveats, limitations and areas for further development. The project includes three sets of indicators, covering different aspects of the topic and released at different levels of maturity.

1. Sustainable finance indicators provide an overview of the issuance and holding of debt instruments with sustainability characteristics by residents in the euro area. These indicators provide information on the proceeds raised to finance sustainable projects and hence the transition to a net-zero economy. These data should bring market transparency and are relevant for the inclusion of climate change considerations in the design and implementation of ECB monetary policy, as well as in economic and financial stability analysis. This dataset is already rather comprehensive and is published as experimental. Remaining limitations are mostly due to the lack of internationally accepted harmonised definitions of certain concepts.

2. Carbon emission indicators of financial institutions[5] provide information on the carbon intensity of the securities and loan portfolios of those financial institutions and thus help to assess the sector's role in financing the transition to a net-zero economy and related risks. The indicators provide information on banks' exposure to counterparties with a high dependence on carbon emission-intensive business models. This information is relevant to assess transition risks in the context of monetary policy, financial stability and banking supervision. However, the underlying dataset has substantial limitations, especially in terms of coverage, as it is compiled using information for only a subset of total loan and securities exposures in the euro area. In addition, the data suffer from intertemporal inconsistencies, as coverage rates, and thus sample composition, vary over time and nominal values are not adjusted for price and exchange rate effects. Consequently, the indicators must be interpreted with caution and seen as a work in progress and analytical in nature.

3. Indicators on the physical risks of loan and security portfolios assess risks stemming from the impact of climate change-induced natural hazards, such as floods and wildfires, on the performance of loans, bonds and equities. The indicators can be used to compare physical risks across countries, across

[4] Analytical indicators, as featured in this report, are data that are at a research or work-in-progress stage and have not yet reached the quality of experimental statistics but are already considered relevant if used with care and accompanied by suitable explanation and caveats.

[5] The financial institutions considered are credit institutions, investment funds, insurance corporations and pension funds.

sectors and across hazards. For some risks, it is possible to rank their relative importance across countries by comparing their magnitude. The underlying data are relevant in the context of the supervision of the banking sector, economic analysis and the assessment of the impact of climate change on financial stability. However, this dataset has limitations, for example with respect to accurately identifying the location and the vulnerability of exposed activities of debtors or the lack of information on risk mitigation measures, such as flood defences and insurance coverage. Therefore, the indicators must be interpreted with caution and seen as a work in progress and analytical in nature.

The ESCB statistical work presented in this paper complements other climate-related activities currently ongoing at international and EU level. This includes work by the International Monetary Fund on estimates of similar indicators based on macroeconomic statistics and by the ECB and the European Systemic Risk Board (ESRB) using exclusively commercial data. In addition, several groups (e.g. the G20, the Financial Stability Board, the Basel Committee on Banking Supervision, the Network for Greening the Financial System) have undertaken or are planning efforts to increase the availability and quality of climate-related data. The analysis presented here benefited from that work. It offers a microdata perspective, relying on public data sources where possible, and will thus contribute to the various international work streams.

The quality of the indicators presented here will further improve as more and better data sources become available. Several regulatory initiatives in the EU will generate new data as a result of new reporting requirements for financial and non-financial institutions concerning sustainability and climate information. These include the Sustainable Finance Disclosure Regulation (SFDR)[6], which will substantially increase the amount of public climate disclosures for environmental, social and governance (ESG) funds. In addition, the entry into force of the EU Taxonomy Regulation[7] will require large financial and non-financial institutions to publish a large number of performance indicators related to their alignment with the taxonomy criteria. Finally, future reporting requirements linked to the Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (ESRS) are likely to substantially increase the availability of granular, externally verified, corporate-level, climate-related information and should allow a better assessment of the exposures of financial institutions' counterparties to transition and physical risk.

6 Regulation (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector (OJ L 317, 9.12.2019, p. 1).

7 Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (OJ L 198, 22.6.2020, p. 13).

2 The indicators in detail

2.1 Experimental indicators on sustainable finance

The experimental indicators on sustainable finance provide time-series information on outstanding amounts and financial transactions relating to issuances and holdings of sustainable debt instruments. This helps analysts understand both the funding needs of sustainable projects and the demand for these debt instruments as investment opportunities.

Sustainable finance indicators are aligned with standard macroeconomic statistical concepts and methods and are broken down according to classical statistical dimensions, such as economic area, institutional sector, maturity, interest rate type, etc. The combination of the ESG dimensions with these classical dimensions facilitates the integration of these indicators into forecast models and other analytical tools and hence their use in combination with existing macroeconomic data sources.

These data are already sufficiently reliable for use in the ECB’s economic analysis and monetary policy design. Other use cases include economic and financial stability analysis and prudential supervision. However, when using the data, analysts should be particularly conscious of the methodological decision to currently include all degrees of assurance in the definition of sustainable debt securities, including self-assessment instruments. If a specific analytical purpose requires a more stringent sustainability concept, these data should not be used.

2.1.1 The indicators in brief

The first set of indicators on sustainable finance that will be regularly compiled and disseminated comprises indicators on issuances and holdings of sustainable debt securities by euro area and EU residents.

1. Issuances of sustainable debt securities

Indicators on issuances of sustainable debt securities are released by issuer area at face, nominal and market value. The breakdown by sustainability classification (green, social, sustainability, and sustainability-linked) is only available for the euro area and the EU as a whole. Breakdowns by issuer sector and individual euro area country are only available for green bonds; the same applies for net issuances (financial transactions), which are available for the euro area only. Securities are considered to fulfil the sustainable criteria if labelled as such by the issuer (i.e. a weak level of assurance is accepted). The new aggregates are available at a monthly frequency around ten working days after the end of the reference period (t+10).

2. Holdings of sustainable debt securities

Indicators on holdings of sustainable debt securities comprise a breakdown by sustainability classification for the euro area aggregate (at face and market value), including a breakdown by issuing counterparty area (euro area, EU, rest of the world). Breakdowns by holding sector and individual euro area country are only available for green bonds; the same applies for financial transactions, which are available for the euro area only. In line with the indicators on issuances, a weak level of assurance is accepted. The new aggregates will be disseminated at quarterly frequency at around t+2 months.

2.1.2 Data sources

The indicators on issuances and holdings of sustainable debt securities are compiled exclusively using official ESCB data sources, namely granular information from the Centralised Securities Database (CSDB) and Securities Holdings Statistics (SHS) (collected on the basis of the SHS Regulation[8]). The estimation process of the experimental indicators is fully embedded in the existing official compilation frameworks. The indicators on issuances of sustainable debt securities are part of the existing CSDB Securities Issues Statistics (CSEC) dataset, whereas the indicators on the holdings of sustainable debt securities are released with the Securities Holdings Statistics by Sector (SHSS) dataset.

2.1.3 Challenges and difficulties

Indicators by sector and country, for both issuances and holdings, only cover green debt securities, which is by far the largest category in the sustainable debt market.

At this stage, as with other similar initiatives on sustainable finance, the indicators presented here rely only on the most loose level of assurance, debt securities are considered sustainable if they are at least labelled as such by the respective issuer (i.e. self-labelled). This means that, in practice, they cover all sustainable instruments classified as such in the CSDB, independent of the actual level of assurance. Once sufficient information is available, data breakdowns regarding the level of assurance (with a second-party opinion and/or certified) will be made available.

The third ESG dimension captured in the CSDB covers the (most globally recognised) underlying standards/frameworks for the classification of sustainable debt securities, e.g. the International Capital Market Association (ICMA) and the Climate Bonds Initiative (CBI) frameworks. No restriction regarding these underlying standards/frameworks was also considered, primarily to ensure consistency with global statistical (G20) standards. For the future, the dissemination of alternative indicators based on selected (more stringent) standards is foreseen. These

8 Regulation (EU) No 1011/2012 of the European Central Bank of 17 October 2012 concerning statistics on holdings of securities (ECB/2012/24) (OJ L 305, 1.11.2012, p. 6).

alternatives will be aligned with decisions taken by the Governing Council in the context of the implementation of the ECB's monetary policy and will take on board upcoming EU legislation (particularly the new EU Green Bond Initiative).

2.2 Analytical indicators on carbon emissions

The analytical indicators on carbon emissions financed by the financial sector and the associated risks in the context of the transition to a carbon-free economy cover two perspectives: the total emissions financed by the financial sector and the exposure of the financial sector to emission-intensive counterparties.

The carbon emission indicators will be useful when analysing the role of the financial sector in financing carbon-related activities and hence assessing the associated transition risks vis-à-vis sectors with carbon-intensive operations. Such indicators can be used to assess intertemporal trends and cross-country differences in the financing of emission-intensive economic activities. However, data in the first release of the indicators suffer from limited coverage that varies across time and jurisdiction (for more detail, see Section 2.2.3). In addition, the share of imputed values in emissions and financial data may be high in certain jurisdictions. This may make some types of analysis of these indicators inadvisable at this stage.

All indicators made available in this dataset are classified as analytical owing to prevailing caveats related to the microdata underlying the indicators.

2.2.1 The indicators in brief

1. Indicators on financing carbon-intensive activities

The first two indicators on carbon emissions financed by financial institutions aim to provide information on how the financial sector contributes to the financing of high-emitting economic activities. This is done by looking at the amount (share) of total carbon emissions from non-financial enterprises that can be linked to financial institutions based on the set of identifiable securities and loan portfolios. The following indicators on *financing carbon-intensive activities* can be used to assess how the debtors/issuers' emissions evolve over time ahead of (and in preparation for) the transition to a net-zero economy.

(a) Financed emissions (FE): Total greenhouse gas (GHG) emissions of a debtor/issuer weighted by the investment as a share of the company's total value.

(b) Carbon intensity (CI): FE divided by the production value of the company weighted by the investment in the company's activities as a share of the company's total value.

The above indicators do not provide information on whether the financing is targeted at making businesses greener. Such information is provided instead by the sustainable finance indicators discussed above. The indicators on FE help users to monitor reduction targets for economic activities, both over time and across sectors, and how these coincide with certain levels of financing. However, because emissions are not normalised, it is not yet possible to disentangle differences due to bank/portfolio size from differences deriving from the emissions themselves.

2. Indicators on exposures to transition risks

The third and fourth indicators consider the transition risks for the financial sector stemming from the exposure of loans and securities portfolios to economic activities with elevated risks (emissions). It should be noted that, at this stage, all indicators capture only emission-intensive activities of the debtors/issuers themselves and do not capture risks stemming from business models based on emission-intensive intermediary products (i.e. emissions generated along the value chain).

The exposure is assessed by capturing the relative amount of financing of economic activities that may be affected by the transition to net zero. Unlike indicators related to the financing of carbon-intensive activities, these indicators use the creditors' portfolio value as a standardisation variable, i.e. they take the investor perspective. Thus, while the metrics cannot be understood as risk measures by themselves, they serve as exposure metrics that can inform risk assessments. They are defined as follows.

(a) Weighted average carbon intensity (WACI): Total GHG emissions of a debtor/issuer standardised by a measure of company production value, weighted by the investment in these activities as a share of the total investment portfolio value.

(b) Carbon footprint (CFP): FE standardised by the total investment portfolio value.

The four indicators are broadly in line with those proposed by the Task Force on Climate-related Financial Disclosures (TCFD)[9], the Partnership for Carbon Accounting Financials (PCAF)[10] and the ECB/ESRB Project Team on climate risk monitoring[11]. However, methodologies and specific implementation assumptions differ widely between compilers, leading to differing results, which highlights the need to develop common methodological and compilation standards.

The indicators have been calculated using two complementary approaches regarding the level of counterparty consolidation: (i) the residency principle, using revenue and emissions data at a single entity level; and (ii) consolidation at group level, i.e. looking at the financial data and emissions of the whole group.

Single entity consolidation allows analysts to focus on domestic emissions and revenues. By tracking financial flows into carbon-intensive activities over time, the indicators on financing carbon-intensive activities can be used to monitor the role of

9 For further information, please visit the TCFD website.

10 For further information, please visit the PCAF website.

11 See ECB/ESRB Project Team on climate risk monitoring, "The macroprudential challenge of climate change", ECB/ESRB, July 2022.

the domestic financial sector in supporting the alignment of the non-financial corporate sector with domestic climate targets, most notably the European Green Deal (i.e. achieving net zero by 2050). Group-level indicators are particularly useful for transition risk analysis, as they focus on the global transition risk of the group, i.e. beyond the boundaries of the domestic economy.

All indicators are compiled by country of the creditor/holder and cover the years 2018 to 2020 at an annual frequency.

2.2.2 Data sources

To analyse the financial sector perspective at a single entity level, individual loan-level data from the Eurosystem's AnaCredit dataset on loans from deposit-taking corporations except central banks (S122)[12] to euro area non-financial corporations (S11) are matched with publicly available emissions data from the European Emissions Trading System (EU ETS)[13]. Loans to entities located in non-euro area countries are excluded. For all AnaCredit-based indicators, Scope 1 emissions[14] from debtors which do not report in the EU ETS are imputed using aggregate data from Eurostat air emissions accounts (AEA)[15].[16] Five estimation methods were developed and tested, of which a waterfall approach of different sources was considered the most advanced, and hence recommended.[17] To cover balance sheet information of debtors, data from Bureau van Dijk's commercial database Orbis are used and any missing data are imputed.

For consolidated group level indicators, SHSS data are used for holder sectors excluding deposit-taking corporations except central banks (S122), investment funds (S124), and insurance corporations and pension funds (S128 + S129). For this set of indicators, corporate (S11) issuers are consolidated at group level, meaning that all global Scope 1 or 2 emissions are accounted for when measuring the finances and risk implied in emissions. The emissions data currently come from private data sources – primarily from Institutional Shareholder Services (ISS), supplemented by data from Refinitiv. Similarly, consolidated firm-level balance sheet data are also taken from Refinitiv and ISS. For SHS-based compilations, only self-reported

---

12 The classification coding system used here relies on the European System of Accounts (ESA) standard. See "European system of accounts – ESA 2010", Eurostat, 2013.

13 More information on the EU ETS is available on the European Commission's website.

14 Scope 1 includes an entity's direct emissions. Scope 2 measures indirect emissions from electricity, heat and steam consumption and therefore reflects an entity's exposure to rising input prices. Scope 3 is defined as all the indirect emissions of an entity and its products, excluding those in Scope 2.

15 More information on AEA is available on Eurostat's website.

16 The imputation procedure depends on employment data and sector classification and can only be conducted where these are jointly available. Details about the imputation procedures applied during the indicator compilation are reported in the technical annex.

17 In total five methods were developed and tested to estimate emissions. Method 1 assumes that emissions are given by average sector-country-year intensities multiplied by the firm size (measured by the number of employees). Method 2 is similar to Method 1, but uses emissions adjusted for dataset-specific sectoral biases in employment figures per sector within a country. Method 3 uses only verified emissions from the EU ETS. Method 4 applies a waterfall model, using ETS data where available and otherwise Method 1. Method 5 is the same as Method 4 but is adjusted for sectoral biases in employment figures per sector within a country (as in Method 2). Method 5 has been used for the compilation of the indicators.

ISS/Refinitiv data are used and no emissions are imputed. The data sources used for group-level indicators are different from those used for single entity indicators, as EU ETS data only cover local emissions and therefore do not entirely capture global transition risk.

Indicators based on AnaCredit only include Scope 1 emissions, while SHS-based indicators are also computed using Scope 2 emissions. This is mainly due to the lack of emissions data for various relatively small enterprises on the debtor side in the AnaCredit dataset. Future work will assess whether Scope 3 data can be included.

2.2.3 Challenges and difficulties

The compilation of carbon emission indicators faces many challenges. These include primarily the general lack of consolidated and unconsolidated corporate emissions data, as well as missing balance sheet information at the same level of detail as the granular loans and securities data. This implies reduced coverage, potential biases and a need for imputation. Specifically, in AnaCredit, on average across all jurisdictions, emissions and balance sheet information are jointly available for only about 47% of outstanding debt, and this coverage varies widely from country to country. Overall, coverage is higher for SHSS indicators but still varies widely across countries.

Consequently, both the levels and intertemporal variation of carbon emission indicators are strongly affected by compositional biases. In particular, the FE indicator needs to be understood as the lower bound of actual financed emissions both at the euro area level and across jurisdictions and hence may be less suited for cross-country comparisons than the relative indicators. Relative indicators, such as the WACI, can be biased either upwards or downwards and also over time, depending on whether the numerator or denominator of the indicator is more strongly affected by a certain composition or temporal effect, but they can be more useful for cross-country comparison.[18]

Similarly, the most appropriate financial denominator to relate emissions to production would be value added (or GDP at the macroeconomic level) as this excludes all purchases of goods and services from external suppliers and hence restricts the scope of the denominator variable to the entity itself. However, such information is typically not available at an appropriate level of detail and hence often replaced with revenue, which poses a risk of significant bias in the (Scope 1 and 2) emission intensities involved in production if large parts of the production process are outsourced to suppliers.

Further challenges are encountered when comparing data over time. This is due to different data coverage rates and because it is currently impossible to disentangle changes in carbon footprints arising from divestment (from high-emission sectors)

[18] The coverage rates are published with the indicators to support a nuanced reading of the indicators and may help to control for the variation in coverage in specific analytical use cases.

and from greening of underlying assets.[19] However, this is needed to assess the effective impact of the measures to finance the transition to a net-zero economy. While not yet included in current indicators, this adjustment will be considered in the future. Moreover, corrections for price movements – exchange rates and inflation, which are particularly relevant in a volatile international economy – will also be studied with the intention of accounting for these as part of scheduled data improvements. Finally, future work will explore the inclusion of Scope 2 emissions for single entity indicators and Scope 3 emissions in general, which represent a major proportion of total emissions.

Finally, further harmonisation efforts are required to address differences in samples, consolidation levels and data availability for SHSS and AnaCredit-based indicators. Specifically, there is a need to extend the analysis of financed local emissions to securities holdings (in addition to loans) and for global transition risks to be considered for loans as well. In this process, the balance sheet and emissions information used across SHSS and AnaCredit compilations may be further harmonised.

2.3 Analytical indicators on physical risks

Global warming is associated with an increase in extreme weather conditions, which in turn are likely to result in more frequent and intense natural hazards. Damage caused by these events can also have an impact on the financial system: companies affected by these hazards might find it difficult to service their debts, or collateral might lose its value. Ultimately, these changes may also have an impact on financial stability. All indicators in this dataset are classified as analytical.

2.3.1 The indicators in brief

Indicators used to quantify physical risks should cover as many acute natural hazards as possible. This report focuses on a subset of hazards selected on the basis of (i) the historical relevance of the hazards in Europe (for instance, from 1980 to 2020 around 77% of all damage costs in the EU28 were caused by meteorological and hydrological events)[20] or future predictions (for example, damage from water stress and wildfires is expected to increase in the coming decades), and (ii) the underlying quality of the data on those hazards. Some hazards, such as heat waves, that have a more indirect effect on human health, are not yet included in this set of indicators.

Physical risk is a result of an interaction of three elements: physical hazards, exposures of assets and assets' vulnerability to those hazards. Correspondingly, the underlying data and the analysis were arranged in three layers. A fourth layer,

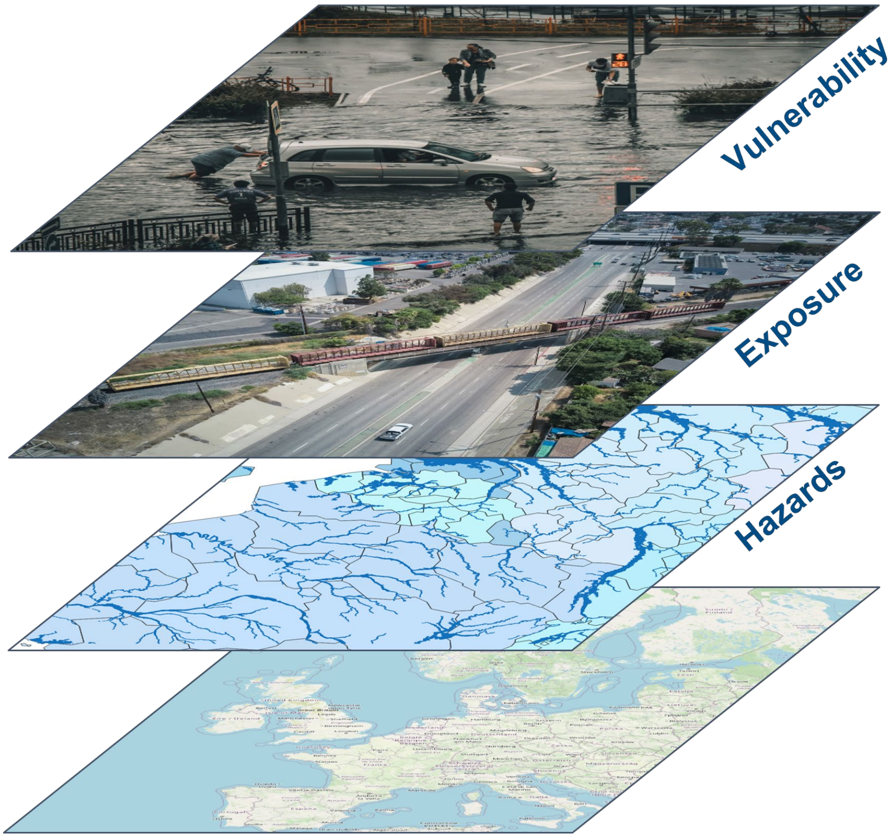
---

[19] A similar analysis of movements over time in financed emissions is provided in "The macroprudential challenge of climate change", op. cit.

[20] See "Economic losses from climate-related extremes in Europe", European Environment Agency, February 2022.

geolocation, links the other three given that each dimension is location-specific (see Figure 1).

Figure 1
Stylised composition of physical risk indicators



Source: ECB.

First, the *hazards* layer describes natural disasters or extreme weather events (e.g. the frequency, severity and probability of such an event at a specific location and under a specific climate scenario). Second, the *exposure* layer provides information on how financial institutions are exposed to risks through their investments (e.g. equity, corporate bonds, loans) and the underlying collateral/physical asset (e.g. the value and location of residential real estate that is mortgaged or the machinery and inventories of corporations). Third, a *vulnerability* assessment is necessary to translate hazard data into expected losses; this contains aspects such as damage functions and (historical) damage costs and is subject to specific vulnerability aspects. Fourth, the availability of suitable and detailed *geolocational* data is a prerequisite to combine the other three data layers.

This report considers seven acute natural hazards for which physical risk indicators are constructed: coastal flooding, river flooding, wildfires, landslides, subsidence, windstorms, water stress. For five of the seven indicators only current hazard profiles are available. For water stress and wildfires, projected data are available for 2030 and 2030-2050 respectively. In contrast to other providers of physical risk indicators, the focus here lies on acute natural hazards rather than on chronic changes in weather extremes. While data availability is better and data processing is easier for chronic hazards, acute hazards can be linked to physical damage in a more intuitive and exact way.[21]

Against this background, three sets of indicators have been developed:

1. Normalised exposure at risk (NEAR): the percentage of the portfolio at risk[22] – where each debtor/issuer's exposure is weighted by a financial risk ratio. This relates the expected annual losses (EAL) to measures of financial performance (revenue) or company size (total assets).[23] The EAL provides a risk estimate that is explicitly based on monetary damages and allows aggregations across hazards, which is not the case for score indicators. At the current stage, underlying data quality and availability are not always sufficient to calculate EAL-based indicators for all hazards. However, EAL-based indicators are available for coastal flooding, river flooding and windstorms.

2. Potential exposure at risk (PEAR): the percentage of the portfolio that is exposed to physical hazards, based on the total financial exposure for all entities that have a risk score above zero (see point 3 below for the risk scale). PEAR offers a potential ("maximum") value to complement the specific value provided by NEAR. Indicators based on total exposures are easy to interpret and less demanding to calculate, as vulnerability data are not needed for their computation (similar to the risk scores below).[24]

3. Risk scores (RS): these complement PEAR by splitting exposures into risk level categories and indicate the percentage of the portfolio that is associated with a specific risk class from 0 (no risk) to 3 (high risk). The scores at group head level (when multiple entities belong to the same group) are calculated using simple averages.[25]

---

21 For instance, an increase in precipitation can result in several natural hazards such as flooding, subsidence or landslides. However, it is not possible to directly measure damages caused by the higher precipitation without being transformed into a natural hazard.

22 This assumes that expected annual losses (EAL) as a share of revenue or total assets equates to the same proportion of the exposure at risk. To construct the indicator: first, the EAL of the debtor/issuer is normalised by using either revenues or total assets to determine a financial risk ratio (FRR); then the FRR is multiplied by the exposure to determine what share of the exposure in a portfolio is at risk for each debtor/issuer. The FRR has a value between 0 and 1. It is bounded at 1 if the EAL exceeds the value of the normalisation variable (revenue or total assets), so the exposure at risk cannot exceed total exposure.

23 Admittedly, a relation between a financial risk ratio and the total exposure might be non-linear and more complex – at lower levels of damages, a company may be able to replace the lost assets, while the translation of the EAL to repayment ability might also depend on many other factors, such as the debt repayment schedule.

24 Vulnerability data are based on historical losses due to natural hazards. However, these are currently neither systematically reported nor collected on a local basis. Ideally, vulnerability data should also involve insurance, mitigation and adaption measures at a very granular level.

25 The simple average assumes that the risk classes assigned to multiple entities within a group have identical weights. Simple averages are rounded up (e.g. an average score of 4.3 is rounded up to 5). The score-based indicators provided in this paper are very similar to those found in the literature (see, for example, ECB/ESRB Project Team on climate risk monitoring, "Climate-related risk and financial stability", ECB/ESRB, July 2021). Calculations using a weighted average RS – with revenue as a proxy for the size of individual entities within a group – yielded very similar results (not depicted in this paper).

Composition of the hazards

The three indicators complement each other and capture different risk dimensions. PEAR incorporates all exposures at risk regardless of hazard intensity. It indicates how widespread the hazard is (e.g. limited for flood risk, common for windstorms). As such, it is complemented by risk scores, which split the exposure into risk level categories, and by NEAR, which equates expected losses with measures of company financial performance.

The report presents a diverse set of hazards from flooding and landslides to wildfires. Each phenomenon requires a dedicated modelling approach and the application of different scientific methods. As a result, hazard dimensions are expressed in different units (e.g. water depth for flooding, soil composition for subsidence) often accompanied by a reclassification of hazard intensities and frequencies as scores. However, given their different natures and sources, such scores are not comparable across hazards.

A damage function is integral to allowing the conversion of hazard intensities to potential monetary loss – which is a common unit that can be used for measurement. For windstorms and coastal and river flooding, damage functions are available and the potential damage as a share of asset value is applied to translate the hazard intensity into monetary values at risk, thereby allowing a comparison across hazards. NEAR is calculated this way for the same three hazards, and thus can be used for relative risk assessments between hazards and countries and further breakdowns.

When analysing the indicators across countries[26], it should be noted that the country breakdown is presented from the point of view of the creditor/holder. As a result, it is possible for a financial institution in a landlocked country to face a coastal flooding risk if it has invested in a company located in a coastal area in another country.

Group head consolidation methodology (for the debtor/issuer)

Data on physical risks can be compiled for a single entity or at consolidated group level. There are several arguments in favour of a single entity level approach for the compilation of physical risk indicators, such as the relevance of individual companies in terms of legal personality, the need for fewer RIAD[27] attributes for the calculation

---

26 Coverage is currently restricted to euro area debtors/issuers and euro area creditors/holders. Hazard data and methodologies are available for the EU, while several sources have global coverage. The main limitations stem from financial exposures, given that there are limited reporting obligations (one of the counterparties should be located in the euro area). While the expansion to EU coverage of debtors has a relatively small impact on loans (loans are typically domestic), the impact on corporate bonds and equity is relatively large (mainly owing to euro area holdings of US securities). Increasing the coverage beyond euro area debtors/issuers will be considered in the future, but the feasibility also depends on the availability of detailed hazard, locational, revenue and tangible asset information.

27 The ESCB's Register of Institutions and Affiliates Data (RIAD) is a master dataset that includes identification and stratification information on around 12 million financial and non-financial entities worldwide (but with a focus on the EU). RIAD stores information on legal entities at the level of a distinct "institutional unit". Where an entity has foreign branches, RIAD contains information (including addresses used for identification of physical risk) on one entity representing the headquarters and all domestic branches and one entity for each country in which foreign branches are established.

and the fact that the consolidated group head approach relies on simplifying assumptions of intra-group risk relationships.[28]

However, the consolidated group approach shows advantages because the physical risk exposure of all subsidiaries within a group are taken on board (including entities that would not be considered otherwise, e.g. when a single entity has no exposure in terms of loans received or securities issued but does face a physical risk at the single entity level) and takes into consideration that an entire group may be affected if certain parts of the group are (severely) at risk. Weighing everything up, the group approach from the point of view of the debtor/issuer was selected to calculate the data published. A domestic focus with regard to the exposures and/or the investors (financial institutions) might also be of interest to users and thus the indicators offer a breakdown into domestic and foreign debtors.

2.3.2 Data sources

Source data for all seven hazards covered are available entirely from public providers. For some hazards, only score indicators can currently be calculated.

Hazards for which the EAL can be computed and the NEAR is consequently available include coastal and river flooding and windstorms. The data for coastal and river flooding are sourced from the European Commission's Disaster Risk Management Knowledge Centre (DRMKC), which is part of the Joint Research Centre (JRC), which also provides damage functions for these hazards on the basis of which the EAL can be calculated. The EAL is calculated for the JRC baseline scenario (2017) and is available at a very high spatial resolution of 100x100m.

Local data for windstorms in Europe are not directly provided by any public source. Windstorm hazard data are derived using the synthetic wind speed dataset of the Copernicus Climate Change Service, which contains recalibrated historical windstorm data from 1986 to 2011. By applying a Gumbel analysis[29] to these data, return periods have been computed at NUTS 3 level.

Score and PEAR indicators are available for all hazards: coastal and river flooding, windstorms, subsidence, landslides, water stress and wildfires.

For subsidence (JRC), only a baseline scenario without information on probability is available, while for landslides (JRC), return periods in the baseline scenario are given. Both datasets are based on data analysis in 2017. Data on water stress are sourced from the World Resource Institute's Aqueduct project and are projected for 2040 under the Representative Concentration Pathway (RCP) 8.5 scenario. This

---

[28] Physical risks for the consolidated group from the debtor/issuer side are derived by summing up the physical risks and exposures of the group's subsidiaries and attributing them to the parent (by risk type, e.g. totals for windstorms or river floods). Ultimate parent information is obtained from RIAD.

[29] The windstorm data were developed in cooperation with researchers from the Windstorm Information Service (WISC) project run by the Copernicus Climate Change Service, which also provides damage functions for windstorms. The Gumbel distribution is used as a model for maximum values of a sample to assess probabilities of extreme values, such as high gust speeds.

“business-as-usual” scenario is chosen to ensure a comprehensive estimation of climate risks.[30]

Wildfire scores are not directly available from public data sources. The JRC provides binary data on wildlife-urban interfaces[31] which offer insufficient information on which to base a score indicator. An alternative has been sourced using the Fire Weather Index published by the Copernicus Climate Change Service, which was enhanced by performing a landcover analysis to detect areas that contain burnable fuel. Furthermore, a regression analysis of historical fires allows the estimation of the future size and location of wildfires, which can then be translated into hazard scores.

The hazard layers capture between 90 and 100% of the geocoded RIAD companies.

Future work will provide baseline indicators as well as projected indicators up to 2050 for different climate scenarios for all hazards considered. For the financial exposures, RIAD, AnaCredit, SHS and Orbis data are combined.

2.3.3 Challenges and difficulties

As with the previous indicators, physical risk indicators also come with caveats which might lead to under or overestimation of risk.

1. Potential overestimation of risk

The comparability between countries may be limited by a lack of information on existing mitigation measures. For instance, while the Netherlands has the highest potential exposure to coastal flooding, flood protection measures are widespread in the country, which lowers the risk significantly. The current indicators do not take these kinds of adaptation measures into account, which implies that the data overestimate the risk for countries with a well-established protection infrastructure.

On the financial side, the current indicators do not account for financial or physical assets pledged as collateral, which should offset potential loan impairment and lower a creditor’s risk. On the other hand, in the case of a natural disaster the physical assets might also be damaged, lowering the collateral value. Future work is expected to incorporate collateral type and potential damage to the collateral in the risk assessment.

While collateral can limit a creditor’s losses, insurance against natural catastrophes increases the recovery capacity of an affected entity, with a positive impact on its ability to repay. However, currently granular data on insurance are not available and only estimations based on macro (country-level) data are possible.

---

30 RPCs describe different greenhouse gas trajectories. For the hazards for which different scenarios are available, RCP 8.5 was chosen, which assumes that greenhouse gases would further increase in the 21st century.

31 Wildlife-urban interfaces are areas in which forests or other types of natural vegetation and (urban) human settlements are in geographical proximity to each other. These areas are seen as more prone to wildfires due to human activities, and wildfires in these areas can cause significant economic damage if they spread to (urban) properties.

2. Potential overestimation or underestimation of risk

In the current calculations of the indicators, the total value of fixed assets is used as a benchmark for estimated losses. In the case of larger companies, the fixed assets might be distributed across various locations with different exposure to physical hazards. Moreover, hazards are linked to a company's registered address, so if one of the company facilities is affected but the headquarters are not, the indicators will underestimate the risk, whereas the risk will be overestimated if the headquarters are exposed and other locations are not. Also, with regard to locations of foreign branches, RIAD data are limited to one entity per country.

Mismeasurement can also stem from estimates of the fixed assets for companies where no financial information is available. Financial statements at firm level currently suffer from limited coverage (in particular smaller companies are often excluded), missing information, reporting lags and other issues in currently available datasets (e.g. a high share of values reported as zero).

3. Potential underestimation of risk

Individual hazards and their related damages are currently considered separately. However, the co-occurrence of events, such as windstorms and coastal flooding, can intensify their impact, leading to greater damage than implied by adding together the individual hazards. Compound events are difficult to model, also for climate scientists, given the limited historical data owing to the low frequency of such high-impact events. Currently only direct damage to facilities via acute hazards is accounted for. Other sources of underestimation could include, for example, the impact of heat stress on labour productivity, chronic climate risks such as sea level rise, broader risk to the economy in which a company generates revenue, etc.

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

For specific terminology please refer to the ECB glossary (available in English only).

PDF ISBN 978-92-899-5504-1, doi:10.2866/486463, QB-04-23-018-EN-N