An estimate of the Uruguayan banking system's carbon footprint

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March 24, 2025

Abstract

Measuring the carbon footprint of economic sectors is essential for assessing climate-related risks, especially for financial institutions. This paper estimates Uruguay's sectoral carbon footprint using an Environmental Input-Output (EIO) approach, focusing on the banking sector. By linking emissions to bank loan portfolios, we examine how credit allocation affects financial institutions' carbon exposure. The results show that indirect emissions reshape sectoral rankings, emphasizing the need to look beyond direct emissions. The banking sector's adjusted carbon footprint has risen over time, driven by sectoral emissions growth and changes in credit-to-output ratios. However, variations among banks highlight the role of credit allocation. Limitations include data aggregation, reliance on historical input-output data, and the inability to distinguish between loans for high-emission activities and green investments. The findings stress the need for better tools to assess financial sector climate risks.

JEL classification: E58, Q54.

Key words: climate change, carbon footprint, banking system, Uruguay.

1 Introduction

The concept of the carbon footprint has gained prominence in recent years due to the increasing urgency of addressing climate change. As highlighted by Wiedmann and Minx (2007), despite its widespread use and application, the term "carbon footprint" lacks a universally accepted definition. This ambiguity extends to measurement methods and the units used to quantify it. These challenges are further compounded by the varying scales at which the carbon footprint can be assessed, including products, cities, firms, economic sectors, or countries.

In the context of economic activity, three primary methodologies are commonly employed to estimate carbon footprints: emission factors from the Intergovernmental Panel on Climate Change (IPCC), Process Analysis (PA), and Environmental Input-Output (EIO) analysis. While the first two approaches focus on direct emissions from specific activities or production processes, the EIO method provides a broader perspective by capturing indirect emissions embedded within economic transactions.

Analyzing emissions beyond direct sources is particularly relevant, as supply chain interactions and intersectoral dependencies significantly contribute to an economy's overall carbon footprint. Direct emissions alone may underestimate the environmental impact of a sector, as they do not account for emissions embedded in inputs sourced from other industries. An alternative estimation, such as the one provided by input-output analysis, offers a more comprehensive understanding of carbon emissions by tracing them along the entire production chain. This broader perspective is essential for policymakers and financial institutions, as it helps identify critical sectors where emissions reductions can have the greatest systemic impact and supports the design of targeted mitigation strategies.

This study adopts the EIO approach to quantify the carbon footprint at the sectoral level in Uruguay, offering an alternative perspective that accounts for emissions beyond those directly generated by economic activities. It complements the study by Barón and Rodríguez (2024), which measures Uruguay's exposure in terms of product, exports and banking credit to sectors vulnerable to transition risks, by replicating the methodology applied by Avilés-Lucero et al. (2021) to the Chilean economy.

The results show that the most significant sectors in terms of emissions vary depending on whether direct emissions or input-output emissions are considered. This analysis also captures the emissions embedded in final demand components such as investment, exports, and private and public consumption.

Understanding the carbon footprint at the sectoral level is particularly relevant for financial institutions, which play a crucial role in funding economic activities. Through their lending activities, banks indirectly contribute to the carbon footprint of the sectors they finance. This paper estimates the carbon footprint of the Uruguayan banking sector by allocating emissions to financial institutions based on their credit exposure to different economic activities. By analyzing how sectoral emissions translate into the banking sector's carbon footprint, this study provides insights into the financial system's role in the transition to a low-carbon economy.

Nevertheless, this analysis has certain limitations. First, the input-output matrix (IOM) used in this study is from 2016, which may not accurately reflect changes in productive processes that have occurred since then. Second, because the carbon footprint is estimated at an aggregated level, it may not capture specific differences in production processes across products or variations in emissions among subsectors. Third, while the financial system may support investments in high-emission sectors, it may also finance green investments and sectoral transitions. However, without further information on specific projects and due to the lack of a green taxonomy, this methodology does not allow for distinguishing between these types of financing. Therefore, the results should be interpreted with caution, and additional information is needed for a more accurate assessment of the banking sector's exposure to transition risks.

This paper is structured as follows. Section 2 provides a brief overview of the literature used to define the carbon footprint and select the methodology, along with key background studies. Section 3 presents the methodology used to estimate the carbon footprint at the sectoral level. Section 4 describes the data employed for the application of this methodology in Uruguay. Section 5 discusses the estimated sectoral carbon footprint, the banking sector's carbon footprint based on its loan portfolio, and the limitations of the analysis. Finally, Section 6 concludes.

2 Related literature

In this section, we present a brief literature review of previous work related to measuring carbon footprints, with a focus on the economic activity sector to define the context and relevance of our work. Additionally, we define what we mean by carbon footprint in the context of this study.

Carbon footprints can be calculated using three primary methodological approaches: IPCC emission factors, bottom-up PA, and top-down EIO analysis. The IPCC emission factors estimate carbon emissions from various activities by employing standardized emission factors. While this method is straightforward, it does not consider the unique circumstances of specific regions and production processes (Xuerou Sheng, 2025). The PA approach provides detailed insights at the product or process level but faces limitations when applied to larger systems, such as entire sectors or economies. This method requires granular data as it breaks down emission sources into different categories for convenient quantification.

In contrast, the EIO approach offers a comprehensive view by utilizing economic IOM combined with environmental data to estimate emissions at the sectoral or national level. As mentioned by Divya Pandey (2011), the EIO methodology allows the entire economic system to be set as a boundary, making it particularly useful for measuring carbon footprints from the demand side. This enables the estimation of emissions associated with household consumption or exports. While EIO analysis assumes some level of homogeneity across products and sectors, it is highly suitable for sector-level analyses due to its robustness and scalability (Wiedmann and Minx, 2007).

Given that our analysis focuses on the sectoral level, we employ an EIO approach. This methodology accounts for indirect emissions across sectors, providing a holistic understanding of carbon emissions and their interconnections within the economy. However, the EIO approach has limitations. One key challenge is the assumption of homogeneity within sectors, which can obscure variations in carbon intensity among different products or processes. Additionally, EIO models often rely on aggregated data, which may not capture specific nuances at a finer resolution. Ensuring the accuracy and consistency of data sources is another challenge, as discrepancies between environmental and economic data can affect the reliability of results (Wiedmann and Minx, 2007).

In our work, the carbon footprint is defined differently from direct emissions by economic activity sector, also known as Scope 1 in the GHG Protocol. We define carbon footprint as the emissions embedded in the production process of each activity (intermediate) or the goods and services included in the final demand. For household final demand, we also consider emissions generated by units for heating or transport. This definition is aligned with the definition presented in Xuerou Sheng (2025).

A key reference for Uruguay is the work of Barón and Rodríguez (2024), which evaluates the exposure of the Uruguayan banking system to sectors that may be vulnerable to transition risks. This study applies two methodologies—one emissions-based and the other sector-based—to measure Uruguay's exposure to transition risk in terms of product, exports, and credit. The analysis maps and classifies economic activities based on their vulnerability to transition risks. The results indicate significant exposure to vulnerable sectors, both from the banking system perspective and at the macroeconomic level. The most exposed sectors represent between 30% (emissions-based approach) and 65% (sector-based approach) of total corporate credit. In terms of Gross Domestic Product (GDP), these sectors account for approximately 14% (emissions-based) to 40% (sector-based). Similarly, Uruguay's reliance on exports from these sectors is substantial, ranging from 70% (emissions-based) to 90% (sector-based) of total goods exports.

The primary distinction of this paper lies in its approach to quantifying emissions. Instead of focusing solely on direct emissions, we utilize the Input-Output Matrix to estimate CO2 emissions embedded in intermediate and final consumption. This alternative perspective allows for a broader understanding of carbon emissions, capturing the indirect contributions of economic activities. Consequently, sectors that rank as major contributors under a direct emissions framework may shift in prominence when their embedded emissions are considered.

Avilés-Lucero et al. (2021) found that in 2017, coal-based electricity generation and the manufacturing industry were the largest direct CO2 emitters in Chile. However, in terms of carbon footprint, the manufacturing and mining industries exhibited the highest levels of embedded CO2. Regarding final demand, exports represented the largest share of the carbon footprint, driven mainly by the external market orientation of the mining sector and parts of the manufacturing industry. In this work, we complement the estimate of Barón and Rodríguez (2024) and reproduce the exercise carried out for Chile, as presented in Avilés-Lucero et al. (2021), for Uruguay. This study serves as the basis for our approach to understanding carbon footprints at the sectoral level and offers a complementary perspective on emissions.

3 Methodology

3.1 Carbon footprint

In this section, we present the methodology used to estimate the carbon footprint of various economic sectors. The approach follows the methodology proposed by Avilés-Lucero et al. (2021) for the case of Chile.

We consider an economy with N economic activities, denoted by $i \in 1, \ldots, N$.

Each activity emits e_i gigagrams of CO_2-equivalent (gg of CO_2-eq) greenhouse gases (GHG) according to the Global Warming Potential (GWP) measure[1]. The emissions vector for all activities is represented as $\mathbf{e} = (e_1, \ldots, e_N)$.

The production vector for these activities, expressed in millions of Uruguayan pesos, is given by $\mathbf{q} = (q_1, \ldots, q_N)$.

Thus, the emissions per unit of value produced are defined as follows:

$$\mathbf{e}^d = \mathbf{e}'\hat{\mathbf{q}}^{-1}, \tag{1}$$

where:

$\hat{\mathbf{q}}$ is a diagonal matrix with the elements of $\mathbf{q}$ on its main diagonal.

$\mathbf{e}'$ represents the transpose of the vector $\mathbf{e}$.

Each element of e^d measures the amount of gg of CO_2-eq directly emitted by the activities per million Uruguayan pesos produced.

[1]Metric measure used to compare the emissions from various GHG gases by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.

According to the input-output model, the production vector $\mathbf{q}$ can be expressed as:

$$\mathbf{q} = \mathbf{A}\mathbf{q} + \mathbf{y}, \tag{2}$$

where:

$\mathbf{A}$ is the matrix of direct coefficients with dimensions $N \times N$. The columns of $\mathbf{A}$ represent the amount of inputs required per unit of value produced.

$\mathbf{y}$ is the final demand vector, expressed in millions of Uruguayan pesos. It includes private consumption, public consumption, exports of goods and services, and gross capital formation.

Equation 2 shows that the production of an activity has two types of uses: as an input for the production of other goods or services ($\mathbf{A}\mathbf{q}$) or to meet final demand ($\mathbf{y}$). Equation 2 can be rewritten as:

$$\mathbf{q} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{3}$$

The matrix $\mathbf{L} \equiv (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse, and its elements show the impact of an exogenous increase in final demand on the production of different activities. For instance, l_{ij} represents the amount of input from activity i required in the production of activity j per unit of final demand for good j.

For a final demand vector $\mathbf{y}$, if activity j demands an amount $l_{ij}y_j$ of inputs from activity i, the direct emissions for producing this input level are $e_i^d l_{ij} y_j$ gg of CO_2-eq. If we account for the CO_2-equivalent emissions from all activities involved in the production of good j, we obtain the emissions embedded in its production (E_j^e):

$$E_j^e = e_1^d l_{1j} y_j + \cdots + e_N^d l_{Nj} y_j \tag{4}$$

We will refer to these embedded emissions as the carbon footprint. The previous expression can be rewritten in matrix form as:

$$\mathbf{E}^e = \mathbf{e}^d \mathbf{L} \hat{\mathbf{y}} = \mathbf{e}^d (\mathbf{I} - \mathbf{A})^{-1} \hat{\mathbf{y}} \tag{5}$$

As Avilés-Lucero et al. (2021) note, if the production of activity j is solely used for intermediate consumption by other industries ($y_j = 0$), its carbon footprint will be zero ($E_j^e = 0$), regardless of its direct GHG emissions. This is because all of its emissions will be channeled to the activities that demand its production. Similarly, in activities where production is only directed to final demand, even if they do not emit GHGs directly, they will have a positive carbon footprint if the inputs used in the production process emit GHGs.

3.2 Carbon footprint at the banking sector

From the previous measures of carbon footprint at the activity sector level, we seek to approximate a measure of the carbon footprint of banks due to the loans they grant. We assigned GHG emissions to each bank according to its share of lending to each of the activity sectors and the estimated carbon footprint for that sector. The carbon footprint of bank i for year y will be:

$$cf_{i,y} = \sum_j \alpha_{i,j,y} E^e_{j,y}, \tag{6}$$

where:

$cf_{i,y}$ is the carbon footprint of bank i in year y
$\alpha_{i,j,y}$ is the share of bank i's credit to sector j relative to the total credit to j from all banks for year y
$E_{j,y}$ is the carbon footprint of sector j in year y

By definition, the shares ($\alpha_{i,j,y}$) for all banks across each sector and year sum to 1, i.e., $\sum_{i,j,y} = 1$. Thus, summing the banks' carbon footprints across all banks and sectors gives:

$$\sum cf_{i,y} = \sum_i \sum_j \alpha_{i,j,y} E^e_{j,y} = \sum_j E^e_{j,y} \tag{7}$$

In case all economic activity sectors (j) are financed by at least one bank, then the total banking credit fully accounts for the carbon footprint of all sectors. This can be seen as a weakness of this measure of banking carbon footprint, given that it is not reasonable to assume that banks are financing the hole emissions of the economic activity sectors because of the loans they grant.

Given this, we decided to calculate an adjusted footprint for each bank, which involves considering the credit-to-output ratio for each sector and adjusting the carbon footprint accordingly. The adjusted carbon footprint of bank i for year j will be:

$$cf\_adj_{i,y} = \sum_j \alpha_{i,j,y} E_{j,y} \frac{cred_{j,y}}{output_{j,y}}, \tag{8}$$

where:

$cf\_adj_{i,y}$ is the adjusted carbon footprint of bank i in year y

$\frac{cred_{j,y}}{output_{j,y}}$ is the credit-to-output ratio for activity sector j in year y

For each bank, the adjusted carbon footprint may vary over time due to three factors: (1) the annual estimation of the carbon footprint of economic activity sectors (sector effect), (2) changes in the share of each bank in the total credit granted by the banking sector (rebalancing effect), and (3) fluctuations in the credit-to-total output ratio of economic activity sectors (structural effect).

To calculate the sector effect ($sector\_eff$) for a bank i over time, we fix both the credit shares of sectors and the credit-to-output ratio at their values of the initial year ($y = 1$) and allow only the estimated carbon footprint of economic activity sectors to vary.

$$sector\_eff_{i,y} = \sum_j \alpha_{i,j,1} E_{j,y} \frac{cred_{j,1}}{output_{j,1}}, \tag{9}$$

For the rebalancing effect ($rebal\_eff$), the carbon footprint of sectors and the credit-to-output ratio are held constant at their values of the initial year ($y = 1$), and only the share of banks in sectoral credit is allowed to vary.

$$rebal\_eff_{i,y} = \sum_{j} \alpha_{i,j,y} E_{j,1} \frac{cred_{j,1}}{output_{j,1}}, \tag{10}$$

Similarly, to calculate the structural effect ($struct\_eff$), the estimated carbon footprint of sectors and the share of banks in sectoral credit are fixed at their values of the initial year ($y = 1$), while only the credit-to-output ratio is allowed to change.

$$struct\_eff_{i,y} = \sum_{j} \alpha_{i,j,1} E_{j,1} \frac{cred_{j,y}}{output_{j,y}}, \tag{11}$$

The adjusted carbon footprints of banks, as well as the calculated effects, are normalized relative to their values in the initial year (i.e., for $y = 1$ all three indicators equal 1). These measures allow us to observe how the adjusted carbon footprint of each bank evolves over time and determine whether changes are driven by sector emissions, changes in the distribution of sectoral credit by banks, or changes at the banking sector in the credit granted to sectors relative to their output.

By summing the adjusted carbon footprints of all banks, we obtain the total adjusted carbon footprint of the entire banking sector:

$$cf\_adj\_banks_{y} = \sum_{i} cf\_adj_{i,y} \tag{12}$$

When aggregating the adjusted carbon footprints of all banks, the total adjusted footprint for the banking system may vary over time due to two main factors: changes in sectoral emissions and changes in the credit-to-output ratios of economic sectors. However, changes in the composition of banks within sectoral credit (rebalancing) do not affect the aggregated adjusted footprint, as the aggregation for the entire banking system eliminates this effect.

One of the main limitations of this approach is that the emissions embedded in the corporate credit of banks do not necessarily mean that banks are financing this emissions, but it could mean that this sectors are investing in new cleaner technologies. Having more information about the specific projects the banks are financing and whether they are aligned or not with the transition to a low-carbon economy would help to make a more accurate assessment of the banking sector's exposure to transition risks.

4 Data

We use the most recent IOM available for Uruguay, corresponding to 2016. The analysis is conducted at the level of economic activity and is aggregated into 11 sectors, as presented in Table 1. The IOM provides a comprehensive depiction of the interrelationships among different industries within the economy.; it presents the production of industries, imports, and their use, showing the economic destination as either intermediate or final.

Table 1: Economic activity sectors in the aggregated IO matrix of 2016

Code	Description
A.1	Agricultural production, forestry, and fishing. Mining and quarrying, and related activities.
A.2	Manufacturing Industries.
A.3	Supply of electricity, gas, steam, and air conditioning, and water supply; sewerage, waste management, and remediation activities.
A.4	Construction.
A.5	Wholesale and retail trade; repair of motor vehicles and motorcycles. Accommodation and food services.
A.6	Transportation and storage. Information and communication.
A.7	Financial and insurance activities.
A.8	Real estate activities.
A.9	Professional, scientific, and technical activities. Administrative and support services.
A.10	Public administration and defense; compulsory social security plans.
A.11	Education. Social services and activities related to human health. Arts, entertainment, and recreation. Other service activities. Activities of households as employers, undifferentiated goods and services production activities of households for own use.

Source: BCU.
Notes: The table shows the economic activity sectors included in the aggregated IOM of 2016 and their description.

The activities are classified according to the Economic Activity Classification (CAE, by its acronym in Spanish), that is an adaptation for National Accounts in Uruguay of the International Standard Industrial Classification of All Economic Activities (ISIC) Revision 4. In this classification economic activities are classified according to the activity they carry out.

In order to measure the carbon footprint of the economic activity sectors we need to compute the vector of direct emissions of these sectors. We use data on emissions from the National Inventory of Greenhouse Gases (INGEI, by its Spanish acronym) of 2012, 2016, 2019 and 2022, compiled by the Ministry of Environment (MA, by its Spanish acronym). We use this time span to incorporate the most recent available data (2022), ensure a sufficiently long period to identify potential changes, and include years surrounding 2016, the reference year for the IOM. The INGEI was developed following the 2006 IPCC Guidelines. It covers the entire national territory and includes both emissions and removals of carbon dioxide (CO_2) as well as emissions of methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6).

The difficulty lies in that the data about emissions that we have in Uruguay comes from the INGEI and the classification used follows a different logic from that of National Accounts. This is a challenge because we need to map both classifications. The emissions are classified into four sectors (Table 2) in the INGEI: AFOLU (Agriculture, Forestry, and Other Land Use), IPPU (Industrial Processes and Product Use), Energy and Waste, and further disaggregated into categories and subcategories.

Table 2: Description of sectors in the National Inventory of Greenhouse Gases

Sector	**Description**
Energy	Emissions generated by the burning of fossil fuels (oil derivatives and natural gas) and fugitive emissions from fossil fuels.
Industrial Processes and Product Use (IPPU)	Emissions from industrial processes, from the use of GHGs in products and from non-energy uses of carbon contained in fossil fuels. Emissions from energy consumption during the industrial process are considered within the Energy Sector.
Agriculture, Forestry and Other Land Use (AFOLU)	Emissions generated in agricultural activities and practices, as well as CO_2 emissions and removals from land use and land use changes.
Waste	Emissions generated by the disposal of solid waste, the treatment of domestic and industrial effluents, and the incineration of waste.

Source: Intergovernmental Panel on Climate Change.
Notes: The table shows the sectors included in INGEI according to Intergovernmental Panel on Climate Change Guidelines and their description.

4.1 Mapping between economic activity sectors and GHG emissions

In this subsection, we outline the greenhouse gas (GHG) emissions from the INGEI that were allocated to each economic activity sector of the IOM and households.

A1: Livestock; land; aggregated sources and non-CO_2 emission sources from land (urea, manure management, rice); gasoline consumption for motor vehicles used in land transportation (according to the share of usage in Supply and Use Tables (COU, by its Spanish acronym), see Table 4); fuel combustion in fishing activities, mobile agricultural machinery, and liquid petroleum gas consumption in stationary activities.

A2: Fuel combustion in the refinery, cement, pulp and paper, food and tobacco industry, and chemical industry; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4); fugitive fuel emissions (these emissions are generated from oil transportation via pipeline and the distribution of natural gas, here we include the oil portion due to the refinery); cement production and lime production; other uses in carbonate processes; carbide production; iron and steel production; use of lubricants; use of paraffin wax; refrigeration and air conditioning; foam blowing agents, fire protection; aerosols; electrical equipment. For the last seven subcategories, we lack information on whether all these emissions correspond solely to the industry or if other sectors contribute. However, since these subcategories belong to the IPPU sector and are closely associated with manufacturing according to INGEI's official documents, we assume for simplicity that all emissions correspond to sector A2.

A3: Fuel combustion for electricity and heat production; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4); fugitive fuel emissions (these emissions are generated from oil transportation via pipeline and the distribution of natural gas, here we include the natural gas portion); waste.

A4: Emissions from fuel combustion in construction.

A5: Fuel combustion primarily for cooking and heating in buildings; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4).

Regarding fuel combustion for cooking and heating in buildings, INGEI data has aggregated information for commercial/institutional use (this includes commercial and institutional buildings, such as public offices, hospitals, educational centers, and restaurants, among others). Since this would cover more than the A5 sector of National Accounts, the emissions were distributed among the sectors A.5, A.7, A.8, A.9, A.10, and A.11 according to the sector's Gross Value of Production (GVP) in 2016 (see Table 3).

A6: Fuel combustion in aviation, land transportation, railways, maritime, and other transport. Land transportation emissions are divided into two: gasoline and diesel. Of the total gasoline emissions, 7% was allocated to the Transportation activity, corresponding to the percentage of gasoline product usage in vehicles related to the Transportation sector. Diesel emissions were fully assigned to the Transportation sector. In the Supply and Use Tables, we have the product "Boiler Fuels (fuel oil and diesel oil)" which includes diesel; this product is used by many activities and not necessarily for transportation, so we cannot identify from its usage which part is used by sectors for transportation or other activities (e.g., households may use it for heating). Therefore, it was decided to allocate all these emissions to the Transportation sector.

A7: Fuel combustion primarily for cooking and heating in buildings; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4).

A8: Fuel combustion primarily for cooking and heating in buildings; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4).

A9: Fuel combustion primarily for cooking and heating in buildings; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4).

A10: Fuel combustion primarily for cooking and heating in buildings; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4).

A11: Fuel combustion primarily for cooking and heating in buildings; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4).

Households: Fuel combustion primarily for cooking and heating; gasoline consumption for motor vehicles used in land transportation (according to the share of usage in COU, see Table 4).

Table 3: Share of GVP for sectors primarily related to Commerce, Services, and Public Offices in 2016

Sector	Share (%)
A.5	27.6
A.7	9.7
A.8	16.0
A.9	13.6
A.10	8.5
A.11	24.7

Source: Own elaboration based on BCU.
Notes: The table shows the share of sectors mainly related to commerce, services, and public offices in the GVP of 2016. The values sum to 100, representing the total participation of these sectors.

4.2 Description

Between 2022 and 2012 GHG net emissions increased by 28%. Specifically, in 2022 Uruguay's GHG net emissions, including the removals related to land use[2], reached almost 28500 gg of CO_2-eq (INGEI, 2024). If we exclude the land category (both its emissions and its removals), total emissions in 2022 were 37510 gg of CO_2-eq. Almost three-quarters of these emissions came from Agriculture, followed by Energy (20%), Waste (5%) and IPPU (2%).

In Figure 1, we show the direct emissions by INGEI sector assigned to each activity sector of the IOM and households, both with and without the land category.

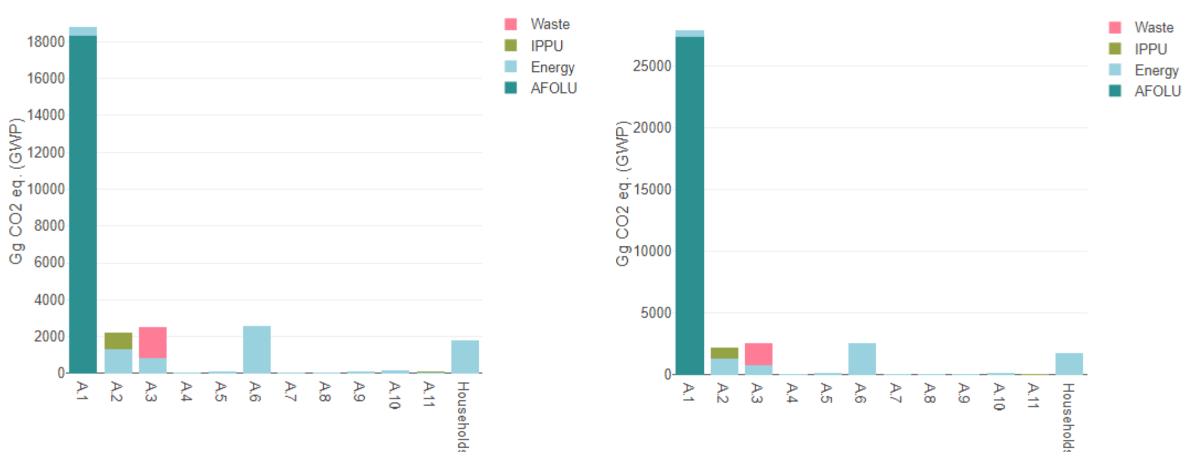
[2] CO_2 removals are mainly explained by increases in carbon stocks due to biomass growth in forest plantation and native forest areas.

Table 4: Share in the use of the product "Gasoline for motor vehicles used in land transportation" according to the 2016 Supply and Use Tables.

Sector	Share (%)
A.1	3.3
A.2	1.1
A.3	1.6
A.4	0.0
A.5	3.9
A.6	7.3
A.7	0.1
A.8	0.2
A.9	3.1
A.10	8.1
A.11	1.5
Household final consumption expenditure	69.8

Source: Own elaboration based on BCU.
Notes: The table shows the share in the use of the product 'Gasoline for motor vehicles used in land transportation' according to the 2016 Supply and Use Tables, considering the intermediate use by economic activity sectors and the final use by households through household final consumption expenditure.

Figure 1: Direct emissions by sector of activity and households according to INGEI sector - 2022



(a) With land (b) Without land

Source: Own elaboration based on BCU and INGEI.

Notes: The figures show the direct emissions (with and without land category) assigned to each economic activity sector of the IOM and households by sector of the INGEI.

5 Results

5.1 Carbon footprint at the sector level

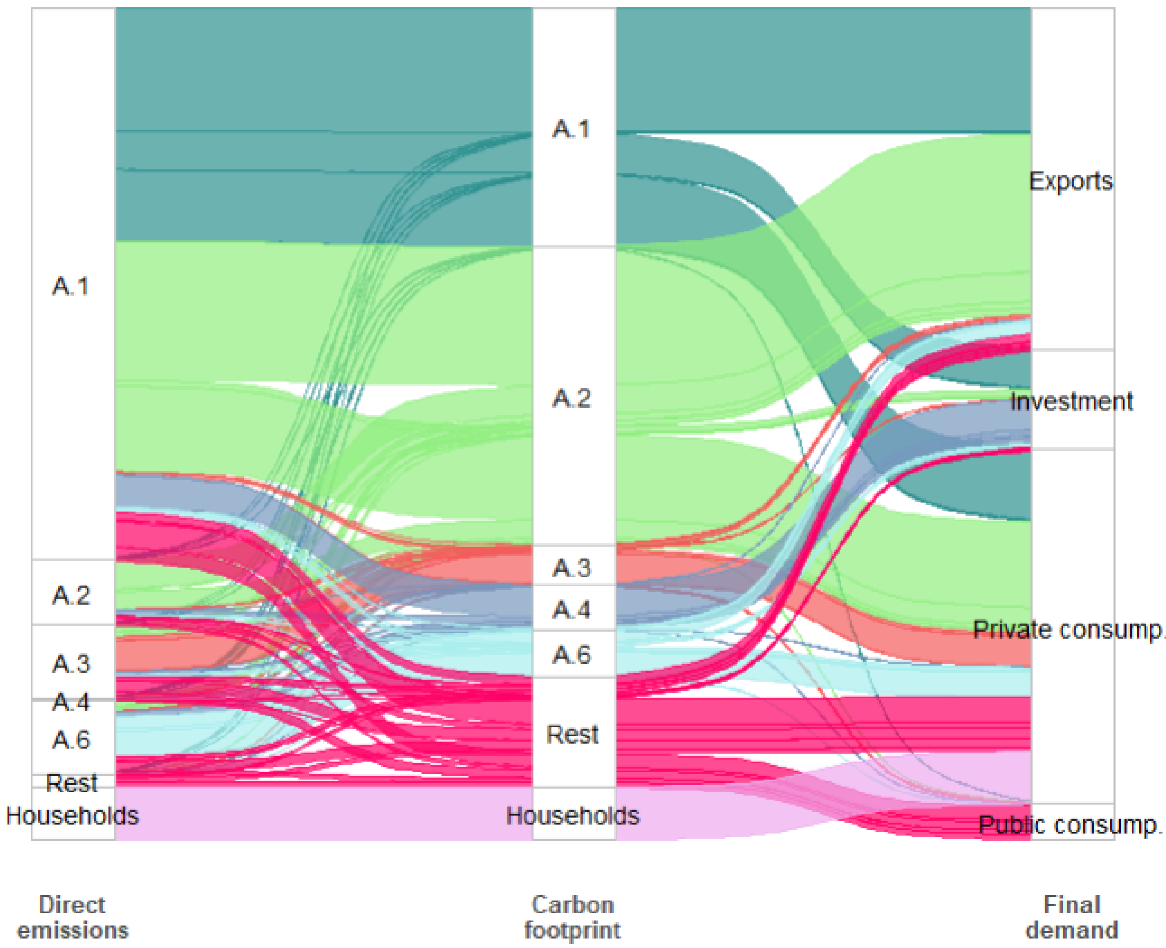
For brevity, the results of the carbon footprint at the sector level are presented for 2022. Figure 2 summarizes the main results, displaying direct emissions by economic activity sectors, the carbon footprint of each sector based on IOM relationships and the final destination of this carbon footprint by final demand component. The case of households differs slightly from that of other sectors. Their carbon footprint primarily stems from direct emissions resulting from fuel combustion for cooking and heating, along with gasoline consumption for land transportation. In terms of final demand, this carbon footprint is attributed to private consumption, which also takes into account the structure of final consumption by economic activity sector.

Figure 3 compares the direct emissions of the sectors with their carbon footprint. Note that the ordering changes, when considering only direct emissions the most emitter sector was the primary sector (A.1) but when we consider carbon footprint the most emitter is the industry sector (A.2). In the case of the electricity, gas, and water sector (A.3) and the transportation sector (A.6), the estimated carbon footprint is lower than the direct emissions. In contrast, for the remaining sectors, primarily those linked to trade and services, an increase in the carbon footprint compared to direct emissions is observed.

Figure 4 presents the composition of the carbon footprint of the economic activity sectors by the sector who generated the direct emission. This figure explains the shift in ranking between carbon footprint and direct emissions observed in the industrial (A.2) and primary sectors (A.1). About half of the primary sector's direct emissions become part of the industrial sector's carbon footprint. The industrial sector in Uruguay has a strong primary sector component and this is reflected in its carbon footprint. According to the 2016 IOM, 40% of the domestic inputs used in the industrial sector come from the primary sector. In particular, nearly half of these inputs originate from livestock farming, which is one of the main sources of GHG emissions in Uruguay.

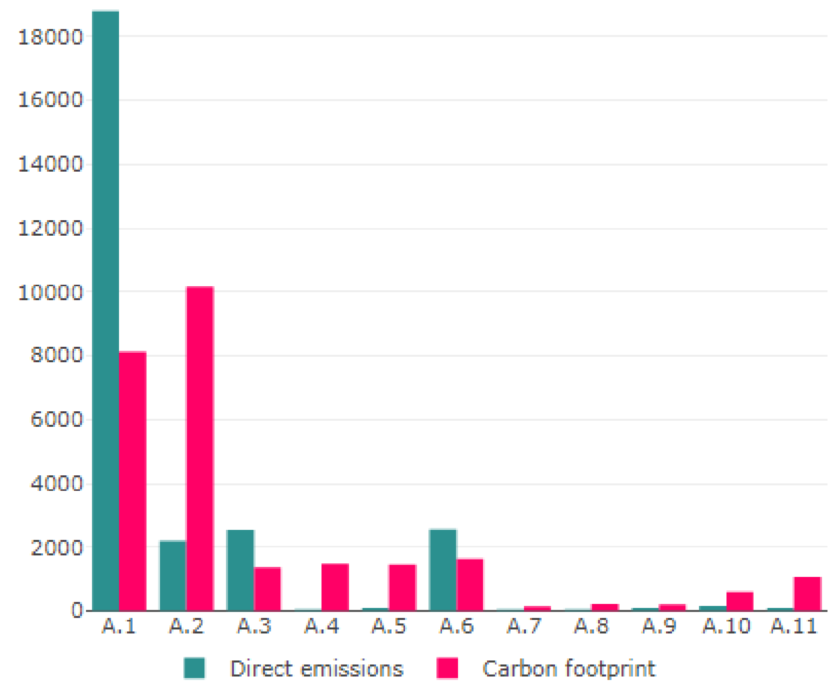
To illustrate one of the limitations of this analysis, it is worth highlighting the case of

Figure 2: Emissions flow 2022: direct emissions, carbon footprint and final demand components



Source: Own elaboration based on INGEI and BCU. Notes: The figure shows the direct emissions by economic activity sectors, the carbon footprint based on IOM relationships and the final destination of this carbon footprint by final demand component. The category Rest includes activity sectors mainly related to services, commerce and public sector, among others (the activity sectors A.5, A.7, A.8, A.9, A.10 and A.11).

Figure 3: Direct emissions and carbon footprint 2022 - Gg CO2 eq. (GWP)

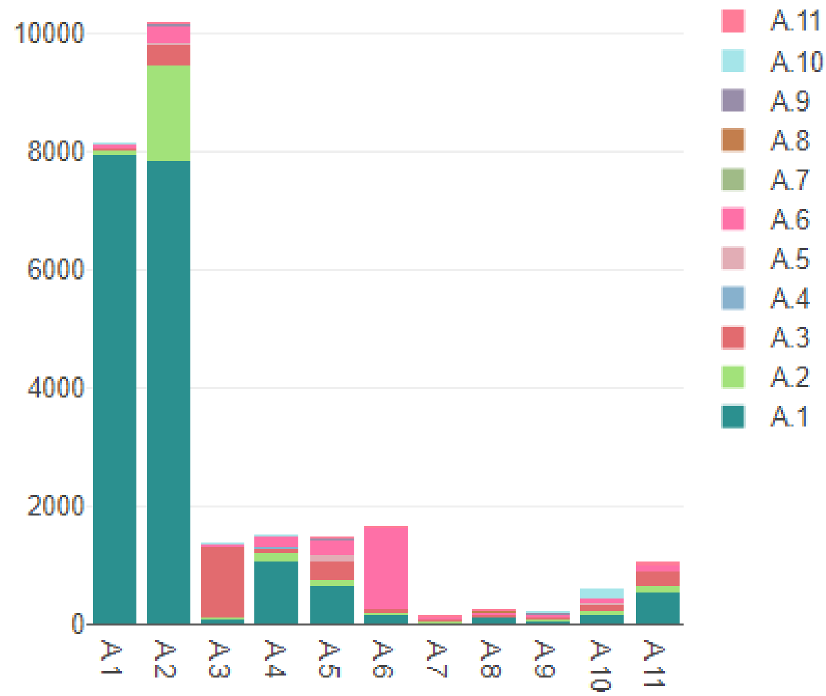


Source: Own elaboration based on INGEI and BCU. Notes: The figure shows the direct emissions assigned to each economic activity sector and its estimated carbon footprint.

the construction sector (A.4), where the carbon footprint also exceeds direct emissions (Figure 3). This sector's carbon footprint primarily consists of emissions associated with inputs from the agricultural sector and, to a lesser extent, the industrial sector (Figure 4). According to the IOM, most of the agricultural inputs used in the construction sector are related to the extraction of stone, sand, and clay, with a smaller proportion coming from forestry activities. However, due to the relatively high level of sectoral aggregation used in this analysis, emissions may be attributed to the construction sector that do not correspond specifically to its inputs but instead, for example, to livestock farming activities. This limitation may potentially lead to an overestimation or underestimation of the carbon footprint in some sectors.

Figure 5 shows how the carbon footprint of each sector accounts for the carbon footprint at the level of final demand component. Private consumption and exports are the components with the largest carbon footprint. The carbon footprint of private consumption mainly consists of contributions from the primary (A.1) and industry (A.2) sectors, along with direct emissions generated by households through fuel combustion

Figure 4: Carbon footprint by economic activity sector 2022 - Gg CO2 eq. (GWP)



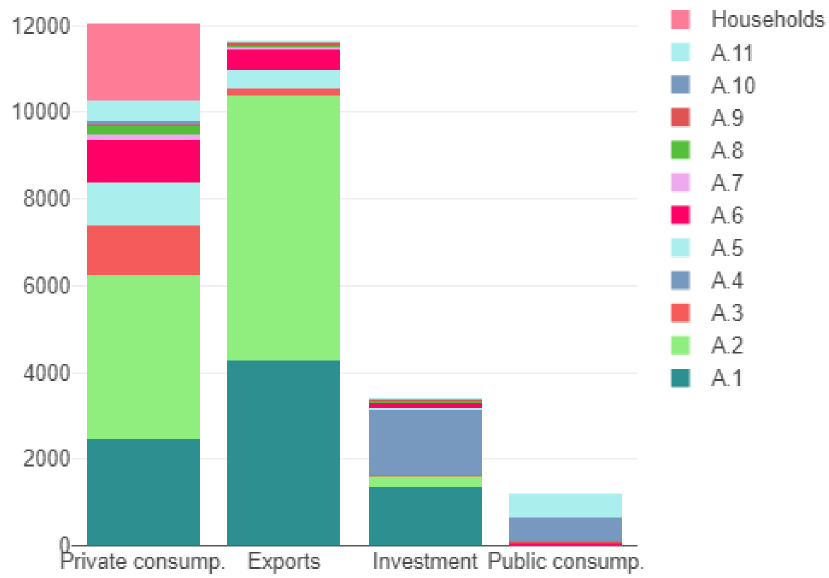
Source: Own elaboration based on INGEI and BCU. Notes: The figure presents the composition of the carbon footprint of the economic activity sectors by the sector who generated the direct emission.

for cooking and heating and gasoline consumption for land transportation. In the case of exports, the primary sector (A.1) and the industrial sector (A.2) also play a significant role, accounting for nearly the entire estimated carbon footprint of this demand component. Approximately 80% of Uruguay's goods exports come from the primary sector or the agro-industrial sector.

5.2 Carbon footprint at the banking sector

We calculated the carbon footprint of the banking sector based on the loans they grant, using GHG emissions, credit, and output data for the years 2012, 2016, 2019, and 2022 as presented in Equation 8. This enables us to analyze the evolution of each bank's adjusted carbon footprint and explore the factors that contributed to its changes. Since an IOM is not available for each of these years, we used the 2016 IOM—the most recent and temporally closest matrix to the years under analysis—to estimate the sector-level carbon footprint.

Figure 5: Final demand components and carbon footprint by economic activity sector 2022 - Gg CO2 eq. (GWP)

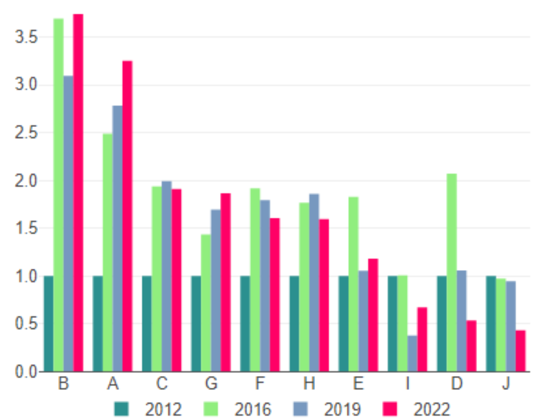


Source: Own elaboration based on INGEI and BCU. Notes: The figure presents the estimated carbon footprint for each final demand component by sector.

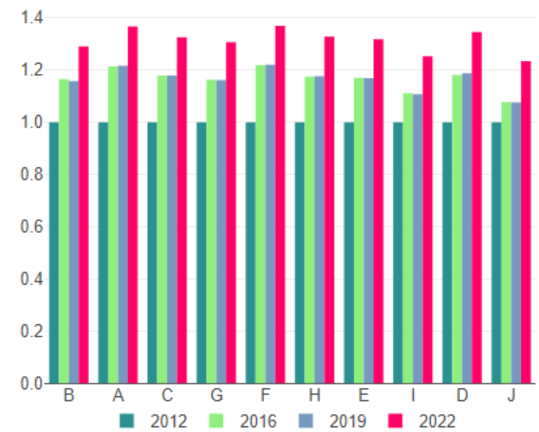
Figure 6 shows the adjusted carbon footprint, sector effect, rebalancing effect, and structure effect for each bank and year. The values of these four variables are normalized to 1 in 2012. For most banks, the adjusted carbon footprint increased from 2012 to 2022 (Figure 6a), while it decreased for three banks and remained relatively stable for one bank. Both the sector and structure effects contributed to an increase in the adjusted carbon footprint at the bank level (Figures 6b and 6d). In contrast, for all banks except two, the rebalancing effect remained stable or decreased between 2022 and 2012.

Figure 7 presents the results of calculating the adjusted carbon footprint for the banking system as a whole (Equation 12), along with the sector effect and structure effect (Equations 9 and 11). The adjusted carbon footprint nearly doubled between 2012 and 2016, for 2019 and 2022 it remained stable in the value of 2016. This increase was driven by higher GHG emissions from various sectors as well as by a change in the credit-to-output ratio across sectors. As shown in Figure 8, in 2022, most sectors had a ratio higher than in 2012, with the agricultural sector standing out in particular. Its ratio almost doubled during the analysis period and is the second most significant sector in terms of carbon footprint according to the measure used in this document.

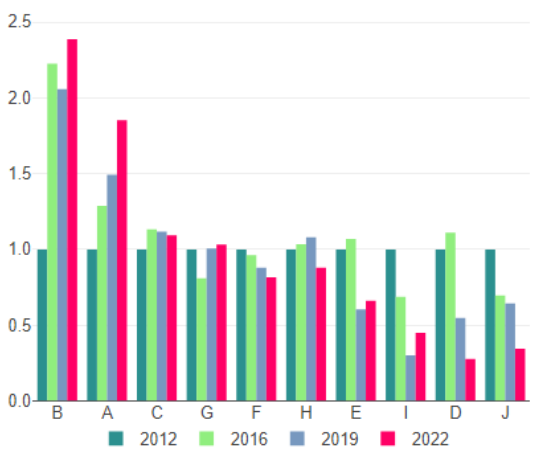
Figure 6: Adjusted carbon footprint at the bank level. Values normalized to 1 in 2012.



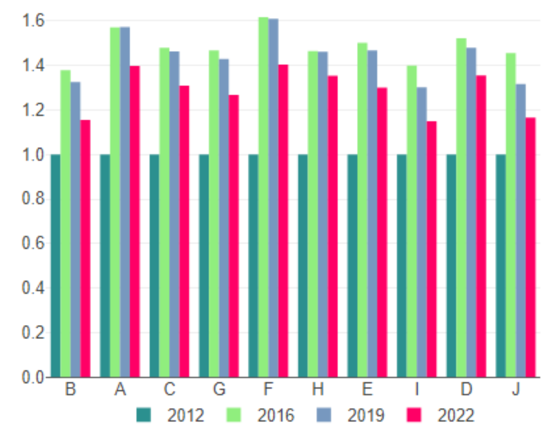
(a) Adjusted carbon footprint



(b) Sector effect



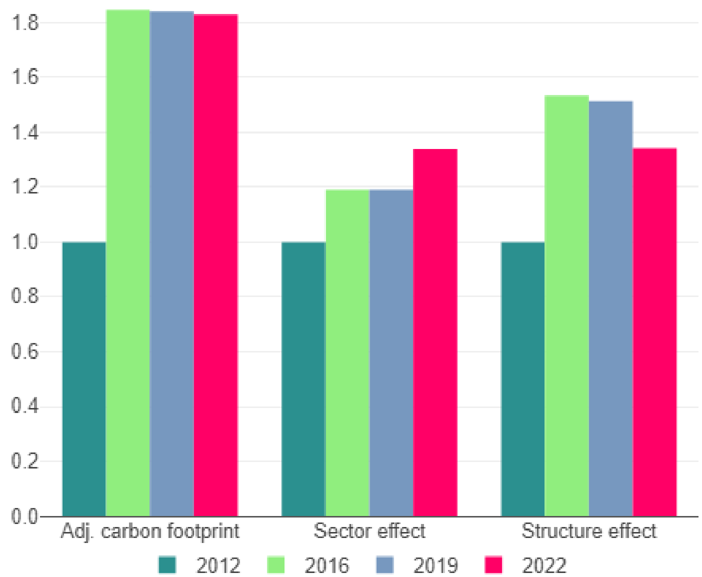
(c) Rebalancing effect



(d) Structure effect

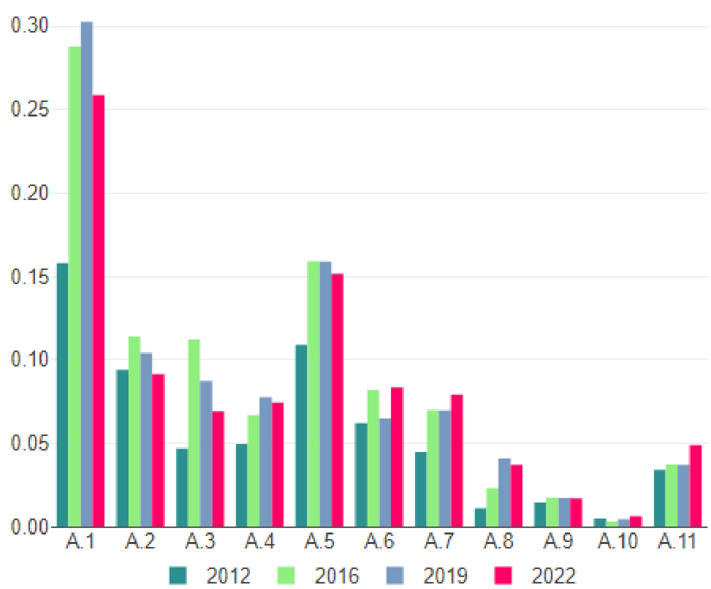
Source: Own elaboration based on INGEI and BCU. Notes: The figures show the adjusted carbon footprint (as presented in Equation 8), sector effect (as presented in Equation 9), rebalancing effect (as presented in Equation 10) and structure effect (as presented in Equation 11) by bank for 2012, 2016, 2019 and 2022.

Figure 7: Adjusted carbon footprint for the banking sector, sector effect and structure effect. Values normalized to 1 in 2012.



Source: Own elaboration based on INGEI and BCU. Notes: The figure shows the adjusted carbon footprint (as presented in Equation 12), sector effect and structure effect for the banking system as a whole for 2012, 2016, 2019 and 2022.

Figure 8: Sectoral credit-to-output ratio



Source: Own elaboration based on BCU. Notes: The figure shows the ratio of banking credit and output for each sector of activity for 2012, 2016, 2019 and 2022.

5.3 Limitations

The results presented in this study should be interpreted with caution. One of the limitations of this work is the level of aggregation of economic sectors. Working with only 11 sectors may affect the precision of the results. While it would be possible to use a higher level of disaggregation, this would require making additional assumptions during the mapping process between the economic sectors in National Accounts and the INGEI sectors where emissions are reported.

It is also important to consider that even if a bank, or the banking system as a whole, exhibits an increase in its carbon footprint due to the loans it grants, understanding the purpose of these loans is crucial. For instance, they may be directed toward investments in cleaner technologies in sectors requiring financing to support their transition. In this context, as countries develop guidelines or taxonomies to assist the financial system in evaluating projects based on environmental and sustainability criteria, it would be desirable to disclose the extent to which the loans granted by the banking system align with these criteria. For example, in 2024, large financial institutions in the European Union were required for the first time to report the environmental sustainability of their activities under the Taxonomy Regulation[3]. However, following the findings of Alessi and Battiston (2022), it is important to recognize that a financial institution may simultaneously hold substantial investments in green activities while also maintaining significant exposures to transition risks. Therefore, both aspects should ideally be considered when evaluating a financial institution's portfolio.

6 Conclusions

This study presents a sectoral assessment of the carbon footprint in Uruguay using the EIO approach, with a specific focus on its implications for the banking sector. The findings highlight that while direct emissions are concentrated in the primary and industrial sectors, the carbon footprint of final demand components, such as exports and household consumption, reflects a broader distribution of emissions across economic

[3] Delegated Act supplementing Article 8 of the Taxonomy Regulation C/2021/4987 OJ L 443, 10.12.2021, p. 9–67.

activities. The results also underscore the significance of indirect emissions, which may shift the ranking of sectors when assessing their total contribution to carbon emissions.

For the banking sector, the analysis reveals that the adjusted carbon footprint of financial institutions has increased over time, largely driven by sectoral emissions growth and changes in the credit-to-output ratio. However, the composition of banks' credit portfolios has also influenced the results, with some institutions experiencing a decline in their relative carbon footprint due to shifts in credit allocation. These findings underscore the importance of considering not only sectoral emissions but also the evolving structure of financial flows when assessing banks' exposure to transition risks.

Despite the robustness of the EIO approach, several limitations must be acknowledged. The level of sectoral aggregation in this study may obscure variations in emissions intensity across different sub-industries. Additionally, the reliance on historical input-output data presents challenges in capturing real-time shifts in production processes and emissions reduction efforts. Moreover, the analysis does not account for the purpose of bank loans—whether they are financing emissions-intensive activities or supporting investments in cleaner technologies. This distinction is critical for understanding the role of financial institutions in facilitating the transition to a low-carbon economy.

Future research should explore more granular sectoral classifications and incorporate firm-level data to enhance the precision of carbon footprint estimations. Additionally, integrating sustainability criteria into financial decision-making, such as green taxonomies and climate-aligned lending practices, will be essential for guiding the banking sector toward a more environmentally responsible role. As climate-related risks become increasingly relevant for financial stability, policymakers and financial institutions must continue refining methodologies for assessing and managing carbon exposure within the banking system.

Glossary

CH_4 Methane.

CO_2 Carbon dioxide.

GWP Global Warming Potential.

HFCs Hydrofluorocarbons.

N_2O Nitrous oxide.

PFCs Perfluorocarbons.

SF6 Sulfur hexafluoride.

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A Appendix