Economic Commentary

The carbon footprint of the assets in the Riksbank's foreign exchange reserves

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SVERIGES RIKSBANK

Table of contents

Introduction

The purpose of this Commentary is to calculate and account for the carbon footprint of the bonds in the Riksbank's foreign exchange reserves that are issued by countries and regions. On 31 March 2022, the carbon footprint of the foreign exchange reserves amounted to 298,000 tonnes of carbon dioxide per billion dollars of GDP. Seen over the last five years, the carbon footprint of the bonds in the foreign exchange reserves has decreased.

In this Commentary, we would also like to describe the method for calculating the carbon footprint for portfolios consisting of bonds issued by countries and regions. Calculation of the footprint is in line with the recommendation for central banks developed by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), which, in turn, is based on recommendations from the Task Force on Climate-related Financial Disclosures (TCFD). The Riksbank uses a calculation method in which emissions of greenhouse gases from each country or region for all goods and services produced within the country/region are set in relation to the value of this output. The result is expressed using the measure carbon intensity.

In this Commentary, we start by describing the composition of the foreign exchange reserves and the Riksbank's work so far on applying sustainability considerations to the management of the reserves. We then describe and analyse the carbon footprint calculation method followed by reporting the carbon footprint of the foreign exchange reserves and analysing the results. Alternative ways of calculating the footprint are also discussed. In the concluding part, we discuss the challenges inherent in the measure and how the measure can be developed and complemented by other forward-looking measures to provide a better indication of climate-related financial risks.

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[1] Emma Brattström was working in the Markets Department when she contributed to this Commentary. She has now left the Riksbank. The authors would like to thank Magnus Andersson, Dag Edvardsson, Alma Frödén, Lina Jacobson, Johan Linder, Marianne Nessén, Tommy Persson, Albina Soultanaeva, Mikael Stenström and Lena Strömberg for his/her/their valuable comments. The views presented in this Commentary are the authors' personal opinions and are not to be regarded as an expression of the Riksbank's view on these issues.

1 Reporting the carbon footprint increases transparency of climate-related risks

For the Riksbank, it is important to understand how climate change affects the value of its own financial assets and how climate-related financial risks can be taken into account in asset management. This Commentary addresses the Riksbank's initial work on calculating, analysing and reporting the carbon footprint[2] for the assets in the foreign exchange reserves, which could be a source of financial risk on the Riksbank's balance sheet. The Riksbank thereby wishes to contribute to increased transparency and a deeper analysis of climate-related reporting.

1.1 The Riksbank's work on taking account of climate change

An important part of the Riksbank's asset management is the work of analysing financial risks. One source of financial risk is the risks arising from climate change – which are usually divided into physical risks and transition risks.[3] Since 2018, the Riksbank has been a member of the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), which recommends central banks to measure the carbon footprint of their financial assets when starting to measure transition risks on the central banks' balance sheets.[4] One measure that is often used is a measure of intensity that shows how much carbon dioxide and other greenhouse gases are emitted annually by a country in relation to its production. This measure thereby indicates the emission intensity of a portfolio of financial assets, which, in turn, can be a sign of the extent of transition risks. The carbon footprint of the assets is also often included in more forward-looking measures, such as stress tests or scenario analyses, which also take into account forecasts of climate change.

Another important part of the Riksbank's work on climate change is promoting the transparency of climate-related information.[5] For this reason, since spring 2021, the Riksbank has reported the carbon footprint of it's holdings of corporate bonds in Swedish kronor.[6] The Riksbank is now expanding this reporting by calculating and reporting the carbon footprint of the assets in the foreign exchange reserves. This is part of the Riksbank's ef-

[2] In this Commentary the term carbon footprint is used interchangeably when referring to the measure used: carbon intensity for individual countries and regions and weighted average carbon intensity (WACI) for the whole portfolio.

[3] Physical risks concern effects caused by climate-related events. These may be the effects of extreme weather such as drought and flooding, or the effects of gradual global warming. Transition risks concern the effects of adapting to a less fossil-dependent economy, such as tighter regulations or changes in energy prices.

[4] See NGFS (2021).

[5] See Sveriges Riksbank (2021b).

[6] See Sveriges Riksbank (2021a). See also the Riksbank's website for the latest calculation of the carbon footprint of corporate bonds.

forts to start reporting climate-related information in line with the NGFS recommendation for central banks, which is based on recommendations from the Task Force on Climate-related Financial Disclosures (TCFD).[7,8]

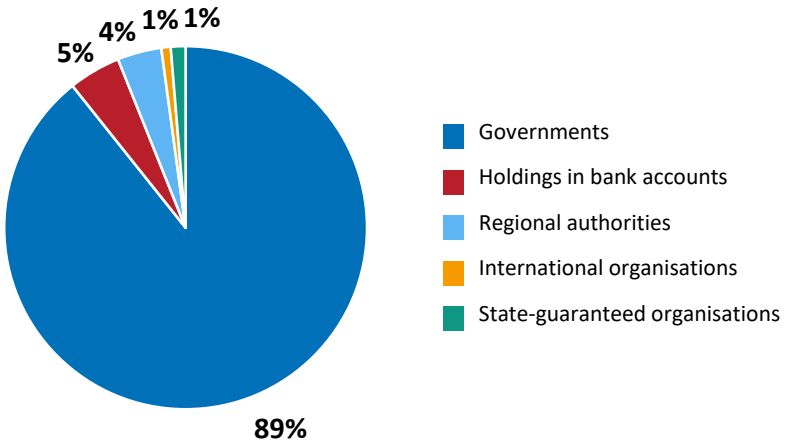
1.2 The Riksbank has foreign exchange reserves to be able to fulfil its statutory objectives and perform its tasks

The Riksbank holds foreign exchange reserves. The purpose of these is to enable the Riksbank to provide temporary liquidity assistance in foreign currency, to buy and sell currency for monetary and exchange rate policy purposes and to fulfil the commitments ensuing from Sweden's membership of the International Monetary Fund (IMF).

So that the Riksbank can be well prepared to use the foreign exchange reserves, these consist mainly of bonds issued by governments (see Figure 1), as such assets can quickly be converted into liquid funds.[9] In addition, the foreign exchange reserves also comprise bonds and other interest-bearing securities with high credit ratings issued by international organisations (such as the Bank for International Settlements (BIS)), regional authorities (bonds issued by Australian states and Canadian provinces), state-guaranteed organisations and holdings in bank accounts.

Figure 1. Distribution of different asset classes in the foreign exchange reserves, 31 March 2022

Per cent



Note. The figure illustrates the foreign exchange reserves' holdings of bonds by type of issuer: governments, regional authorities, international organisations and state-guaranteed organisations. The reserves also hold assets in the form of holdings in bank accounts.

Source: Sveriges Riksbank

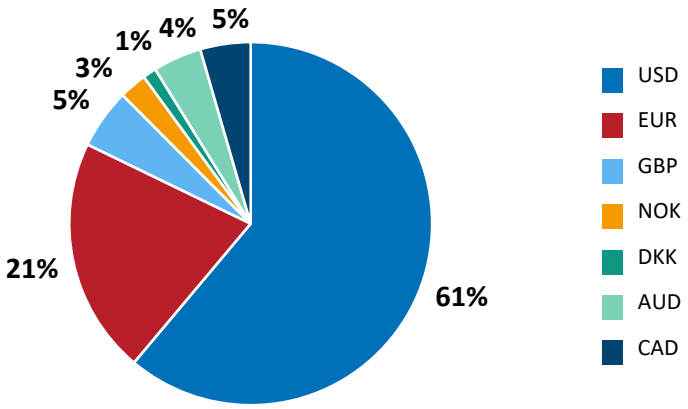
[7] See Joint pledge from the Swedish members of the NGFS, Finansinspektionen and Sveriges Riksbank, at the occasion of the NGFS Glasgow Declaration during COP26, 3 November 2021.

[8] This is also in line with one of the six recommendations made by the NGFS to central banks to achieve robust and internationally consistent reporting of climate and sustainability-related information; see NGFS (2019) and TCFD (2017 & 2021).

[9] See the Riksbank's financial risk and investment policy and underlying regulations, 9 December 2021.

When the Riksbank is deciding which assets are to be included in the foreign exchange reserves, its starting point is the so-called contingency requirement.[10] The foreign exchange is mainly made up of assets in US dollars and euros, but also in pounds sterling and Norwegian and Danish kroner (see Figure 2). The reserves are mostly made up of assets in these five currencies that the Riksbank needs to hold for contingency purposes but, in order to spread the risks, the Riksbank has also chosen to allow a small part of the foreign exchange reserves to consist of assets in Australian and Canadian dollars.

Figure 2. Assets in the foreign currency reserve by currency, 31 March 2022
Per cent



Note. The figure shows the proportion of the assets in the foreign exchange reserves made up by each currency. On 31 March 2022, the total market value of the foreign exchange reserves was SEK 379.4 billion.

Source: Sveriges Riksbank

1.3 How sustainability considerations are applied to the management of the Riksbank's foreign exchange reserves

The Riksbank can apply sustainability considerations to its operations in accordance with the current Sveriges Riksbank Act[11]. The proposed Sveriges Riksbank Act planned to come into force on 1 January 2023 makes it even clearer that the Riksbank shall take sustainability into account in the management of its assets.[12] As far as is possible considering objectives and tasks, the Riksbank chooses a composition of assets for the foreign exchange reserves that limits their total carbon footprint, without substantially reducing the return

[10] Factors affecting the Riksbank's contingency requirement are the Swedish banks' foreign exchange needs in a financial crisis, the need for readiness to make foreign exchange interventions, the size of international commitments and the need to create confidence that the Riksbank has sufficient resources to fulfil its statutory objective and carry out its tasks.

[11] See Sveriges Riksbank (2021a) and Sveriges Riksbank (2021b) p. 6.

[12] See Government Bill 2021/22:41, A new Sveriges Riksbank Act (in Swedish).

or increasing the risk. The Riksbank also makes an assessment based on sustainability factors before new assets are included in the foreign exchange reserves.[13] Considering sustainability has led the Riksbank to adjust its holdings in recent years.[14]

[13] Factors such as climate, social responsibility and governance are assessed. This in order to create good management based on democratic principles; see Sveriges Riksbank (2021b).

[14] In 2019, the Riksbank decided to invest only in Australian states and Canadian provinces with the same or lower carbon footprint as their respective countries. For this reason, the Riksbank sold holdings of bonds issued by the Canadian province of Alberta and the Australian states of Queensland and Western Austral-ia. See Deputy Governor Martin Flodén's speech, Riksbank selling bonds for climate reasons, November 2019.

2 Calculation of the carbon footprint of the Riksbank's foreign exchange reserves

The carbon footprint is a calculation of greenhouse gas emissions resulting, for example, from the production of goods and services in a country or region. The carbon footprint can be reported using various measures. A common one is carbon intensity, which, for countries and regions, is often measured as the emission of greenhouse gases in relation to the value of the production of goods and services. Carbon intensity is also one of the measures most frequently used to assess climate-related risks. It can give an indication of the extent to which an asset portfolio may be affected financially by the transition of a country or region to a less fossil-dependent economy. This is normally referred to as transition risk.

2.1 The carbon footprint shows the emission intensity of a financial asset portfolio

The carbon footprint shows how much carbon dioxide and other greenhouse gases the financial assets in a portfolio generate in relation to the goods and services produced. The measure thus shows emissions per unit of output.

The carbon footprint also takes into account greenhouse gases other than carbon dioxide. Consequently, a standard unit known as carbon dioxide equivalents is used.[15] This measure takes account of the varying extent to which different greenhouse gases affect the climate.

The carbon footprint is a backward-looking measure, as it shows a historical snapshot of emissions from the portfolio's holdings over the past twelve months. A portfolio's carbon footprint is a weighted average of the carbon intensity of the individual portfolio holdings. A portfolio with a low carbon footprint means that the financial assets in the portfolio have been invested in countries or regions with lower greenhouse gas emissions in the production of goods and services within the geographical area's borders. As greenhouse gas intensity is measured in relation to the value of the goods and services produced, the carbon footprint of the portfolio can be compared to other portfolios including those that are of different size.

In addition to displaying a historical snapshot of a portfolio's carbon footprint, the measure can be used to illustrate how the carbon footprint develops over time. The footprint

[15] Carbon dioxide equivalents are a measure whereby the warming potential of different greenhouse gases is translated into a standard unit. This is because emissions of a certain amount of greenhouse gas have different effects on the climate. For example, per tonne of emissions, the greenhouse gas methane contributes 28 times more to global warming than carbon dioxide, which means that one tonne of methane emissions equals about 28 tonnes of carbon dioxide equivalents. See IPCC (2014).

will vary over time as emissions and production change, as well as when the composition of the portfolio changes. The measure is also affected by changes in inflation and exchange rates.

2.2 Challenges inherent in backward-looking measures of greenhouse gas emissions

Backward-looking measures of greenhouse gas emissions – such as carbon intensity – have a number of flaws if they are to be used as measures of financial risk. For instance, they do not capture the efforts of countries or regions to reduce emissions in the future. In addition, carbon intensity may differ significantly between countries and between individual regions within a country, depending on the type of production involved and the location of the production of goods and services. Nor do backward-looking measures capture risks that are dependent on the country's or region's exposure to fossil assets or the costs and/or savings that may be expected to arise as the world transitions to a less fossil-dependent economy.

Despite these shortcomings, there is likely to be a link between carbon intensity and transition risk. The reason for this is that the effects of the climate transition may be more serious for portfolios with relatively higher emissions than for those with lower emissions, which, in turn, may lead to larger losses.[16] The carbon footprint of a portfolio thus not only shows how emission intensive the portfolio in question is, but the footprint can also serve as an indication of the magnitude of the transition risks. The carbon footprint can thus be used both to reduce risks and to improve returns in portfolio management.

2.3 How do climate-related risks affect the economy and the financial system?

Financial risks related to the transition to a less fossil-dependent economy are called transition risks. The transition risks for a country (or region) arise from all the political, legal, technological and market changes that arise from the transition to an economy with lower greenhouse gas emissions. For example, policy decisions such as increasing carbon tax, subsidising renewable energy or banning the use of petrol cars, which are intended to contribute to reducing the use of fossil fuels, would change competition or other conditions for certain markets. In turn, this could increase the sovereign risk, for example, through increased expenditure or reduced tax revenues from previously profitable markets. The transition may also have consequences for the pricing of securities in the financial markets, such as the stock market, the credit market or the commodities market, which, in turn, may affect investors' financial risk.

In October 2020, the International Network for Sustainable Financial Policy Insights, Research and Exchange (INSPIRE) presented a report on the link between climate change and sovereign credit risk that identified six transmission channels through which climate-related risks may increase the sovereign risk, including tax revenue, the balance of trade

[16] See NGFS (2021).

and foreign investment in the country. The analysis shows that higher vulnerability to climate risks leads to significant increases in government borrowing costs.[17] Another report from the Basel Committee on Banking Supervision (BCBS) shows that climate-related risk drivers affect banks' traditional risk categories (credit risk, market risk, liquidity risk, operational risk and reputational risk) rather than giving rise to a new type of risk.[18]

2.4 The carbon footprint of the Riksbank's foreign exchange reserves is calculated using a production-based method

As the Riksbank's foreign exchange reserves consist primarily of bonds issued by governments, this means that the Riksbank uses mainly countries' greenhouse gas emissions for calculating the carbon footprint. The foreign exchange reserves also consist of bonds issued by regions (Australian states and Canadian provinces) and, for these holdings, the respective region's greenhouse gas emissions are used in the calculations.

There is currently no global standard for measuring the carbon footprint of a portfolio of bonds issued by countries or regions, and the methods available are continually being adapted and refined. It is common to use a production-based method to calculate the carbon footprint.[19] This measures emissions from all goods and services produced within the borders of the country/region over a period of one year.[20] The measure thus assumes that a country's national and/or regional government is responsible for all emissions within its jurisdiction. This is in view of its role as executive power with responsibility for governance of the country/region.

The production-based measure calculates greenhouse gas emissions converted into carbon dioxide equivalents in relation to gross domestic product (GDP, the value of goods and services produced in a country or region) over the same period.

2.5 Calculation of the carbon footprint of the foreign exchange reserves

Weighted Average Carbon Intensity (WACI) is used when the Riksbank calculates and reports the carbon footprint of the foreign exchange reserves.[21] The carbon footprint provides an indication of the level of emission intensiveness of the assets to which the Riksbank's foreign exchange reserves are exposed. This is part of the Riksbank's work of calculating and reporting climate-related risks for the Riksbank's financial assets.

The starting point for calculating the carbon footprint is emission data. Figure 3 illustrates greenhouse gas emissions for a number of OECD countries reporting emission data to the

[17] See INSPIRE (2020).

[18] See BCBS (2021).

[19] See NGFS (2021) p. 24.

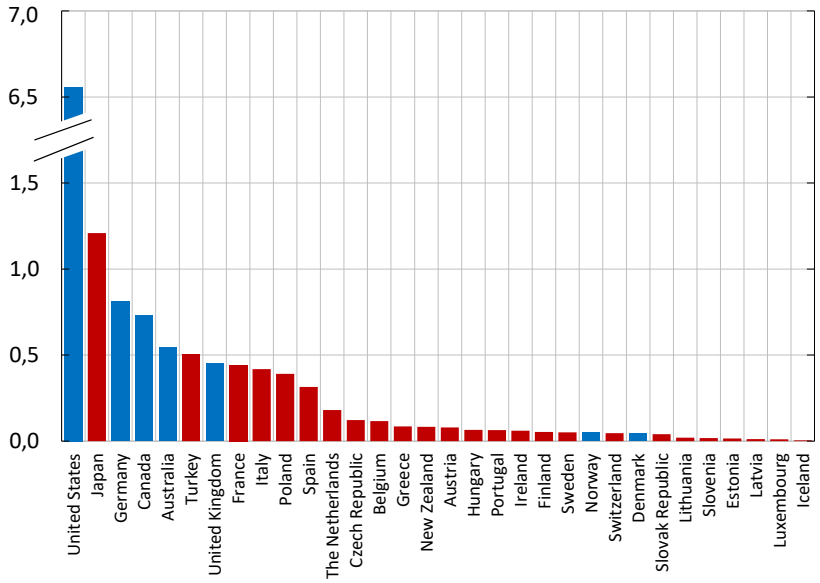
[20] For the Riksbank's holdings in bonds issued by Australian states and Canadian provinces, greenhouse gas emissions are used for each region. For regions, the gross regional product (GRP) is used instead of the country's GDP.

[21] See the Appendix for information on the method used in this Commentary to calculate Weighted Average Carbon Intensity.

United Nations Framework Convention on Climate Change (UNFCCC).[22] The blue columns show the countries whose bonds are included in the Riksbank's foreign exchange reserves as per 31 March 2022. However, emission data do not take into account the fact that countries are different in size and have different conditions in other respects, such as exposure to fossil resources, population size and the size of the economy. This is why the next step places the country's annual greenhouse gas emissions (Figure 3) in relation to its GDP for the corresponding year.

Figure 3. Greenhouse gas emissions for selected OECD countries

Billions of tonnes of carbon dioxide equivalents emitted in 2019



Note. These data refer to greenhouse gas emissions for 2019. The countries marked in blue are those represented in the foreign exchange reserves on 31 March 2022: United States, Germany, Canada, Australia, United Kingdom, Norway and Denmark.

Source: UNFCCC GHG Data Interface

The result is expressed in the unit tonnes of carbon dioxide equivalents emitted per billion US dollars of GDP (Figure 4). This conversion allows fairer comparisons to be made, as emissions per unit of output for each country then become visible. Having said that, it is not entirely uninteresting to compare absolute levels of annual greenhouse gas emissions (Figure 3), as these are also important in the work of establishing climate-related risks in financial asset portfolios and allowing portfolio adjustments that support climate targets.

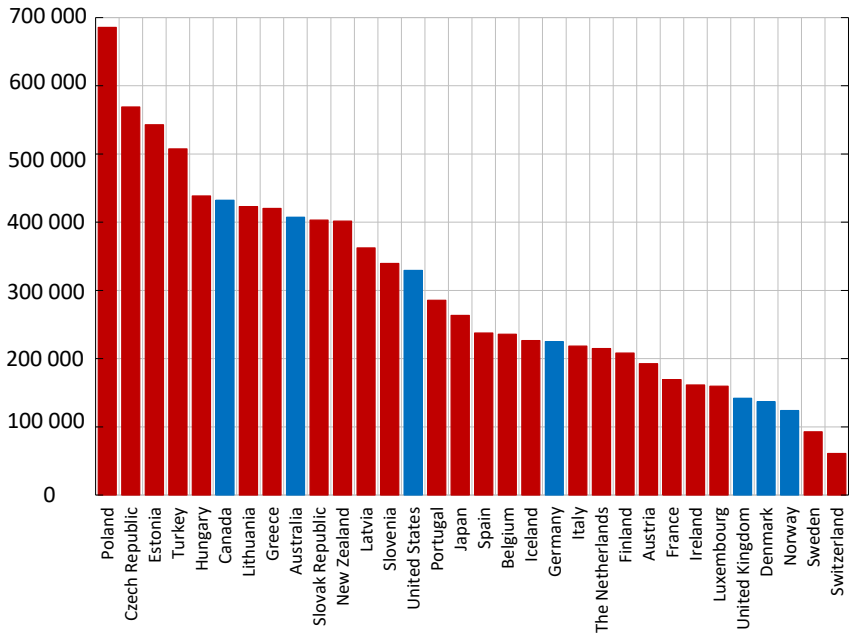
In Figure 4, the countries represented in the Riksbank's holdings in the form of government bonds or bonds issued by regional authorities are marked blue. The United States, which by far releases the most greenhouse gases in total (Figure 3), has a lower carbon intensity than both Australia and Canada (Figure 4), both of which emit less greenhouse gases in absolute terms. This means that US production of a unit of goods and services contributes fewer emissions than that of Australia and Canada. The measure thereby

[22] See the Appendix for information on the data used in this Commentary to calculate Weighted Average Carbon Intensity.

takes into account the fact that larger countries tend to emit more than smaller countries because they tend to produce more and that larger asset portfolios usually account for higher greenhouse gas emissions than smaller portfolios. It is therefore appropriate to use carbon intensity when making comparisons over time and when comparing different asset portfolios. A comparison of carbon intensity is more accurate than just looking at emissions, but it still has its shortcomings. For example, carbon intensity does not take consumption into account, only production. This means, for instance, that the measure does not take into account the fact that some countries, for natural reasons, are in a position to provide the emission-intensive production demanded by other countries that purchase their product. As an example, some countries have abundant natural resources and therefore extract large quantities of raw materials that are then exported to meet demand from other countries. In other words, emission-intensive production only affects the country that produced the emissions, and not the country that imported the products. Nor does the measure take into account the fact that countries with a small population but high GDP, for example because major multinational corporations are domiciled in the country, have a carbon intensity that is lower, all else being equal.

Figure 4. Carbon intensity for selected OECD countries

Tonnes of carbon dioxide equivalents emitted per billion dollars of GDP in 2019



Note. Data from 2019 for greenhouse gas emissions converted into tonnes of carbon dioxide equivalents. Data for GDP are in fixed prices (2015 = 100) converted to US dollars using the respective currency's average exchange rate in 2015 against the dollar. The countries marked in blue are those represented in the foreign exchange reserves on 31 March 2022: Canada, Australia, United States, Germany, United Kingdom, Denmark and Norway.

Source: UNFCCC GHG Data Interface, OECD National Accounts Statistics and the authors' calculations.

Once carbon intensity has been calculated for each issuer, the carbon intensity of each holding is multiplied by the weight of the holding in the foreign exchange reserves. Finally, the weighted carbon intensity of each holding is added to give a weighted average

carbon intensity for the entire foreign exchange reserves. See also the Appendix for a closer description of the data and the calculation method used in this Commentary to calculate Weighted Average Carbon Intensity.

3 The carbon footprint of the assets in the Riksbank's foreign exchange reserves

The carbon footprint of the bonds issued by countries and regions in the Riksbank's foreign exchange reserves – calculated as the Weighted Average Carbon Intensity – is 298,000 tonnes of carbon dioxide equivalent per billion GDP in US dollars on 31 March 2022. Seen over the last five years, the carbon footprint of the assets in the reserves has decreased. Our analysis of the calculation method shows that the variables used need to be adjusted for inflation and exchange rates. As long as there is no global standard or practice that can be applied, transparency about data and calculation method will be very important. There are also other ways of calculating Weighted Average Carbon Intensity for portfolios of bonds issued by countries and regions. These capture a different type of carbon intensity. The results are therefore different.

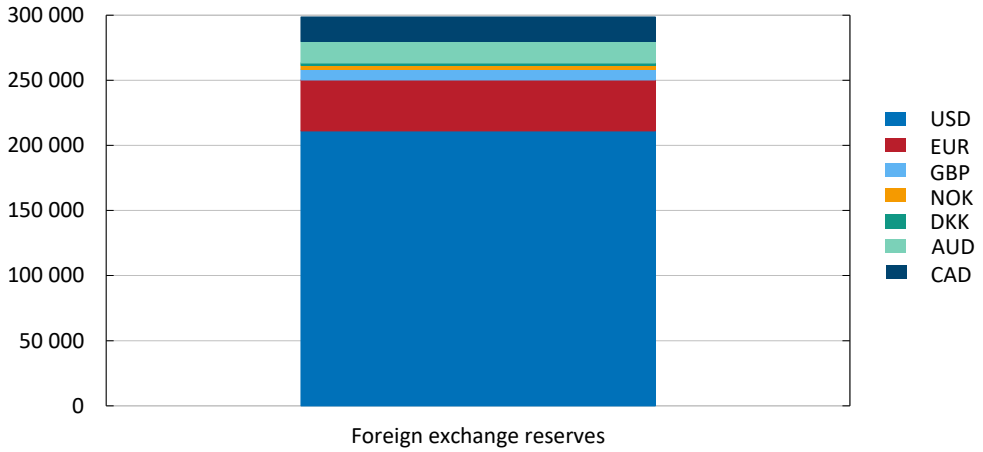
3.1 The carbon footprint of the Riksbank's foreign exchange reserves is calculated for bonds issued by governments and regions

The carbon footprint of the Riksbank's foreign exchange reserves is 298,000 tonnes of carbon dioxide equivalents per billion dollars of GDP on 31 March 2022 (see Figure 5). The carbon footprint is calculated for the foreign exchange reserves' holdings of bonds issued by governments and regions, which together account for more than 93 per cent of the market value of the foreign exchange reserves. The remaining 7 per cent consists of bonds issued by international organisations and state-guaranteed organisations, as well as holdings in bank accounts. For these holdings, either data on greenhouse gas emissions are not available or reporting is not yet sufficiently developed. Consequently, these holdings are not included in the calculations. The carbon footprint of the foreign exchange reserves must therefore be interpreted with a certain degree of caution, since the holdings included have a higher weight in the calculation than if the total holdings in the foreign exchange reserves had been included.

If, instead, we had estimated the carbon intensity of the holdings for which we do not have data with the respective country's carbon intensity, the carbon footprint of the foreign exchange reserves would have been 296,000 tonnes of carbon dioxide per billion dollars of GDP on 31 March 2022, that is to say, 2,000 tonnes of carbon dioxide per billion dollars of GDP lower. The decrease in the footprint is mainly due to the share of assets in

euros[23] (which have a lower carbon intensity) increasing, while the share of assets in US dollars (with a relatively higher intensity) is decreasing (see Figure 4).

Figure 5. The carbon footprint of the foreign exchange reserves on 31 March 2022
Tonnes of carbon dioxide equivalents emitted per billion dollars of GDP in 2019



Note. The carbon footprint of the foreign exchange reserves is based on just over 93 per cent of the foreign exchange reserves' assets, that is to say, the bonds issued by governments or regions.

Source: UNFCCC GHG Data Interface, OECD National Accounts Statistics and the authors' calculations.

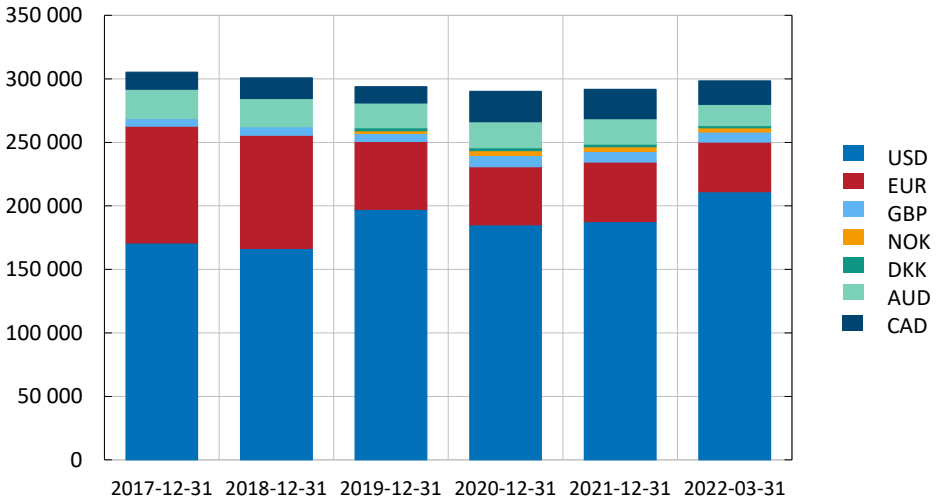
3.2 The carbon footprint of the foreign exchange reserves has decreased over the last five years

Since the end of 2017, the carbon footprint of the foreign exchange reserves has decreased from 305,000 tonnes of carbon dioxide per billion dollars of GDP to 298,000 tonnes, which is a decrease of two per cent (see Figure 6). The biggest decline occurred between 2018 and 2019, mainly due to the fall in carbon dioxide emissions for almost all countries in the foreign exchange reserves in 2019.

[23] For the euro assets, the carbon intensity for Germany is used as an approximation.

Figure 6. Development of the carbon footprint of the foreign exchange reserves

Tonnes of carbon dioxide equivalents emitted per billion dollars of GDP



Note. The carbon footprint of the foreign exchange reserve assets is calculated on the basis of its holdings of bonds issued by states and regions on 31 December 2017 to 31 March 2022. The proportion of bonds issued by states and regions in the foreign exchange reserve is: 96% (31 Dec. 2017), 90% (31 Dec. 2018), 91% (31 Dec. 2019), 75% (31 Dec. 2020), 74% (31 Dec. 2021) and 93% (31 March 2022).

Source: UNFCCC GHG Data Interface, OECD National Accounts Statistics and the authors' calculations.

For the calculations of the carbon footprint in the years 2020 to 2022, reported greenhouse gas emissions data for 2019 are used in the absence of more recent data. Emissions data are reported with a time lag of a year or so, which means that it will take some time before the actual footprint for these years can be calculated. In addition, it should be mentioned that the Riksbank had relatively more holdings in bank accounts and holdings in short-term interest-bearing securities issued by BIS at the end of the years 2020 and 2021, mainly in US dollars but also in euros. The reason was that the Riksbank increased its preparedness to use the foreign exchange reserves because of the corona pandemic by selling U.S. and German government bonds in particular. As a result, the proportion of bonds issued by states and regions at market value was relatively lower for these two years than for the other years (see note to Figure 6).

3.3 Difficulties in calculating the carbon footprint of bonds issued by states and regions

Emissions data are published with a time lag and measured in different ways

The Riksbank uses data on greenhouse gas emissions for countries and regions from the national inventory reports reported to UNFCCC. However, these data are calculated and published with a time lag. At the time of publication of this Commentary, the most recently available emissions data are from the year 2019.

Another challenge with emission data for countries and regions is that emissions can be measured in different ways and data are not always available. This Economic Commentary uses only direct greenhouse gas emissions[24] converted into tonnes of carbon dioxide equivalents excluding land use, land-use change and forestry[25] as a measure. Indirect greenhouse gases are excluded because data are not available for all countries and regions represented in the foreign exchange reserves. The reason why land use, land-use change and forestry are excluded is that it is difficult to compare this component between countries since it can be measured in different ways.[26]

Some countries, such as Australia and Canada, also publish estimates of greenhouse gas emissions and GDP for their regions. If regional data are available, the carbon footprint of the bonds can be calculated more accurately than would have been the case if it had to be estimated based on the country's carbon intensity.

Adjustment for inflation and the effects of exchange rates on GDP

The portfolio-weighted carbon intensity measure recommended by TCFD does not include any adjustment of GDP for fluctuations in exchange rates and inflation. However, the Intergovernmental Panel on Climate Change (IPCC) suggests ways of converting currencies and adjusting for inflation.[27] De Nederlandsche Bank has carried out an in-depth study of various measures of carbon footprint for asset portfolios in the Dutch pension and insurance sector, where the benefits of adjusting for inflation and exchange rates are clearly illustrated.[28] The calculations of the carbon footprint of the foreign exchange reserves use data on the countries' GDP from the OECD. These data are adjusted for inflation and exchange rate fluctuations between the years in order to show, as far as possible, the 'real' development of the carbon footprint of the foreign exchange reserves.[29] The adjustment of data is performed in two stages:

1. GDP for each year is inflated/deflated with the GDP deflator from X year's price level to the desired base year price level.
2. GDP is converted from the holding's currency in year X to US dollars using the base year's exchange rate.

The challenge when it comes to correction for inflation is that there are several measures that can be used to adjust it, for instance the GDP deflator, the consumer price index (CPI) and the producer and import price index (PPI). The GDP deflator and CPI have the best coverage and therefore work best when one wishes to adjust for inflation. In this

[24] The direct greenhouse gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride. The indirect greenhouse gases are nitrogen oxides, carbon monoxide, volatile organic substances except methane and sulphur dioxide.

[25] A large part of the greenhouse gas emissions caused by man stem from various forms of change in land use. The climate reporting sector "Land use, Land-use change and Forestry" (LULUCF) includes reporting of greenhouse gas emissions and natural sinks for the uptake of greenhouse gases as a result of various forms of land-use change initiated directly by man for purposes such as settlements, commercial activities and forestry.

[26] See Fyson, C. L., & Jeffery, M. L. (2019).

[27] See Krey et al (2014).

[28] See De Nederlandsche Bank (2021).

[29] GDP data from OECD National Accounts Statistics use the year 2015 as the base year for the adjustment of inflation and exchange rates for countries. The GDP deflator is used as a measure of inflation. For the regions, the GDP deflator of each country is used when the GDP of each region is adjusted for inflation.

Commentary, the GDP deflator is used as a measure of inflation. The GDP deflator is a broad measure covering all types of goods and services produced in a country and is therefore a good measure for adjusting inflation in the economy as a whole. It is also a more comprehensive measure of inflation than the CPI, because it is not based on a fixed basket of goods. When consumption patterns change or new goods and services are introduced, they are automatically reflected in the GDP deflator for each year, but not in the CPI. The GDP deflator thus captures changes in a country's consumption or investment patterns.

One challenge when one wants to correct for fluctuations in the exchange rate is that it is impossible in practice to find a year when the exchange rate for the currency to which it is converted is not strong/weak in relation to other currencies. Assume, for example, that the currency to which the portfolio's holdings have been converted has appreciated/depreciated significantly for the particular year chosen as the base year. This would result in a higher or lower carbon intensity for the assets, simply due to the exchange rate. This problem would have been smaller if there had been a global standard or practice to consider when choosing a base year. However, the smaller the share of assets in a given currency in relation to the total portfolio value, the less impact the exchange rate will have on the portfolio's carbon footprint.

In this Commentary, we choose to use GDP converted to US dollars instead of Swedish kronor for two reasons. Firstly, because the majority of the foreign exchange reserve assets are in US dollars, which means that the majority of the reserve assets will not suffer any exchange rate effect. Secondly, because we want to report the carbon footprint in a unit that makes international comparisons easier, and here the dollar is preferable. In cases where comparisons are made over several years, GDP data with the same exchange rate for each year are used to eliminate the exchange rate effect between years.

An alternative to adjusting exchange rates in this way is to use purchasing power parity (PPP), as PPP is often used to compare GDP between countries with different currencies. However, there is no major difference if calculating using purchasing power-adjusted GDP. This is because the difference in relative purchasing power between the countries in the foreign exchange reserve is not so great, given that all are industrialised OECD countries. Nevertheless, we have also made calculations based on purchasing power-adjusted GDP at a constant price level to test the reliability of the results. Our calculations show that the choice of method has little impact on the total carbon footprint of the foreign exchange reserves.

The reason for calculating the carbon footprint of asset portfolios varies, which makes it more difficult for a global standard or practice for adjusting inflation and exchange rates to emerge. One or more standards would make it easier to compare different portfolios either with each other or over time. See the Appendix for a closer description of the data and the calculation method used in this Commentary to calculate the Weighted Average Carbon Intensity.

3.4 Other calculation methods lead to different results

There are several different ways of measuring a financial asset portfolio's carbon footprint. TCFD mentions five, including portfolio-weighted carbon intensity that is recommended for this purpose. However, there are also alternatives when it comes to this measure for portfolios of bonds issued by states and regions. One alternative to using GDP as a measure of the country´s or region's output is to use GDP per capita. GDP measures the total economic activity in the country, while GDP per capita gives an indication of the country's welfare, as it gives an indication of how much is produced per person in a country, and thus how productive the country's inhabitants are on average. By dividing greenhouse gas emissions for each country by GDP per capita, a different ratio is achieved between the carbon intensity of the countries and regions and thus the carbon footprint of the entire portfolio. This may in turn lead to two different asset portfolios being related to one another in entirely different ways, depending on the definition of the carbon footprint used. No result is wrong, only different, and the right measure to use is determined by the purpose of the analysis. In this Commentary, the Riksbank uses the production-based measure that uses GDP. This is because the objective is to compare countries based on their total estimated greenhouse gas emissions from the production of goods and services within the country or region.

4 Measuring climate-related financial risks for governments and regions in the future

To link climate-related risks to transition risks, backward-looking measures – such as carbon intensity – need to be complemented by forward-looking measures of transition risks. Various measures of climate-related financial risks are now being developed and the Riksbank is following this development.

4.1 The carbon footprint can be a building block in forward-looking measures

To obtain a more comprehensive analysis of the climate risks of asset portfolios, we need to supplement backward-looking measures of greenhouse gas emissions – such as carbon intensity – with forward-looking measures of transition risks. Such measures are intended to capture the amount and cost of the transition required in a country to reduce emissions, or to measure the degree to which a country is on track to meet various climate targets such as the Paris Agreement. Such measures can be based on country and regional data on greenhouse gas emissions, combined with climate change forecasts. For example, stress tests or scenario analyses can be carried out, thus accounting for the transition risk for an asset portfolio. Another example could be to see how large a share of the countries in a portfolio of bonds have set climate targets.

However, one problem with these measures is that they tend to be more complex and sensitive to assumptions in the calculations than, for example, the carbon footprint. There is at present no single measure that can show the size of the transition risks for a country, but this is being developed.

Transition risks may also need to be supplemented by measuring physical climate risks. In addition, a country can also be affected by environmental risks, such as loss of biodiversity, which can ultimately lead to a reduction in economic activity.

4.2 Climate-related risks materialise at different time horizons

Climate-related financial risks can materialise in the short, medium and long term. The climate-related financial risk is most likely to materialise in the longer term than the non-climate-related financial risks. A typical time horizon when planning to manage traditional financial risks is 3–5 years, while climate-related financial risks are likely to materialise somewhat further ahead than that. Consideration of the time horizon is therefore something that should be included when calculating the carbon footprint. This can be done by taking into account the interest rate risk (duration) or the remaining time to maturity of the bond holdings. If a bond has a longer duration/maturity, the likelihood of a

climate risk materialising during the term of the bond increases and thus has financial consequences for the investor.

4.3 Measurement of climate-related risks is an area still under development

The purpose of this Economic Commentary is to calculate the carbon footprint of the Riksbank's foreign exchange reserves while also analysing the method for calculating the carbon footprint of portfolios consisting of bonds issued by countries and regions. This is a first step in the Riksbank's work of examining how one can measure climate-related financial risks for these assets. New methods of measuring such risks for both portfolios and foreign exchange reserves will evolve over time, and the Riksbank is following this development. Other types of risks associated with sustainability are also increasingly coming into focus. In addition to the climate-related risks, risks related to social responsibility and governance are also becoming increasingly important for asset managers when making assessments before purchasing new assets. This is something that the Riksbank takes into account, in addition to the climate-related risks. The Riksbank will also continue to analyse issues related to climate-related risks in financial asset management. The Riksbank also follows the work of relevant international organizations, networks and standard-setting bodies.

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Data sources

Greenhouse gas emissions and gross national products for countries

UNFCCC Greenhouse Gas Inventory Data, Times series for Annex I countries, GHG total without LULUCF.

Data series from OECD National Accounts Statistics:

- GDP (expenditure approach) in constant prices, constant exchange rates, OECD base year (2015)
- GDP (expenditure approach) in Constant prices, constant PPPs, OECD base year (2015)
- GDP deflator, PPPs and exchange rates (annual average).

Gross regional product for Australia and Canada

Australian Bureau of Statistics (2021), Australian National Accounts: State Accounts, Table 1. Gross State Product, Chain volume measures and current prices, https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-state-accounts

Statistics Canada (2021), Table 36-10-0222-01, Gross domestic product, expenditure-based, provincial and territorial, annual (x 1,000,000), https://doi.org/10.25318/3610022201-eng

Greenhouse gas emissions for Australia and Canada

Department of Industry, Science, Energy and Resources (2021), States and territories greenhouse gas inventory, https://ageis.climatechange.gov.au

Environment and Climate Change Canada (2021), National Inventory Report 1990–2019: Greenhouse Gas Sources and Sinks in Canada, Part 3, (pp. 44–56).

Appendix – Data and calculation method

Data on greenhouse gas emissions

The Riksbank uses data on greenhouse gas emissions from the UNFCCC. However, it is not the UNFCCC that makes the estimates of greenhouse gas emissions. This is done at national level and is shared with the UNFCCC, which then publishes the information. Reported emission data are calculated and published with a time lag. At the time of publication of this Commentary, the most recently available data on greenhouse gas emissions are from the year 2019. Emissions in 2019 will thus be used in the carbon intensity calculations for all years from 2019 and onwards. For the years prior to that, the respective year's greenhouse gas emissions are used. Some countries also report greenhouse gas emissions for their regions and the Riksbank uses these in its calculations for bonds issued by Australian States and Canadian provinces.

Gross domestic product data

The Riksbank uses data on gross domestic product in US dollars for the countries in the foreign exchange reserves from the OECD National Accounts Statistics. The data series used are already adjusted for inflation and exchange rates, where the base year is 2015. The GDP-deflator is used to correct for inflation. As a robustness test, calculations are also made using purchasing-power-adjusted GDP at a constant price level from the OECD National Accounts Statistics and for this data, too, the base year is 2015.

For the Australian states and the Canadian provinces, the gross regional product (GRP) of the respective region is used instead of the country's GDP. These data are adjusted for inflation and exchange rates by the authors' own calculations using data from the OECD National Accounts Statistics. The respective country's GDP deflator is used to adjust to the 2015 price level. The exchange rate used is the annual average for 2015 for each country's currency against the US dollar, as in the OECD calculations for each country.

The portfolio-weighted carbon intensity of the assets in the Riksbank's foreign exchange reserves

The measure shows the exposure of foreign reserves to emission-intensive assets and is the result of a two-step calculation. First, the carbon intensity of the respective holding is calculated by dividing the issuer's annual emissions in tonnes of carbon dioxide equivalents by GDP. This value is then multiplied by the weight the holding has in the Riksbank's portfolio, that is the value of the holdings in relation to the total value of the portfolio, according to the following formula:

$$\sum_{i=1}^{n}\left(\frac{Market\ value\ of\ holding_i}{Total\ portfolio\ value} * \frac{The\ holding's_i\ issuer's\ greenhouse\ gas\ emissions}{The\ holding's_i\ issuer's\ GDP}\right)$$

where:

Variable	Definition
Market value of holding$_i$	The market value in Swedish kronor of a holding in the portfolio.
Total portfolio value	The sum of the market values in Swedish kronor for all holdings in the portfolio that are included in the calculation of the carbon footprint. Only the foreign exchange reserves' holdings of bonds issued by states and regions are included in the calculation of total portfolio value.
The holding's$_i$ issuer's greenhouse gas emissions	Greenhouse gas emissions of the issuer for each holding converted into tonnes of carbon dioxide equivalents. For bonds issued by states and provinces, greenhouse gas emissions are used for the geographical region of the respective issuer.
The holding's$_i$ issuer's GDP	Real GDP/GDP at constant prices (2015 = 100) in billions of US dollars. The GDP deflator is used to correct for inflation. The average exchange rate for 2015 is used in cases where comparisons are made over time to eliminate the effect of fluctuations in the exchange rate between years.

To compare the carbon intensity between different countries/regions and over time[30], the respective country/region's emissions have been divided by GDP at a fixed price level (real GDP). To correct for inflation, we have chosen to use the GDP deflator. For regions, the country's GDP deflator is used. It is appropriate to use real GDP in a comparison of multi-annual statistics to adjust for price changes due to inflation. This is because a country/region with positive inflation year after year will have higher and higher nominal GDP year after year (all else being equal) which will result in a lower and lower carbon footprint as the denominator in the right-hand side of the formula above grows.

For the measure to be comparable, GDP should be expressed in terms of a single currency. GDP is converted into US dollars using the average exchange rate for the year 2015. This facilitates a comparison over several years, since we can thus eliminate the effect of fluctuations in the exchange rate.

[30] See De Nederlandsche Bank (2021).

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