GLOBAL INEQUALITIES IN OWNERSHIP-BASED CARBON FOOTPRINTS OVER 2010-2022

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Global inequalities in ownership-based carbon footprints over 2010-2022

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Abstract

Who owns the firms that produce global greenhouse gas emissions? We provide the first global estimates of ownership-based greenhouse gas emissions across and within 197 jurisdictions from 2010-2022. We link production-based emissions to owners using data on wealth distributions, portfolio compositions by wealth level, public capital stocks, and foreign investment positions, among other sources. We find that a large share of ownership-based emissions is tied to a small number of asset owners. Because top wealth groups hold portfolios that are, on average, more carbon-intensive, inequality in ownership-based emissions exceeds inequality in wealth. Our results suggest that net foreign ownership emissions could play a growing role in shaping emission responsibility between countries and regions. For example, Western Europe stands out as a region where production-based emissions decline over the 2010-2022 period, but foreign ownership-based emissions do not. Although recent policies have begun to reflect concerns raised by consumption-based accounting (such as quotas on the carbon content of imports) the emissions associated with ownership of foreign production remain largely unaccounted for.

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1 Introduction, literature & contribution

The unequal distribution of greenhouse gas emissions (GHG) is a defining feature of global climate change (Bruckner et al., 2022; Chancel, 2022; Ivanova & Wood, 2020; Oswald et al., 2020; Otto et al., 2019; Wiedmann et al., 2020). Recent research has demonstrated a renewed interest in carbon accounting frameworks that move beyond purely production-based or consumption-based approaches.[1] In earlier work, we introduced the concept of ownership-based emission footprints, allocating scope 1 GHG emissions to firm owners, rather than final consumers, revealing that this perspective provides a useful complementary lens for assessing emission inequality within and between countries (Chancel & Rehm, 2025). However, consistent estimates of ownership-based emission footprints at the global level remain unavailable.

In this study, we address these limitations by producing annual, internationally comparable distributional estimates of ownership-based emission footprints within a large set of countries and at the global level over the 2010-2022 period. To do so, we construct a global dataset that integrates the most recent and reliable methods and data sources available, using national wealth distributions from the World Inequality Database (Blanchet et al., 2024), air emissions accounts and global emission databases (Eurostat, 2024; IEA et al., 2024; Remond-Tiedrez & Rueda-Cantuche, 2019), evidence on the asset portfolios held across wealth distributions (Blanchet & Martínez-Toledano, 2023; Buluz et al., n.d.; HFCS network, 2021; Piketty et al., 2018), data on public and private capital stocks (Xiao et al., 2021), and on cross-border investment positions (Cadestin et al., 2018; Damgaard et al., 2024). We define as ownership-based footprints (or emissions) all national emissions in an ownership-based framework (i.e., including government ownership and direct household emissions) and as private ownership-based footprints (or emissions) the subcategory of emissions that are linked to assets and firms owned by private individuals. Our global dataset covers 197 jurisdictions and more than 99% of the world in terms of global greenhouse gas emissions, wealth, population and GDP.

Ownership-based emission footprints offer new insights into the structure of carbon inequality both within and across countries, which cannot be studied in other frameworks. At the global level, they show how the ownership of polluting firms and their associated emissions is concentrated and

[1] See Chancel (2022), Jakob et al. (2021), Kander et al. (2015), Marques et al. (2012), Ortiz et al. (2020), Peters et al. (2015), Pottier and Le Treut (2023), and Starr et al. (2023).

how this concentration has evolved over time. They also reveal whether wealthier groups hold assets that are, on average, more or less carbon intensive than those owned by others. Across countries, ownership-based footprints can identify whether countries' net foreign ownership emissions are positive or negative. A positive position implies greenhouse gas emissions of foreign production owned by domestic investors exceed those in domestic firms owned by foreigners. International ownership patterns of polluting firms and assets remain an overlooked dimension in climate policy research, which has largely focused on policies that are based on the location of producers or consumers (Döbbeling-Hildebrandt et al., 2024; Köppl & Schratzenstaller, 2023), rather than investors, studying instruments such as national carbon taxes (Andersson, 2019), carbon border adjustment mechanisms (Beaufils et al., 2023) or emissions trading schemes (Dechezleprêtre et al., 2023; Klemetsen et al., 2020). Comparing ownership-based footprints with production and consumption-based footprints across countries and regions helps to understand whether ownership structures reinforce other types of global emission imbalances, like those caused by the net emission transfers between regions due to the import and export of goods and services (Grubb et al., 2022). Some earlier studies examined multinational enterprises' emissions (López et al., 2019; Ortiz et al., 2020; Zhang et al., 2020), but these studies typically assign emissions of subsidiaries to the headquarter of the group, rather than to the countries where the ultimate owner individuals are located.

This study makes several contributions. First, it provides the first global distributional estimates of greenhouse gas emissions based on the ownership of emitting firms. Second, it offers the first detailed account of ownership-based emissions within and between a broad set of countries and over time. Third, it traces the evolution of ownership-linked emissions over a twelve-year period. Finally, it uncovers patterns in the cross-border ownership of emissions (such as net foreign ownership emissions), highlighting a new dimension of international climate accountability.

Our method can be summarized as follows: We begin by using cross-country data on foreign investment and economic activity to estimate the share of national production owned by foreign investors. These emissions are then reassigned to the countries where the owners are based. We exclude direct household emissions and split the remaining national emissions between private investors and governments, based on each country's public capital stock. Within countries, we distribute privately owned emissions across the wealth distribution, using additional data on the

weight of equity and private firm ownership across national wealth distributions. Finally, we combine the national distributions to obtain the global distribution of private ownership-based emissions for the years 2010 to 2022. In an extension, we also distribute government and direct household emissions to individuals based on simplified assumptions. We find that these simplified estimates are very consistent with the country-level results for the three countries previously studied in a similar framework (Chancel & Rehm, 2025).

2 Results

2.1 The outsized role of global and national top wealth groups as owners of polluting firms and assets

– Insert Figure 1 –

Results at the global level. Our findings underscore the outsized role of global top wealth groups as owners of polluting firms and assets (Figure 1). In 2022, the global top 1% wealth group (around 80 million individuals) accounted for nearly 41% of private ownership-based emissions (29.9 billion tCO2e), exceeding the group's 36% share in global wealth. More than three quarters of private ownership emissions (77%) can be linked to the global top 10% wealth group. Average per capita emissions from privately owned assets were close to 165 tCO2e for individuals in the global top 1% wealth group (and 33 tCO2e for the top 10%) in 2022. This compares to average global private ownership-based emissions of 4 tCO2e per capita. When looking at all ownership-based emissions (including government ownership emissions, for instance), the global average is 6.5 tCO2e. The average private ownership emissions of an individual in the global top 1% group exceed global per capita emissions by a factor of more than 25. Ownership-based emissions are also significantly more concentrated at the top than consumption-based emissions (Bruckner et al., 2022). We do not find a decline in global top wealth groups' private ownership emissions between 2010 and 2022. Instead, our estimates suggest the top 1% per capita emissions linked to private asset ownership stood at 158 tCO2e in 2010 and 165 tCO2e in 2022. Within the top 10% group, averages were 31 tCO2e per capita in 2010 and 33 tCO2e in 2022. Per capita greenhouse gas emissions registered a very modest decline of approximately 1% over the period at the global level.

– Insert Table 1 –

Global wealth vs. ownership emission shares. Why are the top wealth groups' emission shares from private asset ownership higher than these groups' respective shares in global wealth? We show that the finding can be explained by two effects (Table 1). First, accounting for net foreign ownership emissions increases top wealth groups' emission shares. This implies that members of the global top wealth groups are disproportionally located in countries which tend to own more polluting assets abroad than the rest of the world owns in their own countries (e.g. Germany or the UK). Second, the emission share of top wealth groups increases significantly after accounting for the asset portfolios held across wealth distributions within countries: consistent with earlier work,15 individuals in the top wealth groups hold a larger share of high carbon intensity assets (such as firm equity and self-employed businesses) relative to total wealth, compared to other groups, who tend to hold more low-intensity assets like housing. Accounting for cross-border investment and asset portfolios (jointly) increases the global top 10%'s private ownership emission share from 68% to 77% in 2022.

– Insert Figure 2 –

Country-level results. Country-level estimates confirm that private ownership emissions are highly concentrated among top wealth groups within countries. Per capita values for the national top 1% stand at 36 (Nigeria), 48 (Pakistan), 90-100 (India, Indonesia, Vietnam) to 219 (United Kingdom), 249 (France), 252 (Japan), 331 (Germany), 419 (United States) or 693 (Russia) tCO2e. At 172 tCO2e per person, China's top 1% group lies relatively close to the global top 1% group in terms of its private ownership emissions (165 tCO2e).

Ownership emissions of top wealth groups are several orders of magnitudes higher than production-based per capita emissions in the respective countries (Figure 2).[2] For example, top 1% private ownership emissions exceed per capita production-based emissions by a factor of 16 (China), 24 (United States), 35 (India), 39 (Russia), 35 (Germany), 29 (United Kingdom) and 39 (France) in 2022. The factor lies in the 16-45 range in all top 25 emitting countries in 2022. The highest relative difference is observed in South Africa where the top 1% wealth group's private

[2]Tables presenting detailed results by country are included in Supplementary Information 2.

ownership emissions stand at 385 tCO2e compared to per capita production-based emissions of 8.5 tCO2e in 2022. As a result, the degree of private ownership emissions concentration significantly exceeds the inequality measured in other carbon accounting frameworks (Bruckner et al., 2022; Chancel, 2022; Hubacek et al., 2017; Starr et al., 2023).

In addition, we find that private ownership emissions are more unequally distributed than wealth (or net worth). In 2022, the difference between the private ownership emission share and the top 1% wealth share ranges from 3 percentage points (China, United States) to 16-19 percentage points (France, Germany, India) while other top 25 emitting countries fall within that range. This finding is driven by the portfolio composition across wealth distributions: wealthy individuals tend to possess asset classes that are more carbon intensive than other groups.

Time trend. Between 2010 and 2022, the share of private ownership emissions increased from 54% to 58% of global emissions, due to a relative decline in government-owned emissions and stable private household emissions. At the global level, the increase in the overall share of private ownership emissions (among global emissions) contributed to a growing gap in emissions between top groups and the rest of the population. Private ownership emissions among top wealth groups (both the top 1% and top 10%) increased or declined at a slower rate than overall per capita emissions in most countries that reduced emissions and rose faster than per capita emissions in countries where emissions increased over the same period.[3] For example, in the United States, per capita private ownership emissions decreased by 12% between 2010 and 2022 from 13 to 11 tCO2e while private ownership emissions in the top 1% decreased by 5% from 441 to 419 tCO2e per capita. In comparison, production-based emissions per person in the US decreased by 17% in 2010-2022.

Extension: Including government and household emissions. We also produce simplified global estimates that distribute all emission categories to individuals, i.e. including government ownership and direct household emissions, rather than private ownership emissions only. Under this scenario, the global top 10% accounted for 60% of emissions in 2022 in our benchmark estimate, with bounds ranging from 53% to 66%, depending on the conventions used. Per capita emissions in

[3] In relative terms compared to their 2010 levels. This holds for most top 25 emitting countries in 2022 and at the global level, except for Pakistan, Viet Nam and Argentina, where per capita production-based emissions increased more strongly than top 1% ownership-based emissions in 2010-2022. In Saudi Arabia, production-based per capita emissions increased slightly between 2010 and 2022 while per capita private ownership emissions of the country's top wealth groups declined, although from a comparatively high level. In Australia and Poland, top 10% private ownership emissions decreased more strongly than production-based emissions although from a high baseline in Australia (134 tCO2e in 2010).

the global top 10% wealth group amount to 44 tCO2e and 5 tCO2e in the middle 40% group in 2022, compared to 33 tCO2e and 2 tCO2e when considering private ownership-based emissions only (Figure 1). Private ownership emissions account for almost 80% of total emissions of the global top 1% vs. around 15% in the global bottom 50% wealth group.

Comparison with earlier work. For the three countries previously analyzed in more detail in earlier work (Chancel & Rehm, 2025), we find that our simplified methodology aligns closely with the earlier estimates. For example, top 10% shares in total private ownership-based footprints are comparable in the US (74% using this paper's methodology vs. 72% in the more detailed paper, 2019), Germany (73% vs. 68%, 2017)[4] and France (86% vs. 84%, 2017).

2.2 Net foreign ownership emissions of countries and regions

We identify large differences across countries regarding their net foreign ownership emission position. This perspective complements other approaches used to compare emissions internationally, such those based on comparing production-based and consumption-based emissions. Following our ownership-based framework, a country's footprint includes all direct greenhouse gas emissions (scope 1) of facilities owned by its residents and the government (whether located abroad or in the country), plus the direct household emissions[5] released by its residents. Additional country-level results are provided in Table S2.1 in SI 2.

– Insert Figure 3 –

Western Europe, Japan & Korea. Major Western European countries stand out as both net importers of emissions under consumption-based carbon accounting, and as countries with large positive net foreign ownership emissions in our ownership-based framework. For example, in the UK, France, Italy, Germany, adjusting emissions for cross-border investment increases each country's production-based emissions in 2022 by 40%, 38%, 25%, 16%, respectively (Figure 3). This implies that, in addition to importing (net) emissions through purchasing foreign-made goods, Western European investors also hold significant ownership stakes in polluting production abroad

[4]Wealth inequality estimates for Germany in the year 2017 have been revised since the preparation of the earlier paper. The top 10% wealth share in 2017 is estimated at 59% in the updated WID series used in this paper vs. 56% in the sources used in the earlier paper.

[5]Including, for example, those linked to private heating and transport.

– and these emissions exceed those related to production within Western Europe that is owned by the rest of the world. In 2022, net foreign ownership emissions in the Western Europe region show similar orders of magnitude (+33% of production-based emissions) as the net emissions imported via international trade (+35%). It is important to note, however, that this does not have to be the case in the future: wealthy countries could reduce both their production- and consumption-based emissions, while still maintaining high levels of ownership-based emissions.

We also find a marked increase in net foreign ownership emissions in major Western European countries over 2010-2022. Two simultaneous developments in the country group drive these trends: While production-based emissions (measured in tCO2e per capita) declined, gross foreign ownership emissions (measured in tCO2e per capita)[6] remained stable (or even increased) over the 2010-2022 period. We observe similar patterns in South Korea and Japan.

Central and Eastern Europe. Countries in central and eastern Europe tend to show persistent and significant negative net foreign ownership emissions. This country group includes Poland, Ukraine, Romania, Czechia, Hungary or Bulgaria, for example. The rest of the world tends to own polluting production facilities in these countries, and these emissions exceed emissions released abroad in facilities owned by investors from the respective country. Note that large Western European economies and the United States, whose domestic economies are relatively less carbon intensive per USD of GDP, are among the largest inward investors in many of these countries. Russia also shows a negative net foreign ownership emission position, which appears to be widening over the 2010 to 2022 period. In our dataset, the largest foreign holders of Russian emissions are based in Cyprus and the Bahamas, countries known to hold offshore wealth (Alstadsæter et al., 2018). This may signal that parts of the "foreign"-owned emissions in Russia are in fact owned by Russian residents or expatriates registered in countries such as Cyprus or the Bahamas. There is also strong evidence that Russian-owned assets abroad are structurally underreported (Novokmet et al., 2018). Although our data sources adjust investment figures to account for round tripping, this adjustment is likely imperfect and likely underestimates emissions from Russian residents.

[6] If domestic economies decarbonize, this mechanically influences the measurement of net foreign ownership emissions expressed as a share of production-based emissions. Both the denominator (production-based emissions) and one component in the numerator (ownership emissions attributable to foreign-held domestic productive assets) decline. To account for this, we include gross foreign ownership emissions in tCO2e in Figure 3, a measure that is unaffected by changes in the carbon intensity of the domestic economy. Net foreign ownership emissions (measured in tCO2e) show a more pronounced increase over the 2010-2022 period in the country group, although that increase would partially be a result of the decline in local production emissions.

United States. Despite the United States' substantial negative net foreign investment position, its net foreign ownership emissions position was slightly positive in 2022, at 259 million tCO2e, or approximately 4% of production-based emissions. The difference highlights that a country's net foreign ownership emissions position does not have to mirror its net foreign asset position in direction or size. One reason is that a country's net foreign asset position is composed of a broader set of assets, including sovereign and corporate bonds, than those relevant for ownership emissions.[7] The carbon intensity of domestic production can also differ from that of foreign countries where investors hold their investments. Finally, changes in market values, such as a prolonged boom in local equity valuations, could magnify a country's negative net foreign asset position while they would leave net foreign emission positions unchanged, ceteris paribus (See D.3 in SI 1).

China. China maintained a slightly negative net foreign ownership emissions position from 2010 to 2022, at around -3 to -4% of the country's production-based emissions or -490 million tCO2e in 2022.[8] China appears as a country that both exports (net) emissions via international trade in a consumption-based framework and records a negative foreign ownership emissions position.[9] The gap between production-based and consumption-based emissions in China (i.e. the extent to which the rest of the world imports emissions from China through international trade) has declined over the period, both in relative and absolute terms. At the same time, net foreign emissions remained constant relative to China's domestic production emissions. Emissions from foreign-owned production within China (gross, i.e. without deducting emissions related to Chinese investors' investments abroad) in absolute terms were the highest worldwide in 2022, totaling 613 million tCO2e, compared to 349 million tCO2e in the United States, although these emissions still correspond to a relatively small share of China's production-based emissions (4%).

India. Net foreign ownership emissions are negative in India. The net position is driven by the relatively low emissions linked to India's investment abroad (relative to production-based emissions in the country, which are the fourth highest in the world in 2022), rather than foreigners owning a particularly large share of Indian production and emissions. The net emission position stood at

[7] For example, in 2022, while the net foreign asset position of the US was firmly negative, the US direct investment abroad position (USD 6.2 trillion) exceeded the foreign direct investment in the United States position (USD 5.1 trillion), according to the U.S. Bureau of Economic Analysis (BEA).

[8] When Mainland China and Hong Kong are treated as a single economic entity, the net foreign emissions position narrows to -2% in 2022.

[9] Note that inward FDI stocks in China in 2022 exceeded outward FDI stocks, according to UNCTAD data.

-135 million tCO2e in 2022, or -3.5% of the country's production-based emissions.

Other developing and emerging countries. Other countries outside the high-income group show a relatively consistent pattern. In most cases, net foreign ownership emissions are negative throughout the period, including in Brazil, Indonesia, Mexico, South Africa, Pakistan, Vietnam, Thailand, Nigeria, Argentina, Egypt, Algeria, Bangladesh, the Philippines or Colombia. This indicates that emissions from foreign owned firms operating within these countries exceed the emissions from firms owned by their residents operating abroad. South Africa and Vietnam stand out as countries with both negative net foreign emissions and negative emission transfers through trade (i.e. emissions embodied in their exports exceed those embodied in their imports).

Financial centers and outliers. We find large positive net foreign ownership emissions in countries such as Switzerland, Singapore, Luxembourg and the Netherlands. These positions likely reflect not only foreign investments made by residents of these countries in foreign production activities, but also the role these countries play as hubs for holding foreign firms on behalf of investors based elsewhere (D.2 in SI 2). The study aimed to reduce such distortions by using data sources that identify the countries of ultimate ownership. However, the large positive positions we find in these countries (in % of domestic production emissions) suggest that information about global foreign wealth remains incomplete, and they align with earlier studies showing that too limited transparency about ownership networks can affect climate research40. Aside from Russia and Saudi Arabia, Australia and Canada stand out as the only high-income countries within the top 25 most polluting countries in 2022 with a consistently negative net foreign ownership emission position. These countries have large emission-intensive natural resource sectors so that even limited foreign investment in these countries can result in ownership emissions that exceed those of domestic investors located in these countries investing elsewhere.

3 Discussion

Ownership-based emission footprints highlight a previously underexplored dimension of global climate inequality. Across country groups, we identified stark patterns in net foreign ownership emissions, which intensified in 2010-2022. It is a well-known fact that – while local emissions declined in many industrialized economies – these countries remain large net emission importers

through the purchase of foreign-made goods and services in a consumption-based carbon accounting framework (Grubb et al., 2022). We show that many of these countries are also net emission owners of polluting production facilities abroad. In other words: Not only does Western Europe import foreign-made goods and the embedded emissions, but European investors also own significant parts of the polluting foreign production processes.[10] While local production emissions declined in 2010-2022 (e.g., in large Western European countries and Japan and South Korea), these countries foreign ownership emissions did not. It implies that emission transfers linked to cross border investment gained in importance since 2010, as least in relative terms.

Our results also reveal the extent to which emission footprints of global wealthiest groups go beyond these groups' immediate consumption and lifestyle choices and include the investment decisions they make (Figure 2). A future might be possible in which certain top wealth holders reduce their consumption-based footprint and private energy use, for example through producing their own renewable energy, upgrading their heating systems or driving electric vehicles but continue to hold carbon intensive asset portfolios abroad. Focusing on production or consumption-based estimates might then not be sufficient to assess responsibilities and capacities to mitigate emissions. These challenges could potentially have an impact on which climate policies are considered fair (Dechezleprêtre et al., 2023).

The global patterns we identified could magnify over the coming years, particularly as the transfer of trade-related emissions from lower-income to higher-income countries appears to have peaked, according to some studies (Grubb et al., 2022; Peters et al., 2011; Wood et al., 2020; Yamano et al., 2024). Most global foreign direct investment is now directed towards developing economies, while more than two thirds of that investment still originate from developed countries (see Figure S1.9 in SI 1) and (UNCTAD, 2024). More stringent domestic policies could also incentivize investors to invest their savings more heavily in carbon-intensive foreign production that serve foreign markets.

The global ownership patterns point towards a specific blind spot in climate policies. Countries have introduced policies aimed at reducing local emissions and, increasingly, implement measures to address carbon-intensive imports originating from countries with less stringent climate policies

[10] Interesting patterns also emerge within country groups. The fact that Western European investors are large net emission owners vis-à-vis Eastern European economies adds nuance to climate policy debates within the EU.

(Beaufils et al., 2023). To date, few or no measures have been proposed to address the carbon leakage associated with investors from high-income countries financing emissions-intensive production in developing regions, especially when such activity is tied to serving final demand in other developing countries.

Previously, we suggested that an emissions-adjusted tax on the owners of high-emitting assets could serve as a complementary policy tool to incentive investment in lower emission assets. Additional instruments – such as regulations on foreign carbon-intensive investments held by residents – could also be envisaged to address foreign ownership-based emissions. Before implementation, the impact of such policies will have to be carefully studied, in particular through which channels these policies could contribute to emission reductions, how the economic incidence might be distributed and how such measures could impact economic development efforts. The ownership-based footprints presented in this study provide a starting point for such inquiries at the country and global level.

For such policies to materialize, improvements in foreign ownership emissions transparency will be key. Our study mobilizes the best data sources available to our knowledge to put a spotlight on a new dimension of global emissions dynamics and inequality. But significant improvements remain necessary to increase the quality of global ownership and wealth data, in particular regarding the portfolio compositions across wealth distributions. Recent initiatives, such as the EU Sustainable Finance Disclosure Regulation, show that developments in this direction are possible. Yet the adoption of much more robust and standardized reporting requirements by government, banks, financial institutions, and firms will be necessary to effectively monitor ownership-based emissions and improve current estimates.

This study constitutes the first global account of ownership-based emissions and lays the groundwork for a new research agenda. Advancing this agenda will also require a better understanding of how people perceive carbon footprints, and how wealth-based emissions complement existing production-based and consumption-based accounting methods (Köchling et al., 2025). The retrospective estimates presented here could be expanded to assess future ownership emissions linked to the individual owners of firms involved in planned or ongoing fossil fuel projects (Kühne et al., 2022). More broadly, unequal contributions to emissions should always be considered jointly with other dimensions of climate inequality, including the uneven

distribution of climate impacts as well as the effects of climate change itself on the distribution of income and wealth (Burke et al., 2015; Chancel et al., 2025; Diffenbaugh & Burke, 2019; Emmerling et al., 2024; Hsiang et al., 2017).

4 Methods

4.1 Ownership-based emission footprints for individuals, the government and countries

Private ownership-based emissions are defined as the annual scope 1 greenhouse gas emissions attributable to the capital assets held by an individual. For instance, an individual who owns 50% of a firm's equity would be assigned 50% of that firm's direct emissions. Holding financial assets that do not confer ownership rights, such as corporate or government bonds or bank deposits, does not contribute to an individual's emission footprint in our framework. This new perspective, introduced in earlier work15,53, is intended to complement existing methods that assign emissions to individuals (based on consumption or direct energy use) or to firms (based on production). The rationale is that production emissions are partly the result of decisions made by individuals who own the underlying assets and that these individuals benefit financially from polluting activities. Complementing conventional carbon footprinting approaches with ownership-based footprints can provide a more comprehensive picture of an individual's or country's total emission footprint, particularly for those with substantial wealth.

National emissions in the ownership-based approach ($E_c^{\text{own-natl}}$) in country c are defined as the sum of private ownership-based emissions (E_c^{priv}), government ownership emissions (E_c^{gov}) and direct household emissions (E_c^{HH}), after accounting for the cross-border ownership of polluting assets.[11] The government is attributed ownership-based emissions based on greenhouse gas emissions in firms and activities it (partially) owns. The ownership-based footprint of country c (see the green bars in Figure 1 for the global estimate) can be expressed as a function of the national production-based footprint (E_c^{prod}) and the net foreign emission position ($E_c^{\text{own,abroad}} - E_c^{\text{for-own,dom}}$):

$$E_c^{\text{own-natl}} = E_c^{\text{prod}} + E_c^{\text{own,abroad}} - E_c^{\text{for-own,dom}}$$

[11] Unlike in the earlier study, we do not include emissions from private electricity use in the direct household category due to data limitations as this would require country-level data on this emission category. Instead, these emissions are attributed to the public and private owners of electricity plants.

We can split the total emissions of production located abroad and owned by residents ($E_c^{\text{own,abroad}}$) into the part that is owned by private households ($E_c^{\text{priv-own,abroad}}$) and the government ($E_c^{\text{gov-own,abroad}}$). Then we can define private ownership-based emissions (E_c^{priv}) in c as:

$$E_c^{\text{priv}} = \left(E_c^{\text{prod}} - E_c^{\text{HH}} - E_c^{\text{gov-own,dom}}\right) + E_c^{\text{priv-own,abroad}} - E_c^{\text{for-own,dom}}$$

4.2 Aggregate production-based, consumption-based and ownership-based emission footprints

Production and consumption-based emissions by country are sourced from the Eurostat-FIGARO project's emissions database (January 2025 vintage)17,18. The production-based emissions of the 45 countries included in the FIGARO database account for 79% of global emissions in 2022. For countries not covered in the dataset, we allocate emissions reported under the rest of the world category using country-level emissions data from the EU-EDGAR database (version 8.0)19. We use public and private capital stocks from the IMF Investment and Capital Stock Dataset24 to divide ownership of polluting activities between the government and private households within countries, based on the public capital stock share (s_c^{pub}). In cases where data on direct household emissions are unavailable, we impute missing values using the average share observed across countries and global private household emissions. We use additional data from GCP *Global Carbon Budget 2023* to compare production and consumption-based emissions in countries not covered in the FIGARO database, in particular for the regional comparisons in Figure 354. More details about all data series, imputations and how data sources are combined to arrive at the 197 jurisdictions in the final global dataset are provided in Supplementary Information 1.

4.3 Net foreign ownership emission positions

For each country, we need to construct a proxy for the share of domestic production owned abroad, along with breakdown of investor countries. Standard datasets on international investment stocks include financial assets that do not confer ownership rights over productive assets, such as sovereign or corporate bonds, and they often do not trace investments to their ultimate owner countries, which would distort results. To proxy foreign-owned production, we therefore rely on the share of value-added in foreign-controlled enterprises (ϕ_c) using the OECD Analytical Activities of

Multinational Enterprises (AAMNE) database26. The rationale is that this method can better capture the share of domestic polluting activity owned by foreigners (see D.4 in SI 1). We present results under two alternative methods in Figure S1.1 in SI 1 and demonstrate that the general patterns regarding the international ownership of emissions do not change. Using these alternative methods, the patterns we identify would be magnified (e.g. we would find even larger net foreign ownership emissions in Western Europe), and a greater share of emissions would be attributed to financial centers such as Luxembourg and Switzerland. To allocate foreign-owned emissions to investor countries, we draw on the international FDI dataset developed by Damgaard et al. (2024), which adjusts reported cross-border equity positions for investment in special purpose entities, round-tripping, and offshore investment vehicles. We define the share of country c in the inward investment stock of country c' as $s^c_{c'}$. With this approach, we attempt to identify ultimate investor countries to yield a mapping of global investment-emission linkages that is more aligned with our ownership-emissions concept than relying on conventional bilateral FDI statistics. The study uses the latest available data point for each country, corresponding to 2020 for foreign ownership shares and 2017 for the investor country breakdown of international ownership emissions. In the absence of more recent data, we carry forward the most recent available shares and country breakdowns to subsequent years. Private ownership-based emissions (E_c^{priv}) are then proxied by:

$$E_c^{\text{priv}} = (1 - s_c^{\text{pub}})\Big[(1 - \phi_c)(E_c^{\text{prod}} - E_c^{\text{HH}}) + E_c^{\text{own,abroad}}\Big]$$

With:

$$E_c^{\text{own,abroad}} = \sum_{c' \neq c} s^c_{c'}\, E_{c'}^{\text{for-own,dom}}$$

4.4 Distributional ownership-based emission footprints

This study takes advantage of the unique country-level and global wealth distribution datasets developed over recent decades using the Distributional National Accounts (DINA) methodology (Blanchet et al., 2024; Piketty et al., 2018) by a large international network of researchers. These estimates are consolidated in the World Inequality Database (WID), which over the 2010-2022 period covers 216 countries and jurisdictions. To account for the asset portfolio composition, we rely on a variety of sources, including the Household Finance and Consumption Survey (HFCS) for

European countries (HFCS network, 2021), the DINA micro-files for the US (Piketty et al., 2018), and a recent study for China (Buluz et al., n.d.). Specifically, we use the data series produced by Blanchet and Martínez-Toledano (2023) for European countries and we construct a composite country distribution based on the average wealth portfolios in developed countries for countries without country-level data.[12] The wealth distribution itself is sourced from the WID. We explain the data sources, imputations and additional sensitivity analysis in Supplementary Information 1. We also provide Table S1.5 in SI 1 a list of studies that demonstrate empirically in a large number of countries that the portfolio weight of firm ownership, and private equity in particular, increases with wealth.

Aggregate private ownership emissions in a country (E_c^{priv}) are attributed in proportion to pension, self-employed and equity assets owned by the respective wealth groups within each country. Although housing is a major asset class among wealth owned by households, it has a very low emission intensity in an ownership-based accounting framework based on our earlier work.[13] In the simplified method we use here, we allocate private ownership emissions (E_c^{priv}) only in proportion to pension, self-employment, and equity assets (within countries), and do not assign any emissions to housing assets. We finally aggregate country-level data on wealth and ownership-based emissions to construct the global distribution of both.

When we present estimates on the distribution of national emissions in the ownership-based framework ($E_c^{\text{own-natl}}$), instead of private ownership emissions only, we apply the following attribution method: Emissions from government-owned assets are attributed as a lump-sum amount to individuals within each country if they serve education and health purposes and in proportion to income for other types of government activity. Direct household emissions are assigned, in this scenario, using a wealth-to household emission elasticity parameter that we estimate based on more granular data we have in France, Germany and the United States (Chancel & Rehm, 2025). E.4 in SI 1 provides more details on conventions used and their impact on results. Because the assumptions made will remain subject to debate, these estimates should be understood as providing

[12] Using the wealth composition in China for all countries without country-level portfolio data would reduce the global top 10% private ownership emissions share from 77% to 74% in 2022.

[13] This is due to two reasons: (i) heating emissions are direct household emissions and assigned to tenants, not owners and (ii) emissions from construction are included in the emissions of construction firm owners, as per the ownership logic. For owner-occupied housing, heating emissions are assigned to owners but as private household rather than private ownership emissions.

a general intuition as to how overall emissions may be distributed in an ownership-based framework if government ownership emissions were to be distributed to individuals as well.

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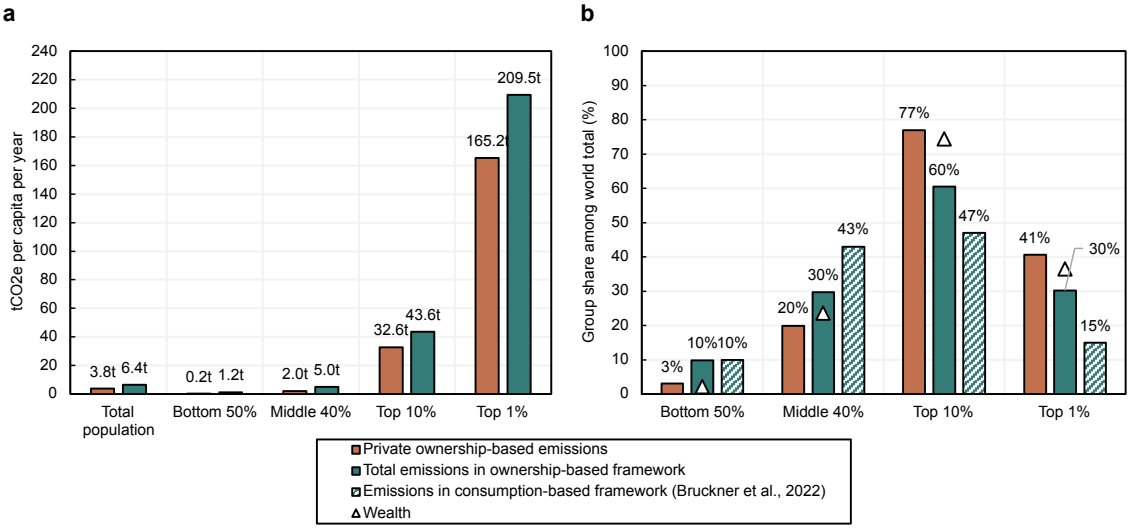
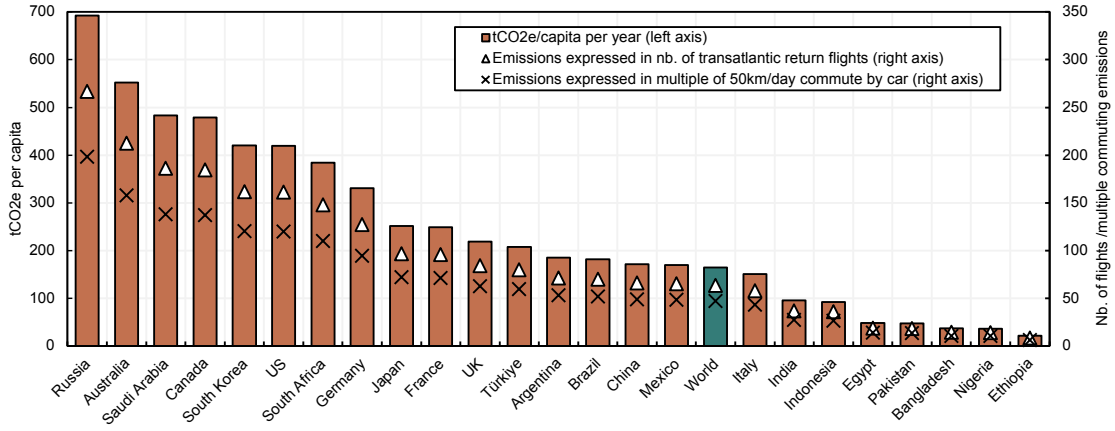
Figures and Tables

Figure 1: Global distribution of ownership-based greenhouse gas emissions in 2022



Note: Groups defined in terms of net wealth. Private ownership-based emissions include scope 1 emissions associated with firms and assets owned by individuals. Total emissions include government ownership emissions and direct household emissions, in addition to private ownership-based emissions. **a** Per capita emission in the group in tCO_2e. **b** Group share in global emissions. Striped bars show results from an earlier study that estimated global emission inequality based on a framework that distributes emissions in a final demand-based framework to final consumers (but based on ranking individuals by emissions rather than wealth).

Figure 2: Top 1% private ownership-based emissions per capita in 2022



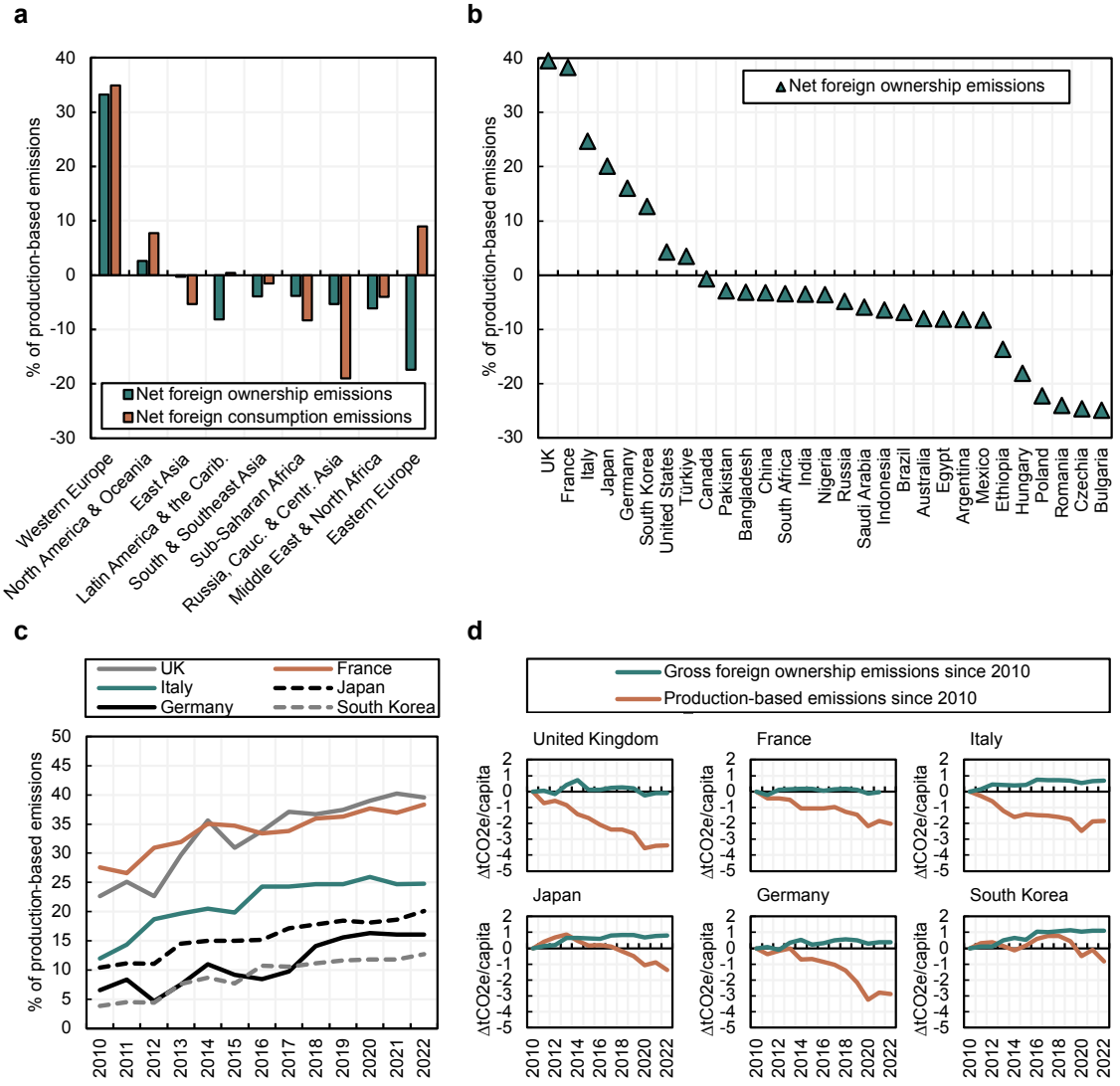
Note: Per capita emissions in the top 1% wealth group expressed in tCO_2e per year (left axis). Private ownership-based emissions include scope 1 emissions of firms and assets owned by individuals. Transatlantic return flight emissions (Paris-New York) in economy class are estimated at 2.6 tCO_2e and include non-CO2 effects. Commuting emissions for a 50km/day trip on 250 days per year using a compact petrol-powered car are estimated at 3.5 tCO_2e. Interpretation: Private ownership emissions of the average individual in the top 1% wealth group in France are similar to (i) the emissions of 90 annual return flights between Paris and New York or (ii) 66 times the emissions produced by a 50km/day commute by car (i.e. similar to driving 3,300 km/day). Countries include G20 members and the five largest countries by population outside the G20. Results for more countries are presented in Table S2.9 in SI 2.

Table 1: Global private ownership-based emissions in 2010 and 2022

Year	Category	Bottom 50%	Middle 40%	Top 10%	Top 1%	Total population
A. Per capita emissions (tCO_2e) by net wealth group						
2010	Private ownership-based emissions	0.2t	1.9t	31.0t	158.3t	3.6t
	Excl. portfolio composition	0.2t	2.5t	28.6t	137.8t	3.6t
	Excl. net foreign ownership emissions	0.2t	2.6t	27.5t	132.1t	3.5t
2022	Private ownership-based emissions	0.2t	2.0t	32.6t	165.2t	3.8t
	Excl. portfolio composition	0.2t	2.7t	29.3t	144.9t	3.8t
	Excl. net foreign ownership emissions	0.3t	2.8t	28.4t	140.0t	3.7t
B. Group shares (%) by net wealth group						
2010	Private ownership-based emissions	3.1%	20.3%	76.6%	38.5%	100.0%
	Excl. portfolio composition	2.2%	27.3%	70.4%	33.9%	100.0%
	Excl. net foreign ownership emissions	2.5%	28.9%	68.6%	32.8%	100.0%
	Net wealth	1.4%	23.9%	74.8%	35.9%	100.0%
2022	Private ownership-based emissions	3.1%	19.9%	77.0%	40.6%	100.0%
	Excl. portfolio composition	3.2%	27.6%	69.2%	33.7%	100.0%
	Excl. net foreign ownership emissions	3.5%	29.0%	67.5%	32.8%	100.0%
	Net wealth	2.0%	23.5%	74.5%	36.4%	100.0%

Note: Private ownership-based emissions include scope 1 emissions associated with firms and assets owned by individuals. *Excl. portfolio composition* refers to estimating private ownership-based emissions without accounting for the changing portfolio composition across the wealth distribution, i.e. using only overall wealth to distribute private ownership-based emissions within countries. *Excl. net foreign ownership emissions* refers to estimating private ownership-based emissions without accounting for cross-border investment, i.e. using only domestic production-based emissions to distribute emissions to asset holders. *Excl. net foreign ownership emissions* also does not account for the portfolio composition so that the additional considerations from the bottom to the upper rows are additive.

Figure 3: Net foreign ownership emissions vs. consumption and production emissions



Note: **a** Net foreign ownership in 2022 and net foreign consumption emissions in selected countries, expressed in % of the region's production-based emissions. Regions with positive net foreign consumption emissions are net importers of emissions through international trade. Consumption-based estimates refer to 2021 and are sourced from the Global Carbon Project's Carbon Budget 2023. The composition of country groupings is shown in Table S1.1 in SI 1. Sensitivity checks by country sample presented in Figure S1.8. Patterns by income group presented in Figure S2.1 in SI 2. **b** Net foreign ownership emissions in selected countries in 2022. Countries include G20 members, the five largest countries by population outside the G20, and five countries from central-eastern Europe. **c** Net foreign ownership emissions in 2010-2022 in the six countries with the largest net foreign ownership position among the top 25 emitters in 2022. **d** Gross foreign ownership emissions and production-based emissions in tCO_2e relative to 2010. See Figure 2.2 in SI 2 for enlarged figures including net foreign ownership emissions.

Supplementary Information

- Supplementary Information 1 (Methods)
- Supplementary Information 2 (Results)