

Measuring the carbon footprints of portfolios

Emission intensities and financed emissions indicators from aggregate data

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Abstract

The exposure to transition risks is commonly related to activities leading to Greenhouse Gas (GHG) emissions, both on the aggregate level as well as for individual agents. In this context, indirect emissions clearly are as important as direct emissions, if transition risk is to be understood as a systemic risk. Total GHG content of output, defined as the sum of direct and upstream indirect emissions, is the most comprehensive measure for transitional risk, as it captures all emissions due to the production of this output and is a metric for the sensitivity of production costs to GHG taxation.

This paper has a focus on financial portfolios. A major problem is erroneous or missing data on emission intensities. The essay describes how industry level data on production interlinkages and direct emissions can be used to generate indicators for direct and indirect emission intensities in portfolios.

The essay starts by giving an overview of relevant standards and discussing how indirect emissions are constituted by production interlinkages. It explains how to approximate intensities using publicly available aggregate information and considers the results for industries, groups of countries, groups of products, with a closer look on Germany. The components of GHG content of Euro area output are computed as a time series.

An important application is presented: the weighted average carbon intensity (WACI) of banks on the country level. Emission intensities are matched with outstanding bank loans according to industry compounds. Exemplary use is made of three statistical sources: the German balance sheet statistics, the Balance Sheet Items (BSI) statistics and BACH data on annual accounts from European countries. According to data from the Corporate Financial Statement Statistics, bank lending in Germany is characterised by a strong and persistent bias towards high emission industries. This bias is entirely due to a disproportionate reliance of the energy, water supply and disposal industries on bank financing. The analysis is corroborated and refined by means of data from the BSI Statistics, uncovering yet another marked overweighting in the portfolio, with relevance for sustainability.

Ultimately, WACIs for France, Italy and Spain are evaluated and compared. The indicator values for France are remarkably low, and the analysis sheds light on the backgrounds for the strong divergence.

Keywords: sustainable finance, greenhouse gas intensities, financed emissions, portfolio footprints

JEL classification: Q56, C67, D24

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1 Introduction and Scope

Carney (2016) identifies transition risk as by far the most important channel through which climate change can affect financial stability. It ‘could result from the adjustment towards a lower-carbon economy. Changes in policy, technology and physical risks could prompt a reassessment of the value of a large range of assets as costs and opportunities become apparent.’ Scientists and analysts attribute the exposure to transition risks principally to activities leading to Greenhouse Gas (GHG) emissions, both on the aggregate level as well as for individual agents. In this context, indirect emissions clearly are as important as direct emissions, if transition risk is to be understood as a systemic risk. Total GHG content of output, defined as the sum of direct and upstream indirect emissions, is the most comprehensive measure for transitional risk, as it captures all emissions that are due to the production of this output and yields a direct metric for the sensitivity of emission of carbon taxes.

In this context, the need emerges to measure and compare carbon footprints and financed emissions of financial portfolios. This is relevant information for investors, financial institutions, regulators, central banks, governments and the public in general. A key problem is incomplete information. The portfolio manager may have company specific information on both direct and indirect emissions, only on direct emissions, or on neither of these. With respect to the missing portions, the evaluation can be informed by industry level metrics, for consistency and to enable the comparison of portfolios. Carbon accountants in companies are in the same situation: if they want to evaluate the GHG content of their inputs, they need to deal with missing direct information.

This paper describes how industry level data on production interlinkages and on direct emissions can be used to generate estimates for indirect and total emission intensities for aggregate portfolios or input compositions. As a result, there is a set of industry, country and time specific GHG-intensities – direct, indirect and total – that can be assigned to the assets of any portfolio or used as an input to carbon accounting when company or product specific information is missing. Depending on the availability of information, one will use industry level information for the entire GHG content of output or only for modelling indirect emissions. The use of statistics for carbon accounting has recently been investigated by von Kalckreuth (2024) and IFC (2024).¹ In the Opening Address at the European Statistical Forum, Köhler-Geib (2025) has suggested political action.

¹ See also Alfieri et al (2024) for a policy-oriented summary.

The paper has a focus on financial portfolios and describes how industry level data on production interlinkages and direct emissions can be used to generate indicators for direct and indirect emission intensities in portfolios.

The essay starts by presenting some of the relevant standards and discussing how indirect emissions are constituted by production interlinkages. It explains how to approximate intensities using publicly available aggregate information. It considers the results for industries, groups of countries, groups of products, with a closer look on Germany. The components of GHG content of the Euro area output are computed as a time series.

An important application is presented: the weighted average carbon intensity (WACI) of banks on the country level. Emission intensities are matched with outstanding bank loans according to industry compounds. Exemplary use is made of three statistical sources: the German balance sheet statistics, the Balance Sheet Items (BSI) statistics and BACH data on annual accounts from European countries. According to data from the Corporate Financial Statement Statistics, bank lending in Germany is characterised by a strong and persistent bias towards high emission industries. This bias is entirely due to a disproportionate reliance of the energy, water supply and disposal industries on bank financing. The analysis is corroborated and refined by means of data from the BSI Statistics, uncovering yet another marked overweighting in the portfolio, with relevance for sustainability.

Ultimately, WACIs for France, Italy and Spain are evaluated and compared. The indicator values for France are remarkably low, and the analysis sheds light on the backgrounds for the strong divergence.

2 Standards for evaluating the climate impact of portfolios

The basis for evaluating the climate impact of portfolios is the principles laid down in GHG Protocol (2011). Indirect emissions are emissions by entities other than the reporting companies that are in a direct or indirect causal nexus to the company's activities. Emissions by energy providers are treated as a separate main category called Scope 2 emissions, as they are akin to direct emissions and their measurement is very specific. All other indirect emissions are gathered under the label of Scope 3 emissions. GHG Protocol distinguishes 15 categories of Scope 3 indirect emissions. Scope 2 emissions and part of Scope 3 emissions are collected as upstream emissions. These are emissions occurring in activities that enable the activities of the reporting company – purchased goods and services, capital goods, fuel and energy related activities other than Scope 2, transportation and distribution, waste generated in operation, business travel, employee commuting and leased assets. The rest of Scope 3 is emissions by other entities during downstream activities, after the product has left the gate or the service has been rendered. It is activities enabled or caused by this output: transportation and distribution, processing of sold goods, leased assets, franchises and – finally – financial investments, as category 15.

Providing financing enables the associated activity. The provider of finance assumes some responsibility, the extent of which can be quantified. For banks or other financing companies, financed emissions will typically be a large multiple of its own direct and Scope 2 emissions. One must not conflate these two types of emissions. Direct and Scope 2 emissions are GHG released by the financing company itself or on its behalf by the energy provider, whereas financed emissions are outside the direct control of the finance provider, and in most cases, there is no indirect control either. This does not mean that they are irrelevant, as enabling the activity of others is the main economic function of finance providers.

As an important principle for measurement, GHG Protocol posits that emissions from investments should be allocated to the reporting company based on the reporting company's proportional share of investment over time. Financing companies are to report at least proportional Scope 1 and 2 emissions of investees. Scope 3 emissions of investee companies are also to be reported, if they are "significant compared to other sources of emissions or otherwise relevant" [p. 53]. Upstream and downstream indirect emissions are the direct emissions of other entities. Thus, emissions are allocated (at least) twice – as Scope 1 and 2 emissions to the company that generates the output, and as Scope 3 category 15 emissions to the financing companies, the providers of equity or debt. If indirect emissions by the investees are considered, emissions will be reported at least four times: as direct or Scope 2 emissions by the producer of an intermediary good, then all the way down the value chain, potentially several times, and again as Scope 3 category 15 emissions by the providers of finance to the value chain companies.

Emission accounting is assigning responsibility, and there are various aspects of responsibility to be accounted for. However, when aggregating company level data, compilers and users need to look carefully at the scope of the underlying indicators, lest the aggregates be meaningless. This is a concern not only for statistics. The emissions attributed to a financial portfolio is an aggregate spanning various financial clients, the number of which may range from a single digit to the entirety of debtors in one country or the whole world.

In the years of its activity between 2015 to 2023, the Task Force on Climate-related Financial Disclosures (TCFD), headed by Michael Bloomberg, worked out climate-related financial disclosure recommendations for informing investors on climate risks and climate related activities of companies. The recommendations cover information and metrics that should generally be part of financial disclosure, not limited to financial companies. There is specific supplemental guidance for financial sector industries: bank, insurance companies, asset managers and asset owners. While the original supplemental guidance of 2016 asks for the disclosure of financed emissions, which is an absolute quantity, the 2017 final report focuses, as a first step, on WACI. Other metrics are deemed useful if they contribute to decision making. The TCFD Implementation Guidance of 2021 contains specific supplemental guidance for the financial sector, defining metrics useful for portfolio evaluation. In

Tables 2 and 3 on pp 50, TCFD recommends financial companies to disclose both financed emissions and the WACI of their portfolio. The tables give specific formulas for the metrics featured above differentiated according to assets classes.

Concerning financial companies, the Implementation Guidance points to the standards published by the Partnership for Carbon Accounting Financials (PCAF). PCAF is a world-wide association of financial institutions developing and implementing a harmonized approach to disclose the GHG emissions associated with their loans and investments. The PCAF describes in detail how to compute financed emissions. The 3rd edition of the standard introduced in December 2025, distinguishes 10 asset classes. The PCAF norms are of high relevance for banks. The EU ESRS standard for the implementation of the CSRD cites the PCAF standard as applicable for the disclosing of Scope 3 emissions by financial institutions, especially regarding financed emissions.

Scope 3 emissions of investees pose a special problem. Data are often unavailable, especially for smaller companies, or they are not reliable. Therefore, PCAF used a 'phase-in-approach': The reporting of portfolio related Scope 3 emissions was mandatory only with respect to those investees that belonged to industries where the disclosure of Scope 3 emissions was obligatory. This limitation was dropped in the 3rd edition of the standard. According to PCAF (2025), it is now mandatory to report Scope 1, Scope 2 and Scope 3 emissions of investees associated with equity and bonds of listed companies, as well as for loans to listed and unlisted companies in the portfolio of financial institutions:

Financial institutions shall report the absolute scope 1, scope 2 and scope 3 emissions of borrowers and investees across all sectors. Financial institutions shall separately disclose absolute scope 3 emissions from scope 1 and 2 emissions of borrowers and investees.²

For data on emissions, PCAF mentions three types of data sources: reported emissions of companies, physical activity-based emissions, and economic activity-based emissions. The latter should be estimated using official statistical data or acknowledged environmentally extended input-output (EEIO) tables:

Option 3: economic activity-based emissions, where emissions are estimated by the reporting financial institution based on economic activity data collected from the borrower or investee company (e.g., euro/dollar of revenue or euro/dollar of sectoral assets) and then allocated to the reporting financial institution using the attribution factor. The emissions data should be estimated using official statistical data or acknowledged environmentally extended input-output (EEIO) tables providing region- or sector-specific average emission factors expressed per economic activity (e.g., tCO₂ e/€ or \$ of revenue or tCO₂ e/€ or \$ of sectoral assets).³

² PCAF (2025), p.40 for equity and bonds of listed firms, and identically p.56 for business loans to listed and unlisted companies and to unlisted equity. Note that the current EU ESRS points to the edition of the PCAF standard released in 2022 that still maintains the phase-in approach.

³ PCAF (2025, p.45.

This paper is about how to use official data to compute emission intensities that can be used to generate activity-based emissions. These intensities and estimates are the basis for all types of indicators used in portfolio evaluation and in statistical measurement of emission financing.

3 Direct and indirect emissions with production interlinkages

At the outset of the analysis, it is meaningful to look at direct and indirect emissions, and the way in which the latter derive from the former by way of production interactions. Concerning a commodity, direct emissions are the emissions associated with the production activity proper, i.e. Scope 1 emissions. Indirect emissions associated with the production are the sum of emissions along the value chain of this product, i.e. the emissions associated with the production of the inputs, and the production of the inputs required to produce the inputs, and so forth. In the language of the GHG Protocol, these are Scope 2 and upstream Scope 3 emissions.

To specify the objects of measurement, one needs a model of production interactions. This section exposes production interlinkages and the accumulation of GHG content in the value chain by means of a Leontief model of production on the firm level.⁴ The implicit linearity assumption is convenient, because it allows the relevant parameters to be derived from simple aggregate ratios. At the same time, the assumption is rather general, because in most cases, linearity can be achieved by replication in the long run. The model is set up in terms of physical units, in the way Leontief himself set up his analysis originally.⁵

In production planning, every process is defined by a *bill of material* (BoM) that specifies all inputs, plus a *route sheet* that explains how to combine them. A complex production process may be decomposed into several stages. Consider the BoM, the input requirements, of product k , collected in a column vector:

$$\mathbf{a}_k = (a_{1k} \quad a_{2k} \quad \dots \quad a_{Kk})',$$

with a_{ik} being the quantity of good i that enters the production process of product k . The index k takes values from 1 to K . Let the amount of GHG emitted directly in the production of good k be given as d_k . Both a_{ik} and d_k are scaled as per unit of good k . Let scalar g_i be the (total) GHG content of good i , i.e. the total quantity of GHG that is emitted in the production of one unit, directly and along the value chain. Frequently used terms for this concept are “embodied” or “embedded” or “total” emissions. List the GHG contents of all goods in a column vector as well:

⁴ The micro framework is adapted from von Kalckreuth (2025). The present paper works out the relationship with standard IO modelling.

⁵ See the essays collected in Leontief (1985), specifically Leontief (1956).

$$\mathbf{g} = (g_1 \quad g_2 \quad \dots \quad g_K)' .$$

The GHG content of product k is given as the sum of direct and indirect emissions, cradle to gate. Indirect emissions are direct emissions at earlier stages of the value chain. They are defined recursively as the GHG contents of inputs:

$$g_k = d_k + \mathbf{g}'\mathbf{a}_k = \underset{\text{direct em.}}{d_k} + \sum_{i \text{ indirect em.}} g_i a_{ik} . \quad (1)$$

The equation is both general and encompassing. It relates to products and activities and – for a defined time span – to enterprises and sectors as well. As it stands, it is a definition. It helps us understand the problems associated with gathering and processing information. For actual computation, values for all the g_i corresponding to the production of product k are required. With these at hand, we could calculate the GHG content of the product in a straightforward way from direct emissions and the BoM. This is like computing the energy content of food: it is enough that producers know the composition of their product and the energy content of the ingredients.

If the relevant elements of $\mathbf{g}$ are unknown, we can use equation (1) iteratively and try to compute the GHG contents involved, going up the value chain from more complex intermediate inputs down to primary and primitive inputs. It is helpful to note that equation (1) and the corresponding equations for all other goods constitute a simultaneous equation system. The structure is well known from linear production planning and Input-Output (IO) analysis, pioneered by Wassily Leontief, and it was indeed the same author who first proposed using IO models for analysing pollution generation associated with inter-industry activity. Conceptually, we can solve for the GHG values of all products simultaneously. Let

$$\mathbf{A} = (\mathbf{a}_1 \quad \mathbf{a}_2 \quad \dots \quad \mathbf{a}_K)$$

be the matrix of the BoMs for all output goods, $1, \dots, K$. In the language of IO theory, $\mathbf{A}$ is a symmetric product-by-product input requirement matrix. With $\mathbf{d}$ being the column vector of the direct emissions per unit of output, one may write

$$\mathbf{g}' = \mathbf{d}' + \mathbf{g}'\mathbf{A} .$$

(1)'

This is simply equation (1), written as a system in matrix algebra. This structure corresponds to the (open) Leontief model of production.⁶ Reordering and post-multiplying the so-called “Leontief inverse” $(\mathbf{I} - \mathbf{A})^{-1}$ yields:

⁶ Note that IO analysis is typically concerned with sectoral interlinkages, not with the level of individual products. See Miller and Blair (2022), Chapter 13, for the extension of basic IO analysis to environmental issues. The structure outlined here corresponds to the “dual” price system that results from the Leontief structure, yielding a linear relationship between the values added of industries and the prices of goods; see Pasinetti (1977), Chapter 4.

$$\mathbf{g}' = \mathbf{d}'(\mathbf{I} - \mathbf{A})^{-1}. \quad (2)$$

The GHG content of products (product k and all the others) result from their own direct emissions and the direct emissions of all the intermediate goods used for their production by intermediation of a matrix derived from the BoM that reflects the interlinkages in production. If the coefficients in the GHG equation refer to empirical production technologies being used to produce goods, $1, \dots, K$, it can be taken for granted that the inverse exists and all its elements are non-negative.⁷

Ultimately, all GHG content derives from direct emissions in the production of final or of intermediate output. The GHG content collects emissions along the entire value chain – the GHG content of earlier stages of production are absorbed into the GHG content of final production. Thus, the GHG content of final production will be identically equal to total direct emissions. The Leontief matrix in eq. (2) serves to redistribute direct emissions for products or industries to the quantities of final output. With the linear technology defined above, let $\mathbf{q}$ be the vector of total outputs for all goods and $\mathbf{f}$ the quantities of final outputs that are not used in the production process again. Total output consists of intermediary inputs and final output. With the symmetric product-by-product requirement matrix $\mathbf{A}$ defined above, we have:

$$\mathbf{A}\mathbf{q} + \mathbf{f} = \mathbf{q} \quad \text{or} \quad \mathbf{f} = (\mathbf{I} - \mathbf{A})\mathbf{q} \quad \text{or} \quad \mathbf{q} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{f}. \quad (3)$$

This is the basic equation of Input-Output Analysis, relating the production of total (and intermediate) output to the quantity of final demand. The formal structure is related to the pair (1)' and (2) for emission intensities.⁸ The GHG content of total output is equal to the sum of direct emissions in the process of production of all products:

$$\mathbf{g}'\mathbf{f} = \mathbf{d}'(\mathbf{I} - \mathbf{A})^{-1}(\mathbf{I} - \mathbf{A})\mathbf{q} = \mathbf{d}'\mathbf{q}.$$

The direct emissions in the production of good A will be part of the indirect emissions of good B if A enters as input in the production of B. Summing up total GHG content of outputs over products and industries will therefore involve double counting. Measures of aggregate GHG content over industries or products are to be interpreted cautiously. It is more revealing to compute the average GHG intensity of output.⁹ For a given good or industry, it displays total emission per unit of output and, by separately looking at direct and indirect emission, allows us to evaluate how much of this is

⁷ If some of the relationships are estimated, postulated or extrapolated from the past, as will be the case in real-world implementations, the existence of non-negative solutions $\mathbf{g}$ given non-negative elements in $\mathbf{A}$ and $\mathbf{d}$ cannot be taken for granted a priori. For a non-negative solution to exist, it is necessary and sufficient that all principal minors of $\mathbf{I} - \mathbf{A}$ are positive (Hawkins-Simon conditions). Equivalently, all characteristic roots of $\mathbf{A}$ are less than 1. See, for example, Takayama (1985), Chapter 4, specifically the summary collection on p. 386. Intuitively, the amount of direct carbon emissions needed may not “explode” as we use equation (1) recursively. Iteratively, the Leontief inverse can be computed as a power series, $(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \dots$. This expansion will converge if and only if the eigenvalues of $\mathbf{A}$ stay within the unit circle. See, for example, Schumann (1968), pp. 35 ff, or Pasinetti (1976), Chapter 4, specifically pp. 66 ff. and the references to the appendix.

⁸ Note, however, that $\mathbf{d}'$ and $\mathbf{g}'$ in equations (1) and (2) are row vectors. Alternatively, one may write equation (2) as $\mathbf{g} = \mathbf{L}'\mathbf{d}$, with $\mathbf{L}$ the shorthand notation for the Leontief matrix, $(\mathbf{I} - \mathbf{A})^{-1}$.

⁹ We will reserve the term “intensity” for GHG emissions per unit of value. GHG content as defined above is a physical measure.

due to emissions along the value chain. This distinction has clear policy implications. If a high GHG content in the output of an industry is predominantly driven by value chain emissions, then regulating direct emissions in the production processes (of that industry) will be largely inefficient.

In sum, this model of production interactions embodies:

- Direct emissions – Scope 1 – collected in a product level vector $\mathbf{d}$
- Total GHG content, the sum of Scope 1, Scope 2 and upstream Scope 3: $\mathbf{g}' = \mathbf{d}'(\mathbf{I} - \mathbf{A})^{-1}$
- Indirect emissions cradle to gate, Scope 2 plus upstream Scope 3: $\mathbf{g}' - \mathbf{d}' = \mathbf{d}'(\mathbf{I} - \mathbf{A})^{-1} - \mathbf{d}'$

All these quantities are given in terms of intensities. The GHG Protocol defines Scope 2 emissions as the emissions that physically occur at the facility where electricity is generated, i.e. as Scope 1 emissions of the energy provider.¹⁰ In the terminology set up above, this is:

$$sc2_k = d_e a_{ke}.$$

See Appendix 1 for two alternative derivations and a numeric example.

4 Aggregate data for generating measures of GHG intensities

What has been derived so far are exact expressions for GHG content and indirect emissions in a modelling context. No estimation is involved. In statistical work, there is no information on individual supply chains of companies, still less on the product level. This may change in the future, due to the global advent of e-bills. Furthermore, systems of carbon accounting are being developed, with companies passing their information on direct and indirect emissions down the supply chain.¹¹

In the meantime, it is necessary to find proxies for the indirect emission intensities for portfolios, consisting of many entities. From IO tables there is information on production interlinkages, both on the level of industries and product groups. The two are not identical, because “industries” are defined as activities, not as products. There is a close correspondence, because activities relate to a main “product”, but industries may produce other products, too. To facilitate the argument, let us assume for a moment that all output of companies belongs to the same product group.

We can derive GHG intensities for product groups in exact analogy to the product level GHG contents per unit of output considered above. The real-world data from statistical agencies concerning production interactions are in terms of Euro value of input of product group i needed to produce one unit of output from group k . This makes a rescaling necessary. All emission intensities are stated as GHG equivalents per Euro of output. Let $\mathbf{e}$ be a vector of direct (Scope 1) emissions of product groups per Euro of output. Let further $\mathbf{c}$ be the vector of total GHG intensity of product

¹⁰ WBCS and WRI (2004) p. 25 and 27. The rationale for GHG Protocol Scope 2 emission reporting is to collect under one umbrella an important part of indirect emissions that (a) is measured with relative ease and (b) can be addressed by directed decisions or policy-making, such as replacing electricity from coal by nuclear or solar energy.

¹¹ See Kaplan and Ramanna (2021), IFC (2024), von Kalckreuth (2022/2025).

groups, defined as the sum of direct and indirect intensities per Euro value of output. Total GHG intensity of output is the additional emission of GHG equivalents caused by an increase of (final) output by one Euro. Let finally **B** be a matrix of production interactions, defined in monetary terms and referring to products groups. The element $b_{i,k}$ gives the Euro value of input of group i needed to produce one additional Euro value of output of group k . Thus, all elements in matrix **B** are ratios of quantities, stated in Euro values.

The relationship between matrix **A** in Section 1 and matrix **B** in this Section is one of aggregation and rescaling: The elements of **B** can be derived from those of **A** if price and product group of each product is known. From a counterpart of equation (1) one has:

$$\mathbf{c}' = \mathbf{e}' + \mathbf{c}'\mathbf{B},$$

or, as above:

$$\mathbf{c}' = \mathbf{e}'(\mathbf{I} - \mathbf{B})^{-1} = \mathbf{e}'\mathbf{L}, \text{ with } \mathbf{L} = (\mathbf{I} - \mathbf{B})^{-1} \text{ as the industry level Leontief matrix.}$$

To obtain the indirect emissions, one may subtract the direct emissions from total GHG content:

$$\mathbf{n}' = \mathbf{c}' - \mathbf{e}' = \mathbf{e}'(\mathbf{L} - \mathbf{I}).$$

These vectors give intensities for the output of that product group that can be interpreted as group averages. To evaluate portfolios, the intensities are attributed to the entities. Using weights derived from the available measures of activity and financing structure, they will be aggregated to intensities of financed activity.

It is necessary to point out that these total emission and indirect emission intensities computed from industry aggregates are generally not fit to be used on the entity level, eg for small scale portfolio management purposes. Concerning a specific entity, the industry level intensities may grossly overstate or understate the micro level intensities. First, for some industries, there is a huge variation in total emission intensities between companies, while other industries are reasonably homogeneous.¹² Second, concerning direct and indirect emissions, the degree of integration may vary a lot between of companies. One company may actually host the entire value chain, such that most or all of total emissions will show up as direct emissions, or it harbours only one link of the value chain, such that almost all of its carbon footprint results from indirect emissions.¹³ Ultimately, the quantification of large input output matrices and emission intensities by statistical institutes involves estimation and guesswork and is not beyond doubt.¹⁴

¹² This has been thoroughly investigated by [von Kalckreuth \(2024\)](#) on the basis of US company level direct emissions information and simulations using the detailed BEA Input-Output tables that distinguish 405 industries.

¹³ Thus, as a proxy for the entity level, the total emission intensity indicators may be better than either the direct or the indirect emission intensity indicators.

¹⁴ The process is described by [Moll \(2024a\)](#) and [Moll \(2024b\)](#) in presentations given at the 2024 Hamburg workshop on carbon content measurement.

Considering large portfolios of companies, such as all debtors of Euro area banks, the inter-industry deviations will cancel out. Technically, using industry level indicators for evaluating aggregate bank holdings means the transformation from aggregate indicators to other, even more aggregated indicators, in a reweighting process that involves the entity level. With a portfolio encompassing countries, such as the one considered by the Eurosystem Climate Change Statistics,¹⁵ the estimated portfolio emission intensities will be as exact as the underlying aggregate information if there is no selectivity bias. Such a bias may arise if bank clients have emission intensities different from firms that finance themselves in other ways, especially if the within-industry heterogeneity is large. A bank may be, for example, lending specifically to green energy companies. In those cases, the average intensities of energy companies can be misleading.

The procedure described above amounts to a straightforward transfer of the underlying concept to a statistical measure. Some remarks and caveats are in order at this point:

- Mathematically, using Euro values as numeraire for input and output is innocent. On the timeline, however, the elements of the interaction matrix and the intensities (both the direct emission intensity and the total GHG intensity) will be sensitive to relative price changes and price level shifts, respectively. This effect needs to be recognised, isolated and possibly removed in statistical work.
- Similarly, the relationship between Euro values and output quantities will also depend on the market structure. There may be industries with a high degree of monopolistic power, where quantities per unit of value are smaller than in a hypothetical case in which these industries were fully competitive. In other industries, production may be subsidized or differently taxed. For comparability, all ratios should be stated in basic prices. In the case of state production, market prices are widely uninformative and in National Accounting, revenue is replaced by total cost. The interpretation remains the same: The total GHG intensity c_k of a product group is the additional GHG emission generated along the value chain if the (final) output of group k is increased by the equivalent of one Euro, with a valuation corresponding to that group of products.
- Input-Output Tables do not include the production interdependencies constituted by capital inputs. In National Accounts, capital goods are treated as part of final demand. Thus, the emissions embodied in their construction will not be assigned to the commodities being produced with the help of their services.
- In the relationship between product-level outcomes and group-level outcomes, there is a potential *aggregation bias*.¹⁶ The Leontief matrix is a non-linear transformation of the origi-

¹⁵ Statistics Committee's Expert Group et al (2024).

¹⁶ Miller and Blair (2023), Sect. 4.9, pp. 161.

nal input coefficients. The group averages of GHG values at the product level may not correspond exactly to the result of computing GHG content at the group level. In a simulation by von Kalckreuth (2022/2025) using German data, the aggregation bias does not have any noticeable impact on emission intensities.

- To characterise firm level entities, one may want to account of the fact that the output of real-world companies often falls in more than one product group. Companies may be regarded as representatives of their respective industry. To better approach the production interlinkages between companies, one may use for **B** a symmetric industry-by-industry matrix instead of a product-by-product matrix. The direct emission intensities **e** then also needs to be appropriately defined in terms of industries.
- Moving to the industry level is not enough to fully reflect micro reality, because the activity of one company may correspond to more than one industry. In practical classification work, the most important activity is chosen to classify the whole entity. To address this issue, one needs micro level information on the industry composition of the companies' activity.

5 Multiregional IO data and Air Emission Accounts

To evaluate the carbon footprint of portfolios, emission intensities are required that are industry specific, country specific and vary over time. To obtain an encompassing picture, not only direct intensities are needed, but also indirect intensities (Scope 2 and upstream Scope 3) and the total GHG content. IO models yield vital information on industry level production interactions.

Input-Output tables are generated from the supply and use tables in National Accounts. Graph 1 gives a stylized representation. By means of so-called make matrices that depict the product composition of the output of industries, compilers rearrange data to obtain a correspondence between product (groups) and industries. In the following, an industry-by-industry matrix is assumed. Dividing all columns by the value of total output of the respective industry and dropping the lines pertaining to primary factors (labour and capital), as well as the columns collecting final uses, one obtains a matrix of “direct requirements”. It shows, by industry, the value of output of each industry, which is directly needed to produce one additional unit of output. This matrix has the information content and the structure of matrix **B** in Section 2. To be produced, these inputs need their own specific inputs. A “total requirement” matrix gives, by industry, the value of output of each industry needed overall to produce one additional unit of *final* output. This is the Leontief matrix, $\mathbf{L} = (\mathbf{I} - \mathbf{B})^{-1}$ we have encountered above.¹⁷

¹⁷ A complete, yet concise description on how to get from supply and use tables to the total requirement matrix is [published on the website of the BEA](#).

Graph 1: Supply and use table¹⁸

	Industry A	Industry B	Industry C		Final use		Σ
Product A	-	40	200		10		250
Product B	50	-	50		150		250
Product C	30	70	-		400		500
Labour	120	100	150				
Capital	50	40	100				
Σ	250	250	500				1000

National Input-Output information is insufficient. Euro Area countries are open economies, among each other and with respect to the rest of the world, and they derive much of their inputs from the outside world. For these inputs, it is the value chains and the emission intensities in the exporting country that matter. This is being addressed by Multiregional Input-Output Tables (MRIOTs). Such tables are a record of input and production for a given set of industries, in and among several countries. Formally, such tables distinguish inputs and outputs among $N \times K$ sectors, with N the number of countries and K the number of industries. Each combination of industry and country defines a sector, and the supply of tires from Germany to the French automobile industry is recorded in a cell that is different from the one that has the supply of tires from Italy for French automobiles. A requirement matrix for M industries in N countries will have $(M \cdot N)^2$ entries to be filled. Implicitly, the supply and use data from MRIOTs embody a complete picture of international and inter-industry trade. Graph 2, taken from the FIGARO documentation, shows the relationship between national Input-Output-Tables and an MRIOT in a stylised way.

[FIGARO](#), the inter-country Input-Output tables of Eurostat, features 64 industries and 46 countries, plus the “rest of the world”. With its [Inter-Country Input-Output \(ICIO\)](#) tables, the OECD produces Input-Output tables relating 76 countries and 45 industries. At the IMF, a new IO data base is about to be published that will give data availability a new order of magnitude. The Multi-Analytical Regional Input Output Table (MARIO) is projected to encompass 212 economies, 144 industries and 178 products. It is planned to initially provide data for the years 1990 to 2022.¹⁹ In spite of its much more detailed industry breakdowns, MARIO is projected to be fully consistent with FIGARO.

¹⁸ By courtesy of Stephan Moll, Eurostat.

¹⁹ See Guilhoto et al (2023).

Graph 2: Multiregional Input Output Tables (MRIOTs)²⁰

FIGARO IC-IOI		Intermediate use									Final use									Total Use (TU)
at basic prices		Country A			Country B			Country C			Country A			Country B			Country C			
		Product 1	...	Product 64	Product 1	...	Product 64	Product 1	...	Product 64	Fd1	...	Fd5	Fd1	...	Fd5	Fd1	...	Fd5	
Country A	Product 1																			
	...																			
	Product 64																			
Country B	Product 1																			
	...																			
	Product 64																			
Country C	Product 1																			
	...																			
	Product 64																			
Value added (B1G)																				
Compensation of employees (D1)																				
Gross operating surplus (B2A3G)																				
Other net taxes on production (D29X39)																				
Output (P1)																				
Key:		Cross-border flows of intermediate goods and services									Cross-border flows of final goods and services									
		Domestic flows of intermediate goods and services									Domestic flows of final goods and services									

At this point in time, the most appropriate database for the purpose of computing carbon footprints of portfolios in Europe and probably beyond is FIGARO. The data base is continuously updated and nowcasted and can be directly used with the EU member countries air emission accounts.

Air Emission accounts are part of the Central Framework of the [System of Environmental Economic Accounting \(SEEA\)](#), maintained and developed by the United Nations. The System of Environmental Economic Accounting (SEEA) is a framework that describes the interactions between the economy and the environment, and the stocks and changes in stocks of environmental assets. It is a satellite account of the System of National Accounts (SNA) and uses definitions of sectors, industries, time and space consistent with the National Accounts. The Eurostat Air Emission Accounts feature greenhouse gas emissions originating from the EU economy – economic actors and households residing in the EU – as defined and delineated in Eurostat National Accounts. Air Emission Accounts are published in December (T+11m). Their legal base is given by EU regulation 691/2011 on European environmental economic accounts, incl. air emissions accounts. Consistent with National Accounts and FIGARO, Eurostat Air Emission Accounts data provide data for 64 industries, covering the following substances: CO₂, N₂O, CH₄, HFC, PFC, SF₆, NF₃, and GHG total.

Based on FIGARO, Eurostat produces industry level carbon footprints (in terms of metric tons). Appendices 2 and 3 depict the industries and the geographical units covered by FIGARO.

²⁰ Again, by courtesy of Stephan Moll, Eurostat.

6 GHG footprints by country / industry

This section briefly discusses how to extract the necessary information from the publications by Eurostat. Data can be obtained free of charge at the [Input-Output data section](#) of the Eurostat website. It is useful to consult the following Excel documents containing instructions:

- [Description of the FIGARO tables](#), with general information on FIGARO
- [Greenhouse gas emission footprints - estimates based on FIGARO ICIOT](#). Also see the [methodological note](#).

Note that the total carbon and GHG content intensities on the level of industries are not part of the publication program. The statistics gives country specific carbon footprints of five aggregate final demand categories.²¹ Additionally, it specifies, for each pair of country and industry, the direct and indirect contribution to this total footprint. Direct intensities, as a necessary input for computing GHG contents, are not readily accessible either. However, both, the direct and the total intensities by country and A64 industry, can be recovered from the published IO data.

The following elements are required, for each year:

- 1) the multi-country technological coefficient matrix, labelled above as matrix **B**. Download the industry-to-industry level data as flat files. Assemble the matrices. Divide by county/industry output, given identically as the column sum or the row sum;²²
- 2) the Leontief matrix, computed as $\mathbf{L} = (\mathbf{I} - \mathbf{B})^{-1}$;
- 3) the vector **e** of direct emission intensities. While for European countries the emission levels according to industry are published as part of the emission statistics, the emissions of non-European countries are not. It is difficult to retrieve them elsewhere, in the required composition. The Eurostat carbon footprint data are organised as a matrix, with country/industry sources of emissions in the rows and final output demands in the columns. Thus, the *levels* of direct emissions (in tons) are implicitly given as row sums of the carbon footprint matrix. Download the flat files on the website above, recover the matrix, compute the row sums and divide them by nominal output computed as part of Step 1 above.

The FIGARO Input-Output matrix is published in July of each year, for all years from 2010 to t-2. Thus, the data containing (the end of) 2023 are available in July 2025. The carbon footprint data that contain the required information on direct emissions are available only in November of the same year, with an update in January. In the meantime, one needs to estimate the complete vector of direct intensities based on the published intensities for EU countries and the set of intensities in the year before.

²¹ For each country, the statistics gives carbon footprints of final consumption expenditure of general government, final consumption expenditure of households, final consumption expenditure of non-profit institutions serving households, gross fixed capital formation.

²² The minimal numerical differences are probably due to rounding issues.

It is also worth mentioning that the industry level outputs implicit in the FIGARO IO matrix do not always fully represent the existing information. National statistical agencies retain the right to have their industry outputs treated as confidential, and where this right is exercised, published IO data have undergone procedures designed to mask the output level values. Thus, the intensities calculated for small industries of small countries should be treated with some caution. For calculating GHG footprints of larger, diversified portfolios, this caveat is immaterial.

Let $\mathbf{L}$ be the Leontief matrix of the requirement matrix $\mathbf{B}$. The element l_{ik} of $\mathbf{L}$ gives us Euro value of country/industry i production required *over all production stages* to enable country/industry k to produce one additional unit of output:

$$\mathbf{L} = (\mathbf{I} - \mathbf{B})^{-1} = \begin{pmatrix} l_{11} & \cdots & l_{1K} \\ \vdots & \ddots & \vdots \\ l_{K1} & \cdots & l_{KK} \end{pmatrix}.$$

This encompasses *the direct requirements for i* in the production process of k , i.e. the value b_{ik} , plus all of input i needed to produce the inputs, including the production of b_{ik} .

The direct emissions intensities by country/industry are collected in a diagonal matrix:

$$\hat{\mathbf{e}} = \begin{pmatrix} e_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e_K \end{pmatrix}.$$

We have

$$\mathbf{R} = \hat{\mathbf{e}} \cdot \mathbf{L} = \begin{pmatrix} e_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e_K \end{pmatrix} \cdot \begin{pmatrix} l_{11} & \cdots & l_{1K} \\ \vdots & \ddots & \vdots \\ l_{K1} & \cdots & l_{KK} \end{pmatrix} = \begin{pmatrix} e_1 l_{11} & \cdots & e_1 l_{1K} \\ \vdots & \ddots & \vdots \\ e_K l_{K1} & \cdots & e_K l_{KK} \end{pmatrix}. \quad (4)$$

We may call this the “emission requirement matrix”. A typical element, $e_i l_{ik}$, will give us the emissions in kg required for providing the output of country/industry i to enable country/industry k to produce one additional unit (1000 €) of output.

Summing up over all the elements of one column gives us the carbon footprint, the sum of direct and all indirect emissions of country/industry k , as an intensity:

$$\mathbf{c}' = \mathbf{1}' \mathbf{R}, \text{ or simply } c_i = \sum_{k=1}^K r_{ki}.$$

It is useful to check whether one can reproduce the published Eurostat carbon footprints of final demand aggregates using these intensities.

For the German machine and equipment manufacturing in 2018, one thus obtains a direct GHG emission intensity of .009 kg/€ of output, which is low, but a considerable total GHG intensity (GHG content) of .301 kg/€, due to the use of high emission intensity inputs. See Graph 3 below for an illustration. The emission requirement matrix enables the user to calculate carbon footprints

or all combinations of countries and industries. It allows to isolate the contribution of one specific industry, i.e. electricity. On its own, it does not allow to distinguish direct and indirect intensities.

A look at equation (4) and the formal derivation shows that the measures for total emission and indirect emission intensities depend on the information on direct emissions at the various interlinked stages of production. Thus, the indicators on Scope 1, Scope 2 and Scope 3 intensities are interdependent. This may create a consistency problem if the information base for direct emission is different from the industry level emission and output data that Eurostat provides. Different direct emission intensities on the entity level measurement, as compared to the aggregate level, would have resulted in different total emissions and indirect intensities. Obviously, those divergences would occur not only in the industry itself where such differences occur, but also in all other (upstream) industries. A similar problem results if Scope 2 intensities are measured on the entity level. This is an issue for portfolios consisting of entire industries or countries, not for the portfolio of, say, one bank, where direct emissions can well be different from the aggregate average.

7 Industry level emission intensities: some descriptive results

Graph 1 below shows the resulting direct and indirect emission intensities resulting from combining the data on direct emissions with the FIGARO input output information on value chains. The graph shows both the wide diversity of outcomes and the possibility to analyse and compare countries and industries. These are the data that are to be assigned to companies in a financial portfolio—either both the direct and indirect intensities, or the indirect intensities only, in case there is company-level information on direct emissions from other sources.

Graph 1: Direct and indirect emission intensities by industry

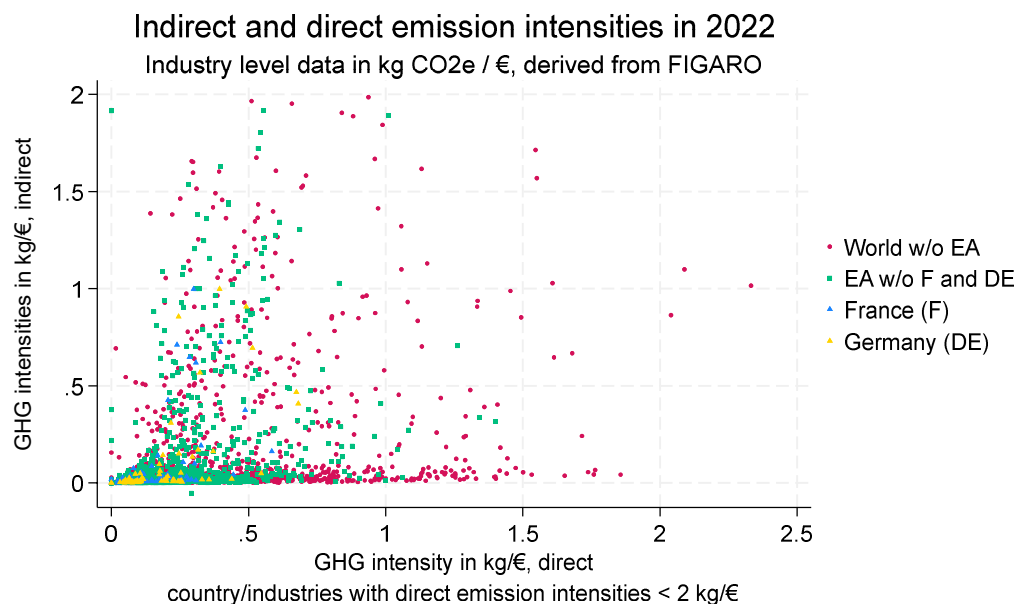


Table 1 shows a grouping of full GHG content and its components (direct plus upstream indirect emissions) according to economic area. The average GHG content of Chinese production, measured as an intensity, is impressive. The reason for the divergence to other economic areas may be due to the structure of output, to the GHG content pattern, or to both.

Table 1: GHG intensities according to economic areas of the world

	Direct	Sc 2 indir	Upstr indir	GHG content
	kg/€	kg/€	kg/€	kg/€
Euro Area	0.080	0.014	0.211	0.290
Other Europe	0.115	0.025	0.230	0.345
USA	0.113	0.027	0.165	0.278
China	0.336	0.139	0.877	1.213
Japan	0.138	0.044	0.339	0.477
ROW	0.382	0.084	0.506	0.888
Total	0.244	0.069	0.450	0.693

Sources: FIGARO input-output tables by industry, released July 2024, environmental footprints based on FIGARO, 2024 edition, up-dated on 30.01.2025, author's calculations

Table 2 illustrates two ways to take the output structure into account. Calculating the Chinese average emission intensities using the EA output structure for weighting leads to a total GHG content intensity of .977 kg per € of output. This comparison, however, ignores the technology constraints – the Chinese output in emission intensive industries is high also because their gross output is needed as intermediate input to produce final output. A consistent counterfactual is the GHG intensity that would result from producing the Euro area final output based on the technology and the emission intensity of Chinese production. This counterfactual leads to a weighted average GHG content of 0.784 kg per Euro – still quite high compared with the GHG intensity in Europe, the US and Japan, but in line with the numbers for the Rest of the World.

Table 3 makes a similar comparison for broad categories of industrial activities, comparing full GHG contents and indirect emissions. It is readily seen how important energy, manufacturing and agriculture are as drivers of emissions.

Table 2: GHG content of economic regions: standardizing the output structure

Weighting	individual entity gross output kg/€	Euro area gross out- put kg/€	Euro area final de- mand kg/€
Euro Area	0.290	0.290	0.233
USA	0.278	0.402	0.301
China	1.213	0.977	0.784
Japan	0.477	0.450	0.357

Sources: FIGARO input-output tables by industry, released July 2024, environmental footprints based on FIGARO, 2024 edition, up-dated on 30.01.2025, author's calculations

Table 3 makes a similar comparison for broad categories of industrial activities, comparing full GHG contents and indirect emissions. It is readily seen how important energy, manufacturing and agriculture are as drivers of emissions.

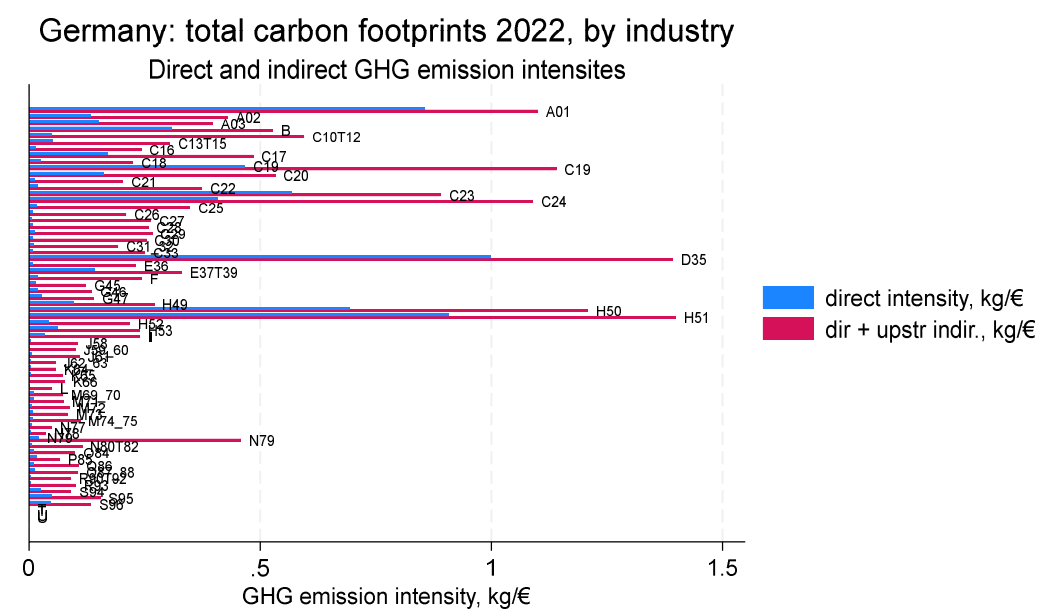
Table 3: Average GHG intensities 2022 in the world by broad activities

	Direct kg/€	Sc 2 indir kg/€	Upstr indir kg/€	GHG content kg/€
Primary	1.122	0.090	0.557	1.680
Manufacturing / re- pair	0.202	0.082	0.803	1.004
Energy / water / sewerage	2.720	0.498	1.093	3.813
Construction	0.039	0.024	0.682	0.721
Trade	0.041	0.038	0.200	0.241
Transport	0.313	0.046	0.351	0.664
Other services	0.012	0.037	0.167	0.178
Total	0.244	0.069	0.450	0.694

Sources: FIGARO input-output tables by industry, released July 2024, environmental footprints based on FIGARO, 2024 edition, up-dated on 30.01.2025, author’s calculations.

Graphs 2 and 3 look at Germany. Graph 2 gives the GHG content intensities for all of the 64 industries distinguished by FIGARO. Graph 3 provides a magnifying glass on industrial output – mining and quarrying, manufacturing and repair, utilities, and construction. Industrial output is emission intensive in general, and extremely diverse.

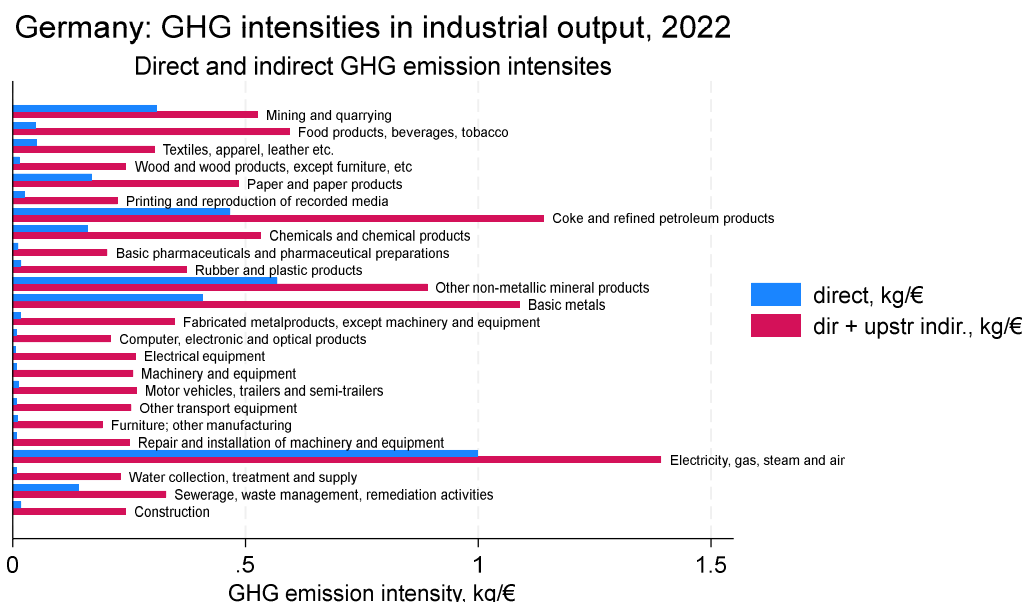
Graph 2: Germany – direct and indirect emissions for all industries



A look at these graphs shows clearly that for many industries, indirect emissions are the driver of their overall carbon footprint. Some industries use rather carbon-intensive inputs, and thus they

generate considerable emissions indirectly, even if they look almost “clean” when judged by their direct emissions alone.

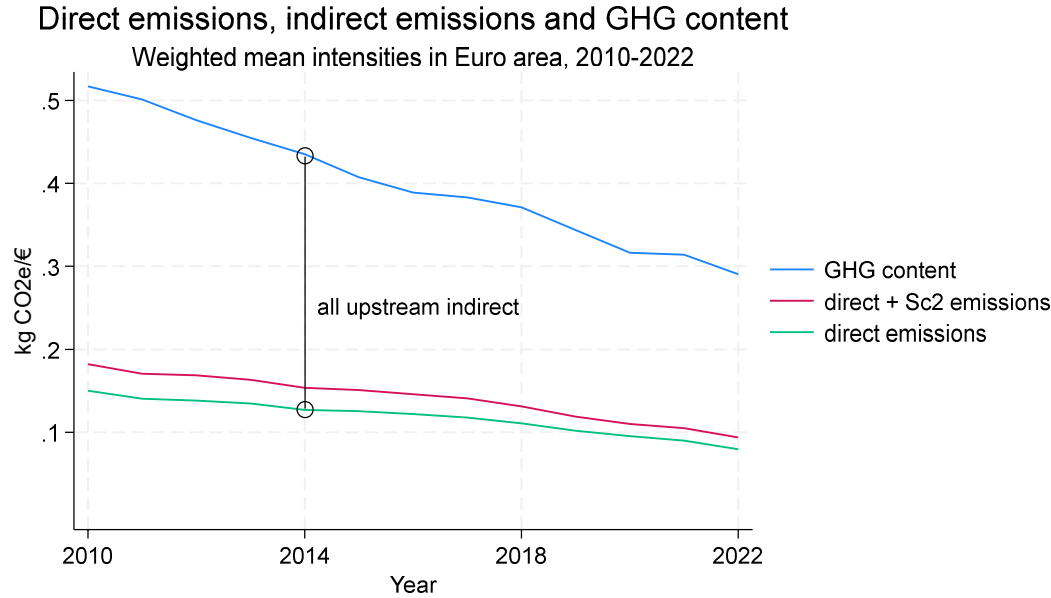
Graph 3: Germany – direct and indirect emissions for industrial output



Graph 4, finally, considers the average carbon footprint of a very large range of activities – the output of all Euro area countries. This is computed by weighting the intensities as seen in Graph 1 for 2021 by industry output of successive years. It is seen that nominal carbon intensity is going down markedly. This is partly due to price inflation. The denominator is output value in nominal Euro, so *ceteris paribus*, with physical intensities constant, intensities will decrease when prices are trending upward. The graph gives no clue, to say the least, on whether net zero by 2050 is a realistic goal.

The graph shows explicitly the three components of total GHG content. Interpreting it, one needs to be aware that much of what is shown as indirect emissions is also part of the direct emissions component underneath – namely all the emissions by Euro area companies in the course of production of input goods used in the production of Euro area companies. A curve with average GHG content per unit of final output (not shown) would be approximately on the same level with a likewise defined curve of direct emissions, as globally the sum of GHG contents of final output is identically equal to the sum of direct emissions that have been incurred in its production.

Graph 4: Output-weighted mean emission intensities for the Euro area



8 Measures to evaluate portfolios

As mentioned already, emissions attributed to a financial portfolio are a specific category of Scope 3 (downstream) emissions. This section introduces, in a generic fashion, the principal indicators being used in analysis and reporting. The four types of indicators presented here are featured by the TCFD, and the PCAF provides detailed asset specific guidance on two of them, Financed Emission and Carbon Intensity. The European System of Central Banks uses these indicators to compile statistics of the carbon emissions financed by the financial sector, see Statistics Committee's Expert Group et al (2024), Section 3.2.

Financed emissions (FE) are given as the sum of the emissions that can be attributed to the investees, scaled by the share of the investor in the total financing of the investment:

$$FE = \sum_i \text{investment}(i) \frac{\text{emissions}(i)}{\text{total assets}(i)},$$

with i being the index for the portfolio item, i.e. the investment and the investee. The result is GHG emissions enabled by the financing services of the reporting financial company, measured in tons. Depending on the assets concerned, this definition will be made more specific, e.g. to home loans, equity portfolios, or bank loans to non-financial companies. The emissions considered can be of any Scope, e.g. Scope 1 and 2 emissions. One disadvantage is that, besides the emissions, a quantification of the enterprise value is needed.

Larger financial institutions will automatically have larger financed emissions. A companion indicator that normalizes FE by the size of the portfolio is the *Carbon Footprint* (CFP) of a portfolio:

$$CFP = \frac{\text{financed emissions}}{\text{portfolio value}} = \sum_i \frac{\text{investment}(i)}{\text{portfolio value}} \frac{\text{emissions}(i)}{\text{total assets}(i)}.$$

A widely used alternative is the *Weighted Average Carbon Intensity* (WACI). This indicator is an average of the carbon intensity of the investees' output, with portfolio shares as weights. This metric needs no information on the value of total assets or equity with respect to the investee. Instead, one requires information on the size of the relevant output, very often in the form of sales or revenue. A generic formulation is the following:

$$WACI = \sum_i \frac{\text{investment}(i)}{\text{portfolio value}} \frac{\text{emissions}(i)}{\text{output}(i)}.$$

Again, the featured emissions can be of any type. In practice, the output metric in the denominator may depend on availability. However, the emission intensities being summed up need to be commensurable – sales or revenue in trade or the financial industry do not depict economic activity in the same way as in manufacturing.

The *Carbon Intensity* (CI), another widely used portfolio metric, aims to link the financed emission to the output that is enabled by the financing. It may be interpreted as a measure of efficiency, in very much the same way as the GHG intensity of a single company or product:

$$CI = \sum_i \frac{\text{investment}(i)}{\text{total assets investee}(i)} \text{emissions}(i) / \sum_i \frac{\text{investment}(i)}{\text{total assets investee}(i)} \text{output}(i).$$

This metric needs both information on the financial value tied to the investee and on the size of its economic activity, such as revenues. The indicator provides information very similar to WACI, but it looks deeper into the process of generating output. If companies vary considerably in the amount of financing they need to generate their output (and their emissions), the enabling effect of the portfolio may be better described by CI than by WACI.

9 A prototype portfolio of bank loans

This section serves for demonstrating the use of aggregate emissions data for evaluating large portfolios. As a micro level data base, I use annual accounts information from private companies in the Bundesbank's JANIS database, a research data set that has been developed from proprietary and confidential information.²³ The following may provide an intuition and serve as a guide for practical data work.

I take a sample of 2000 annual accounts two years: 2019 and 2022, giving a view on portfolio footprints just before and right after the Covid pandemic. A key variable on the company level is total

²³ JANIS collects annual financial statements of German non-financial corporations that are submitted to the Bundesbank for credit assessment purposes. For research purposes, the data are augmented and completed by financial statements from public sources. The data are anonymized and strictly confidential. Rules apply to data processing and tabulation to make re-identification impossible. See the data report by Becker et al. (2025) and the [JANIS website](#). I use vintage 19972024-2, distributed on 12.11.2025.

output, as output is the denominator of the intensities. I calculate output emulating the National Accounts (NA) definition:

$$\begin{aligned}\text{Output} &= \text{Sales} \\ &+ \text{Increase or decrease in finished or unfinished goods} \\ &+ \text{Own work capitalized}\end{aligned}$$

For gross and retail trade, output according to the NA definition is given by the margin of sales and inventory changes over expenses for purchased goods. On the company level, this is:

$$\begin{aligned}\text{Output} &= \text{Sales} \\ &+ \text{Increase or decrease in finished or unfinished goods} \\ &+ \text{Own work capitalized} \\ &- \text{expenses for purchased goods.}\end{aligned}$$

Financial services are not part of the JANIS data base, but activities auxiliary to financial services are in the sample. I exclude head offices. Financial assets that have head offices as counterparties need to be assigned emission factors geared to the principal activity of the whole company or group, which is not feasible in the anonymised setting. I also exclude sections T and U of NACE, which denote activities of non-business clients.

For both reference years, I exclude the largest centile in terms of both bank debts and output, to mimic the portfolio of a medium-sized bank that is active in financing corporate activity. In the first step, 2000 companies are randomly drawn from the annual accounts of 2019. A number of 1,079 of these are also part of the 2022 data (panel companies). The 921 companies that have dropped out between 2019 and 2022 are replaced by randomly drawn companies from the 2022 data, to keep the size of the sample constant at 2000 and emulate a floating composition of clients.

In the JANIS data, the “stayers”, as one may call the companies present in both reference years, are systematically larger than companies present in only one of the two reference years, i.e. the “leavers” and the “entrants”, respectively. In the sample portfolio, the companies no longer available in 2022 are replaced by a group of companies consisting of both stayers and entrants in JANIS, and the replacement companies are considerably larger than those having left. This makes the overall size of the portfolio grow: the average output of sample companies in 2022 is 42.5% larger than in 2019.²⁴ It is also worth mentioning that a considerable part of the companies randomly drawn for both reference years (845 in 2019 and 829 in 2022) does not have any liabilities to banks. I main-

²⁴ The selectivity induced by replacing the leavers from 2019 with a random sample from the entire cross-section of 2022 is not avoided by drawing from the new entrants, as these will also be systematically different from the leavers. Instead, one may think of replacing the leavers of 2019 by entities that are present in 2022, but not three years later, in 2025. Apart from this replacement being somewhat counterintuitive, the required data are not available at the time of drafting. Therefore, the present analysis will aim at looking through the differences induced by a floating portfolio structure, as it is unavoidable in real world analysis anyway.

tain these companies in the sample, because they may induce systematic differences between portfolio weighted and output weighted average emission intensities. Table 4 gives an overview of the sample structure.

Table 4: Two samples of 2000 German companies -- structural characteristics

	# com- panies	# w/o bank debts	Mean output, €m	Mean total assets, €m	Mean bank debts, €m	Aggregate bank debts, €m
2019						
Panel companies	1079		20,346	24,443	2,409	2,599,684
Exits	921		4,668	3,947	582	535,981
All companies	2000	845	13,126	15,005	1,568	3,135,665
2022						
Panel companies	1079		22,580	26,811	2,440	2,633,080
Replacements	921		14,151	17,692	1,988	1,831,176
All companies	2000	829	18,698	22,612	2,232	4,464,256

The annual accounts data are matched with direct, indirect and total intensities generated as described in the preceding sections.

Table 5: Portfolio structure and emission intensities -- two samples of 2000 companies each

	Manufacturing Energy, water				Other			
	Primary	and repair	sewerage	Construction	Trade	Transport	services	Total
2019								
Portfolio structure								
# companies	19	152	110	14	67	81	1,557	2,000
# with bank debts								1,155
# present in both years								1,079
Mean output, k€	3,290	33,712	18,989	57,900	43,834	20,185	8,731	13,126
Aggregate output, k€	62,510	5,124,265	2,088,748	810,606	2,936,865	1,635,001	13,593,917	26,251,912
Mean bank debts, k€ ¹⁾	1,476	1,678	1,432	50	2,154	3,950	1,432	1,568
Aggregate bank debts, k€	28,043	255,105	157,537	695	144,295	319,919	2,230,071	3,135,665
Output-weighted intensities (based on industry level information within types of activity)								
Direct int, kg/€	1.1553	0.1303	0.1161	0.0083	0.0106	0.9808	0.0265	0.1137
Scope 2 int, kg/€	0.0259	0.0314	0.0276	0.0155	0.0111	0.1689	0.0148	0.0283
Upstream indir int, kg/€	0.2959	0.4746	0.4336	0.2823	0.2774	0.4110	0.1300	0.2605
GHG content, kg/€	1.4512	0.6049	0.5497	0.2906	0.2881	1.3918	0.1565	0.3742
2022								
Portfolio structure								
# companies	20	139	121	20	82	93	1,525	2,000
# with bank debts								1,171
# present in both years								1,079
Mean output, k€	3,594	50,335	30,703	35,409	48,274	31,275	12,484	18,698
Aggregate output, k€	71,877	6,996,518	3,715,095	708,170	3,958,457	2,908,592	19,037,956	37,396,665
Mean bank debts, k€ ¹⁾	1,297	2,506	1,294	1,856	2,528	5,929	2,057	2,232
Aggregate bank debts, k€	25,933	348,380	156,556	37,128	207,278	551,434	3,137,547	4,464,256
Output-weighted intensities (based on industry level information within types of activity)								
Direct int, kg/€	0.8204	0.1076	0.0624	0.0060	0.0085	0.8074	0.0218	0.1028
Scope 2 int, kg/€	0.0209	0.0266	0.0217	0.0137	0.0093	0.1541	0.0131	0.0271
Upstream indir int, kg/€	0.2477	0.3894	0.3386	0.2574	0.2507	0.3551	0.1225	0.2284
GHG content, kg/€	1.0681	0.4970	0.4011	0.2634	0.2593	1.1625	0.1443	0.3312

1) Means are calculated over all companies, incl. those with no bank debts.

Table 5 gives descriptive statistics on the portfolio structure of the two samples. To describe the portfolio, I gather significant activities in six baskets: Primary production (mining and agriculture),

Manufacturing and repair, Energy, water and sewerage, Construction, Trade and Transport. The remaining companies have been grouped as Other Services. These companies are relatively small and clean on average; they comprise around three quarters of all companies, and half of the output. The table gives mean and aggregate output, as well as mean and aggregate bank debts. It also renders output-weighted average emission intensities: direct, Scope 2, upstream indirect and total GHG content, cradle to gate. To compute those averages, I use the original FIGARO industry classification on the level of single companies.

Table 6: Output and portfolio WACI

	Output WACI	Portfolio WACI
2019		
Direct intensity, kg/€	0.1137	0.1728
Scope 2 intensity, kg/€	0.0283	0.0365
Upstr indirect intensity, kg/€	0.2605	0.1968
GHG content, kg/€	0.3742	0.3696
2022		
Direct intensity, kg/€	0.1028	0.1440
Scope 2 intensity, kg/€	0.0271	0.0352
Upstr indirect intensity, kg/€	0.2284	0.1663
GHG content, kg/€	0.3312	0.3103

Output WACI is an average of industry-level emission intensities characteristic for assets, weighted by output. Portfolio WACI is an average over the same intensities, using aggregate portfolio weights of banks.

Table 7: Financed emissions

	Abs. values in t CO2e	Carbon Intensity (CI) in kg CO2e/€
2019		
Financed direct emissions	353,218	0.1577
Financed Scope 2 emissions	78,615.90	0.0351
Financed upstream indirect emissions	636,005	0.2840
Financed GHG content	989,223	0.4417
<i>Financed output, m€</i>	<i>2,239,551</i>	
2022		
Financed direct emissions	392,351	0.1431
Financed Scope 2 emissions	96,220.80	0.0351
Financed upstream indirect emissions	655,099	0.2389
Financed GHG content	1,047,449	0.3820
<i>Financed output, m€</i>	<i>2,742,135</i>	

Financed emissions is industry level emission intensity, multiplied by output and scaled by the share of bank finance in total finance as given by total assets. Financed output is output scaled by the share of bank finance. The ratio gives the quantity of CO2e that can be attributed to one unit of bank finance.

Tables 6 and 7, finally, characterise the portfolio emissions. To ease comparison and orientation, I put the tables side by side. Table 6 renders the portfolio WACI, together with the corresponding output WACIs again separated according to the four types of emission intensities featured in this text. There are substantial differences between portfolio and output WACI for direct and Scope 2 emissions, with portfolio WACI higher in both reference years. This, however, is all but compensated by lower upstream indirect emission WACIs. Output and portfolio WACIs are rather similar for total GHG content. Table 6 looks at financed emissions. These are computed by multiplying the emission intensities with company specific output, scaling the results with the share of banking finance in total assets. The left column gives the total quantities, in tons of CO2e for the four emission concepts. These numbers are not easily interpreted. Total financed emissions do not vary much between the reference years, although nominal financed output increases considerably. This is partly due to the modified structure of the sample, as explained above. As a result, the ratio, nominal portfolio carbon intensity, is decreasing.

It is interestingly to compare portfolio WACI and CI. In both cases, emission indicators are attributed to portfolio items. In the case of WACI, it is the simple and straightforward GHG intensities. The underlying question is to what degree the financing that is provided to companies will favour high emission activities. The carbon intensity of finance answers a slightly different and more specific question: how much emissions are generated per Euro of bank finance? If bank finance has a high share in total finance, a higher share of these companies' emissions are attributed to the

creditor bank. The comparison shows that CIs are higher than WACIs. This means that the financing share tends to be higher for high emission companies.

10 Is the German banking industry divesting from transition risk?

This section looks on the evolution of a special portfolio, the portfolio of loans to non-financial companies in Germany held by commercial banks. The same question has been addressed by Maza (2022) regarding the Spanish banking system.²⁵ The information on portfolio composition comes from the Corporate Financial Statement Statistics maintained by the Deutsche Bundesbank. For compounds of industries, size classes and legal forms, it features both the total volumes of non-financial companies' balance sheet positions and the structural ratios, as a means of providing benchmarks and insights into the evolution of structures. The data can be found and downloaded on a [dedicated page](#) of the Deutsche Bundesbank website. As of 18.12.2024, industry level data were available for the years 1999 to 2022. Given the availability of FIGARO based emission information, one may look at the period 2010-2022.

Aggregate information is available for the industry compounds listed in Table 8. The table lists, for the year 2022, aggregate sales, estimated by scaling up the available information from annual reports, average total GHG content computed for the aggregates from the more detailed industry level data compiled as discussed above, and bank loans („Amounts owed to credit institutions”): short term, long term and the totals.

It needs to be pointed out that these data do not identically reflect the lending behaviour of German banks: part of the loans were made by banks outside Germany, and, on the other side, loans of German financial institutions to non-financial companies outside Germany are not included. Furthermore, head offices and their financing are excluded from the statistics. Bank loans taken by the head office and passed on to an affiliate company may enter as “liabilities to affiliated companies”.

Based on this information, it is easy to compute the weighted average carbon intensity (WACI) of banks' loan engagement.²⁶ This is a weighted average of the industry GHG or carbon intensity, where the weights are given by the share of the respective industry in the overall loan portfolio. This indicator can be compared with the weighted average using industry outputs. If the WACI of bank loans is below the output-weighted average, this means that banks, in their credit portfolio, put a lower weight to high emission industries than what is implied by the composition of output. Additionally, a time series can reveal whether the attitude of banks towards high emission industries has changed over time. Table 9 depicts the weighted averages computed for the compounds with industry specific data in the balance sheet statistics. The weighted averages are computed for

²⁵ Besides national Input-Output data, Maza (2022) uses loan data from the quarterly financial reporting statements on credit exposure to resident companies, as well as data from the Spanish Corporate Financial Statement Statistics.

²⁶ An overall WACI for the banking sector additionally requires data on bond holdings and equity investments.

the large subset of 17 industries with specific information on aggregate bank loans from the Corporate Financial Statement Statistics, see the indented entries in Table 8.

Table 8: Revenue, average GHG content and bank loans to NFC in Germany, 2022

Statistical Aggregates	Total revenues (bn €)	Av. GHG content (kg/€)	Short term bank loans (bn €)	Long term bank loans (bn €)	All maturities (bn €)
Total	8,929.74	0.33	248.03	392.50	640.53
Production	4,655.83	0.46	127.63	212.96	340.59
Manufacturing	2,708.44	0.41	66.20	93.46	159.66
Food, beverage and tobacco	255.01	0.59	7.11	10.76	17.87
Textiles, apparel, leather, leather goods and shoes	26.67	0.30	1.05	1.10	2.15
Wood and paper products and printing	112.90	0.35	2.91	5.81	8.73
Chemicals and pharmaceuticals	325.99	0.44	9.24	8.75	17.99
Rubber and plastic, glass, and other non-metallic mineral products	172.52	0.56	5.72	7.95	13.67
Manufacture of basic metals and fabricated metal products	353.41	0.68	11.05	15.46	26.51
Manufacture of computer, electronic and optical and electrical equipment	257.31	0.24	7.27	7.18	14.45
Manufacture of machinery and equipment	319.99	0.26	8.95	7.83	16.78
Manufacture of transport equipment	634.67	0.27	8.95	21.92	30.87
Energy and water supply, disposal	1,469.88	1.07	39.19	92.89	132.08
Construction	454.35	0.24	21.86	25.36	47.22
Wholesale and retail trade; repair of motor vehicles and motorcycles	2,748.24	0.14	69.88	64.82	134.70
Motor vehicles and motorcycles: Wholesale and retail trade and repair	335.35	0.12	22.01	10.46	32.47
Wholesale trade, except of motor vehicles and motorcycles	1,710.70	0.14	34.29	30.87	65.16
Retail trade, except of motor vehicles and motorcycles	702.18	0.14	13.58	23.49	37.07
Transportation and storage	455.84	0.38	16.84	53.63	70.47
Information and communication	374.83	0.08	7.43	11.74	19.17
Business services	579.51	0.09	20.66	32.69	53.36

Sources: Deutsche Bundesbank Corporate Financial Statement Statistics, published 18.12.2024, FIGARO input-output tables by industry, released July 2024, Environmental footprints based on FIGARO, 2024 edition, updated on 30.01.2025, author's calculations. The category "Total" refers to all manufacturing, mining and quarrying, energy and water supply, disposal, construction, trade, transportation and storage, accommodation and food service activities. Not all of these activities are part of the subtotals nor are they fully reflected in the breakdowns.

The result is striking! GHG intensities are much higher in the portfolio of banks financing companies than in the output of these same companies, and the relationship has not changed over time. This means that the engagement of banks, measured by the weight of an industry in their portfolio,

is increasing in carbon intensity. Indeed, there is a strong positive correlation between the shares of industries in the aggregate portfolio of banks and their GHG intensities. For 2022, this correlation is 0.4256. As the correlation between output shares and GHG intensities is negative in 2022, the correlation between the *difference* between the weights in the portfolio and in the output is even higher, at 0.5847.

Table 9: Average GHG intensities in Germany: Output and portfolio WACI

year	Direct intensities, weighted by		GHG content intensities, weighted by	
	output	portfolio	output	portfolio
2010	0.202	0.441	0.615	0.861
2016	0.158	0.404	0.473	0.749
2022	0.095	0.207	0.323	0.442

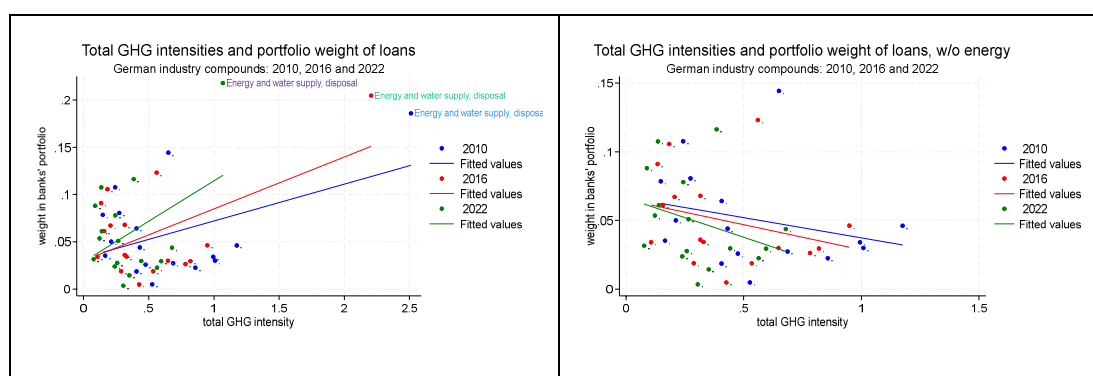
Weighted averages using weights in the bank lending portfolio and in the output composition, respectively. The averages are computed for the industry compounds with specific information on aggregate bank lending, see Table 8, indented industries

Graph 5 plots the combinations of total GHG intensities and portfolio weights for three years: 2010, 2016 and 2022. The left-hand side depicts the combinations for all 17 industries, with linear regressions fitting the data for the respective year. It becomes immediately apparent that there is one compound that has both an extremely high GHG intensity and a disproportionately large weight in the portfolio of banks: the sector formed by energy, water supply and disposal. The right-hand side shows the scatterplot for a set of industries that excludes energy.

Graph 5: Total GHG intensities and portfolio weights in end of 2010, 2016 and 2022

Including energy, water supply and disposal

Excluding energy, water supply and disposal



With this modification in the comparison, the bias towards high emission industries disappears; see Table 10 for the adjusted numerical values. From a statistical point of view, it is tempting to dismiss the pronounced dependence of the energy compound as an “outlier”. Statisticians speak of “outliers” to qualify results that are driven by random variations, and not by the underlying systematic relationship. The data points depicted here, however, are large aggregates itself. The loans to utility providers are an important part of the overall loan engagement, consisting of individual loans involving many borrowing companies and lending banks.

Maza (2022), looking at loans to Spanish non-financial companies, similarly observes that the carbon intensity in the portfolio of Spanish banks clearly exceeds the carbon intensity in the overall production of the economy most of the time. Towards the end of the data horizon, in 2018 and 2019, the carbon intensity of the portfolio approaches the overall average, due to a decarbonisation of activities as part of the portfolio, not to changes in the portfolio structure. In the publication, it is not indicated whether energy plays a specific role in this outcome.

Table 10: Removing energy. Average GHG intensities in Germany, output and portfolio weights (WACI)

Direct emissions and GHG content, energy etc. excluded

year	direct int., weighted by		total int., weighted by	
	output	portfolio	output	portfolio
2010	0.100	0.124	0.497	0.484
2016	0.080	0.096	0.378	0.374
2022	0.054	0.060	0.275	0.267

Source: see Table 9.

There is a caveat concerning the result in Germany: bank loans taken by head offices are outside the scope of the statistical data source. This may affect the results to the degree that head offices may pass on these funds to their affiliates. Part of the “loans to affiliated companies” in the balance sheet statistics thus may be originate in bank loans to the group.

11 A check through the lens of Banking Statistics

It is worthwhile to explore why the direct engagement of banks to German utilities is so disproportionately large. Utilities are predominantly in public ownership, managed by local or municipal authorities. These same authorities are also owners of the so-called *Sparkassen*, an important part of the German retail banking system. A priori, with information asymmetries in mind, it would not be surprising if public utilities get much of their financing from the likewise public local *Sparkassen* system, thereby circumventing the complications of attracting other sources of debt finance or equity. For similar reasons, it may also be that state-owned *Landesbanken* have a special focus on utilities.

The Balance Sheet Items (BSI) statistics is maintained by Euro Area (EA) central banks. It allows to track the aggregate lending behaviour of the banking system in the EA and the constituent countries. There is a common core, identical for all EA countries, and national extensions. The BSI for Germany, maintained by the Deutsche Bundesbank, allows the tracking of lending behaviour by type of bank, and the differentiation according to industry is more granular than in the common core. German BSI data can be [accessed in tables](#) and [downloaded as time series](#). With these data, it is possible to check whether the concentration of bank lending in utilities is due to the engagement of *Sparkassen* and *Landesbanken*. Furthermore, one can cross-validate the results on portfolio concentrations by means of an independent set of data.

11.1 What banks are the lenders to utilities in Germany?

Applying BSI data to the question at hand, the tentative explanation put forth above can be clearly dismissed. Table 11 considers the share of utilities in the portfolio of all banks, of *Landesbanken*, of *Sparkassen*, and of the latter two groups jointly. While state-owned *Landesbanken* are indeed slightly more invested in utilities compared to the entire banking system, this is not true if one combines their engagement with that of *Sparkassen*. During the last twelve years, the engagement of the joint group closely mirrors the engagement of all banks.

Table 11: Share of energy, waste, mining and quarrying in the loans made by type of banks

	All banks	Landesbanken	Sparkassen	Landesbanken and Sparkassen (weighted av.)
01/2011	8.12%	9.78%	9.73%	9.76%
01/2017	10.95%	12.75%	11.77%	11.77%
01/2023	10.09%	13.77%	8.37%	10.17%

Source: Balance Sheet Items for German banks, Table 8 a and b, [Banking statistics, Time series downloaded 11.04.2025](#)

11.2 Cross validation – and some interesting new results

Like the Corporate Financial Statement Statistics, the German BSI has industry level data suitable for calculating an aggregate GHG footprint of the loans portfolio of German banks. The type of information in the two statistical publications is similar though not identical. The German BSI yields information on banks with residence in Germany, not on all banks, and the industry differentiation in manufacturing is available only for loans to domestic enterprises. But apart from that, the BSI covers a wider range of creditors, including head offices, financial companies and real estate companies.

Table 12 displays the building blocks for calculating the weighted average carbon intensity (WACI) of the loans portfolio and to compare it to the weighted average GHG intensity of output. Column 2 gives the output according to industry (from FIGARO), and Column 3 the bank loans to companies according to industry. Columns 6 and 7 give the direct GHG intensities and the total GHG intensities (GHG contents) that also include the embodied emissions in the value chain, cradle to gate. As has been shown, deviations of WACI from the average GHG intensity of productions result from weight differentials – portfolio weights minus weights in aggregate output. Columns 4 and 5 compute these weight differentials for two portfolios. The first, labelled “All industries”, encompasses the loans to all companies, except for financial companies (including head offices). A second portfolio called “Production, trade, transport” more closely resembles the portfolio that was formed and investigated above with the help of the Corporate Financial Statement Statistics. In the second, more restricted portfolio, the industries *Agriculture, forestry, fishing, All real*

estate and *All services, incl. professions* have been excluded. This modifies both the portfolio weights and the weight differentials.

In the more restricted portfolio “Production, transport trade” there is a substantial overweighting of electricity, gas, water and waste, while the overweighting of this type of debtors is rather limited in the broad portfolio “All industries”. The broad portfolio, however, shows a massive overweighting of real estate. The share of real estate in the portfolio of German banks surpasses its share in the output by a whopping 26.5 percentage points. In nominal terms, the outstanding loans are larger than the entire output according to the standards of National Accounts. Table 12 is arranged in a way that enables comparison with Table 8, which has the aggregate outputs and the associated loans according to industry for the Corporate Financial Statement Statistics. The rows and data points that are salient for understanding the different results marked using bold type and red colour.

**Table 12: WACI for loans by German banks to domestic companies in 2022:
Output, loans and weight differentials for two portfolios according to German BSI**

	Output	Loans	Weight differentials		Direct intensity	GHG content
BSI Industry	mil €	mil €	All industries	Production, trade, transport	kg / €	kg / €
Agriculture, forestry, fishing	79,516	56.27	2.26%	-	0.797	1.046
Food products and beverages; tobacco products	228,654	19.81	-2.16%	-2.19%	0.048	0.595
Textiles, apparel and leather goods	24,813	3.58	-0.15%	-0.01%	0.051	0.305
Wood & wood prod.; pulp, paper, printing; furniture; manuf. nec	173,757	19.06	-1.40%	-1.02%	0.056	0.286
Chemical industry, pharmaceuticals, coke, refined petroleum products	321,814	16.52	-3.74%	-4.89%	0.192	0.587
Rubber and plastic products	103,958	7.90	-1.05%	-1.17%	0.018	0.373
Other non-metallic mineral products	60,349	5.11	-0.58%	-0.60%	0.568	0.890
Basic metals and fabricated metal products	298,605	24.55	-2.91%	-3.07%	0.192	0.679
Computer, electronic and optical products	246,306	16.47	-2.63%	-3.13%	0.007	0.239
Machinery & equipment incl installation and repair; transport equipment	885,506	46.98	-10.19%	-13.21%	0.010	0.262
Electricity, gas, water, waste	335,244	137.65	3.45%	14.13%	0.712	1.040
Construction	452,609	108.77	-0.04%	6.77%	0.018	0.243
Wholesale and retail trade; repair of motor vehicles	681,598	155.09	-0.59%	8.81%	0.022	0.135
Transportation and storage; post and courier services	463,080	65.20	-2.85%	-0.42%	0.164	0.385
All real estate	485,257	552.22	26.51%	-	0.001	0.049
All other services, incl professions	1,942,379	405.19	-3.93%	-	0.011	0.093
Total – production, transport, trade	4,276,291	626.69				
Total – all industries	6,783,443	1,640.37				

Sources: German Balance Sheet Items Statistics, downloaded 14.04.2025; FIGARO input-output tables, by industry, released July 2024; Environmental footprints based on FIGARO, 2024 edition, updated on 30.01.2025; author's calculations.

Tables 13 and 14 give the weighted GHG intensities of output and of loans for the two portfolios described above. While the “all industries” portfolio does not have a WACI that is markedly different from the carbon intensity of output, the results for the “production, transport, trade” portfolio resembles the results for the Corporate Financial Statement Statistics. The overweighting of utilities leads to an excess of the WACI in this analysis as well.

It is interesting to see the reason why the excess of WACI over the weighted average intensity of output does not result for the broader portfolio. This portfolio includes Agriculture, which is both GHG intensive and heavily bank financed. But the effect of Agriculture is more than compensated by something else. Table 12 indicates a huge concentration of loans to the real estate industry.

In economic terms, this industry is essentially about wealth management. This is the reason why credit financing is large compared to output and it also explains why the measured GHG intensities are low. The heating of houses and office buildings creates significant aggregate emissions, but these emissions are attributed to the industries of the respective users or to private households, respectively, not to the real estate companies.

Table 13: BSI results – All industries except fin. intermediation.
Direct int. and GHG content with output and portfolio weights (WACI)

Year	Direct int., weighted by		GHG content, weighted by	
	output	portfolio	output	portfolio
2010	0.182	0.218	0.545	0.472
2016	0.145	0.225	0.421	0.432
2022	0.090	0.108	0.293	0.248

Weighted averages using weights in the bank lending portfolio and in the output composition, respectively.

At this point one may doubt that WACI catches all relevant information. WACI is meant to be an indicator of transition risk, but the real estate industry may not be characterised well by the low values for direct intensity and GHG content. A sudden and marked price increase of carbon fuel may obliterate older buildings or those buildings difficult to heat in an eco-efficient way, and it may devalue large homes relative to smaller ones, following the shift of preferences and cost structures. This may well affect the finances of the real estate industry.

Table 14: BSI results – Production, transport trade.
Direct int. and GHG content with output and portfolio weights (WACI)

Year	Direct int., weighted by		GHG content, weighted by	
	output	portfolio	output	portfolio
2010	0.253	0.401	0.752	0.841
2016	0.204	0.420	0.583	0.787
2022	0.123	0.204	0.397	0.453

Weighted averages using weights in the bank lending portfolio and in the output composition, respectively.

12 France, Italy and Spain: what drives their differences?

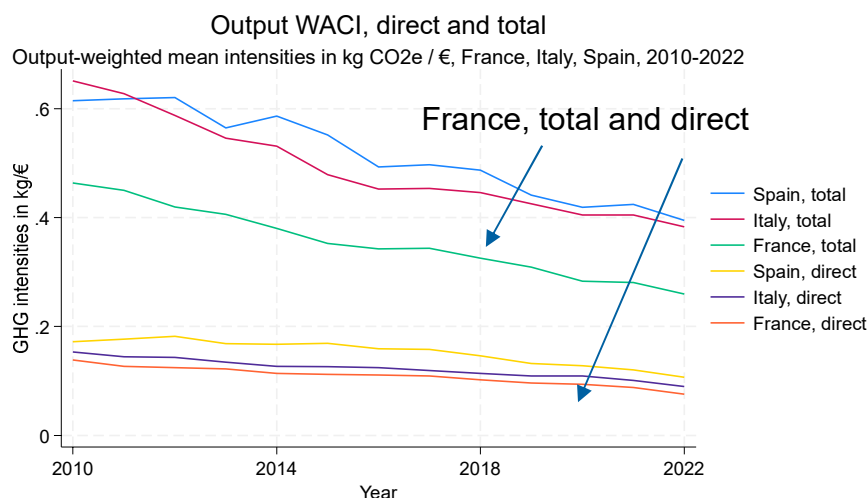
To point out the analytic potential of systematically comparing national outcomes, this section shows how international harmonised balance sheet data can be used to compute WACIs for three large European countries, using harmonised definitions and portfolio compositions.

The European Committee of Central Balance Sheet Data Offices (ECCBSO) is an organised network of European National Central Banks that maintain Balance Sheet Data Statistics. By collecting annual account data of non-financial corporations and working out harmonisation rules for diverging national account standards, the international body makes available harmonized statistical data for a large variety of industries. The central banks of Austria, Belgium, Croatia, France, Germany, Hungary, Italy, Luxembourg, Poland, Portugal, Slovakia and Spain are participating, with the ECB as observer. The ECCBSO publishes BACH,²⁷ a data base that contains statistical data on individual level annual accounts, as opposed to consolidated level accounts. Not every country level data set covers every industry. This exercise uses BACH to directly compare France, Italy and Spain. For Germany, not all necessary industry information is available.

The first step is to combine the direct, indirect and total intensities computed from FIGARO and emission statistics with the information on portfolio. Like in the case of Germany in Section 8, the relevant portfolios are the holdings of loans to non-financial companies by banks world-wide. In the analysis, 38 industries are distinguished: All of manufacturing is considered on the two digit-level and the rest of the economy on the level of sections.

Calculating WACI with output weights and portfolio weights, as above, reveals a striking difference between France on the one hand and Italy and Spain on the other hand. Graph 6 shows time series of WACIs for direct emissions and total emissions (GHG content) with output weights, Graph 7 is a corresponding visualisation for portfolio weights. Table 15 renders the WACIs for direct intensity and total GHG contents.

Graph 6: Output WACI for France, Italy and Spain: direct and total intensities



Graph 7: Portfolio WACI for France, Italy and Spain: direct and total intensities

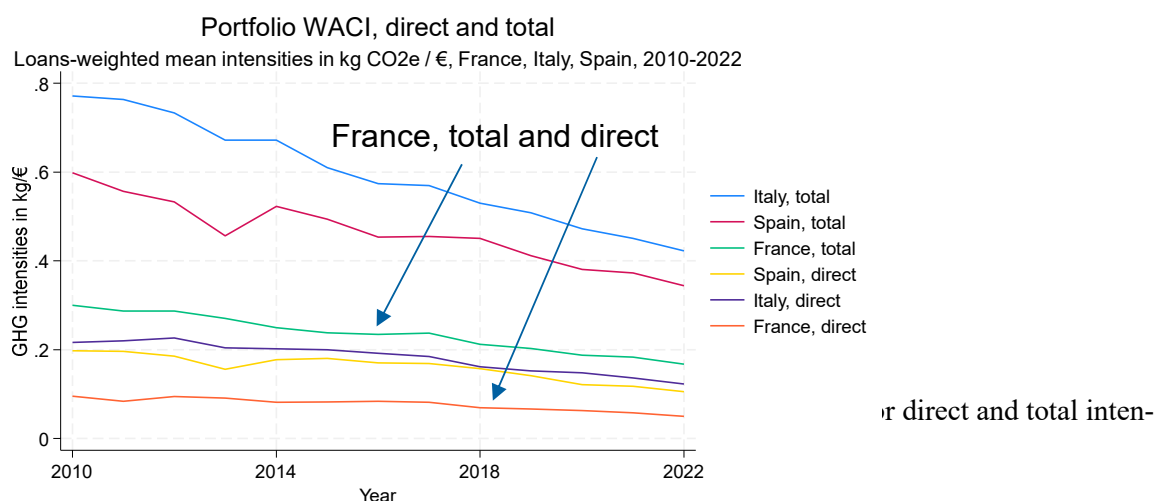


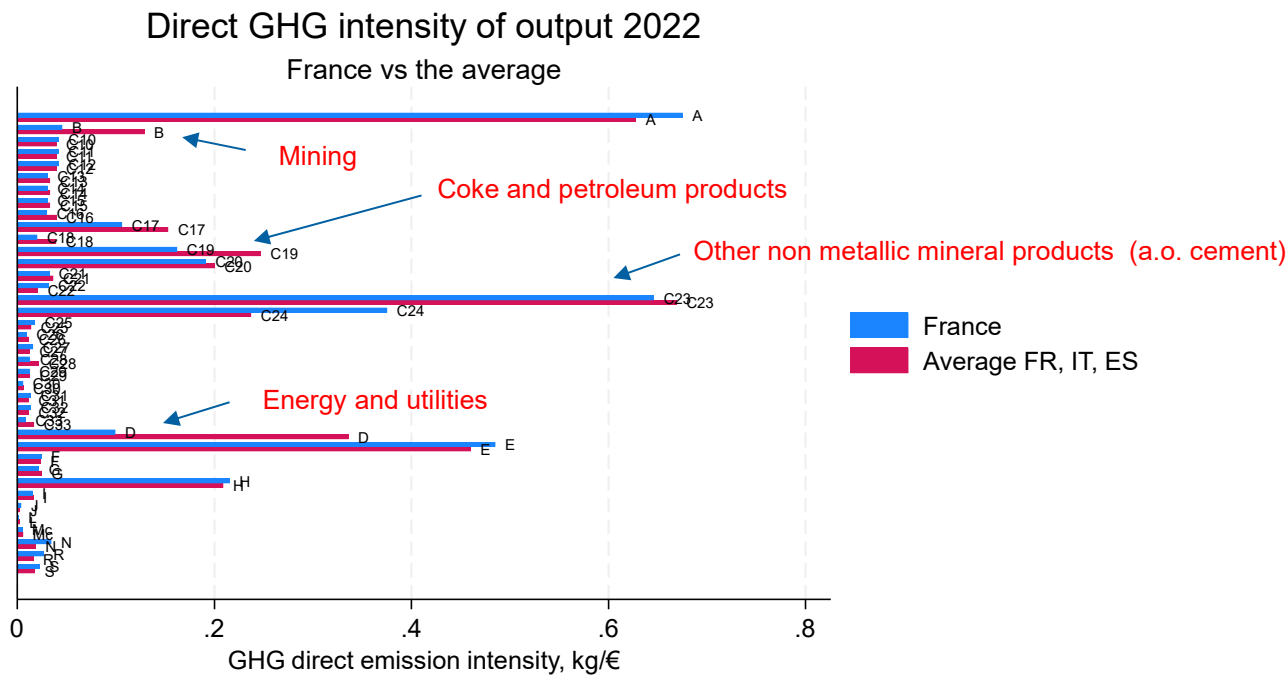
Table 15: WACI for FR, IT and ES in 2022

Country	direct intensity weighted by		total intensity weighted by	
	output	portfolio	output	portfolio
FR	.076	.050	.259	.168
IT	.090	.122	.383	.423
ES	.107	.105	.395	.344

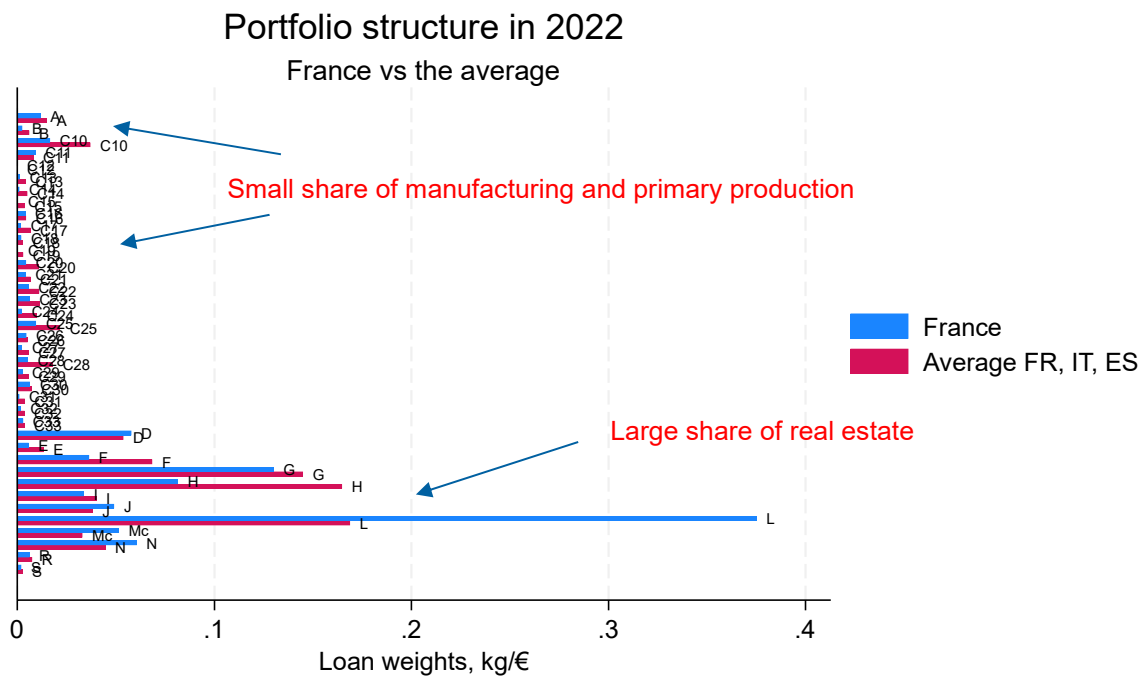
Average intensities in kg/€ of 2022, respectively using weights in the bank lending portfolio and in the output composition. Averages are computed for 38 industry compounds with specific information on aggregate bank lending from BACH.

To interpret these differences, it is necessary to look at the components of WACI. WACI is a weighted sum of intensities, with the weights given by output shares or portfolio shares, respectively. Graph 8 gives a visual overview, comparing French data with the simple arithmetic average of the three countries, including France. The graph shows that in three industries at the bottom of the value chain, intensities in France are very low: energy and utilities, coke and petroleum products and mining. These lower intensities feed into the value chain and make for low indirect intensities at later stages, specifically in manufacturing.

Graph 8: direct GHG intensities of output: France vs the average



Graph 9: The structure of bank loans to companies: France vs the average



Graph 9 makes a similar comparison of portfolio weights. In this graph, the outstanding difference between France and the average of the three countries is the high share of loans to real estate companies. While the industry has a weight of only 8.7% in national output, its share in the loans to

banks is 37.5% in France, as opposed to only 0.5% in Italy and 12,5% in Spain. The companies active in real estate have a low carbon intensity, both direct and with regards to the value chain – the activity is financial and administrative. This depresses the carbon intensity of the portfolio in France. However, as in the case of Germany, the low intensity may mask a considerable susceptibility to climate risks.

13 Important insights

The exercise conducted in this paper yields several important insights. Dealing with large portfolios, it is simple and efficient to use industry specific intensities – the more granular, the better. Both direct and total intensities (GHG contents) are needed to understand the climate implications of financing. This type of data is provided by national and international statistical agencies, and it is important to make them easily accessible. This paper makes use of a wealth of information provided by official statistics: FIGARO, emission accounts and data on bank lending, but is by no means easy to put this information to use.

Emission intensity data needs to be international, the GHG contents need to be computed on the basis of multiregional models. The paper shows the huge discrepancies between the same industries in different geographic area, and substituting, e.g., Chinese intensities by US intensities in case the former are not available, is of no use at all. Unfortunately, this is a common practice. This type of information can be an important public good, as it may serve as a source of reference values for carbon accountants to fall back upon when specific data is not available in parts of the supply chain.

WACI can be an important tool for supervisors. For the example case of Germany, our brief analysis has uncovered some quite interesting concentrations in the loans portfolio of banks. Such concentrations are easy to detect and yield important insights. The same type of analysis can be carried out for the credit portfolio of large commercial banks. The industry level intensities need to be assigned to companies using activity information of high quality. If there is company specific data, e.g. from disclosures, these can be combined with the industry specific information considered here.

Ultimately, it became clear that, in isolation, WACI as an indicator of transition risk is limited – the real estate industry may be quite vulnerable to transition risk, something that is not apparent from looking at the direct intensities and the GHG contents.

14 Selected literature and additional applications

Calculating production-based carbon footprints and total carbon intensities from IO tables and direct emission vectors is standard in the literature; see e.g. Miller and Blair (2023) Ch 13, Wiebe and Yamano (2015), Yamano and Guilhoto (2020) and the official definitions in the United Nations

(2017). Suh (2010) is a collection of essays on aspects of Input-Output Economics in Industrial Ecology. For the topic of this note, see specifically Munksgaard et al (2010). [Desnos et al \(2023\)](#) is a compilation of methods on climate stress testing. See specifically Sect. 4.2 and 4.3 on indirect emissions.

Leontief (1970) himself introduced pollution by augmenting the technology matrix to include a row of pollution generation coefficients; see Qayum (1991, 1994) for a consistent reformulation. The derivation from a micro level production interactions perspective is due to von Kalckreuth (2022). On a sectoral level, the direct approach, postulating a proportional relationship between output and pollution, was first advanced by Just (1974) and Folk and Hannon (1974).

Section 4 has already pointed to the two major endeavours regarding the use Multiregional IO data with industry level emissions data to derive carbon footprints, FIGARO and the OECD work based on ICIO. For the United States, a SEEA-style Air Emission Account is still missing. Chambers (2023)²⁸ derives GHG contents for the industries of the US economy using BEA Input-Output tables and an experimental dataset on emissions.

EXIOBASE²⁹ is an academic project specialising on environmental issues. It comes in two varieties, monetary and hybrid. The monetary version features 44 countries, 5 Rest of World regions, 200 products, 163 industries, 3 employment skill levels per gender, 417 emission categories, and 662 material and resources categories. The baseline tables have been assembled for the year 2011 and are nowcasted up to 2020.

For the future, if IO-powered statistical output is to be relevant for carbon accounting or CBAM-type administrative work, we need more disaggregation (e.g. according to types of electricity production, types of agricultural products), and physical supply and use information for some key products like energy, steel, cement and meat. The data need to be timely and of high quality, incorporating as much direct measurement as possible. Moreover, the existing information needs to be centrally and easily accessible. In short, we need the breadth and depth of EXIOBASE in combination with FIGARO's timeliness and degree of integration with National Accounts.³⁰

References

ALFIERI, Alessandra, Lauren HOLLOWAY, Ulf von KALCKREUTH, Stephan MOLL, Christian SCHMIEDER, Bruno TISSOT Carbon accounting: policy solutions for an important information gap, SUERF Policy Brief No 1045, 5 Dec 2024, <https://www.suerf.org/publications/suerf-policy-notes-and-briefs/carbon-accounting-policy-solutions-for-an-important-information-gap/>

²⁸ See [Chambers \(2023\)](#), with data appendix presenting the detailed industry results, and a presentation ([Chambers 2024](#)).

²⁹ See [Stadler et al. \(2018\)](#) and the [EXIOBASE](#) site.

³⁰ See Alfieri et al (2024) for a policy-oriented discussion.

BECKER, Thorsten., Elena BIEWEN, Dennis HÜWEL, Simone SCHULTZ, [*Individual financial statements of non-financial firms \(JANIS\), Data Report 2025-08*](#). Deutsche Bundesbank, Research Data and Service Centre, last accessed 11.02.2026.

CARNEY, Mark, Resolving the climate paradox. Arthur Burns Memorial Lecture, Berlin, September 22, 2016.

CHAMBERS, Matthew L. Proof of Concept for a U.S. Air Emissions Physical Flows Account, [*BEA Working Paper Series, WP 2023-2*](#), 2023.

DESNOS, Baptiste, Le GUENEDAL, Théo, MORAIS, Philippe and RONCALLI, Thierry. From Climate Stress Testing to Climate Value-at-Risk: A Stochastic Approach (July 1, 2023). Available at SSRN: <https://ssrn.com/abstract=4497124> or <http://dx.doi.org/10.2139/ssrn.4497124>.

FOLK, Hugh and Bruce HANNON. An Energy, Pollution and Employment Policy Model. In: Michael Macrakis (ed): *Energy: Demand Conservation and Institutional Problems*. Cambridge, MA: MIT Press, 1974, 159-173.

GUILHOTO, Joaquim, Gregory LEGOFF, Achille PEGOUE, Maria BORGA, Erich STRASSNER, IMF Multi-Analytical Regional Input-Output (IMF-MARIO) Database, [*Paper presented at the 29th Meeting of the London Group on Environmental Accounting*](#), September 11-14 2023, Pretoria, South Africa. See this [link for detailed presentation slides](#).

IFC (Irving Fisher Committee on Central Bank Statistics), Empowering carbon accounting: from data to action, by Alessandra Alfieri, Lauren Holloway, Ulf von Kalckreuth, Stephan Moll, Christian Schmieder, Bruno Tissot, IFC Report No 16, 31. Oct 2024. Available at https://www.bis.org/ifc/publ/ifc_report_16.pdf, last accessed 22.01.2025.

JUST, James. Impacts of New Energy Technology Using Generalised Input-Output-Analysis. In: Michael Macrakis (ed): *Energy: Demand Conservation and Institutional Problems*. Cambridge, MA: MIT Press, 1974, 113-128.

von KALCKREUTH, Ulf. Product carbon contents – an encompassing and market based information system, Latin American Journal of Central Banking, <https://doi.org/10.1016/j.latcb.2025.100170>, August 2025, in press, accessible online. A prior version was published under the title ‘Pulling ourselves up by our bootstraps: the greenhouse gas value of products, enterprises and industries.’ [*Deutsche Bundesbank Discussion paper 23/2022*](#), July 2022.

von KALCKREUTH, Ulf. Harnessing the power of Input-Output analysis for sustainability, IFC Working Papers No 24, 13 December 2024. Available at <https://www.bis.org/ifc/publ/ifcwork24.htm>, last accessed 22.01.2025.

KAPLAN, Robert S. and Karthik RAMANNA. Accounting for Climate Change. *Harvard Business Review* 99(6), 2021b: 120-131. Available at <https://hbr.org/2021/11/accounting-for-climate-change>, last accessed 22.01.2025.

KÖHLER-GEIB, Fritzi, Emission data – a mission for statistics. Opening address at the 2025 conference of the European Statistical Forum, 16.01.2025 in Brussels. Available at <https://www.bundesbank.de/en/press/speeches/emission-data-a-mission-for-statistics-941768>, last accessed 22.01.2025

LEONTIEF, Wassily, Factor proportions and the structure of American trade: further theoretical and empirical analysis. Originally published in the *Review of Economics and Statistics*, reprinted in Leontief, Wassily, *Input-Output Economics*. 2nd ed. New York: Oxford University Press, 1986.

LEONTIEF, Wassily. *Input-Output Economics*. 2nd ed. New York: Oxford University Press, 1986.

LEONTIEF, Wassily. Environmental Repercussions and the Economic Structure: An Input-Output Approach. *Review of Economics and Statistics* 52 (1970): 262-271.

MAZA, Luis Ángel, An estimation of the carbon footprint in Spanish credit institutions' business lending portfolio – Experimental statistics for credit institutions in Spain. 11th Biennial IFC Conference on “Post-pandemic landscape for central bank statistics” BIS Basel, 25-26 August 2022. Available at https://www.bis.org/ifc/publ/ifcb58_19.pdf, last accessed 23.03.2025.

MILLER, Ronald E. and Peter D. BLAIR. *Input-Output Analysis. Foundations and Extensions*. 3rd ed. Cambridge, etc.: Cambridge University Press, 2022.

MOLL, Stephan. Levelling up: Statistics. [Presentation, 2024a](#), Workshop on carbon content measurement for products, organisations and aggregates: creating a sound basis for decision making, Hamburg, 21.-23.02.2024.

MOLL, Stephan. What do Statisticians offer? Practical experiences and examples of the European Statistical System. [Presentation, 2024b](#), Workshop on carbon content measurement for products, organisations and aggregates: creating a sound basis for decision making, Hamburg, 21.-23.02.2024.

MUNKSGAARD, Jesper, Jan Christoph MINX, Line Block CHRISTOFFERSON, and Liselotte PADE. Models for National CO₂ Accounting. In: Suh, Sangwon (Ed.). *Handbook of Input-Output Economics in Industrial Ecology*. Dordrecht etc.: Springer, 2010, pp. 533-558.

PASINETTI, Luigi L. *Lectures on the Theory of Production*, London and Basingstoke: McMillan, 1977.

PCAF. *The Global GHG Accounting and Reporting Standard Part A: Financed Emissions*. Third Edition, December 2025.

WIEBE, Kirsten S. and Norihiko YAMANO. Estimating CO₂ emissions embodied in final demand and trade using the OECD ICIO 2015. Methodology and results. [OECD Science, Technology and Industry Working Paper, 2016/05](#), Paris 2016.

QUAYUM, Abdul. Inclusion of Environmental Goods in National Income Accounting. *Economic Systems Research* 6 (1994): 159-169.

SCHUMANN, Jochen. *Input-Output-Analyse*. Berlin, Heidelberg, New York: Springer 1968.

SUH, Sangwon (Ed.). *Handbook of Input-Output Economics in Industrial Ecology*. Dordrecht etc.: Springer, 2010.

STATISTICS COMMITTEE EXPERT GROUP ON CLIMATE CHANGE AND WORKING GROUP ON SECURITIES STATISTICS, *Climate change related statistical indicators*, [Statistical Paper Series 48](#), April 2024.

TAKAYAMA, Akira. *Mathematical Economics*, New York: Cambridge University Press, 2nd ed. 1985.

UNITED NATIONS. [System of Environmental-Economic Accounting 2012 – Central Framework](#), United Nations, New York, 2014.

UNITED NATIONS. [System of Environmental Accounting 2012, Applications and Extensions](#), United Nations, New York, 2017.

WRI and WBCSD [World Resources Institute and World Business Council for Sustainable Development]. *The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard*. Revised Edition, WRI, 2004.

YAMANO, Norihiko and Joaquim J. M. GUILHOTO. Emissions Embodied in International Trade and Domestic Final Demand. Methodology and results using the OECD Inter-Country Input-Output Database. [OECD Science, Technology and Industry Working Papers 2020/11](#), Paris, 2020.

Appendix 1: GHG content – delving deeper

To create a firm intuition for the analytics of GHG content, this appendix provides two instructive derivations of the metric in addition to the one given in the text, and a numeric example.

1. Deriving GHG content from total requirements

The GHG content of one unit of output can be derived from total input requirements. This is the standard formulation of a carbon footprint in environmental economics. See Miller and Blair (2023), pp 618-625, as well as the equations given by SEEA for computing environmental pressures in general.³¹ As has been shown in equation (3), the Leontief matrix collects the total amount of goods needed to provide *one unit of output for final use*. Consider the elements of that matrix:

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \begin{pmatrix} l_{11} & \cdots & l_{1K} \\ \vdots & \ddots & \vdots \\ l_{K1} & \cdots & l_{KK} \end{pmatrix}.$$

Here, l_{ij} is the amount of product i needed per unit of final output of product j . This includes the direct requirements of i in the production process of j , i.e. the quantity a_{ij} , plus the total amount of i needed to produce the other inputs of the production process. With the direct emissions as an outcome of production at hand, one can calculate the total emissions per unit of output. The elements $\mathbf{d}$, the direct emissions per unit of output produced, may be collected in a diagonal matrix³²:

$$\hat{\mathbf{d}} = \begin{pmatrix} d_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & d_K \end{pmatrix}.$$

Premultiplying a matrix with a diagonal matrix is tantamount to multiplying each column with the corresponding element in the diagonal matrix:

$$\hat{\mathbf{d}} \cdot \mathbf{L} = \begin{pmatrix} d_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & d_K \end{pmatrix} \cdot \begin{pmatrix} l_{11} & \cdots & l_{1K} \\ \vdots & \ddots & \vdots \\ l_{K1} & \cdots & l_{KK} \end{pmatrix} = \begin{pmatrix} d_1 l_{11} & \cdots & d_1 l_{1K} \\ \vdots & \ddots & \vdots \\ d_K l_{K1} & \cdots & d_K l_{KK} \end{pmatrix}.$$

This yields, for each product k , the total emission generated in order to provide the required quantities of product 1, 2, ... The matrix is especially useful in order to isolate the (total) emissions due to a specific intermediate product, such as energy.

To obtain the total emissions due to the production of one unit of final output, one may sum up the column elements, to obtain equation (2):

³¹ United Nations, [System of Environmental Accounting 2012, Applications and Extensions](#), New York, 2017, Section 3.3, pp 51, specifically equations 3.1 and 3.2.

³² The “hat-matrix” has the elements of the vector on the diagonal, with all other elements zero.

$$\mathbf{g} = \begin{pmatrix} g_1 \\ \vdots \\ g_K \end{pmatrix} = \begin{pmatrix} 1 & \cdots & 1 \end{pmatrix} \begin{pmatrix} d_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & d_K \end{pmatrix} \cdot \begin{pmatrix} l_{11} & \cdots & l_{1K} \\ \vdots & \ddots & \vdots \\ l_{K1} & \cdots & l_{KK} \end{pmatrix} = \mathbf{1}' \hat{\mathbf{d}} \cdot \mathbf{L} = \mathbf{d}' \mathbf{L}.$$

2. The IO price model – the analogy to value added

Equation (1) corresponds to a price equation for the value of output, given the prices of primary factors. See Miller and Blair (2023), pp. 44 and more generally Pasinetti (1977), Ch 4. Let $\mathbf{p}$ be a column vector of output prices and $\mathbf{v}$ a vector of value added (wages and profits) as a remuneration for primary inputs, labour and capital. As the value added is given as the difference between output prices and the costs of intermediate products, we obtain:

$$\mathbf{p}' = \mathbf{v}' + \mathbf{p}' \mathbf{A}, \text{ and therefore } \mathbf{p}' = \mathbf{v}' (\mathbf{I} - \mathbf{A})^{-1}.$$

This is simply equation (1) and (2) in a different guise. Note that there are row vectors on both sides of the equation because the analysis proceeding input by input, not output by output.

3. A numeric example

It may help to look at a numeric example for the relationship between direct emissions and total GHG content. Consider a toy universe of three goods, with the following values for the input requirement matrix $\mathbf{A}$, the direct emission intensities $\mathbf{d}$ and the final output quantities $\mathbf{f}$:

$$\mathbf{A} = \begin{pmatrix} .179 & .233 & .261 \\ .217 & .133 & .087 \\ .107 & .167 & 0 \end{pmatrix}; \quad \mathbf{d} = \begin{pmatrix} 15 \\ 3 \\ 14 \end{pmatrix}; \quad \mathbf{f} = \begin{pmatrix} 10 \\ 18 \\ 15 \end{pmatrix}.$$

This leads to the following expressions for the Leontief inverse $\mathbf{L}$, the total output $\mathbf{q}$ and the GHG content $\mathbf{g}$ of all goods:

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \begin{pmatrix} 1.3895715 & .45085101 & .4019022 \\ .36889529 & 1.2927497 & .2087509 \\ .21028966 & .26413026 & 1.0778649 \end{pmatrix}; \quad \mathbf{q} = \mathbf{L} \mathbf{f} = \begin{pmatrix} 28.039566 \\ 30.089711 \\ 23.025215 \end{pmatrix}; \quad \mathbf{g} = \mathbf{L}' \mathbf{d} = \begin{pmatrix} 24.894314 \\ 14.338838 \\ 21.744895 \end{pmatrix}.$$

The sum of GHG contents is, in this closed economy, identical to the sum of direct emissions:

$$\mathbf{g}' \mathbf{f} = \mathbf{q}' \mathbf{d} = 833.21564.$$

Appendix 2: Products and Industries in FIGARO – Source: Eurostat FIGARO

FIGARO - EU Inter-Country Supply, Use and Input-Output Tables (EU IC-SUIOTs)
Release: December 2023

Products (CPA 2.1)		Industries (NACE Rev.2)	
Code	Label	Code	Label
CPA_A01	Products of agriculture, hunting and related services	A01	Crop and animal production, hunting and related service activities
CPA_A02	Products of forestry, logging and related services	A02	Forestry and logging
CPA_A03	Fish and other fishing products; aquaculture products; support services to fishing	A03	Fishing and aquaculture
CPA_B	Mining and quarrying	B	Mining and quarrying
CPA_C10T12	Food, beverages and tobacco products	C10T12	Manufacture of food products; beverages and tobacco products
CPA_C13T15	Textiles, wearing apparel, leather and related products	C13T15	Manufacture of textiles, wearing apparel, leather and related products
CPA_C16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
CPA_C17	Paper and paper products	C17	Manufacture of paper and paper products
CPA_C18	Printing and recording services	C18	Printing and reproduction of recorded media
CPA_C19	Coke and refined petroleum products	C19	Manufacture of coke and refined petroleum products
CPA_C20	Chemicals and chemical products	C20	Manufacture of chemicals and chemical products
CPA_C21	Basic pharmaceutical products and pharmaceutical preparations	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
CPA_C22	Rubber and plastic products	C22	Manufacture of rubber and plastic products
CPA_C23	Other non-metallic mineral products	C23	Manufacture of other non-metallic mineral products
CPA_C24	Basic metals	C24	Manufacture of basic metals
CPA_C25	Fabricated metal products, except machinery and equipment	C25	Manufacture of fabricated metal products, except machinery and equipment
CPA_C26	Computer, electronic and optical products	C26	Manufacture of computer, electronic and optical products
CPA_C27	Electrical equipment	C27	Manufacture of electrical equipment
CPA_C28	Machinery and equipment n.e.c.	C28	Manufacture of machinery and equipment n.e.c.
CPA_C29	Motor vehicles, trailers and semi-trailers	C29	Manufacture of motor vehicles, trailers and semi-trailers
CPA_C30	Other transport equipment	C30	Manufacture of other transport equipment
CPA_C31_32	Furniture and other manufactured goods	C31_32	Manufacture of furniture; other manufacturing
CPA_C33	Repair and installation services of machinery and equipment	C33	Repair and installation of machinery and equipment
CPA_D35	Electricity, gas, steam and air conditioning	D35	Electricity, gas, steam and air conditioning supply
CPA_E36	Natural water; water treatment and supply services	E36	Water collection, treatment and supply
CPA_E37T39	Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services; remediation services and other waste management services	E37T39	Sewerage, waste management, remediation activities
CPA_F	Constructions and construction works	F	Construction
CPA_G45	Wholesale and retail trade and repair services of motor vehicles and motorcycles	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
CPA_G46	Wholesale trade services, except of motor vehicles and motorcycles	G46	Wholesale trade, except of motor vehicles and motorcycles
CPA_G47	Retail trade services, except of motor vehicles and motorcycles	G47	Retail trade, except of motor vehicles and motorcycles
CPA_H49	Land transport services and transport services via pipelines	H49	Land transport and transport via pipelines
CPA_H50	Water transport services	H50	Water transport
CPA_H51	Air transport services	H51	Air transport
CPA_H52	Warehousing and support services for transportation	H52	Warehousing and support activities for transportation
CPA_H53	Postal and courier services	H53	Postal and courier activities
CPA_I	Accommodation and food services	I	Accommodation and food service activities
CPA_J58	Publishing services	J58	Publishing activities
CPA_J59_60	Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services	J59_60	Motion picture, video, television programme production; programming and broadcasting activities
CPA_J61	Telecommunications services	J61	Telecommunications
CPA_J62_63	Computer programming, consultancy and related services; information services	J62_63	Computer programming, consultancy, and information service activities
CPA_K64	Financial services, except insurance and pension funding	K64	Financial service activities, except insurance and pension funding
CPA_K65	Insurance, reinsurance and pension funding services, except compulsory social security	K65	Insurance, reinsurance and pension funding, except compulsory social security
CPA_K66	Services auxiliary to financial services and insurance services	K66	Activities auxiliary to financial services and insurance activities
CPA_L	Real estate services	L	Real estate activities
CPA_M69_70	Legal and accounting services; services of head offices; management consultancy services	M69_70	Legal and accounting activities; activities of head offices; management consultancy activities
CPA_M71	Architectural and engineering services; technical testing and analysis services	M71	Architectural and engineering activities; technical testing and analysis
CPA_M72	Scientific research and development services	M72	Scientific research and development
CPA_M73	Advertising and market research services	M73	Advertising and market research
CPA_M74_75	Other professional, scientific and technical services and veterinary services	M74_75	Other professional, scientific and technical activities; veterinary activities
CPA_N77	Rental and leasing services	N77	Rental and leasing activities
CPA_N78	Employment services	N78	Employment activities
CPA_N79	Travel agency, tour operator and other reservation services and related services	N79	Travel agency, tour operator and other reservation service and related activities
CPA_N80T82	Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	N80T82	Security and investigation, service and landscape, office administrative and support activities
CPA_O84	Public administration and defence services; compulsory social security services	O84	Public administration and defence; compulsory social security
CPA_P85	Education services	P85	Education
CPA_Q86	Human health services	Q86	Human health activities
CPA_Q87_88	Residential care services; social work services without accommodation	Q87_88	Residential care activities and social work activities without accommodation
CPA_R90T92	Creative, arts, entertainment, library, archive, museum, other cultural services; gambling and betting services	R90T92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities
CPA_R93	Sporting services and amusement and recreation services	R93	Sports activities and amusement and recreation activities
CPA_S94	Services furnished by membership organisations	S94	Activities of membership organisations
CPA_S95	Repair services of computers and personal and household goods	S95	Repair of computers and personal and household goods
CPA_S96	Other personal services	S96	Other personal service activities
CPA_T	Services of households as employers; undifferentiated goods and services produced by households for own use	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
CPA_U	Services provided by extraterritorial organisations and bodies	U	Activities of extraterritorial organisations and bodies

Appendix 3: Geographical units in FIGARO – Source: Eurostat FIGARO

FIGARO - EU Inter-Country Supply, Use and Input-Output Tables (EU IC-SUIOTs)
Release: December 2023

FIGARO countries (EU-27)		FIGARO countries (non-EU + W2)	
Code	Label	Code	Label
BE	Belgium	AR	Argentina
BG	Bulgaria	AU	Australia
CZ	Czech Republic	BR	Brazil
DK	Denmark	CA	Canada
DE	Germany	CH	Switzerland
EE	Estonia	CN	China
IE	Ireland	ID	Indonesia
EL	Greece	IN	India
ES	Spain	JP	Japan
FR	France	KR	South Korea
HR	Croatia	MX	Mexico
IT	Italy	NO	Norway
CY	Cyprus	RU	Russia
LV	Latvia	SA	Saudi Arabia
LT	Lithuania	TR	Turkey
LU	Luxembourg	UK	United Kingdom
HU	Hungary	US	United States
MT	Malta	ZA	South Africa
NL	Netherlands	FIGW1	Rest of the world
AT	Austria	W2	Domestic (home or reference area)
PL	Poland		
PT	Portugal		
RO	Romania		
SI	Slovenia		
SK	Slovakia		
FI	Finland		
SE	Sweden		