SOVEREIGN ASSETS AND SUSTAINABLE AND RESPONSIBLE INVESTMENT: THE IMPORTANCE OF CLIMATE METRICS

2025

BANCO DE ESPAÑA
Eurosistema

Documentos Ocasionales
N.º 2512

Fernando Arranz Gozalo, Clara I. González Martínez
and Mercedes de Luis López

SOVEREIGN ASSETS AND SUSTAINABLE AND RESPONSIBLE INVESTMENT:

THE IMPORTANCE OF CLIMATE METRICS

SOVEREIGN ASSETS AND SUSTAINABLE AND RESPONSIBLE INVESTMENT: THE IMPORTANCE OF CLIMATE METRICS (*)

Fernando Arranz Gozalo (**)

BANCO DE ESPAÑA

Clara I. González Martínez (***)

BANCO DE ESPAÑA

Mercedes de Luis López (****)

BANCO DE ESPAÑA

(*) The authors would like to express their gratitude to Juan Ayuso, Emiliano González, Ricardo Gimeno, Emilio Rodríguez, Alberto Fernández, Ainhoa Diez-Caballero and Carlos González for their comments and suggestions, and to the participants in the internal seminar at the Banco de España.
(**) f.arranz@bde.es
(***) clara.gonzalez@bde.es
(****) mercedes.luis@bde.es

Documentos Ocasionales. N.º 2512

June 2025

https://doi.org/10.53479/41247

The Occasional Paper Series seeks to disseminate work conducted at the Banco de España, in the performance of its functions, that may be of general interest.

ISSN: 1696-2230 (online edition)

Abstract

Climate change presents challenges to global growth and financial stability, and has an impact on asset returns. An increasing number of investors are incorporating sustainable and responsible investment criteria into their portfolio management and active ownership practices. Accordingly, different climate metrics need to be developed and applied to identify and manage exposure to climate-related financial risks. This paper seeks to provide greater clarity on different climate metrics, particularly for their application to portfolios with sovereign assets, given the lack of harmonisation in this asset class. There is ongoing debate about the variables to use and the normalisation of greenhouse gas emissions. This paper proposes specific metrics for sovereign assets that characterise the transition risk associated with investments and are also suitable for the disclosure of such information. Additionally, the paper evaluates their practical application in theoretical portfolios and analyses the advantages and limitations of each metric. It concludes by identifying future challenges – such as data availability, the harmonisation for mixed-asset portfolios – and emphasises the importance of developing forward-looking methodologies to assess long-term climate goals.

Keywords: climate change, disclosure, sovereign assets, sustainable investment.

JEL classification: E58, G12, Q54.

Resumen

El cambio climático presenta desafíos para el crecimiento global y la estabilidad financiera, y tiene efectos en las rentabilidades de los activos. Cada vez es mayor el número de inversores que incorporan criterios de inversión sostenible y responsable en la gestión de sus carteras y en el ejercicio activo de la propiedad. Para ello, es relevante el desarrollo y aplicación de diferentes métricas climáticas para identificar y gestionar la exposición al riesgo financiero relacionado con el clima. Este documento contribuye a aportar mayor claridad sobre las distintas métricas climáticas; en particular, para su aplicación a una cartera con activos soberanos, dada la falta de armonización existente en esta clase de instrumento. Existe un debate abierto sobre las variables a utilizar, así como la normalización de las emisiones de gases de efecto invernadero. El documento propone métricas específicas para activos soberanos que permitan caracterizar el riesgo de transición de la inversión, permitiendo al mismo tiempo que sean empleadas para la divulgación de este tipo de información. Además, el artículo evalúa su aplicación práctica en carteras modelo y analiza las ventajas y limitaciones de cada métrica. Se termina identificando los desafíos futuros, como la disponibilidad de datos, la armonización de divulgaciones y la adaptación de métricas para carteras mixtas, y se subraya la importancia de desarrollar metodologías prospectivas para evaluar el cumplimiento de los objetivos climáticos a largo plazo.

Palabras clave: cambio climático, divulgación, activos soberanos, inversión sostenible.

Códigos JEL: E58, G12, Q54.

Contents

1 Introduction

Climate change poses challenges to global growth and financial stability, whether due to its physical effects or as a result of the transition to a low-carbon economy. Climate risks can affect asset returns, which is why some investors may incorporate environmental, social and governance (ESG) factors into investment decisions and active ownership practices (PRI, 2021). An investor with a sustainable and responsible investment (SRI) objective seeks to improve the risk-return profile of their portfolio by taking financially relevant ESG criteria into account, thereby protecting the portfolio from environmental risks. The number of institutional investors and asset managers, including central banks, that consider SRI or ESG factors has increased significantly in recent years.[1] At the same time, initiatives, guidelines and common frameworks have been introduced, under which the industry makes commitments and develops such investment strategies.[2]

According to the Network for Greening the Financial System (NGFS, 2019), there are five possible investment strategies for investors to incorporate sustainability factors into their asset management (including negative screening, best-in-class, ESG integration, thematic, and active ownership strategies).[3, 4] Regardless of the SRI strategies used or the objectives set (such as decarbonising a portfolio) climate risk must be measured, both for risk management purposes and for meeting disclosure requirements. These will require available quality data for each asset type, and metrics that show how "polluting" or "green" a portfolio or specific group of assets is. Developing and applying different climate metrics is important from an investment perspective, as this allows for the identification of climate risk exposure, tracking progress and setting decarbonisation goals. A lack of understanding of the key factors behind these metrics can affect investment decisions, strategic asset allocation or the development of a sustainable investment strategy.

This paper aims to provide greater clarity on the various climate metrics applicable to an asset portfolio, specifically regarding sovereign assets, given the current lack of harmonisation in this asset class. Sovereign assets, mostly bonds and bills, are those exclusively issued by a country's government to raise funds and financial resources for fulfilling its obligations and providing services. Although there are various risks associated with sovereign assets, such as country risk linked to solvency, it is also necessary to assess and manage the climate-related transition risk stemming from countries' greenhouse gas

1 The percentage of central banks with an established SRI policy for their own portfolios has increased from 33% in 2020 to 77% in 2023, according to NGFS (2024b).

2 See González and Triebskorn (2023) for more details on various initiatives for achieving net zero in portfolio management.

3 These strategies consist of: (i) exclusion or negative screening, which involves excluding controversial companies, sectors or countries from the investment universe; (ii) best-in-class, which involves positive selection or adjusted weighting by comparing ESG characteristics with similar companies, for example, within the same sector; (iii) ESG integration, which involves incorporating sustainability into quantitative analysis along with profitability and risk in investment criteria; (iv) impact or thematic investing, where the strategy is aligned with a non-financial SRI objective (for example, constructing green bond portfolios focused on sustainability projects); and (v) voting and engagement, focused on changing a company's behavior by emphasising good governance aspects.

4 For a more detailed analysis of the various sustainability strategies that can be adopted in portfolio management and their combination with the risk-return profile of financial assets, see Gimeno and Sols (2020).

(GHG) emissions. It is up to the portfolio manager to strategically allocate sovereign assets based on the different metrics and variables used.

Sovereign investment is especially important for long-term institutional investors such as pension funds and insurance companies, as well as for central banks. In fact, according to NGFS (2020), investments in sovereign, sub-sovereign and supranational and agency bonds constitute one of the main asset classes within a thematic or green bond investment strategy.[5] For example, in 2021 the Eurosystem agreed on a common stance to apply SRI principles to non-monetary policy portfolios, i.e. investment or own portfolios denominated in euros,[6] with a view to contributing to the transition to a low-carbon economy and to the European Union's climate goals. In addition, there was a commitment to disclosure aligned with the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) and, from 2023, all euro area central banks began publishing annual reports specifically addressing the financial aspects of climate risks, with a focus on developing metrics.[7]

In recent years, climate-related disclosures have increased, in line with existing standards, such as the TCFD recommendations published in 2017. More recently, global standards are being developed by the International Sustainability Standards Board (ISSB), and at the European level, the European Commission has approved the Corporate Sustainability Reporting Directive with technical support from the European Financial Reporting Advisory Group. These standards aim to make information more available and comparable and focus in particular on the disclosure and measurement of the emissions and carbon footprint of companies or investment portfolios in the corporate sector. However, assessment and disclosure methodologies are still being developed, and there is no regulatory framework for quantifying the carbon footprint of a country or government, and thus for applying this to sovereign asset investment.

Given the importance of having a framework for sovereign asset investment, this paper contributes to the analysis and development of metrics for assessing and disclosing the transition risks associated with climate change for sovereign assets. Section 2 reviews the progress made so far on measurement and disclosure methodologies for sovereign assets and Section 3 proposes the development of specific metrics for these types of instruments. Section 4 presents a practical application based on several model portfolios, evaluating different metrics.

5 For central banks' own portfolios, investing in labelled bonds, mainly green bonds, is the most common strategy, followed by the exclusion or negative screening strategy and the best-in-class selection (NGFS, 2024b).

6 See the press release "Eurosystem agrees on common stance for climate change-related sustainable investments in non-monetary policy portfolios", dated 4 February 2021.

7 The reports of all Eurosystem central banks can be downloaded here: https://www.ecb.europa.eu/ecb/climate/climate-related-financial-disclosures/html/index.en.html.

2 Greenhouse gas emissions and sovereign assets

The most frequently published climate change indicators are those related to the volume of greenhouse gas emissions, particularly direct emissions. The indicators associated with such data are often referred to as backward-looking because they help analyse how emissions have evolved over time and develop metrics such as the carbon footprint. In this area, many indicators and methodologies are still under development. Using information and data on GHG emissions presents several challenges, mainly in terms of their availability and quality, the lack of which makes it difficult to verify and compare different sources or data providers. Indeed, depending on the source, different levels of granularity can be found, which also complicates aggregation (NGFS, 2024b). This backward-looking information serves as the basis for developing forward-looking indicators and tools to analyse compliance with the temperature reduction commitments set in the Paris Agreement.

There is currently no clear consensus on the definition of measurement methodologies and metrics (both backward-looking and forward-looking) for sovereign assets. Some frameworks are being developed, as explained in this section, but there are ongoing debates around the main variables to be used for developing an investment strategy, such as the scope of emissions associated with a sovereign asset, and for normalising emissions (i.e. expressing the pollution of an issuer relative to a comparable unit) and attributing them (i.e. determining the portion of pollution for which the investor holding the asset is responsible). These factors are not as clearly defined as in the case of other assets, such as corporate bonds.

The following subsections provide an overview of some of the industry's key initiatives, focusing on their backward-looking aspects. First, the GHG Protocol, which provides a framework for GHG emission accounting, followed by the Assessing Sovereign Climate-related Opportunities and Risks (ASCOR) project, which develops a climate-focused assessment of countries based on past GHG emission data. Also described is the private Partnership for Carbon Accounting Financials (PCAF) initiative, applied by the industry and whose application to sovereigns is recommended for the financial sector. Lastly, several academic papers analysing the climate characteristics of sovereign bond investments are cited.

2.1 Greenhouse Gas Protocol

The Greenhouse Gas Protocol (GHG Protocol) initiative was launched 20 years ago through a partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).[8] This alliance sought to address the need for international standards for corporate GHG accounting and reporting. To this end, the protocol provides standardised global frameworks to measure and manage GHG emissions from private and public sector operations and value chains, and mitigation actions for these emissions.

8 See https://ghgprotocol.org.

The GHG emission accounting rules are provided by the Corporate Accounting and Reporting Standard (GHG Protocol, 2015). The protocol's five basic principles are relevance, completeness, consistency, transparency and accuracy. This standard is targeted at companies and organisations and is used by a large number of businesses. For the public sector, there is a Mitigation Goal Standard for countries and cities and the Compact of Mayors, through which hundreds of cities have committed to using the GHG Protocol for Cities. The initiative also works with governments, industry associations, NGOs, businesses and other organisations.

The first edition of the Corporate Standard was published in 2001, providing requirements and guidance for companies and other organisations preparing a GHG emissions inventory at the corporate level. The standard covers the accounting and reporting of the six GHGs included in the Kyoto Protocol.[9, 10] This guide has been updated over the years, most recently in 2015[11] to provide guidance on how to measure emissions from purchased or transferred electricity[12] (losses associated with the electricity transmission and distribution system) and how to account for emissions across value chains.

When determining operational boundaries (i.e. identifying emissions associated with an entity's operations, whether direct or indirect),[13] the GHG Protocol defines three types of emissions known as scope 1, 2 and 3 emissions.[14] These "scopes" identify sources of direct and indirect emissions, aiming to improve transparency and be of use to different climate change organisations and policies. Specifically, scope 1 emissions are direct emissions from sources owned or controlled by the company,[15] scope 2 emissions are indirect GHG emissions from the generation of electricity acquired (either purchased or otherwise brought into the organisational boundary of the company) and consumed by the company; and finally, scope 3 emissions are all other indirect emissions that arise from activities of the company derived from sources not owned or controlled by it, such as those occurring in the organisation's value chain (see Figure 1).

At the public sector level and building on the work of the corporate sector, in 2010 the Protocol developed an accounting guide that interprets the principles of the Corporate Standard for the unique structures and needs of United States federal, state, municipal and local government operations, known as the GHG Public Sector Standard. This standard

9 The Kyoto Protocol was adopted under the umbrella of the United Nations Framework Convention on Climate Change (UNFCCC) at COP3 (UNFCCC, 1997).

10 The GHG emissions covered were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6) (UNFCCC, 1997). Additionally, the GHG Protocol covers nitrogen trifluoride (NF_3).

11 See GHG Protocol (2015).

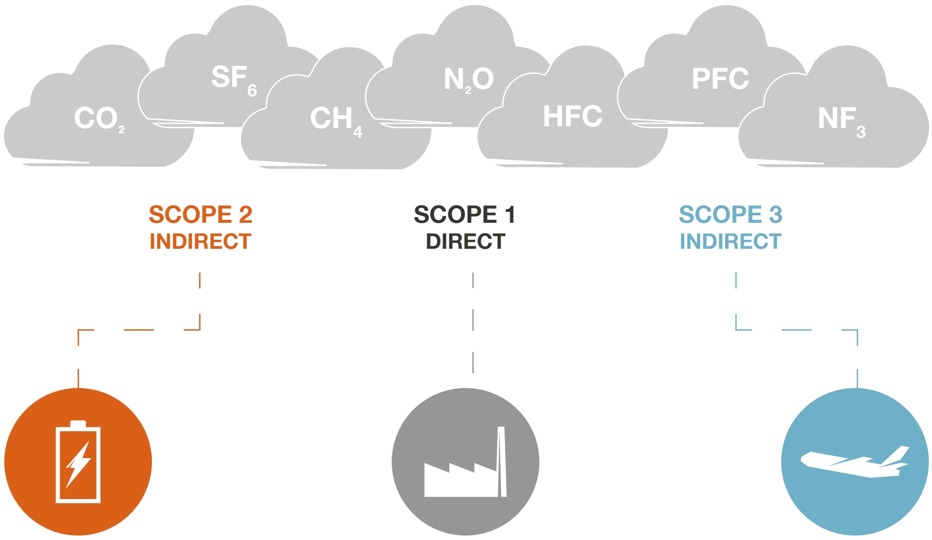
12 The term "electricity" encompasses electricity, steam and heating or cooling.

13 The terms described as "direct" and "indirect" should not be confused with their use in national GHG inventories, where direct emissions are the six gases of the Kyoto Protocol and indirect emissions are the precursors of other gases.

14 When discussing GHG emissions for sovereigns, scopes are not usually distinguished; other naming conventions are used as explained in Section 3.

15 Direct CO_2 emissions from biomass combustion should not be counted as scope 1 emissions; they should be reported separately. Similarly, GHG emissions not covered by the Kyoto Protocol should not be included.

Figure 1
Scopes and emissions across the value chain. GHG Protocol



SOURCE: Banco de España, drawing on GHG Protocol.

aims to address the need for harmonised accounting guidance that can be applied at all government levels and to the public sector in the same way the WRI/WBCSD Corporate Standard was applied to the private sector. Lastly, the Public Standard addresses the issue of double-counting corporate GHG emissions – as these are also included in country emissions – and the need to avoid this practice as far as possible.

2.2 Assessing Sovereign Climate-related Opportunities and Risks project

The ASCOR project seeks to address the challenge of evaluating sovereign debt from a climate perspective using a tool that helps investors assess the climate risk exposure of sovereign issuers. It is a publicly available, open-source tool created by a coalition of international investors formed by asset managers, investor networks and academic collaborators, including the Transition Pathway Initiative, born within the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science.

In the second half of 2023 they published an initial assessment of 25 sovereign issuers with the goal of receiving feedback. The first report, along with a pilot assessment, was published in December 2023 and in late 2024 the analysis was extended to 70 countries. The ASCOR methodology is public,[16] and its framework is based on seven principles:

i) The indicators are assessable using publicly available data;

16 See https://transitionpathwayinitiative.org/publications/uploads/2023-ascor-framework-methodology-note.

Figure 2
Pillars of the ASCOR framework

Pillar 1: Emissions pathways (EP)	Pillar 2: Climate policies (CP)	Pillar 3: Climate finance (CF)
– EP1. Emissions trends – EP2. 2030 targets – EP3. Net-zero targets	– CP1. Climate legislation – CP2. Carbon pricing – CP3. Fossil fuels – CP4. Sectoral transitions – CP5. Adaptation – CP6. Just transition	– CF1. International climate finance – CF2. Transparency of climate costing – CF3. Transparency of climate spending – CF4. Renewable energy opportunities

SOURCE: Scheer et al. (2024).

ii) The indicators are assessable objectively using a transparent methodology;

iii) The indicators are clear, useful and accessible to investors;

iv) The indicators are chosen in a way that does not unnecessarily add to the reporting burden of sovereigns;

v) The indicators are pitched at the national level;

vi) The framework has been developed in line with the principle of common but differentiated responsibilities and respective capabilities, as outlined in the UNFCCC; and

vii) The framework focuses on managing sovereign climate-related risks and opportunities through policies and goals that countries can implement.

When assessing each country, the ASCOR framework considers a series of binary indicators, such as the result of the response to whether the analysed country has taken a specific action, and a quantitative metric is determined by grouping into three pillars and areas (see Figure 2):

- The first pillar focuses on “Emissions pathways”, which considers: (i) emissions trends, (ii) 2030 targets, and (iii) net-zero targets.

- The second pillar considers “Climate policies” through the analysis of: (i) climate legislation, (ii) whether there is a carbon pricing system, (iii) whether there is a commitment to end fossil fuel use, (iv) sectoral transition strategies, (v) the existence of a national adaptation plan, and (vi) whether a just transition is carried out.

- Lastly, the third pillar focuses on "Climate finance", assessing: (i) international climate finance, (ii) transparency of climate costs, (iii) transparency of climate expenditure, and (iv) opportunities related to renewable energy.

The ASCOR project uses the analysis of past data through its first pillar, asking three questions related to the sovereign's GHG emissions profile in the last five years, and whether it is aligned with a 1.5°C temperature increase. In particular, the methodology behind the backward-looking indicators used by ASCOR (Scheer et al., 2024) to analyse emissions trends draws on nine combinations of absolute and relative metrics.[17] GHG emissions are obtained from the PRIMAP-hist database, using the CR (country reported data priority) scenario, which prioritises the emissions data that countries report individually to the UNFCCC, and from the Global Carbon Project (GCP) database. The normalisation data for relative emissions are obtained from the World Bank.

2.3 Partnership for Carbon Accounting Financials approach

PCAF is one of the few initiatives that include sovereign assets in their approach to assessing climate-related risks. This initiative, led by the banking industry, was launched in 2015 by Dutch financial institutions and later expanded to North America in 2018 and globally in 2019. Its aim is to measure and disclose the GHG emissions from their financial activities.

PCAF has developed a global GHG accounting and reporting standard, which provides detailed methodological guidance for measuring and disclosing GHG emissions associated with six asset classes: (i) listed equities and (ii) unlisted equities; (iii) project financing; (iv) commercial real estate; (v) mortgages; and (vi) loans for motor vehicles (PCAF, 2022). This standard aims to equip financial institutions with transparent and harmonised methodologies for measuring and reporting emissions financed through loans and investments, in accordance with the GHG Protocol Corporate Accounting and Reporting Standard and the GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard.

Regarding sovereign debt, PCAF includes in its analysis sovereign bonds and loans of any maturity issued in local or foreign currency and warns about the difficulty of extending this methodology to those issued by regions within a country due to the lack of quality data and the fact that these issuers are not directly subject to international GHG inventory standards. For this reason, PCAF did not explicitly include regional financial instruments as sovereign assets in its first edition, although its latest public consultation did include a proposal for sub-sovereign debt (at the regional, city and local levels), which was largely based on the guidance for sovereign assets (PCAF, 2024). It also recognises the limitation of the double-counting problem when emissions from a portfolio containing both sovereign and sub-sovereign debt at different levels are counted twice or even three times.

17 In Section 3, these combinations are defined and analysed within the design of climate metrics for sovereign assets.

According to PCAF, entities should report the scope 1, 2 and 3 emissions of their borrowers, from the investor's perspective. Under this approach, a sovereign issuer is mainly viewed as a national territory, and its direct GHG emissions (scope 1) are those generated within its borders and include domestic consumption and exports. Scope 2 would include emissions attributable to the purchase (in this case, the import) of electricity, steam, heat and cooling from outside the country's territory. Finally, scope 3 emissions would relate to all other (non-energy) imports of goods or services from outside the country as a result of activities carried out within the country. This approach would be consistent with GHG accounting for sovereign debt emissions from a consumption-based perspective.

2.4 Literature on sovereign asset investment analysis

There is little research, either by the industry or academia, that analyses the challenges of climate-related assessment of sovereign bonds as investment assets. The literature highlights the need to focus on the GHG emissions associated with sovereigns when analysing their carbon footprint. Also, choosing appropriate methodologies and metrics is crucial for implementing decarbonisation strategies. Many papers highlight the complexity, due to various factors, of measuring the carbon intensity of sovereign bonds, in contrast to corporate debt. Additionally, the importance of assessing climate-related financial risks is emphasised on account of their impact on returns and market spreads.

Desme and Smart (2018) argue that sovereign bonds are financial instruments that provide capital to national governments, which means the primary focus should be on the GHG emissions associated with this agent when analysing a sovereign's carbon footprint. The choice of methodology and metrics for sovereign bonds is key when applying a decarbonisation strategy to sovereign instrument portfolios. Cheng, Jondeau and Mojon (2022) adopt a consumption-based approach,[18] scaled by population, when constructing a portfolio of sovereigns with decreasing carbon footprints, following the approach of other research papers (Burns, Alexeyev, Kelly and Lin, 2016; Desme and Smart, 2018) and stating that this metric captures carbon leakage, especially in advanced economies where consumed goods and services are more likely to be imported. Regarding the normalisation factor, there is a debate over using one variable or another, as per capita emissions are aligned with the Paris Agreement, unlike calculations based on GDP, which show income bias, according to Leadbetter, Farooqui and Emery (2022).

Domínguez-Jiménez and Lehmann (2021) highlight that long maturities, the government's ability to affect taxation and regulation, and wide-ranging expenditures make it more complex to measure the carbon intensity of sovereign bonds compared to corporate debt. Given these particularities, assigning the emissions of the entire country to the central government as an issuer is a possibility. However, the authors note that combining sovereign and private sector bonds would result in a double-counting problem. Other research has

18 A consumption-based approach is calculated by adjusting territorial emissions for trade. See Section 3.1 for more details.

focused more on studying climate risks associated with sovereign bonds from different angles. For example, Battiston and Monasterolo (2019) develop a methodology for climate-financial risk assessment under uncertainty, such as in a disorderly transition scenario, using integrated assessment models.

The way sovereign debt pollution (and intensity) is measured is important, as it has been observed that the transition risk of this debt – measured, among other indicators, by CO_2 equivalent emissions – significantly impacts returns and spreads in markets (Collender, Gan, Nikitopoulos, Richards and Ryan, 2022). For carbon-intensive countries, the cost of climate misalignment can affect sovereign risk and portfolio returns (Battiston and Monasterolo, 2020). Finally, concerning the pollution-risk binomial, it has been observed that countries with more carbon-intensive economies are not necessarily the most exposed to transition risks (Lancesseur and Lorans, 2021).

Regarding the use of an integrated approach in a sovereign portfolio, Bank for International Settlements (2022) addresses the methodological and data challenges faced by central banks when incorporating climate-related risks into their international reserve management frameworks. The difficulty of modelling climate factors and their connection to portfolio risk-return characteristics is highlighted, and the lack of comprehensive, timely and accurate climate risk data is noted as a key challenge. Cheng, Jondeau and Mojon (2022) propose a strategy to build sovereign bond portfolios with progressively decreasing carbon footprints. This strategy suggests a new benchmark consistent with the Paris Agreement, which passive investors can use to build a net-zero portfolio while maintaining the financial characteristics of a benchmark portfolio. The strategy rewards sovereign issuers that have made greater efforts to reduce carbon intensity, measured by total domestic emissions per capita. This net-zero portfolio could reduce carbon intensity without affecting the financial performance of the portfolio.

3 Designing climate metrics for sovereign assets

One of the main problems when designing climate metrics for sovereign assets is the lack of a framework explicitly designed for them, given their specificities and how they differ from corporate assets. Most market standards are designed for the latter, most notably the standard developed by the TCFD, which develops recommendations and metrics from a business perspective (see Box 1), meaning, for example, that these metrics focus on how to estimate the carbon footprint of corporate investments. However, the TCFD has not developed an equivalent standard for other types of assets, such as bonds issued by governments or supranational entities, so adapting these metrics poses a challenge, as shown below.

3.1 Key elements in determining GHG emissions from sovereign bonds

When determining the GHG emissions associated with sovereign bonds, three key elements need to be considered: (i) allocation; (ii) normalisation; and (iii) attribution.

The first element is the allocation of GHG emissions to the country issuing bonds. For corporate issuers, the allocation of emissions is more standardised within the industry, and as previously mentioned, according to the recommendations of the GHG Protocol, carbon emissions are divided into direct emissions (scope 1), indirect emissions related to the consumption and acquisition of energy (scope 2) and other indirect emissions (scope 3). However, this standardisation does not directly apply to sovereign issuers and three different methodologies can be identified for allocation.

First, the *production/country factor or method,* which captures territorial emissions, i.e. those produced within a country's physical borders. These emissions can be considered both including and excluding those related to land use, land-use change and forestry (LULUCF, see Box 2).

Second, the *consumption factor or method,* wich takes into account the sovereign's trade structure, considering GHG emissions associated with the consumption of goods and services by domestic agents. This method includes emissions from imports and excludes those from exports, and addresses the problem of carbon leakage that arises due to changes in countries production and consumption.

Both approaches – production and consumption – entail double-counting when combining different types of assets in a single portfolio.[19] This is because a portfolio that combines sovereign, corporate and sub-sovereign bonds already incorporates the emissions attributable to companies, in addition to those from regions or sub-sovereign entities within the issuing country. Therefore, an alternative approach explored in this paper

19 Regarding the issue of double-counting, PCAF recognises that it poses a challenge for a financial institution with investment portfolios in multiple asset classes, requiring separate reporting for each asset class to avoid it.

Figure 3
Variables by type of approach

	Sovereign and sub-sovereign		
	Approach		
	Country	Government	Consumption
GHG emissions allocation	Emissions produced within a country's physical borders, including domestic consumption and exports Excluding and including LULUCF GHG emissions	Central government's direct and indirect emissions	Domestic demand emissions, taking into account trade effects (including imports and excluding exports)
Normalisation	GDP (PPP)	Central government final consumption expenditure	Population
Attribution	GDP (PPP)		

SOURCE: Banco de España (2024).

is the *government factor or method,* which captures GHG emissions associated with the public sector (institutions and government expenditure)[20] within a country's territory, similar to the production approach, but limited to the public sector. Allocating emissions to the central government minimises the problem, but does not fully eradicate it. It also allows for the possible aggregation of emissions by enabling an integrated strategy that treats the sovereign as another economic agent.

The government approach, along with the production and consumption approaches (see Figure 3), is part of the common disclosure framework developed by the Eurosystem for the annual publication of climate-related information on the investment portfolios of each national central bank (NCB) in the Eurosystem and the European Central Bank (ECB).[21]

20 For more details on this approach, see Banco de España (2024).

21 Eurosystem NCBs and the ECB published this information for the first time in March 2023. All reports can be found at: https://www.ecb.europa.eu/ecb/climate/climate-related-financial-disclosures/html/index.en.html.

Once carbon emissions have been allocated to the sovereign issuer, the next step is *normalisation.* To relativise the emissions of an issuer, these must be expressed in a comparable unit, either relating to economic activity such as GDP (usually adjusted for purchasing power parity (PPP)) or public expenditure, or another indicator such as population.

Furthermore, the indicator chosen to normalise CO_2 equivalent tonnes (tCO_2e) is not independent of the allocation method selected. In practice, the industry typically uses GDP as the denominator for the production-based approach, population for the consumption-based approach,[22] and public expenditure for the government-based approach. As Section 4 shows, the choice of allocation and normalisation method will have an impact on the relative position of each sovereign's debt.

Lastly, after obtaining a country's GHG emissions, both in absolute and relative terms, the next aspect to consider is the emissions financed through the allocation of an attribution factor to determine what portion of the pollution is the responsibility of the investor holding that asset in their portfolio. To do so, the contribution of the investor's position in the total capital structure needs to be analysed. In the case of sovereigns, this would be reflected most directly in the country's total debt, although the attribution can also be done based on GDP.

Each option has its advantages and limitations. The most direct equivalent of the corporate approach, which uses enterprise value including cash, for sovereigns would be the country's total debt since it considers the portion of financing that investors actually take into account. There is also a one-to-one ratio between sovereign debt and the sovereign issuer's capital structure. However, there are also limitations, as sovereigns are rarely primarily financed by debt; tax revenue must also be considered. On the other hand, there are arguments in favour of using PPP-adjusted GDP. It would be ideal for the financial institution's share of emissions to be proportional to its exposure to the borrower's total value. Furthermore, a country's production is more closely linked to the emissions generated. Finally, volatility in the PPP-adjusted GDP (or GDP (PPP)) data series must also be considered. An example of how this debate has translated into practice is the PCAF recommendation to use PPP-adjusted as an attribution factor, while recognising the limitations and considering other possible measures.[23]

Depending on the approach used for the allocation of GHG emissions, the normalisation indicator and the attribution factor, the possible equivalent to sovereign assets is summarised in Figure 3 and applied to the metrics recommended by the TCFD in the following section.

22 PCAF uses the per capita consumption-based approach, arguing that these emissions reflect the demand side of the economy. ASCOR, on the other hand, analyses emissions under three alternatives: two using the territorial approach, one excluding and one including LULUCF emissions and a third using the consumption-based approach (excluding LULUCF). For each of these three approaches, absolute emissions, per capita intensity and intensity per GDP adjusted for PPP are analysed (Scheer et al., 2024).

23 PCAF acknowledges that it is studying the total capital stock (indicator provided by the International Monetary Fund) as an attribution factor, a measure of the total value of gross fixed capital formation in the economy.

3.2 Climate metrics for sovereign assets

The most widely followed framework for applying and disclosing climate metrics is that developed by the TCFD (see Box 1). This task force created a guide of indicators to assess and manage climate risks, with specifics for some industries (TCFD, 2021a and 2021b). Regarding the financial sector, especially banks, insurance companies, asset owners and portfolio managers, several metrics are recommended based on asset type, such as listed and unlisted equities, corporate bonds, business loans, project financing, real estate, mortgages and vehicle loans. The four metrics recommended by the TCFD for investment portfolios and their disclosure are: (i) total carbon emissions; (ii) carbon footprint; (iii) carbon intensity; and (iv) weighted average carbon intensity (WACI).

These metrics and their adaptation to sovereign assets are described below, considering the different allocation, normalisation and attribution factors mentioned in Section 3.1. As noted earlier, these adapted metrics, following TCFD recommendations, are included in the Eurosystem's common and coordinated disclosure framework, under which all NCBs and the ECB publish their disclosures annually,[24, 25] in fulfilment of the annual disclosure commitment made in February 2021 as part of the common stance for applying SRI principles to non-monetary policy portfolios.[26, 27] The Banco de España publishes an annual report dedicated exclusively to the financial disclosure of the climate-related aspects of these portfolios.[28]

The first and most widely used metric is the calculation of the total absolute emissions (TAE) of carbon associated with a portfolio, expressed in tCO_2e. This involves calculating total scope 1 and scope 2 emissions allocated to an investor based on their share of a company's market capitalisation or total capital structure (debt + equity) (see Equation 1). For example, if an investor owns 10% of a company's market capitalisation, they are attributed 10% of its GHG emissions.

Equation 1. Total absolute emissions (TAE)

$$\text{Total absolute emissions} = \sum_{n}^{i} \frac{\text{current value of investment}_i}{\text{issuer's market capitalisation}_j} \times \text{issuer's (Scope 1 and Scope 2) GHG emissions}_i$$

SOURCE: TCFD (2021a and 2021b).

For a sovereign bond portfolio, the TAE, expressed in tCO_2e, is calculated based on the investor's share of a country's total GDP – usually adjusted for PPP – or total debt (see Equation 2). That is, owning 10% of a country's GDP or total debt means the investor would

24 Eurosystem NCBs and the ECB published this information for the first time in March 2023. All reports can be found at: https://www.ecb.europa.eu/ecb/climate/climate-related-financial-disclosures/html/index.en.html.

25 See the annex with the summary of the metrics used in the disclosure of Banco de España (2024).

26 See the press release "Eurosystem agrees on common stance for climate change-related sustainable investments in non-monetary policy portfolios", dated 4 February 2021.

27 See the press release "The Banco de España adopts the Eurosystem's common stance for sustainable investment", dated 4 February 2021.

28 See Banco de España (2023 and 2024) and https://www.bde.es/wbe/en/publicaciones/informes-memorias-anuales/memoria-sobre-informacion-climatica-de-las-carteras-propias-del-bde/.

be attributed 10% of the country's GHG emissions under the territorial or consumption-based approach, or 10% of the central government's emissions under the government-based approach.

Equation 2. Total absolute emissions for sovereigns

$$\text{Total absolute emissions} = \sum_{n}^{i} \frac{\text{current value of investment}_i}{\text{GDP (PPP)}_i \text{ or Debt}_i} \times \text{issuer's (Scope 1 and Scope 2) GHG emissions}_i$$

SOURCE: Banco de España.

Since the TAE is an absolute measure that does not adjust for the volume of investments, its use for comparing across portfolios and over time is limited, as it depends heavily on the size of the portfolio. To overcome this limitation and provide a more useful picture, it is essential to accompany this metric with others that adjust for differences in the size of investments. One such metric is the so-called carbon footprint, which relates the total GHG emissions associated with a portfolio to its volume and is expressed in tonnes of CO_2e (tCO2e) per million euro (see Equation 3). This enables comparison of portfolios of different sizes and at different times.

Equation 3. Carbon footprint

$$\text{Carbon footprint} = \frac{\sum_{n}^{i} \left(\frac{\text{current value of investment}_i}{\text{issuer's market capitalisation}_i} \times \text{issuer's (Scope 1 and Scope 2) GHG emissions}_i \right)}{\text{current portfolio value (\$M)}}$$

SOURCE: TCFD (2021a and 2021b).

In the case of the carbon footprint of a sovereign portfolio, the total GHG emissions are normalised by the investment amount. This metric is expressed in tCO_2e per million invested, as shown in Equation 4.

Equation 4. Carbon footprint for sovereigns

$$\text{Carbon footprint} = \frac{\sum_{n}^{i} \left(\frac{\text{current value of investment}_i}{\text{GDP (PPP)}_i \text{ or Debt}_i} \times \text{issuer's (Scope 1 and Scope 2) GHG emissions}_i \right)}{\text{current portfolio value (\$M)}}$$

SOURCE: Banco de España.

It is also important to quantify the carbon emission efficiency of a portfolio by normalising the size of each issuer in relation to its revenue, for which the metric called carbon intensity is used. This metric measures the volume of GHG emissions normalised by an economic activity measure. In the case of corporate investment, it involves considering the issuer's or company's revenue and is expressed in tCO_2e per million of revenue (see Equation 5).

Equation 5. Carbon intensity

$$\text{Carbon intensity} = \frac{\sum_{n}^{i} \frac{\text{current value of investment}_i}{\text{issuer's market capitalisation}_i} \times \text{issuer's (Scope 1 and Scope 2) GHG emissions}_i}{\sum_{n}^{i} \left(\frac{\text{current value of investment}_i}{\text{issuer's market capitalisation}_i} \times \text{issuer's revenue (\$M}_i) \right)}$$

SOURCE: TCFD (2021a and 2021b).

In the sovereign context, the carbon intensity metric allows for the attribution of scope 1 and 2 GHG emissions by normalising the total carbon emissions relative to a measure that enables comparison of each sovereign's pollution intensity, whether by a monetary unit such as GDP or public expenditure, or by population. It is measured in tCO_2e per million of revenue or per capita (see Equation 6).

Equation 6. Carbon intensity for sovereigns

$$\text{Carbon intensity} = \frac{\text{Total absolute emissions}}{\sum_n^i \left(\frac{\text{current value of investment}_i}{\text{GDP (PPP)}_i \text{ or Debt}_i} \times \text{GDP (PPP)}_i \text{ or Debt}_i \text{ or Gov. expend.}_i \text{ or Population}_i \right)}$$

SOURCE: Banco de España.

Lastly, the final metric recommended by the TCFD is the calculation of the weighted average carbon intensity (WACI), which measures a portfolio's exposure to entities that are more carbon-intensive and is expressed in tCO_2e per million of revenue (see Equation 7). The carbon intensity of each issuer is calculated by normalising its GHG emissions by a measure of its economic activity. The WACI of a portfolio is calculated by weighting the carbon intensity of each securities issuer by the relative weight of the investments in them.

Equation 7. Weighted average carbon intensity (WACI)

$$\text{WACI} = \sum_n^i \left(\frac{\text{current value of investment}_i}{\text{current portfolio value}} \times \frac{\text{issuer's (Scope 1 and Scope 2) GHG emissions}_i}{\text{issuer's revenue}_i \text{ (\$M)}} \right)$$

SOURCE: TCFD (2021a and 2021b).

The WACI for the exposure of a portfolio to carbon-intensive sovereign issuers is expressed in tCO_2e per million of GDP (PPP) or public expenditure, or per capita, and it would be calculated as follows:

Equation 8. WACI for sovereigns

$$\text{WACI} = \sum_n^i \left(\frac{\text{current value of investment}_i}{\text{current portfolio value}} \times \frac{\text{issuer's (Scope 1 and Scope 2) GHG emissions}_i}{\text{GDP (PPP)}_i \text{ or Gov.Expend.}_i \text{ or Population}_i} \right)$$

SOURCE: Banco de España.

3.3 Advantages and disadvantages of the climate metrics

The metrics outlined in the previous subsection are used to measure the climate performance of a sovereign bond portfolio over time. Absolute metrics do not allow for comparability either across portfolios or over time. Relative metrics, on the other hand, address this limitation and, in principle, no single metric has significant advantages over the others, apart from the possibility of comparing across portfolios and over time. The usefulness of a given metric will depend on the intended purpose or focus (e.g. portfolio emissions management, setting decarbonisation goals, or an SRI strategy). The conceptual differences between them, in terms of the questions that investors may seek to address, are discussed in more detail below.

Starting with the only absolute metric, TAE has three clear limitations. First, in a portfolio composed of multiple asset classes, not just sovereign bonds, using both the production and consumption-based approaches may result in double-counting. Second, it prevents comparisons over time, since it is highly dependent on portfolio size. For instance, portfolio growth may outpace reductions in carbon emissions, obscuring the real change in the portfolio's pollution. Lastly, it makes it difficult to compare portfolios with each other or against a benchmark index. To overcome this and provide a more useful picture, it is essential to accompany this metric with others that correct for investment volume differences.

Among the relative metrics, WACI can be interpreted as a country's carbon efficiency in producing or providing services, expressed in terms of its economic output (GDP), public spending or population. It levels the playing field by eliminating the bias of large countries over small ones. WACI serves as a starting point for measuring a portfolio's potential exposure to a country's transition risks and is relevant for comparing countries based on sectoral exposure. It is an easily defined metric with good data availability and coverage, although it faces challenges with regard to regional assets, as there is currently no market standard for calculating the carbon intensity of such bonds. Though widely used in the financial sector, it requires more communication effort than other metrics with which the public is more familiar, such as the carbon footprint.

However, WACI is subject to exogenous fluctuations unrelated to decarbonisation, driven by various factors, such as price inflation, that are potentially more pronounced than in other metrics such as the carbon footprint. These fluctuations result from portfolio-specific characteristics, such as the currency basket and geographical investment composition. By design, GDP-normalised metrics are prone to artificial portfolio decarbonisation over time, with the greening observed being the result of macroeconomic fluctuations. Moreover, using WACI may create undesirable countercyclical effects where the need for corrective actions arises during economic recessions. While the standard WACI is valid for observing and comparing portfolios at a specific time, to observe real improvements in sustainability over time requires adjustments for inflation and exchange rates.

The carbon footprint is a useful measure to understand emissions relative to the invested value. It is a size-adjusted measure of a portfolio's climate impact and aids asset management. When using debt as an attribution factor, the carbon footprint can be seen as the share of a country's financing that results in specific GHG emissions. It is more suitable for comparing investments in different sovereign assets and making strategic asset allocations and asset selection based on their contribution to total portfolio emissions. Additionally, using debt as the attribution factor reduces the inflation effect on the metric. By adding up proportional GHG emissions based on the investor's ownership share, the metric links emission ownership more intuitively to responsibility. For portfolio management, it seems more appropriate as it allows for investment comparison and asset allocation and selection. Using debt also tends to make it less volatile than WACI. Debt is generally seen as a more stable balance-sheet metric than revenue, especially in key transition sectors such as fossil fuels.

It should be noted that the carbon footprint is also prone to fluctuations due to inflation, but less markedly than WACI. On the other hand, it is less suitable for measuring transition risk compared to WACI. In terms of advantages, being a relative metric, it largely eliminates the bias of small versus large portfolios and takes into account economic output or market value. It also has good data coverage, although with less clarity and accuracy for sub-sovereign, agency and supranational issuers. Lastly, it is a more intuitive concept for the public.

Carbon intensity is a metric that can be used to compare the level of emission intensity of different asset classes, portfolios and even countries. It is also a useful metric for selecting the best performers within the same sector to rebalance a portfolio towards a low-carbon trend or to set limits on portfolio emissions. However, like the above-mentioned metrics, the reduction or increase in emissions may be driven by volatility in the selected economic metric used as the denominator. It should be noted that countries exposed to high-emitter sectors are often directly linked to volatile commodity prices (e.g. oil, gas and coal).

Since all these metrics have strengths and weaknesses (see summary in Table 1), they should all be monitored. Short-term volatility illustrates the need to disaggregate and decompose them to examine the underlying drivers of changes in and the performance of the metrics. Emissions attribution should be calculated similarly to the performance attribution in investment management, by breaking down the overall change in a metric into its components. This breakdown can help portfolio managers see the factors affecting the carbon changes in the portfolio and improve understanding of decarbonisation progress and the effects of portfolio allocations.

Table 1
Advantages and disadvantages of climate metrics for their application to sovereigns

Metric	Advantages	Disadvantages
TAE	— Easy to define due to data availability and coverage	— Prevents temporal comparability — Difficult to compare across portfolios or indices — Double-counting in the case of a portfolio with different types of assets
WACI	— Equal treatment of countries — Measures potential exposure to transition risks — Allows temporal and cross-portfolio or index comparisons — Easy to define due to data availability and coverage	— Lack of a market standard for regional assets — Requires greater communication effort — May show fluctuations unrelated to decarbonisation — May create countercyclical characteristics
Carbon footprint	— Allows temporal and cross-portfolio or index comparisons — Enables strategic allocation and asset selection — Reduces the potential effect of inflation — Easy to define due to data availability and coverage — More intuitive concept and easier to communicate	— Lack of a market standard for regional assets — May show fluctuations unrelated to decarbonisation — Less suitable for measuring transition risk
Carbon intensity	— Allows temporal and cross-portfolio or index comparisons — Enables strategic allocation and asset selection — Easy to define due to data availability and coverage	— Lack of a market standard for regional assets — Requires greater communication effort — May show fluctuations unrelated to decarbonisation — May create countercyclical characteristics

SOURCE: Banco de España.

Box 1

RECOMMENDATIONS FROM THE TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES FOR THE DISCLOSURE OF CLIMATE METRICS

At the global level, the Task Force on Climate-Related Financial Disclosures (TCFD) was created as a working group in late 2015 by the Financial Stability Board at the request of the G20. It consisted of 31 private-sector members led by Michael Bloomberg. In 2017 the TCFD developed a set of recommendations for the disclosure of climate risks and opportunities with the aim of guiding businesses primarily in disclosing how they integrate climate aspects across four areas of an organisation: (i) governance; (ii) strategy; (iii) risk management; and (iv) metrics and targets (TCFD, 2017). Each of these blocks has specific recommendations, which are outlined in Figure 1. In the case of metrics, the TCFD recommends publishing scope 1 and 2 GHG emissions and considering scope 3 emissions, as well as a set of specific metrics as detailed in Section 3. It also recommends describing medium and long-term goals, along with interim targets. By 2023 over 4,850 companies and institutions globally had adopted the TCFD recommendations, and the amount of information disclosed regarding each recommendation has been increasing.[1]

The TCFD provided further detail on its recommendations through guidelines for certain topics and sectors, especially in the case of metrics and targets (TCFD, 2021a and 2021b). Specifically, it recommends: (i) describing the metrics used to assess climate-related risks and opportunities aligned with the organisation's strategy and risk management process; (ii) disclosing scope 1 and 2 GHG emissions, and where appropriate, scope 3 emissions and their associated risks; and (iii) publishing the targets used to manage and track progress toward these goals. The TCFD also recommends publishing interim targets that accompany medium and long-term goals. Furthermore, the TCFD developed a set of indicators to assess and manage climate risks, providing specifics for certain industries, such as the financial sector (TCFD, 2021a and 2021b).

The TCFD recommendations inspired the development of several guidelines and even regulations on disclosure, such as those in the European Commission's sustainable finance efforts and disclosures by institutions such as central banks. An example is the common disclosure framework developed by the Eurosystem central banks for use in their climate-related disclosure reports on investment portfolios, which is based on the TCFD's four-pillar framework,[2] particularly regarding the proposed metrics.[3]

The International Sustainability Standards Board (ISSB) took over the TCFD's monitoring responsibilities from 2024.[4] The relevance of the TCFD lies in its widespread application across the corporate and financial sectors. The ISSB has developed two global standards on sustainability disclosure that incorporate the TCFD recommendations and expand on some sections. Specifically, IFRS S1 outlines the disclosure requirements for a company regarding sustainability-related risks and opportunities in the short, medium and long term.

Figure 1
TCFD recommendations

Governance	– Board oversight – Role of management
Strategy	– Risks and opportunities – Impact on the organisation – Resilience of the strategy
Risk management	– Risk identification and assessment processes – Risk management processes – Integration into overall risk management
Metrics and targets	– Climate-related metrics – Scope 1, 2 and 3 GHG emissions – Climate-related targets

SOURCE: TCFD (2023).

1 See TCFD (2023) for more details.

2 See NGFS (2021 and 2024c).

3 See https://www.ecb.europa.eu/ecb/climate/climate-related-financial-disclosures/html/index.en.html.

4 An organisation created at COP 26 in November 2021 by the International Financial Reporting Standards (IFRS) Foundation. See "IFRS Foundation welcomes culmination of TCFD work and transfer of TCFD monitoring responsibilities to ISSB from 2024", https://www.ifrs.org/news-and-events/news/2023/07/foundation-welcomes-tcfd-responsibilities-from-2024/.

Box 1

RECOMMENDATIONS FROM THE TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES FOR THE DISCLOSURE OF CLIMATE METRICS (cont'd)

Additionally, IFRS S2 focuses on climate-related aspects, including progress towards achieving set goals and compliance with legal or regulatory requirements. Regarding metrics and targets, this standard requires the disclosure of industry-specific metrics for the company's business model and activities. For example, while the TCFD suggested including scope 3 emissions if appropriate, IFRS S2 mandates their disclosure and the establishment of a framework for their measurement.

At the same time, at the European level, the Corporate Sustainability Reporting Directive (CSRD)[5] also drew inspiration from the TCFD, though its approach is broader as it includes environmental, social and governance (ESG) considerations, in contrast to the strictly climate-focused perspective of the TCFD. The CSRD adopts a double-materiality approach, compared to the single materiality approach of the TCFD. This means that companies will need to report both the impact of ESG factors on their business and the impact their business has on ESG factors.[6]

5 Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022.

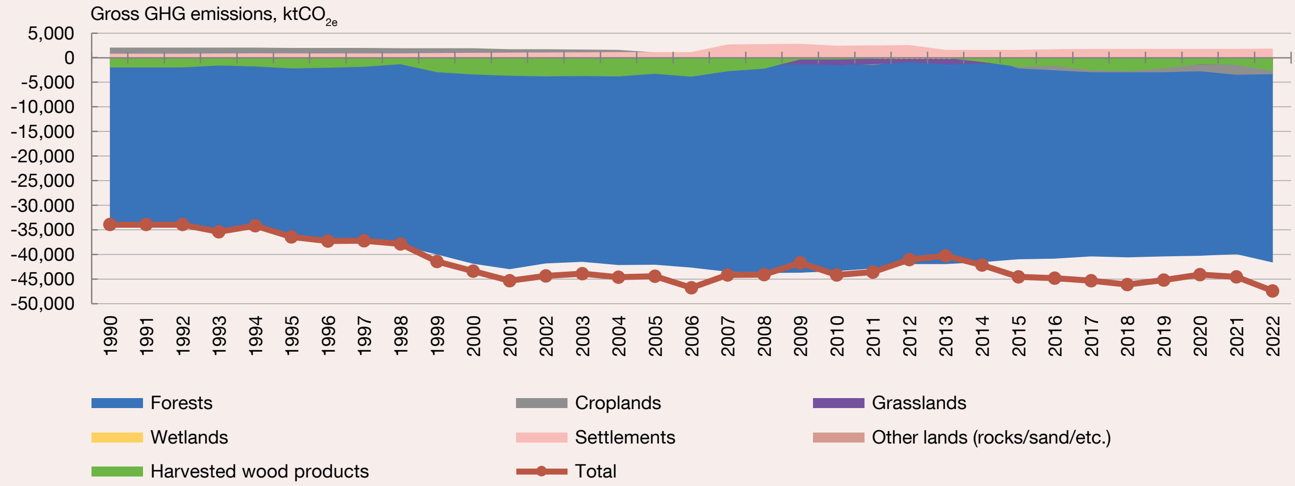
6 In February 2025 the European Commission presented a new package of proposals to simplify EU sustainability and investment rules, including changes in sustainability reporting under the CSRD.

Box 2

GHG EMISSIONS RELATED TO LAND USE, LAND-USE CHANGE AND FORESTRY

LULUCF stands for land use, land-use change and forestry. These activities are linked to climate change, as human activity affects the carbon reservoir and the carbon cycle interactions between ecosystems and the atmosphere. To achieve net-zero emissions, mitigation actions that capture carbon are necessary. Through these activities, different mitigation strategies can be carried out to help remove GHG emissions from the atmosphere via ecosystems (forests, wetlands, croplands, etc.). In Spain,[1] LULUCF activities have a sink effect, meaning that if they are accounted for, the country's total GHG emissions are reduced due to carbon capture, with the forest sector being the largest contributor (see Chart 1). However, in other regions, the effect may be the opposite, as some of these activities may have adverse side effects on ecosystems, such as increased land and water use (e.g. wildfires or destruction of ecosystems such as wetlands).

Chart 1
LULUCF GHG emissions in Spain, by sector. 1990–2022



SOURCES: Ministerio para la Transición Ecológica y el Reto Demográfico and Observatorio Climático (SEO BirdLife).

1 For more details, see the Ministry for the Ecological Transition and the Demographic Challenge website.

4 Assessment of climate metrics applied to a sovereign asset portfolio

This section addresses the practical application of climate metrics in the context of investing in sovereign assets. It begins with a review of the main data sources available and their relevance to GHG emissions analysis. The implications of using different emissions measurement approaches are discussed using practical examples. In addition to examining the use implications of absolute metrics, normalisation factors are explored to understand the impact of choosing between different sovereigns. Lastly, a practical application of these metrics is presented through a theoretical exercise involving several investment portfolios, highlighting the challenges faced by portfolio managers when choosing methodologies and calculating climate metrics for sovereign assets to optimise risk management and enhance investment sustainability.

4.1 Data sources

Unlike corporate issuers, where data collection is based on data in their reports, or even data modelled by different estimates, for sovereign issuers, public data sources can be used to gather GHG emissions data. The primary source of GHG emissions data for each country is the contributions of the sovereigns to the UNFCCC.

Countries that are parties to the Convention, adopted in 1992 and in force since 1994, must submit their national GHG inventories according to the guidelines agreed thereunder.[29] Annex I Parties (developed countries) report their inventories annually, while non-Annex I Parties (developing countries) do so in their annual communications and the frequency of updates may vary depending on their capacities and national circumstances. The inventories are closely linked to the nationally determined contributions, as they serve to assess progress and compliance (or lack thereof) with the established emission reduction targets.

One of the main obstacles regarding GHG emissions data for sovereigns is the time lag in updating inventories. Annex I countries usually report data annually, covering the period from 1990 to the latest available year, which typically has a two-year lag (i.e. parties that updated their reports in 2024 include GHG emissions data up to 2022). In the case of EU countries, a preliminary report is usually published with data for a more recent year (e.g. in 2024 a preliminary estimate of 2023 emissions was published), thus reducing the natural lag to one year compared with the latest available data, making the gap similar to that of corporate issuers.

Various public databases are available to obtain GHG emissions data on sovereign issuers, mainly from international institutions, although there are also open projects where data can be found. The World Bank offers a database of different GHG emissions data for sovereigns, including total GHG emissions excluding and including

29 For more information, see https://unfccc.int/topics/mitigation/resources/registry-and-data/ghg-data-from-unfccc.

LULUCF[30] emissions for over 260 countries. The data are partially obtained from Emissions Database for Global Atmospheric Research (EDGAR) and Climate Watch, with contributions to the UNFCCC being part of their primary sources. The OECD database is another public source where GHG emissions can be obtained from different approaches, combining raw emissions data from the International Energy Agency with its input-output tables. In the case of European countries, Eurostat provides a GHG emissions database with data from inventories submitted to the UNFCCC, and the European Environment Agency provides information on the progress of all EU countries, as well as the targets set by the countries,[31] among other available data.

Lastly, Our World in Data is an open-access platform born from the collaboration between the University of Oxford and Global Change Data Lab, which provides different approaches to GHG emissions for sovereign issuers. It obtains data from various sources, notably the Global Carbon Project. This project, led by a team from the University of Exeter, provides information on carbon emissions and their trends through the Global Carbon Budget. It also offers GHG emissions from a consumption perspective, meaning those attributed to the consumption of goods and services. This is calculated by adjusting territorial emissions for trade, with consumed emissions being production-based emissions minus emissions attributed to exports plus emissions attributed to imports.

Apart from public access data sources, there are several private climate data providers that offer GHG emissions for different debt issuers. For sovereign issuers, the primary source is the contributions to the UNFCCC from different countries, but in some cases, providers offer some specific methodology. This is the case for the government-approach for emissions, which, while it has the aforementioned advantages, its main limitation is the current lack of development in data access. This continues to make double-counting a future challenge to address when calculating climate metrics for sovereign assets.

4.2 Allocation: implications of using a production or a consumption-based approach

The first challenge that arises when applying climate metrics to sovereign assets is deciding which GHG emissions to use, in other words, choosing the numerator. As discussed in Section 3, there are various approaches to incorporating a country's GHG emissions. To use the equivalent volume of the issuer's scope 1 and 2 GHG emissions in this case, either a production or consumption-based approach can be applied. This subsection will focus on highlighting the differences between these approaches. As previously mentioned, a production-based approach considers all emissions produced within the territory, meaning the total volume is directly linked to the development level of a country's primary and secondary sectors. In contrast, a consumption-based

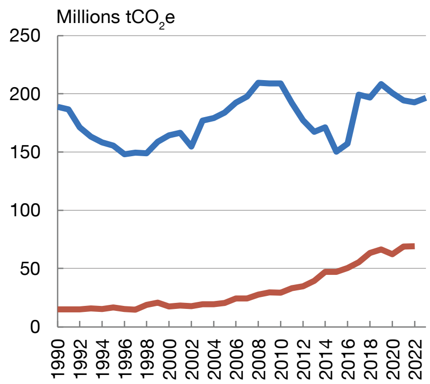
30 See Box 1.

31 For example, see "Approximated estimates for greenhouse gas emissions" for 2023 on the website here.

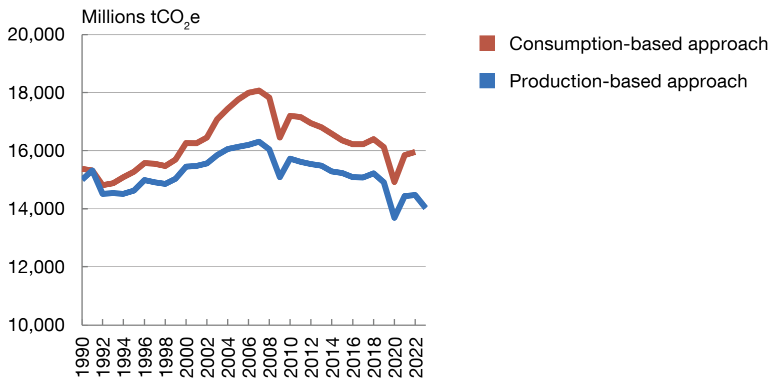
Chart 1

Absolute GHG emissions: production and consumption-based approaches (a) (b)

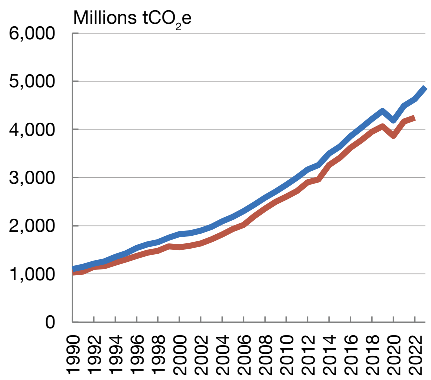
1.a Low-income countries



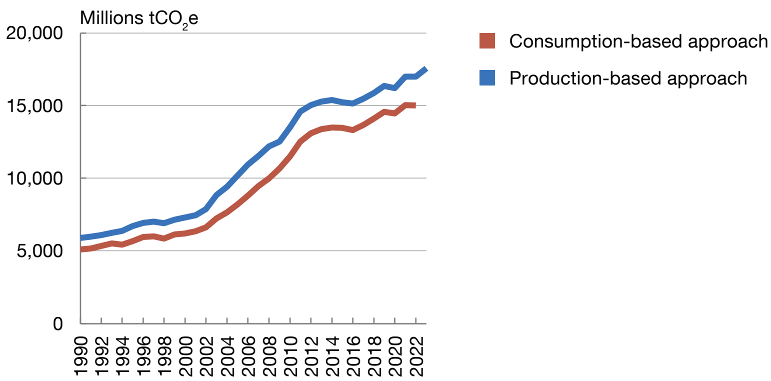
1.b High-income countries



1.c Lower-middle-income countries



1.d Upper-middle-income countries



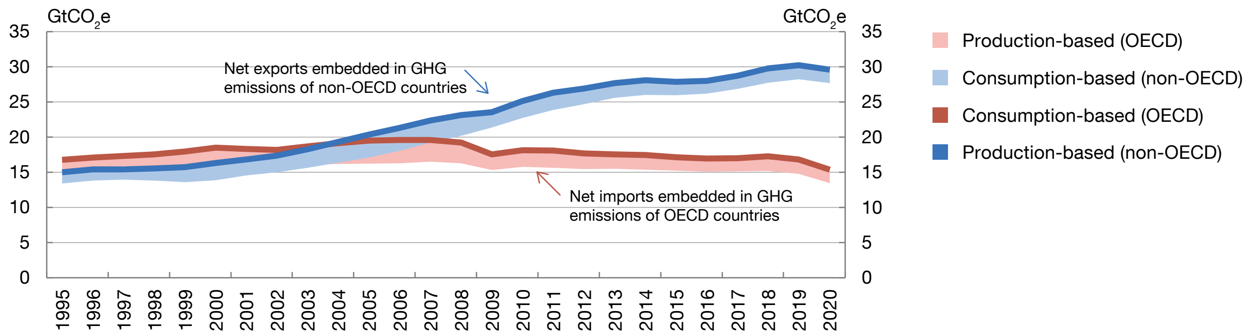
SOURCE: Banco de España, drawing on data from Global Carbon Budget (2024) and Our World in Data.

a Latest available year for GHG emissions data: 2022 for the consumption-based approach and 2023 for the production-based approach.
b Excluding LULUCF GHG Emissions.

approach accounts for a country's emissions by factoring in external trade-related emissions (including imports and excluding exports). Therefore, the level and evolution of GHG emissions will depend on countries' development level and economic structure, according to the chosen approach.

In other words, the approach to GHG emissions can be viewed from the perspective of emissions produced or emissions consumed. Therefore, a sovereign issuer being deemed to be "polluting" compared with its peers will depend on the choice of approach, especially when comparing countries at different levels of development. This difference can be observed in Chart 1, which shows the change in GHG emissions under both approaches since 1990 for different groups of countries according to their income level. The clearest divergence between the two approaches is observed for low-income countries (see Chart 1.a) and, to a lesser extent, for high-income countries (see Chart 1.b). For the first group of peers, production-based emissions are much higher than consumption-based ones, and for the second group, consumed emissions are higher than those produced within their territory.

Chart 2
GHG emissions: comparison of production and consumption-based approaches for OECD countries



SOURCE: Banco de España, drawing on OECD data.

That is to say, if a sovereign's consumption-based GHG emissions are higher than its production-based GHG emissions, it is a net importer of CO_2e. Conversely, a country with territorial emissions higher than consumption emissions is a net exporter of GHG emissions. This can be seen clearly in Chart 2, which compares net CO_2e exports/imports between OECD and non-OECD countries. First, we observe that since the 1990s, the OECD has been a net importer of GHG emissions. This situation remains relatively stable, peaking in 2006 and narrowing slightly in the wake of the 2007-08 global financial crisis, when consumed emissions fell more than produced emissions. Second, non-OECD countries are exporters of CO_2e, a differential that remains practically stable, but with an increase in both produced and consumed GHG emissions being observed.

4.3 Normalisation: implications of using a GDP or population-based approach

As seen in the previous subsection, there are differences when choosing one GHG emissions approach over another. This choice has implications for absolute metrics, such as TAE, and relative metrics, especially the carbon footprint, which is the TAE normalised for portfolio size. The next challenge is how to carry out the normalisation, i.e. the denominator to be used under each of these approaches, which will, in turn, impact the relative metrics, such as WACI or carbon intensity, (see Section 3.2).

When choosing the normalisation factor, there are several possibilities, with the most used in the industry being PPP-adjusted GDP or total population. Typically, territorial emissions are presented normalised for GDP, and consumption-based emissions per capita. However, this is not always the case. The selection of one approach or another, i.e. production or consumption-based GHG emissions, as well as the use of GDP or population as the normalisation factor, results in different outcomes in the calculation of a country's climate metrics. This is relevant in the application of an SRI strategy, as, depending on whether tilting, best-in-class or even negative screening is applied, the resulting portfolio will be sensitive to the selection of the target metric.

Therefore, there are four possible combinations when calculating a sovereign's carbon intensity. These are:

i) Production-based GHG emissions per capita;

ii) Consumption-based GHG emissions per capita;

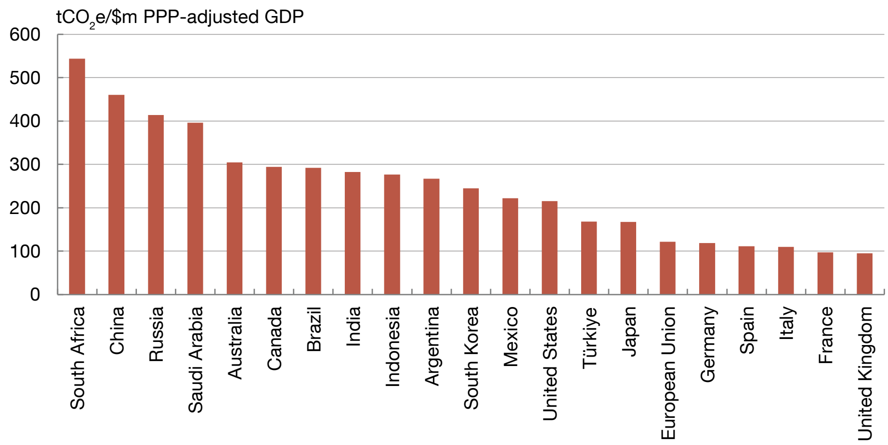
iii) Production-based GHG emissions normalised for PPP-adjusted GDP;

iv) Consumption-based GHG emissions normalised for PPP-adjusted GDP.

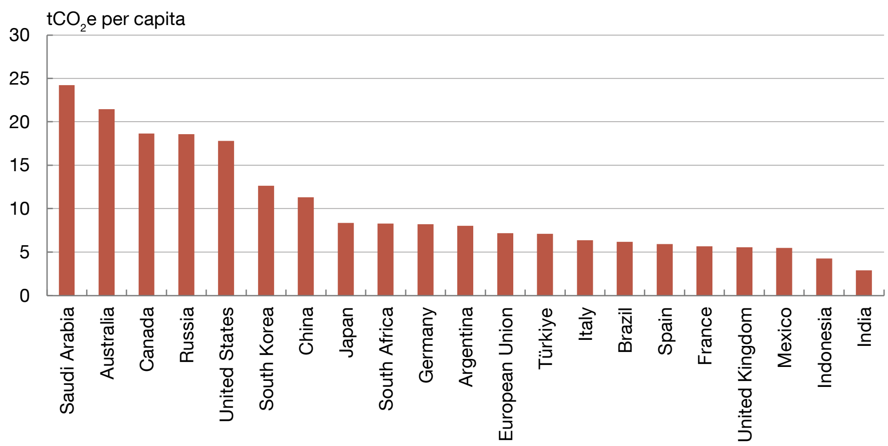
Starting by keeping the numerator unchanged – in this case, production-based GHG emissions – and analysing how it varies according to the denominator – PPP-adjusted

Chart 3
Production-based GHG emissions, by denominator. GDP and population (a) (b) (c)

3.a Production-based GHG emissions per million dollars of GDP (PPP-adjusted)



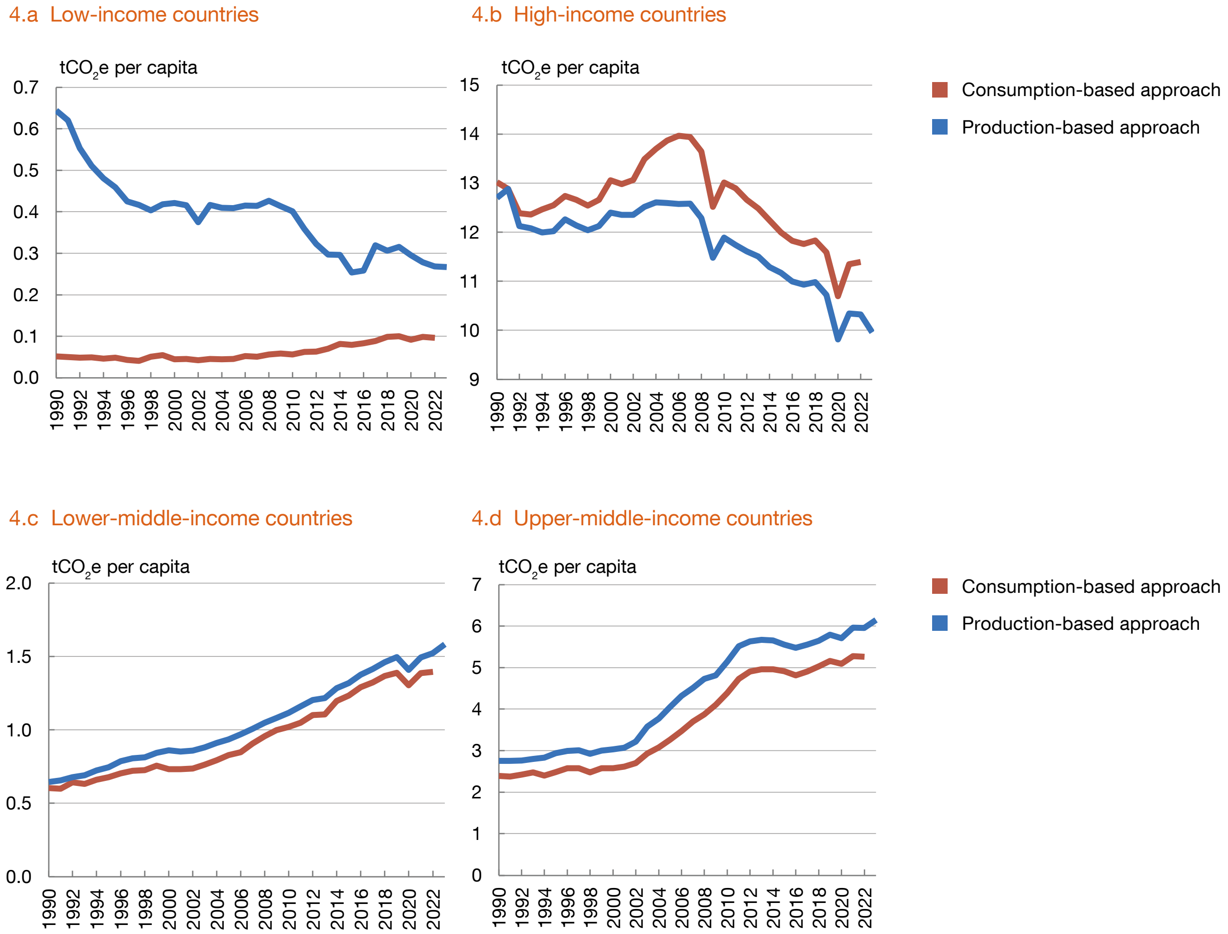
3.b Production-based GHG emissions per capita



SOURCE: Banco de España, drawing on data from the World Bank (EDGAR Database).

a Territorial GHG emissions excluding LULUCF GHG emissions.
b G20 members plus Spain.
c Latest available year (2023).

Chart 4
Per capita GHG emissions: production and consumption-based approaches (a) (b)



SOURCE: Banco de España, drawing on Global Carbon Budget (2024) and Our World in Data.

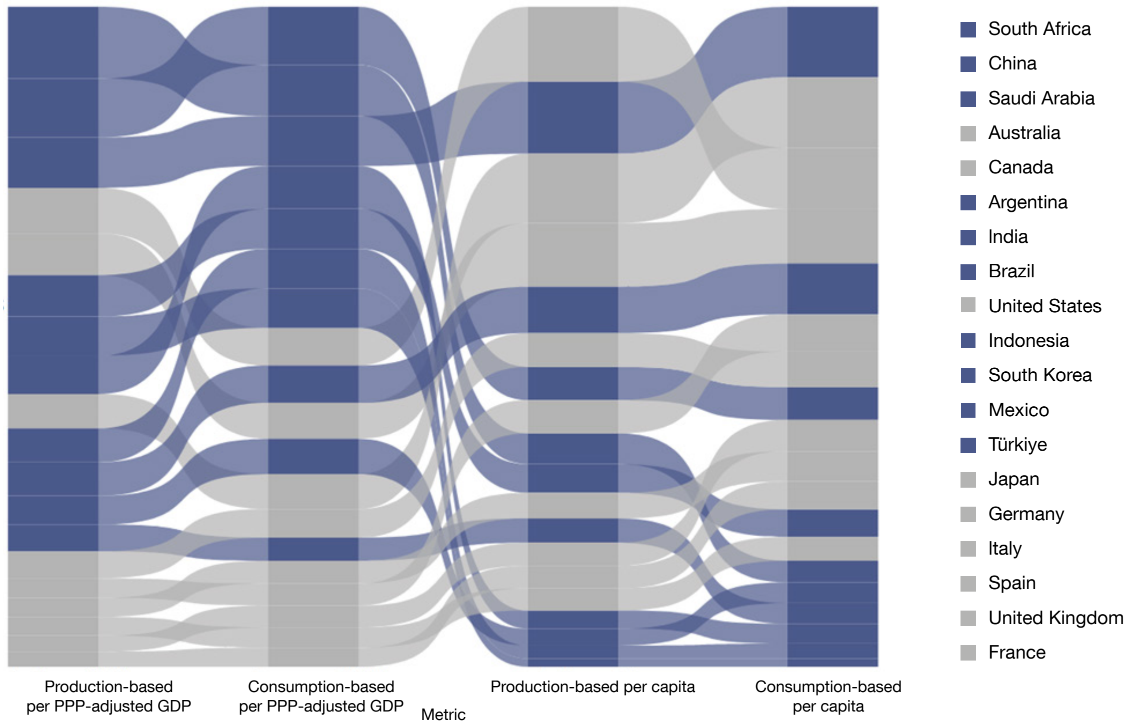
a Latest available year for GHG emissions data: 2022 for the consumption-based approach and 2023 for the production-based approach.
b LULUCF GHG emissions not included.

GDP or population – (options i and iii), the relative order of G20 sovereign issuers varies (see Charts 3.a and 3.b). For example, India would be among the top half of the most polluting G20 countries if carbon intensities are ranked by GHG emissions per million US dollars of PPP-adjusted GDP. Conversely, it is the least polluting sovereign in the group if the relative metric is carbon intensity per capita. The United States is in the less polluting half when normalised for GDP, but it is the fifth most polluting country per capita. Similarly, the most fossil-fuel dependent economies (e.g. Saudi Arabia, Australia and Canada) appear in the more polluting half, while EU countries (such as Spain, France and Italy) are in the less polluting half in both cases.

If the denominator is now kept fixed, using population as the normalisation factor applied both to the production and the consumption approaches (options i and ii), Chart 4 shows the two alternatives for the same groups of countries as in previous charts. The evolution within the same groups is very similar to the absolute emissions, except for

Chart 5

Comparison of approaches and variables (a) (b) (c)



SOURCE: Banco de España, drawing on ISS, C4F and World Bank data.

a Territorial GHG emissions excluding LULUCF GHG emissions.
b G20 members plus Spain. Russia is not available. Emerging countries are shown in blue and developed countries in grey.
c Latest available year (2021).

low-income countries where the downward trend in production-based emissions is much more pronounced than the absolute measure, and the rise in consumption-based emissions is less pronounced. This suggests that the larger population in this group of countries causes their carbon intensities to fall or rise at a slower rate than absolute emissions. Additionally, by levels, we observe that the countries with the highest per capita intensities (both for production and consumption-based GHG emissions) are those sovereigns with higher income.

Lastly, by maintaining the sample of countries (G20) and comparing carbon intensity under the four above-mentioned possibilities, Chart 5 shows how the relative order of the most carbon-intensive sovereigns changes depending on the indicator used. Additionally, the colours differentiate the group to which the issuer belongs: blue for emerging countries and grey for developed countries.[32] The flow chart illustrates how countries' positions vary and how using GDP as the normalisation factor systematically underestimates the GHG emission intensities of developed countries as, when using per capita emission intensities, emerging countries are found in the less polluting quartiles.

32 According to the IMF classification.

4.4 Attribution: implications of using the GDP or debt approach

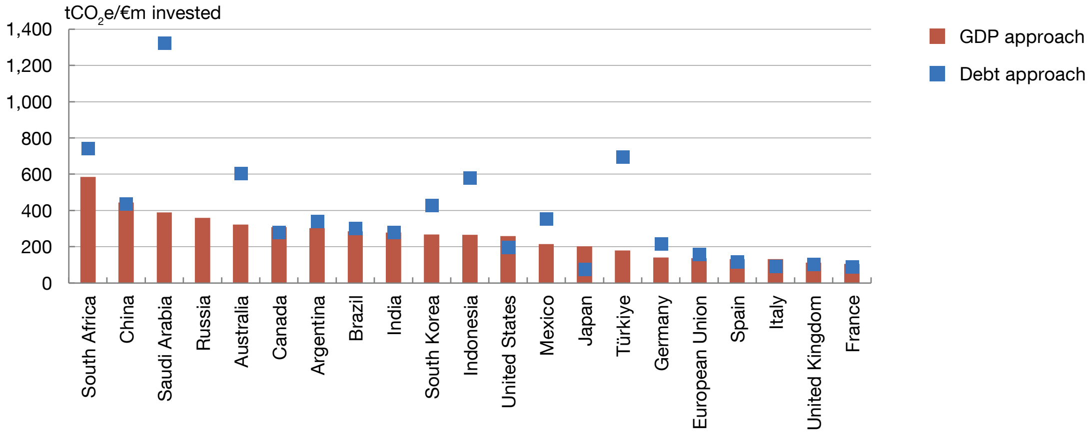
Lastly, the implications of using one attribution method or another need to be analysed, i.e. the factor used to attribute the corresponding portion of the issuer's pollution based on the holdings in the portfolio. This choice has implications for absolute metrics, such as TAE, and for relative carbon footprint metrics, i.e. TAE normalised for portfolio size, and carbon intensity.

Chart 6.a shows the portion of pollution assigned to an investment of €1 million in each of the G20 sovereign issuers, by attribution factor. For example, for an investment in one of the countries with the lowest proportion of GHG emissions using the GDP approach

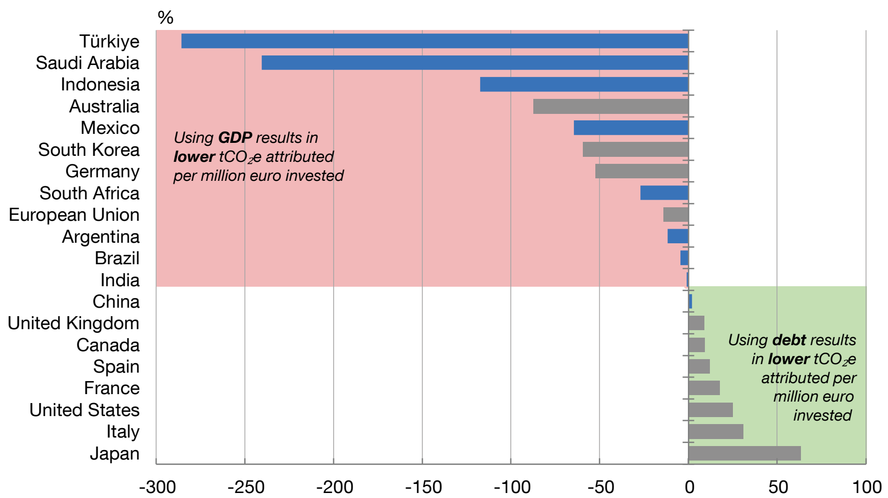
Chart 6

Attribution of GHG emissions, by factor: GDP and debt (a) (b) (c)

6.a Differences in attribution between GDP and debt



6.b Change in GHG emissions attributed per million euro invested when shifting attribution from debt to GDP



SOURCE: Banco de España, drawing on ISS and World Bank data.
In the case of the Banco de España, the data providers used in the calculation of metrics for the annual climate report are the Institutional Shareholder Services Group of Companies (ISS) and Carbon4 Finance (C4F), as a result of the joint tender conducted by the Eurosystem (Banco de España, 2023 and 2024).

a Territorial GHG emissions excluding LULUCF GHG emissions.
b G20 members plus Spain.
c Latest available year (2022).

(Türkiye), 180 tCO_2e would be attributed, which would be almost four times more (694 tCO_2e) if debt is used. In the case of holding a Japanese bond, fewer GHG emissions would be attributed using debt (74 tCO_2e) compared with using GDP as the attribution factor (202 tCO_2e). Lastly, there is a series of countries (e.g. Canada, Argentina, Brazil, India, Spain, United Kingdom) where the use of a debt-based or GDP-based attribution factor does not significantly alter the attributed GHG emissions.

This difference can be observed as a percentage of the tCO_2e attributed to €1 million using debt as the attribution factor compared with using GDP as the denominator (see Chart 6.b). The sovereigns located in the upper half, with negative figures, are those for which the use of GDP as an attribution factor results in a lower attribution of GHG emissions. Conversely, in the lower half are the countries where using debt assigns fewer GHG emissions to each holder. Additionally, it is observed that issuers from developed countries (in grey) tend to be attributed less pollution if debt is used. The opposite is true for emerging countries (in blue), with lower tCO_2e per million euro invested when using GDP as the factor, except for Australia, South Korea and Germany.

4.5 Hypothetical sovereign asset portfolio exercise

After reviewing in the previous subsections how absolute GHG emissions vary according to the type of approach used and carbon intensities depending on the normalisation factor, this subsection will conduct a simulation exercise for several hypothetical sovereign bond portfolios. The analysis will be carried out using two of the most used relative climate metrics in the industry: carbon footprint and WACI. These metrics will be applied to the three approaches (production, excluding and including LULUCF emissions, consumption and government) using PPP-adjusted GDP[33] as the attribution factor and PPP-adjusted GDP, population and government consumption, respectively, as normalisation factors in line with standard market use (see Figure 3).

The exercise focuses on three portfolios in which each issuer is equally weighted and the sovereign composition varies:

i) The first, composed of emerging market countries belonging to the G20;

ii) The second, composed of developed market countries of the G20 (including Spain); and

iii) A third portfolio composed of euro area sovereigns.

The results of the relative WACI and carbon footprint metrics can be found in Table 2 and Charts 7.a and 7.b. These metrics have been applied under the three approaches

33 Due to the design of the formula, using GDP as the attribution factor results in the same WACI and carbon footprint figures for the production-based or country-based approach, regardless of whether LULUCF emissions are excluded or included.

Table 2

WACI and carbon footprint metrics for three hypothetical portfolios (a)

tCO_2e/€m PPP-adjusted GDP, government expenditure and per capita (WACI)
tCO_2e/€m invested (carbon footprint)

Group of sovereigns	WACI				Carbon footprint			
	Production-based excl. LULUCF	Production-based incl. LULUCF	Consumption-based	Government-based	Production-based excl. LULUCF	Production-based incl. LULUCF	Consumption-based	Government-based
G20 emerging market (b)	405.9	381.6	9.0	261.8	405.9	381.6	415.5	47.8
G20 developed market	238.0	221.4	12.4	139.1	238.0	221.4	264.8	27.3
Euro area	179.4	170.4	11.6	83.0	179.4	170.4	261.2	17.1

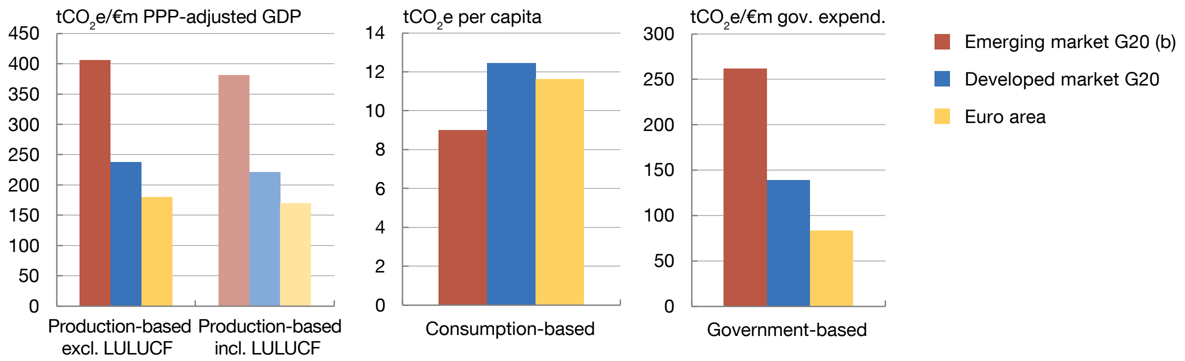
SOURCE: Banco de España, drawing on ISS, C4F and World Bank data.

a Data from 2021.
b GHG emissions including LULUCF for Saudi Arabia (G20 emerging market) not available.

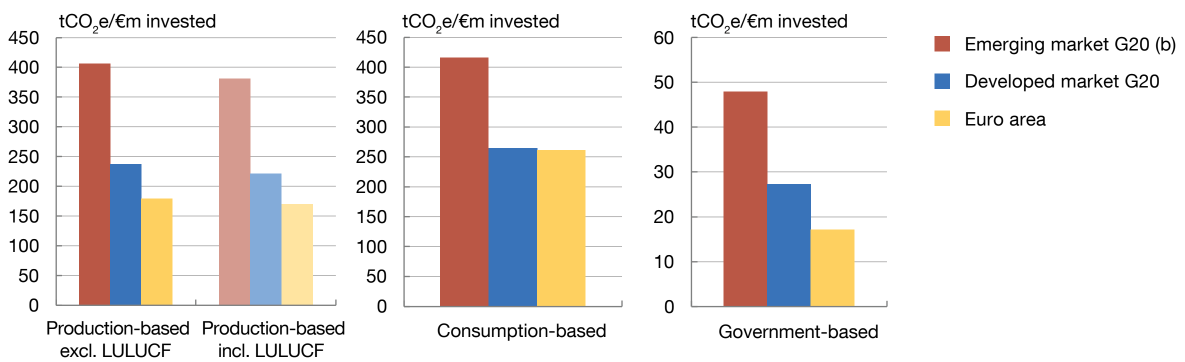
Chart 7

WACI and carbon footprint metrics for three hypothetical portfolios (a)

7.a WACI



7.b Carbon footprint



SOURCE: Banco de España, drawing on ISS, C4F and World Bank data.

a Data from 2021.
b GHG emissions including LULUCF for Saudi Arabia (G20 emerging market) not available.

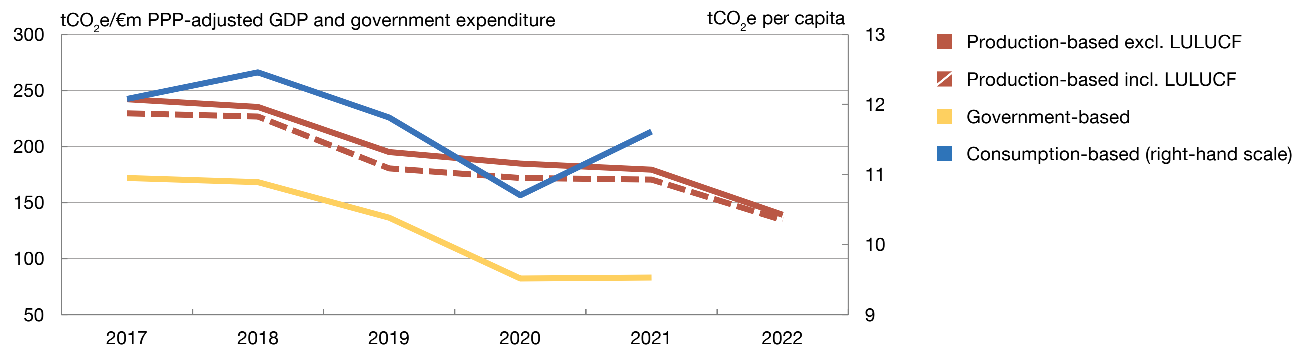
considered in Section 3.1, namely the country (or production) approach (excluding and including LULUCF emissions), the consumption approach and the government approach. As mentioned above, the latter has a territorial perspective but only considers GHG emissions related to public sector activity. For this approach, the normalisation factor used is the government expenditure of the issuer, while for the other two approaches (country and consumption) PPP-adjusted GDP and population, respectively, are used, in line with standard market use.

Focusing the analysis on WACI, the result of this theoretical exercise is the average carbon intensities of the issuers that make up the portfolio, as their assets are equally weighted. As can be observed, for the country approach, WACI is higher for the emerging market countries portfolio, while for the consumption approach, the developed sovereign's portfolio is more carbon-intensive, which is in line with previous sections. The sensitivity of the carbon footprint metric to the attribution factor is observed once again. In this exercise PPP-adjusted GDP was used, which overestimates the footprint of the portfolio of countries with lower GDP (the emerging market countries). Even under the consumption approach, this group has a higher carbon footprint than the developed countries portfolio. Lastly, for both metrics

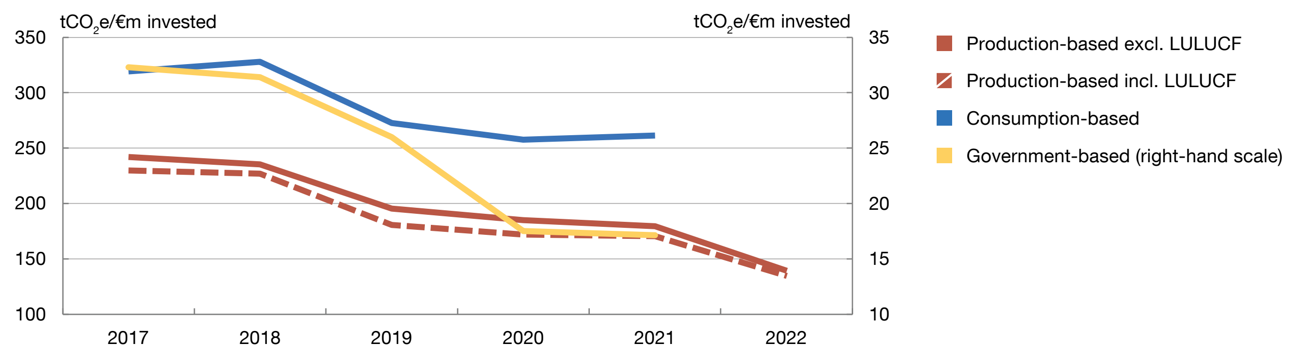
Chart 8

WACI and carbon footprint for an equally weighted portfolio of euro area bonds

8.a WACI



8.b Carbon footprint



SOURCE: Banco de España, drawing on ISS, C4F and World Bank data.

and all portfolios, the figures under the country approach including LULUCF emissions are lower than excluding them, as these activities generally have a sink effect and, as a result, lead to a decrease in the country's total GHG emissions.

For all the hypothetical portfolios analysed, pollution is slightly lower under the government approach than under the country approach (see Table 2 and Charts 7.a and 7.b). The territorial perspective is the same, but different sectors of the economy are considered. This difference is especially relevant in the case of the government approach metric. This is because the attribution factor is the same. However, the GHG emissions change from those recorded within the territory for all sectors to those recorded only in the public sector, which would allow for a combination with other assets (including the private sector) if a portfolio with bonds from different economic sectors were held.

In the case of the euro area, a better relative performance is observed compared with the G20 developed market countries portfolio, its closest equivalent, under all three approaches and for the two metrics calculated. This may be due to the greater regulatory development in Europe aimed at making headway in attaining the targets of the Paris Agreement. Additionally, Charts 8.a and 8.b show the changes from 2017 to 2021 in the WACI and carbon footprint of the equally weighted euro area sovereign portfolio under the three approaches, and up to 2022 under the country approach. In all combinations, an improvement in climate metrics is observed, reflecting the gradual headway in the fight against climate change.

5 Conclusions and challenges

The development of data, metrics, methodologies and tools to assess climate risks, as well as their impacts and related opportunities, in connection with sovereign bonds has received comparatively less attention, as noted by the NGFS.[34] Some of the challenges are global in nature, as it remains difficult to accurately quantify the impact of climate change, particularly as regards transition risks, on the financial performance of sovereign bonds. There is currently no consensus on the methodologies and metrics to assess the climate risks associated with these assets. An ongoing debate concerns which core variables to use, how to normalise them, i.e. how to compare an issuer's pollution relative to a standard unit, and how to attribute emissions, which enables the determination of the portion of emissions for which an investor holding a given asset is responsible.

As seen throughout this paper, GHG emissions can be approached either from a production or a consumption perspective. The comparison between sovereigns will not only depend on the chosen approach, but also on a country's stage of development and economic structure, as well as inter-country consumption dynamics. In low-income countries, territorial emissions are significantly higher than consumption-based emissions, making them net exporters of pollution. In contrast, the opposite is true for more developed countries.

As demonstrated, climate metrics for sovereigns each have their advantages and limitations. They all serve different needs, and it is crucial to understand their components to assess their impact on portfolios and discover opportunities. The TAE metric reveals the overall level of GHG emissions but does not allow for comparisons across portfolios or over time. Among the relative metrics, WACI captures transition risks and is useful for comparing issuers based on sectoral exposure. However, it is subject to fluctuations unrelated to decarbonisation. The carbon footprint is better suited for comparing investments in different sovereign assets and for making strategic asset allocations and selections based on their contribution to a portfolio's total emissions. Lastly, carbon intensity is helpful for comparing emission intensity across asset classes, portfolios and issuers, making it valuable for selecting the top performers within a sector.

Looking ahead, there are three key challenges. First, the availability and quality of sovereign climate data. Unanswered questions include data coverage (particularly the development of government-approach emissions data), the need for methodologies to account for scope 3 emissions at the country level, progress towards greater disclosure harmonisation, and time lags in data publication by countries themselves. Secondly, it is necessary to make progress in the development of methodologies that adjust for the various fluctuations to which the data are exposed, such as the effects of inflation and exchange rates. Lastly, the issue of double-counting and the need to adapt metrics in the

34 See NGFS (2024a) for further details on these challenges.

case of portfolios composed of sovereign assets and other types of assets, such as sub-sovereign and corporate bonds, among others, must be addressed. This would enable a more efficient and integrated asset allocation and security selection process.

Measuring, reporting and assessing carbon emissions is essential, but this is only one component of a broader set of investment tools aimed at decarbonising portfolios. What matters is not only the current level and trend of emissions but also where a country or portfolio is expected to stand in the future. This highlights the importance of forward-looking metrics, which assess alignment with the temperature-reduction goals set out in the Paris Agreement established at the 2015 UN Climate Change Conference (COP21).[35] These forward-looking methodologies are still being developed for sovereign and corporate issuers alike. Some examples include the Science Based Targets initiative, which involves setting science-based emissions reduction targets, and the Paris Agreement Capital Transition Assessment, which has designed a methodology to evaluate the alignment of financial portfolios under various climate scenarios.

Several climate-financial indices are also being developed, such as those created by the European Commission under Regulation (EU) 2019/2089, which introduced two benchmarks: one for the EU climate transition and another for Paris Agreement alignment, alongside related disclosure requirements. Since these methodologies are still evolving, they present several challenges. As NGFS (2022) points out, forward-looking data and metrics are not as easily observable as historical data, making them harder to access, especially as their development often relies on third parties or external data providers. Therefore, the development of forward-looking indicators will be essential to evaluating the transition to a net-zero carbon economy, and their standardisation across a broad set of assets will be crucial for comparability and integration into investment decision-making processes.

35 Félez, González and Triebskorn (2025).

References

Banco de España. (2023). *Climate-related aspects of the Banco de España's non-monetary policy portfolios,* March. https://www.bde.es/f/webbde/INF/MenuHorizontal/Publicaciones/OtrasPublicaciones/Fich/InformeAnalisisClimatico_Marzo_2023_Ing.pdf

Banco de España. (2024). *Climate-related aspects of the Banco de España's non-monetary policy portfolios,* June. https://www.bde.es/f/webbe/SES/Secciones/Publicaciones/PublicacionesAnuales/aspectos_climaticos/fich/InformeAspectosClimaticos_Junio_2024_Ing.pdf

Battiston, Stefano, and Irene Monasterolo. (2019). "A climate risk assessment of sovereign bonds' portfolio". Institute for Ecological Economics. https://research.wu.ac.at/en/publications/a-climate-risk-assessment-of-sovereign-bonds-portfolio-3

Battiston, Stefano, and Irene Monasterolo. (2020). "The Climate Spread of Corporate and Sovereign Bonds". SSRN. July 1, 2020.https://ssrn.com/abstract=3376218

Bank for International Settlements. (2022). *Incorporating climate related risks into international reserve management frameworks*. Consultative Group on Risk Management. July 2022. https://www.bis.org/publ/othp54.pdf

Burns, Susan, Jag Alexeyev, Ronna Kelly and David Lin. (2016). "Carbon disclosure and climate risk in sovereign bonds. A project of Global Footprint Network". Finance for Change. December 2016. https://www.footprintnetwork.org/content/documents/2016-Carbon_Sovereign_Bonds.pdf

Cheng, Gong, Eric Jondeau and Benoît Mojon. (2022). "Building portfolios of sovereign securities with decreasing carbon footprints". BIS Working Papers No 1038. September 2022. https://www.bis.org/publ/work1038.pdf

Collender, Sierra, Baoqing Gan, Christina Sklibosios Nikitopoulos, Kylie-Anne Richards and Laura Simone Ryan. (2022). "Climate Transition Risk in Sovereign Bond Markets". SSRN. November 29, 2022.https://ssrn.com/abstract=3861350

Desme, Gautier and Lauren Smart. (2018). "Accounting For Carbon: Sovereign Bonds". Trucost ESG Analysis. S&P Global. https://www.spglobal.com/spdji/en/documents/education/education-accounting-for-carbon-sovereign-bonds.pdf

Domínguez-Jiménez, Marta and Alexander Lehmann. (2021). "Accounting for climate policies in Europe's sovereign debt market". Policy Contribution. 10/21. https://www.jstor.org/stable/resrep32395

Félez, Ignacio, Clara Isabel González and Elena Triebskorn. (2025). "The puzzle of forward-looking climate transition risk metrics. Documentos Ocasionales, 2515, Banco de España. https://www.bde.es/wbe/es/publicaciones/analisis-economico-investigacion/documentos-ocasionales/the-puzzle-of-forward-looking-climate-transition-risk-metrics.html

GHG Protocol. (2015). *A Corporate Accounting and Reporting Standard.* https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

GHG Protocol. Página web https://ghgprotocol.org

Gimeno, Ricardo and Fernando Sols. (2020). "Incorporating sustainability factors into asset management". Financial Stability Review, Issue 39, Autumn 2020, pp. 177-197. https://www.bde.es/f/webbde/GAP/Secciones/Publicaciones/InformesBoletinesRevistas/RevistaEstabilidadFinanciera/20/Sustainability_factors.pdf

González, Clara Isabel and Elena Triebskorn. (2023). "The road to net zero: the role of transition plans and forward-looking indicators in portfolio management". Economic Bulletin - Banco de España, 2023/Q3, 14. https://doi.org/10.53479/34645

Lancesseur, Nicolas and Thomas Lorans. (2021). "Anticipating the climate change risks for sovereign bonds". FTSE Russell. https://www.lseg.com/en/ftse-russell/research/anticipating-climate-change-risks-sovereign-bonds

Leadbetter, Joe, Shikeb Farooqui and Teal Emery. (2022). "Another way of looking at a country's carbon footprint: a tale of Switzerland and South Africa". Emso Asset Management. https://emso.com/docs/1d37859fad945759.pdf

Network for Greening the Financial System. (2019). *A sustainable and responsible investment guide for central banks' portfolio management*. October.

Network for Greening the Financial System. (2020). *Progress report on the implementation of sustainable and responsible investment practices in central banks' portfolio management*. December.

Network for Greening the Financial System. (2021). *Guide on climate-related disclosure for central banks*. December.

Network for Greening the Financial System. (2022). *Final report on bridging data gaps*. July.

Network for Greening the Financial System. (2024a). *Considering climate-related risks and transition impact in the sovereign investments of central banks*. Technical Document. May.

Network for Greening the Financial System. (2024b). *Sustainable and responsible investment in central banks' portfolio management – Practices and recommendations*. June.

Network for Greening the Financial System. (2024c). *Guide on climate-related disclosure for central banks.* Second edition*.* June.

Partnership for Carbon Accounting Financials. (2022). *The Global GHG Accounting and Reporting Standard Part A: Financed Emissions*. Second Edition. December.

Partnership for Carbon Accounting Financials. (2024). *The Global GHG Accounting and Reporting Standard Part A: Financed Emissions. New guidance and methods for public consultation*. November.

Principles for Responsible Investment. (2021). *Principles for Responsible Investment*. Annual Report, 2021.

Scheer Antonina, Johannes Honneth, Setenay Hizliok, Simon Dietz and Carmen Nuzzo. (2024). "ASCOR framework: methodology note". Transition Pathway Initiative Centre, London School of Economics and Political Science. https://transitionpathwayinitiative.org/publications/uploads/2024-ascor-framework-methodology-note-version-1-1.pdf

Task Force on Climate-related Financial Disclosures. (2017). *Recommendations of the Task Force on Climate Climate-related Financial Disclosures*. June.

Task Force on Climate-related Financial Disclosures. (2021a). *Guidance on Metrics, Targets, and Transition Plans*. October.

Task Force on Climate-related Financial Disclosures. (2021b). *Annex: Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures*. October.

Task Force on Climate-related Financial Disclosures. (2023). *2023 TCFD Status Report: Task Force on Climate-related Financial Disclosures*. October.

United Nations Framework Convention on Climate Change. (1997). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. Kyoto Climate Change Conference - December 1997.

Annex

Table A1.1
Metrics for sovereign assets

Metric	Formula
Weighted average carbon intensity (tCO_2e/€m GDP (PPP), gov. expenditure or per capita)	$\text{WACI} = \sum_n^i \left(\frac{\text{investment value}_i}{\text{current portfolio value}} \times \frac{\text{GHG emissions}_i}{\text{GDP (PPP)}_i \text{, gov. expend.}_i \text{ or population}_i} \right)$
Total absolute emissions (tCO_2e)	$\text{Total absolute emissions} = \sum \left(\frac{\text{investment value}_i}{\text{GDP (PPP)}_i} \times \text{GHG Emissions}_i \right)$
Carbon footprint (tCO_2e per €m invested)	$\text{Carbon footprint} = \frac{\sum_n^i \left(\frac{\text{investment value}_i}{\text{GDP (PPP)}_i} \times \text{GHG Emissions}_i \right)}{\text{current portfolio value}}$
Carbon intensity (tCO_2e/€m GDP (PPP), gov. expenditure or per capita)	$\text{Carbon intensity} = \frac{\sum_n^i \left(\frac{\text{investment value}_i}{\text{GDP (PPP)}_i} \times \text{GHG Emissions}_i \right)}{\sum_n^i \left(\frac{\text{investment value}_i}{\text{GDP (PPP)}_i} \times \text{GDP (PPP)}_i \text{, gov. expend.}_i \text{ or population}_i \right)}$

SOURCE: Banco de España (2024).

BANCO DE ESPAÑA PUBLICATIONS

OCCASIONAL PAPERS

2411 JOSÉ MANUEL CARBÓ, HOSSEIN JAHANSHAHLOO and JOSÉ CARLOS PIQUERAS: Análisis de fuentes de datos para seguir la evolución de *Bitcoin*.

2412 IVÁN KATARYNIUK, RAQUEL LORENZO ALONSO, ENRIQUE MARTÍNEZ CASILLAS and JACOPO TIMINI: An extended Debt Sustainability Analysis framework for Latin American economies.

2413 Survey of Household Finances (EFF) 2022: methods, results and changes since 2020. (There is a Spanish version of this edition with the same number).

2414 ÁNGEL ESTRADA, CARLOS PÉREZ MONTES, JORGE ABAD, CARMEN BROTO, ESTHER CÁCERES, ALEJANDRO FERRER, JORGE GALÁN, GERGELY GANICS, JAVIER GARCÍA VILLASUR, SAMUEL HURTADO, NADIA LAVÍN, JOËL MARBET, ENRIC MARTORELL, DAVID MARTÍNEZ-MIERA, ANA MOLINA, IRENE PABLOS and GABRIEL PÉREZ-QUIRÓS: Analysis of cyclical systemic risks in Spain and of their mitigation through countercyclical bank capital requirements. (There is a Spanish version of this edition with the same number).

2415 CONCEPCIÓN FERNÁNDEZ ZAMANILLO and LUNA AZAHARA ROMO GONZÁLEZ: Facilitadores de la innovación 2.0: impulsando la innovación financiera en la era *fintech*.

2416 JAMES COSTAIN and ANTON NAKOV: Models of price setting and inflation dynamics.

2417 ARTURO PABLO MACÍAS FERNÁNDEZ and IGNACIO DE LA PEÑA LEAL: Sensibilidad a los tipos de interés soberanos de la cartera de colateral elegible para los préstamos de política monetaria.

2418 ANTONIO F. AMORES, HENRIQUE BASSO, JOHANNES SIMEON BISCHL, PAOLA DE AGOSTINI, SILVIA DE POLI, EMANUELE DICARLO, MARIA FLEVOTOMOU, MAXIMILIAN FREIER, SOFIA MAIER, ESTEBAN GARCÍA-MIRALLES, MYROSLAV PIDKUYKO, MATTIA RICCI and SARA RISCADO: Inflation, fiscal policy and inequality. The distributional impact of fiscal measures to compensate for consumer inflation.

2419 LUIS ÁNGEL MAZA: Una reflexión sobre los umbrales cuantitativos en los modelos de depósito de las cuentas anuales y su posible impacto en el tamaño empresarial en España.

2420 MARIO ALLOZA, JORGE MARTÍNEZ, JUAN ROJAS and IACOPO VAROTTO: Public debt dynamics: a stochastic approach applied to Spain. (There is a Spanish version of this edition with the same number).

2421 NOEMÍ LÓPEZ CHAMORRO: El camino hacia la supremacía cuántica: oportunidades y desafíos en el ámbito financiero, la nueva generación de criptografía resiliente.

2422 SOFÍA BALLADARES and ESTEBAN GARCÍA-MIRALLES: Fiscal drag: the heterogeneous impact of inflation on personal income tax revenue. (There is a Spanish version of this edition with the same number).

2423 JULIO ORTEGA CARRILLO and ROBERTO RAMOS: Parametric estimates of the Spanish personal income tax in 2019. (There is a Spanish version of this edition with the same number).

2424 PILAR L'HOTELLERIE-FALLOIS, MARTA MANRIQUE and DANILO BIANCO: EU policies for the green transition, 2019-2024. (There is a Spanish version of this edition with the same number).

2425 CATERINA CARVALHO-MACHADO, SABINA DE LA CAL, LAURA HOSPIDO, SARA IZQUIERDO, MARGARITA MACHELETT, MYROSLAV PIDKUYKO y ERNESTO VILLANUEVA: The Survey of Financial Competences: description and methods of the 2021 wave.

2426 MARINA DIAKONOVA, CORINNA GHIRELLI and JUAN QUIÑÓNEZ: Economic Policy Uncertainty in Central America and the Dominican Republic.

2427 CONCEPCIÓN FERNÁNDEZ ZAMANILLO and CAROLINA TOLOBA GÓMEZ: *Sandbox* regulatorio español: impacto en los promotores de los proyectos monitorizados por el Banco de España.

2428 ANDRES ALONSO-ROBISCO, JOSE MANUEL CARBO, EMILY KORMANYOS and ELENA TRIEBSKORN: Houston, we have a problem: can satellite information bridge the climate-related data gap?

2429 ALEJANDRO FERNÁNDEZ CEREZO, BORJA FERNÁNDEZ-ROSILLO SAN ISIDRO and NATIVIDAD PÉREZ MARTÍN: The Banco de España's Central Balance sheet data office database: a regional perspective. (There is a Spanish version of this edition with the same number).

2430 JOSE GONZÁLEZ MÍNGUEZ: The Letta report: a set of proposals for revitalising the European economy. (There is a Spanish version of this edition with the same number).

2431 MARIYA MELNYCHUK and JAVIER MENCÍA: A taxonomy of macro-financial risks and policies to address them.

2432 DMITRY KHAMETSHIN, DAVID LÓPEZ RODRÍGUEZ and LUIS PÉREZ GARCÍA: El mercado del alquiler de vivienda residencial en España: evolución reciente, determinantes e indicadores de esfuerzo.

2433 ANDRÉS LAJER BARON, DAVID LÓPEZ RODRÍGUEZ and LUCIO SAN JUAN: El mercado de la vivienda residencial en España: evolución reciente y comparación internacional.

2434 CARLOS GONZÁLEZ PEDRAZ, ADRIAN VAN RIXTEL and ROBERTO PASCUAL GONZÁLEZ: Navigating the boom and bust of global SPACs.

2435 PATROCINIO TELLO-CASAS: El papel de China como acreedor financiero internacional.

2436 JOSÉ RAMÓN MARTÍNEZ RESANO: CBDCs, banknotes and bank deposits: the financial stability nexus.

2501 PEDRO DEL RÍO, PAULA SÁNCHEZ, MARÍA MÉNDEZ, ANTONIO MILLARUELO, SUSANA MORENO, MANUEL ROJO, JACOPO TIMINI and FRANCESCA VIANI: La ampliación de la Unión Europea hacia el este: situación e implicaciones para la economía española y la Unión Europea.

2502 BANCO DE ESPAÑA: La accesibilidad presencial a los servicios bancarios en España: informe de seguimiento 2024.

2503 ANDRÁS BORSOS, ADRIAN CARRO, ALDO GLIELMO, MARC HINTERSCHWEIGER, JAGODA KASZOWSKA-MOJSA and ARZU ULUC: Agent-based modeling at central banks: recent developments and new challenges.

2504 ANDRES ALONSO-ROBISCO, ANDRES AZQUETA-GAVALDON, JOSE MANUEL CARBO, JOSE LUIS GONZALEZ, ANA ISABEL HERNAEZ, JOSE LUIS HERRERA, JORGE QUINTANA y JAVIER TARANCON: Empowering financial supervision: a SupTech experiment using machine learning in an early warning system.

2505 JÉSSICA GUEDES, DIEGO TORRES, PAULINO SÁNCHEZ-ESCRIBANO and JOSÉ BOYANO: Incertidumbre en el mercado de bonos: una propuesta para identificar sus narrativas con GDELT.

2506 LAURA JIMENA GONZÁLEZ GÓMEZ, FERNANDO LEÓN, JAIME GUIXERES PROVINCIALE, JOSÉ M. SÁNCHEZ and MARIANO ALCAÑIZ: Evolución de la investigación neurocientífica del efectivo: revisión y perspectivas actuales.

2507 LUIS FERNÁNDEZ LAFUERZA, IRENE ROIBÁS and RAQUEL VEGAS SÁNCHEZ: Indicadores de desequilibrios de precios del mercado inmobiliario comercial.

2508 ALEJANDRO FERRER and ANA MOLINA: The interaction of liquidity risk and bank solvency via asset monetisation mechanisms. (There is a Spanish version of this edition with the same number).

2509 ALEJANDRO FERRER and ANA MOLINA: Interacción entre riesgo de liquidez y solvencia bancaria a través de los mecanismos de monetización de activos. (There is a Spanish version of this edition with the same number).

2510 ISABEL ALCALDE and PATRICIA STUPARIU: Financial education at an early age. (There is a Spanish version of this edition with the same number).

2511 ALEJANDRO GONZÁLEZ FRAGA, AITOR LACUESTA GABARAIN, JOSÉ MARÍA LABEAGA AZCONA, MARÍA DE LOS LLANOS MATEA ROSA, SOLEDAD ROBLES ROMERO, MARÍA VALKOV LORENZO and SERGIO VELA ORTIZ: Estructura del mercado de electrolineras.

2512 FERNANDO ARRANZ GOZALO, CLARA I. GONZÁLEZ MARTÍNEZ and MERCEDES DE LUIS LÓPEZ: Sovereign assets and sustainable and responsible investment: the importance of climate metrics. (There is a Spanish version of this edition with the same number).

2513 IRMA ALONSO-ÁLVAREZ and DANIEL SANTABÁRBARA: Decoding Structural Shocks in the Global Oil Market.

2514 JOSÉ MANUEL CARBÓ, CLAUDIA TOLEDO and ÁNGEL IVÁN MORENO: Hacia un diccionario panhispánico de sentimiento de la estabilidad financiera.

2515 IGNACIO FÉLEZ DE TORRES, CLARA I. GONZÁLEZ MARTÍNEZ and ELENA TRIEBSKORN: The puzzle of forward-looking climate transition risk metrics.

2516 MIGUEL GARCÍA-POSADA: Un análisis de los efectos de la introducción del procedimiento especial de insolvencias para microempresas sobre la propensión a concursar.

2517 ADRIAN VAN RIXTEL: Whatever it takes? Economic policymaking in China in the context of a possible deflationary spiral.