Global Carbon Inequality, 1990-2019

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Abstract

This paper estimates global greenhouse gas (GHG) emissions inequality between 1990 and 2019, based on a newly assembled global dataset of income and wealth inequality from the World Inequality Database and on Environmental Input-Output tables. I find that the richest 10% of the global population emits nearly 48% of global emissions in 2019, the top 1% emits 17% of the total, whereas the poorest half of the global population emits 12% of global emissions. While two thirds of the inequality in individual emissions was due to emissions inequalities *between* countries in 1990, the situation has almost entirely reversed in 2019: 63% of the global inequality in individual emissions is now due to gaps between low and high emitters *within* countries. Most of emissions of top global emitters come from their investments, rather than from their consumption: investments represent 70% of emissions from the global top 1% in 2019, vs. 58% in 1990. This has major implications for contemporary debates on a fair transition. My main results appear to be robust to a wide range of parametric assumptions on the relationship between economic inequality and emissions at the country level, but they remain preliminary by construction: significant transparency efforts should be made by governments to allow a proper monitoring of carbon inequalities in the future.

JEL codes: D30, F64, 013, Q56

INTRODUCTION

Climate change and economic inequalities are among the most pressing challenges of our times. They are also interrelated: failure to contain climate change is likely to exacerbate inequalities within and between countries (Burke, Hsiang, and Miguel, 2015; Dell, Jones, and Olken, 2012; Diffenbaugh and Burke, 2019; Hallegatte and Rozenberg, 2017) while economic inequalities within countries tend to slow the implementation of climate policies (Chancel, 2020b; United Nations Development Programme, Human Development Report Office, 2019). In order to properly analyze the complex web of interactions between economic inequality and climate change, systematic data is needed on the distribution of greenhouse gases (GHG) emissions between individuals and across the globe. Such information is currently missing.

As a matter of fact, researchers, policymakers and civil society struggle to establish basic facts about individuals' carbon footprints inequality across the world. National carbon footprints (i.e. emissions net of the GHG content of goods and services traded with the rest of the world) are not published by most statistical institutions (and when they are, this is done with several years of delay). In addition, official publications about GHG emissions are almost systematically blind to the distribution of these emissions: i.e. which groups of the population contribute to GHG emissions growth. The present paper addresses this issue by combining recent conceptual and empirical progress in income and wealth inequality measurement, with novel data on the GHG content of individuals' consumption and investments, to present and discuss basic facts about the global inequality of carbon emissions.

The rest of this paper is organized as follows: (i) section I presents the main data sources and measurement methods mobilized, (ii) section II presents our main results on the global inequality of carbon emissions, (iii) section III discusses these results. The Methods section as well as the Supplementary Information document present additional methodological details.

Measuring the global inequality of individual carbon emissions

Taking stock of recent progress in global inequality research

The past two decades were marked by important breakthroughs in researchers' ability to monitor global income and wealth inequality(Chancel et al., 2022; Piketty and Saez, 2014). The standard source of information mobilized to track inequality within countries is via household surveys. While surveys constitute a rich source of information to track the various facets of socio-economic inequality, they do not provide statistics comparable across countries, typically fail to properly measure incomes and wealth at the top of the distribution and are typically not consistent with macroeconomic totals(Alvaredo et al., 2018a; Atkinson and Piketty, 2010).

The Distributional National Accounts (DINA) methodology(Alvaredo et al., 2020; Piketty, Saez, and Zucman, 2018), developed by a large network of researchers affiliated with the World Inequality Database (wid.world), in partnership with national and international statistical organizations and the United Nations, seeks to address these issues by systematically combining household surveys with additional sources of information on economic inequality. These additional sources of information include, in particular, administrative tax data and National Accounts. On the one hand, tax data offer a more reliable account of income and wealth dynamics among wealthy groups than those reported by individuals in household surveys. Tax data also enable long term comparisons, spanning over decades (and centuries, in some countries). On the other hand, the use of National Accounts concepts makes it possible to compare income or wealth levels more systematically across countries.

DINA made it possible to improve our collective understanding of the ultimate beneficiaries of economic growth within countries and at the global level. This body of work revealed that most societies went through a decline in inequality between the 1920-1970s and then observed a return of inequality since the 1980s (Alvaredo et al., 2018b). Such findings generated significant academic and public debates on the causes and consequences of inequality within nations. While such dynamics can have important impacts on the inequality of carbon emissions, the interactions between income, consumption, wealth and GHG emissions have attracted only a limited amount of attention to date (Hubacek et al., 2017; Oswald, Owen, and Steinberger, 2020). In fact, there have been no attempts to measure to dynamics of the global distribution of carbon emissions taking stock of recent progress in global inequality research.

The link between carbon emissions inequality and economic inequality

The study of the global inequality of individual carbon emissions faces informational, conceptual and methodological challenges. Most countries do not publish standardized data sources on individual emissions levels. Such information can be reconstructed from household surveys mentioned above and with additional data on energy. Data on individual emissions inequality have been produced for several countries and years by researchers mobilizing Input-Output tables (see below) (Druckman and Jackson, 2008; Lenzen et al., 2006; Pachauri, 2004; Weber and Matthews, 2008a).

The literature typically finds that carbon emissions associated to individual consumption depend on several factors including income and expenditure as well as households' location, technologies, occupation, habits, age or regulations (Buchs and Schnepf, 2013; Chancel, 2014; Lenzen et al., 2006; Peters et al., 2006; Roca and Serrano, 2007; Weber and Matthews, 2008b; Wier et al., 2001). While non-income factors play a significant role in determining direct individual emissions levels (i.e. emissions stemming from the direct use of energy, such as emissions associated to car driving), income is found to be the main driver of indirect emissions (emissions associated to energy mobilized to produce goods and services consumed by individuals), and of overall individual emissions. At a given income level, two individuals may indeed have different heating or transportation needs, implying different direct energy requirement and different direct emissions levels. However, when taking into account the carbon content of their overall consumption and of their indirect energy requirements (the energy used to produce the clothes or appliances they buy, the food they eat, the services they purchase, etc.), income differences explain most of the differences observed in carbon footprints.

The limited set of available studies measuring the *elasticity* of individual carbon emissions (or the strength of the relationship between rising individual income and CO_2 emissions, see Methods)[1], is contained in the 0.5-0.9 range depending on countries and model specifications, with a median value around 0.5-0.8 (Buchs and Schnepf, 2013; Lenzen et al., 2006; Peters et al., 2006; Roca and Serrano, 2007;

[1] In a model of the form $log(CO_2) = \alpha . \log(income)$, where α is the elasticity

Weber and Matthews, 2008b; Wier et al., 2001) (see **Supplementary Information**, Table 1).[2] Using these observed regularities, and taking stock of recent progress in income inequality measurement, it is possible to estimate emissions inequalities between world individuals in a relatively straightforward manner.

Getting macroeconomic emissions levels right: Input-Output tables

The best way to obtain internationally comparable direct and indirect emission levels of individuals is via the Input-Output (IO) framework. The IO framework is quantitative model of the economy, initially developed to represent interdependencies between different economic sectors (households, governments, firms) within and between a countries (Leontief, 1986). The framework was extended to economy-environment interactions (Leontief, 1970) to better understand the material content of production and the impact of environmental policies and relatively recently to study international flows of carbon embodied in international trade (Davis and Caldeira, 2010; Peters, 2008).

In the context of carbon accounting, the strength of the IO framework is that it relies on a systematic representation of the world economy which avoids any double-counting: the same tonne of carbon cannot be ultimately attributed to two different agents[3]. The environmental IO approach is also particularly useful because it can distinguish between emissions from household consumption, emissions associated to firms investments and to government expenditures – in line with National Accounts concepts (Chancel, 2020a; UN et al., 2008).

IO estimates typically find that 60-70% carbon footprints can be traced to households (or individuals)' private consumption, 10-20% to public consumption [4] and 15-25% of emissions are associated to firms' investments. Notable variations occur across countries.[5]

Based on aggregate IO totals, on observed micro-level regularities between emis-

[2] See also (**;Pottier2020**) for a discussion of this methodology

[3] In other carbon accounting methodologies, such as the life-cycle analyses, the issue of double counting is omnipresent

[4] i.e. these correspond to emissions of the government, which are associated to public spending (i.e. collective consumption expenditure such as schools, healthcare, defense, etc.)

[5] Estimates obtained with (Manfred et al., 2013; Timmer et al., 2015; Tukker et al., 2014).

sions and income, as well as our original dataset of global income inequality data, I distribute the totality of global GHG emissions to world individuals. I assume that: (i) aggregate carbon footprints of the household sector in a given country are distributed following a power law of individual income. I test a wide range of parametric assumptions to accommodate for a diversity of relationships between carbon emissions and income (see Methods); (ii) aggregate emissions associated to investments and capital stock replacement are distributed following the distribution of asset ownership within countries; (iii) aggregate emissions from the Government sector (emissions from the public health sector, education, infrastructure defense, etc.) are distributed equally to individuals. I also test multiple parametric assumptions and define more than 20 scenarios, which are presented in the **Supplementary Information** (SI) to this paper.

Our dataset of global carbon emissions contains more than 140 countries, over the 1990-2019 period. For each of these countries, I estimate emissions levels and thresholds for 127 generalized percentiles (i.e. each percentile within the bottom 99% of the population and I split the top 1% group into groups of 0.1%, up to the top 0.001%).

THE GLOBAL INEQUALITY OF INDIVIDUAL CARBON EMISSIONS

Carbon inequality levels within and between world regions

Figure I presents average GHG emissions by region in 2019, while SI Table 2 presents these values as a ratio world average. Per capita emissions in Sub-Saharan Africa (1.6 tonnes per person per annum) represent just one quarter of the average global per capita emissions. Thus, average emissions in Sub-Saharan Africa are close to 50% above the 1.5°C sustainable level and about half of the 2°C budget. At the other end of the spectrum, per capita emissions in North America are 21 tonnes per capita (three times the world average and six times higher than the 2°C sustainable level). In between these two extremes stand South and South-East Asia, at 2.5 tonnes per capita (40% of the current world average and 80% of the 2°C budget) and Latin America at 4.8 tonnes (70% of world average, 1.4 times the 2°C budget), followed by the Middle East and North Africa, East Asia, Europe, and Russia and Central

Asia, whose averages fall in the 7.5-10 tonnes range (between one and 1.5 times the world average, and two to three times more than the 2°C sustainable level). Note that these values include emissions embedded in the goods and services traded with the rest of the world (see Methods and SI Table 3).

[Figure 1 about here.]

Significant inequalities in carbon footprints are observed in every region of the world. Figure II presents the carbon footprints of the poorest 50%, the middle 40% and the richest 10% of the population across the regions. In East Asia, the poorest 50% emit on average around three tonnes per annum, while the middle 40% emit nearly eight tonnes, and the top 10% almost 40 tonnes. This contrasts sharply with North America, where the bottom 50% emit fewer than 10 tonnes, the middle 40% around 22 tonnes, and the top 10% over 70 tonnes of carbon dioxide equivalent. This in turn can be contrasted with the emissions in Europe, where the bottom 50% emit nearly five tonnes, the middle 40% around 10.5 tonnes, and the top 10% around 30 tonnes. Emissions levels in South and South East Asia are significantly lower, from one tonne for the bottom 50% to fewer than 11 tonnes on average for the top 10%.

It is striking that the poorest half of the population in the US has emission levels comparable with the European middle 40%, despite being almost twice as poor. This difference is largely due to the carbon-intensive energy mix in the US, where emissions from electricity are about twice as much as in the European Union. In the US, basic infrastructure consumes much more energy (because of the more widespread use of cars, for example), and devices tend to be less energy efficient (on average, cars are larger and less fuel efficient in the US than in Europe).

[Figure 2 about here.]

Nevertheless, European emissions remain very high by global standards. The European middle class emits significantly more than its counterparts in East Asia (around 10.5 tonnes compared with eight tonnes) and all other regions except North America. Yet it is also remarkable that the richest East Asians and the richest 10% in the Middle East emit more than the richest Europeans (39 tonnes, 34 tonnes, and 29 tonnes, respectively). This difference results from the higher income and wealth inequality levels in East Asia and the MENA region than in Europe, and to the fact that investments by wealthy Chinese are associated with significant volumes of emissions.

Turning to other regions, I find that Russia and Central Asia have an emissions profile close to that of Europe, but with higher top 10% emissions. Sub-Saharan Africa lags behind, with the bottom 50% emissions around 0.5 tonnes and top 10% emissions around 7 tonnes per person per annum. Overall, it stands out that only the poorest 50% of the population in Sub-Saharan Africa and South and South-East Asia come in under the 1.5°C per capita budget. Measuring levels against the 2°C per capita budget, I observe that the bottom half of the population in each region is below or close to the threshold. In fact, it is striking that the bottom 50% in high and middle income regions such as Europe, and Russia and Central Asia emit levels that fall within the 2°C budget. This shows that climate mitigation is largely a distributional issue, not only between countries but also within them.

Global carbon inequality between individuals

Figure III present the inequality of carbon emissions inequality between individuals at the world level. The global bottom 50% emit on average 1.6 tonnes per annum and contribute 12% of the total. The middle 40% emit 6.6 tonnes on average, making up 40.4% of the total. The top 10% emit 31 tonnes (47.6% of the total). The top 1% emits 110 tonnes (16.8% of the total). Global carbon emissions inequality thus appears to be very great: close to half of all emissions are due to one tenth of the global population, and just one hundredth of the world population (77 million individuals) emits about 50% more than the entire bottom half of the population (3.8 billion individuals).

[Figure 3 about here.]

Table I presents more details on the global distribution of carbon emissions. The bottom 20% of the world population (1.5 billion individuals) emit fewer than 1.8 tonnes per capita per annum. In fact, about one billion individuals emit less than a tonne per capita. The entry threshold to get in the middle 40% is 3.1 tonnes, and it takes 13 tonnes per capita per annum to get in the top 10%. It takes 130 tonnes to break into the global top 0.1% group of emitters (7.7 million individuals).

[Table 1 about here.]

The evolution of individual carbon emissions inequalities

How has global emissions inequality evolved over the past decades? A simple way to represent the evolution of carbon emissions inequality is to plot average emissions growth rate by percentile of the global income distribution. Global polluters are ranked from the least emitter to the richest on the horizontal axis of Figure IV, and their per capita emissions growth rate is presented on the vertical axis. Since 1990, average global emissions per capita grew by about 7% (and overall emissions grew by 58%). The per capita emissions of the bottom 50% grew faster than the average (32%), while those of the middle 40% as a whole grew more slowly than the average (4%), and some percentiles of the distribution actually saw a reduction in their emissions of between five and 25%. Per capita emissions of the top 1% emissions grew by 26% and top 0.01% emissions by more than 110%.

Per capita emissions matter, but understanding the contribution of each group to the overall share of total emissions growth is critical. Groups starting with very low per capita emissions levels can increase their emissions substantially over a given period, yet still contribute very little to the overall growth in global emissions. This is in effect what has happened since 1990 (see Table II, last column). The bottom half of the global population contributed only 16% of the growth in emissions observed since then, while the top 1% (77 million individuals) was responsible for 21% of emissions growth. These values are reported in the two boxes of Figure IV

[Figure 4 about here.]

[Table 2 about here.]

One of the most striking results shown in Figure IV is the reduction in the emissions of about 15-20% of the world population, which largely corresponds to the lower and middle income groups of the rich countries. In these countries, the working and middle classes have reduced their emissions over the past 30 years. To be sure, these reductions are insufficient to meet the goals of the Paris Climate Agreement to limit global warming to 1.5°C or 2°C, but they contrast nevertheless with the emissions of the top 1% in these countries (and at the global level), which have significantly increased. Such a gap in carbon mitigation efforts between the rich and the less well-off in rich countries raises important questions about climate policies. In societies where the standards of living of the wealthy also shape the emissions of other social groups, this can have consequences for future emissions patterns. These dynamics also fuel criticisms of environmental policies such as carbon taxes, which have been shown to affect working and middle classes disproportionately in several countries (more on this below).

Figure VIII presents the evolution of the top 1% and the bottom 50% shares in total emissions between 1980 and 2019. Between 1990 and 2019, the global bottom 50% increased its share of the total, from around 9.5% to 12%, but at the same time, the top 1% share rose from 14% to close to 17%. Put differently, the gap in emissions between the top of the distribution and the bottom remained substantial over the entire period.

The rise in top 1% emissions is due to the increase in income and wealth inequalities within countries and to the rising share of their emissions from the assets they own. I find that around half of emissions from the global top 1% stemmed from asset ownership in 1990 and this value has risen over 70% in 2019.

[Figure 5 about here.]

What has been driving the dynamics of global carbon inequality over the past decades: average emission differentials between countries, or inequalities within them? Figure VI compares the share of global emissions that is due to within-country differences with the between-country differences. In 1990, most global carbon inequality (63%) was due to differences between countries: then, the average citizen of a rich country polluted unequivocally more than the rest of the world's citizens, and social inequalities within countries were on average lower across the globe than today. The situation has almost entirely reversed in 30 years. Within-country emissions inequalities now account for nearly two thirds of global emissions inequality. As for income, this does not mean that there do not remain significant (often huge) inequalities in emissions between countries and world regions, on the contrary. In fact, it means that on top of the great inter-national inequality in carbon emissions, there also exist even greater inequalities in emissions between individuals. This has major implications for global debate on climate policies.

[Figure 6 about here.]

Figure 7 (top panel) shows the geographical breakdown of each group of emitters. More precisely, the graph tells us about the share of population of each region in each percentile of the global carbon distribution. It shows, for example, that China, Latin America, and MENA are well represented among the low emitters as well as among the high emitter groups. This reflects the dual nature of these societies, where extreme polluters live close to very low polluters. Europe and North America are essentially represented in the top half of the global distribution (right hand side of the graph). The representation gap between Europe and North America among the very top of the distribution is clear in this graph, as is the large representation of Chinese among the highest polluters.

Figure 7 (bottom panel), provides another representation of the global carbon distribution. Each color wedge is proportional to the population of a region, and the total colored area represents the global population. The graph summarizes key insights about the global distribution of carbon emissions presented above.

[Figure 7 about here.]

The role of investment related emissions

A the top of the global distribution of emitters, I find that a majority of emissions comes from investments, rather than from consumption (see Figure 8). In 2019, 70% of emissions come from investments in the central scenario. This value was 58% in 1990. Figure 8 provides values for alternative scenarios, which all show a significant increase in emissions from investments over the period considered. These results have important implications for climate policies and the fair transition debate, which we discuss in the following section.

[Figure 8 about here.]

Discussion

Our results highlight the very large inequality in carbon emissions at the global level: while a tenth of the global population is responsible for nearly half of all emissions, a half of the population emits no more than 12% of it. Inevitably, the current lack of individual level data on carbon emissions inequality renders any global estimation exercise challenging. However, our results are found to be quite robust to a large set of parametric assumptions, which is presented in the Supplementary Information. In my extreme lower-bound scenario, the global top 10% emissions' share nears 45%, which is still considerably high. In my extreme upper-bound scenario, the global top 10% emissions' share is of 56%. More realistic lower-upper bounds fall in the range 46%-52.5%,[6], that is within a 5-10% range of our benchmark estimate. I also observe that global dynamics between 1990-2019 are very robust across these different scenarios, and are not particularly sensitive to potential changes in choices of parameters over time. In SI figure 3, I reproduce Figure IV across dozens of scenarios and find that the pattern and levels are consistent with our benchmark scenario.

A striking result from this paper is the reduction of per capita GHG footprints since 1990, for a large segment of the population in rich countries - and not for the richest groups in these countries. Indeed, the bottom 50% in Europe and the US saw their emissions reduced by approximately 15%-20% over the period considered, whereas emissions of the top 1% increased significantly within countries and at the global level. Such differentiated trends are explained by the rise of income, consumption and wealth inequalities within countries.

When expressing European and US 2030 climate targets in per-capita terms (i.e. about 5 tonnes of CO2 in Europe and about 10 tonnes of CO2 in the US), I find that the bottom 50% of the population already meets the 2030 targets (see SI). This is not the case for the middle 40% and top 10% of the income distribution, which remains largely above per-capita 2030 climate targets. This raises important questions for the design of climate policies in the years to come: how to ensure that regulations,

[6] i.e. elasticity values ranging between 0.5 and 0.8, closer to values observed in the literature for carbon-income relationships

tax instruments and other policies effectively address emissions of the wealthy, who represent a disproportionate share of national (and global) emissions? How to ensure that climate policy tools do not place too much burden on lower-income groups?

There is no straightforward answer to such questions, but it appears that little has been done over the past decades to regulate and tax the carbon content of wealth ownership. Carbon taxation so far has essentially been seen as a tax on consumption, and has often had disproportionate impacts on lower-income groups because taxes on consumption of basic goods (such as energy) tend to be regressive. Taxes on the ownership of polluting assets, or on dividends from pollution, could become attractive tools in contexts where carbon taxes on consumers face the risk of political backlash(Chancel, 2020b; Sterner, 2012). The informational, technical and economic conditions under which such taxes on carbon investments is a matter of further research.

CONCLUSION

This paper mobilizes state-of-the art data on global income and wealth inequality and systematically combines it with carbon footprints estimates to track the distribution of individual carbon emitters between 1990 and 2019.

I find that the global inequality of carbon emissions is both high and persistent, despite strong economic growth in the emerging world over the past three decades. The top 10% of emitters are responsible for around 48% of global emissions while the entire bottom 50% emits 12% of emissions in 2019. While significant inequalities in average emissions persist between countries, I find that the bulk of global inequalities in individual emissions is now due to within-country inequalities.

Over the past decades, emissions growth dynamics, driven by within country inequality growth dynamics, have been highly unequal. In rich countries, emissions of lower income groups declined while emissions of top groups increase significantly. In emerging countries (such as China), I find that emissions of top income groups are now comparable to top groups in rich countries. Our results highlight the need for more policy instruments specifically addressing emissions of the wealthy.

I stress at the outset that a lot of work still needs to be made to properly track carbon emissions inequality between and within countries. Absent such information, designing fair climate policies will remain an overly challenging task.

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METHODS

Economic inequality dataset

Our economic inequality datasets are those developed in the context of the World Inequality Database (wid.world), which now provides income and wealth inequality series for 174 countries over the 1990-2020 period, i.e. more than 97% of the world population and 97% of global Gross Domestic Product or global income. WID.world contains reproducible inequality statistics based on the systematic combination of household surveys, tax data and national accounts, produced by an international network of researchers contributing to the dataset. The general set of guidelines and methods underlying these data series is described in the Distributional National Accounts Guidelines (Alvaredo et al., 2020). Table section 7 of the Supplementary Information presents inequality levels and macroeconomic indicators for each country used in this study.

The concept of income used in this paper is equivalent to income measured after the operation of pension and unemployment systems (these represent the bulk of in-cash redistribution in most countries, which are thus taken into account in our income inequality estimate) and before the operation of other income and wealth taxes and transfers. Note that I opt for a relatively low benchmark emissions-income elasticity value (0.6) to account for the fact that I use income, rather than consumption inequality series.

Multi-regional Carbon Emissions Input-Output estimates

Aggregate carbon emissions data are based on multi-regional Input-Output (MRIO) tables. MRIO provide net emissions (i.e. emissions net of carbon embedded goods and services trade with the rest of the world), by institutional sectors of an economies. Institutional sectors are households, government and private investments (or Gross Fixed Capital Formation). In National Accounts, these sectors constitute ”Final Demand”. The sum of all ”Final Demand” in an economy is equal to Gross Domestic Product (GDP).[7].

Our benchmark MRIO data source is the Global Carbon Project (GCP)(Friedlingstein et al., 2020), which I see as a global reference data source. In certain cases, GCP does not provide data for a given country or for a given type of emissions. In order to cover all countries and all types of emissions, I also rely on the EORA dataset(Manfred et al., 2013).[8].

Distribution of carbon emissions to individuals

In line with the National Accounts Methodology, I decompose national-level distributions (of income, wealth or carbon emitters) in 127 generalized-percentiles: 99 percentiles from $p = 0\%$ to $p = 99\%$, 9 tenths of a percentile from $p = 99\%$ to $p = 99.9\%$, 9 hundredths of a percentile from $p = 99.9\%$ to $p = 99.99\%$, 10 thousandths of a percentile from $p = 99.99\%$ to $p = 100\%$.

[7]Changes in inventories and stocks are also reported in the dataset. Since they only represent a marginal fraction of emissions, I include them in GFCF totals so as to keep fully consistent datasets which always match with aggregate totals. I also include emissions of Non-Profit Institution Serving Households in the Household Sector as a first approximation.

[8]For details on the construction of aggregate series used in this study and on WID.world, see Burq and Chancel(Burq and Chancel, 2021)

In order to determine carbon emission levels associated to each of these generalized-percentiles of income, in each country of the world, I proceed as follows. Average per capita emissions at percentile p, in a given year and country are defined as:

$$E_p^{tot} = E_p^{cons} + E_p^{inv} + E_p^{gov} \tag{1}$$

Where E_p^{cons}, E_p^{inv}, E_p^{gov} are individual average footprints at percentile p, associated to consumption, private investment and public spending, respectively. More precisely:

$$E_p^{tot} = f(E^{cons}, Y_p, \alpha, \beta) + f(E^{inv}, W_p, \gamma) + f(E^{gov}, y_p, \delta) \tag{2}$$

Where E^{cons} is the average carbon footprint associated to consumption in the country, Y_p the average income level of individuals in percentile p, α the elasticity of household consumption carbon emissions to income (in a model of the form $E_p^{cons} = E^{cons} \times Y_p^{\alpha}$), β a minimum threshold of emissions in the country, corresponding to a fraction of average consumption-related emissions; E^{inv} is the average emissions level associated to investments (or asset ownership, in our framework), γ the elasticity of wealth to investment emissions; E^{gov} is the average emission level of the government sector (associated to in-kind redistribution) and δ, is the elasticity of government emissions to income. Given that distribute consumption emissions, investment emissions and government emissions using different elasticity values, the overall elasticity of emissions to income is not constant across the income spectrum.

I use the following range of parameters to estimate emissions within countries: $\alpha = (0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1)$; $\beta = (0; 0.1; 0.2; 0.3)$; γ=1; δ=0 (in our benchmark scenario, government emissions are distributed equally to individuals in a country). In all countries I assume that emissions are split equally within households.

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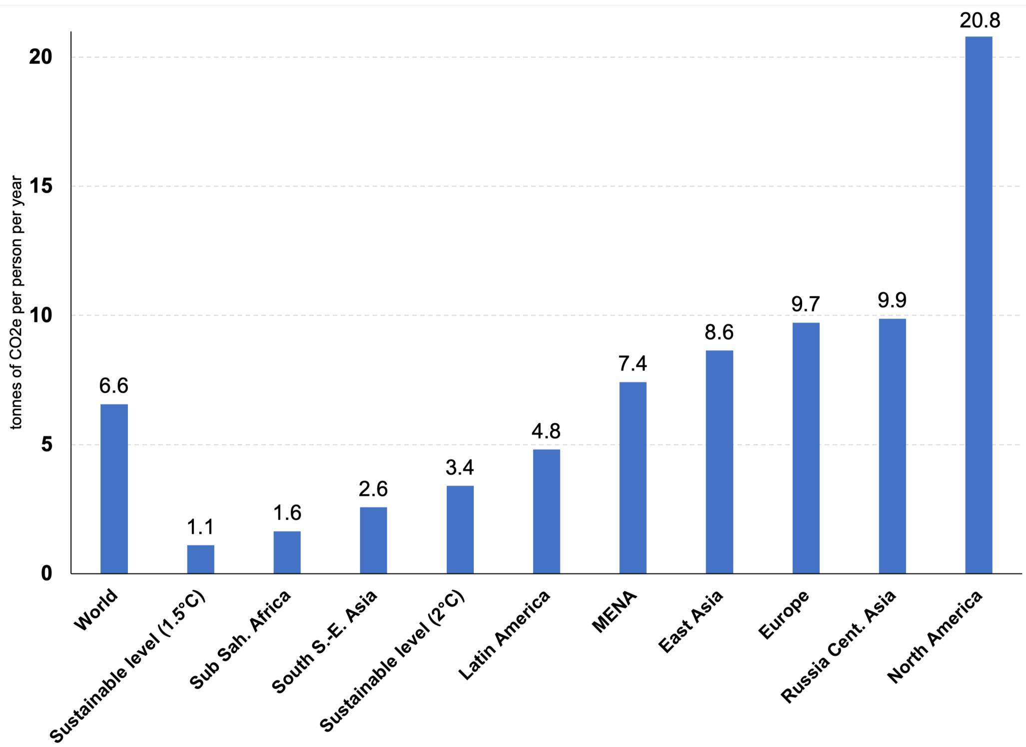
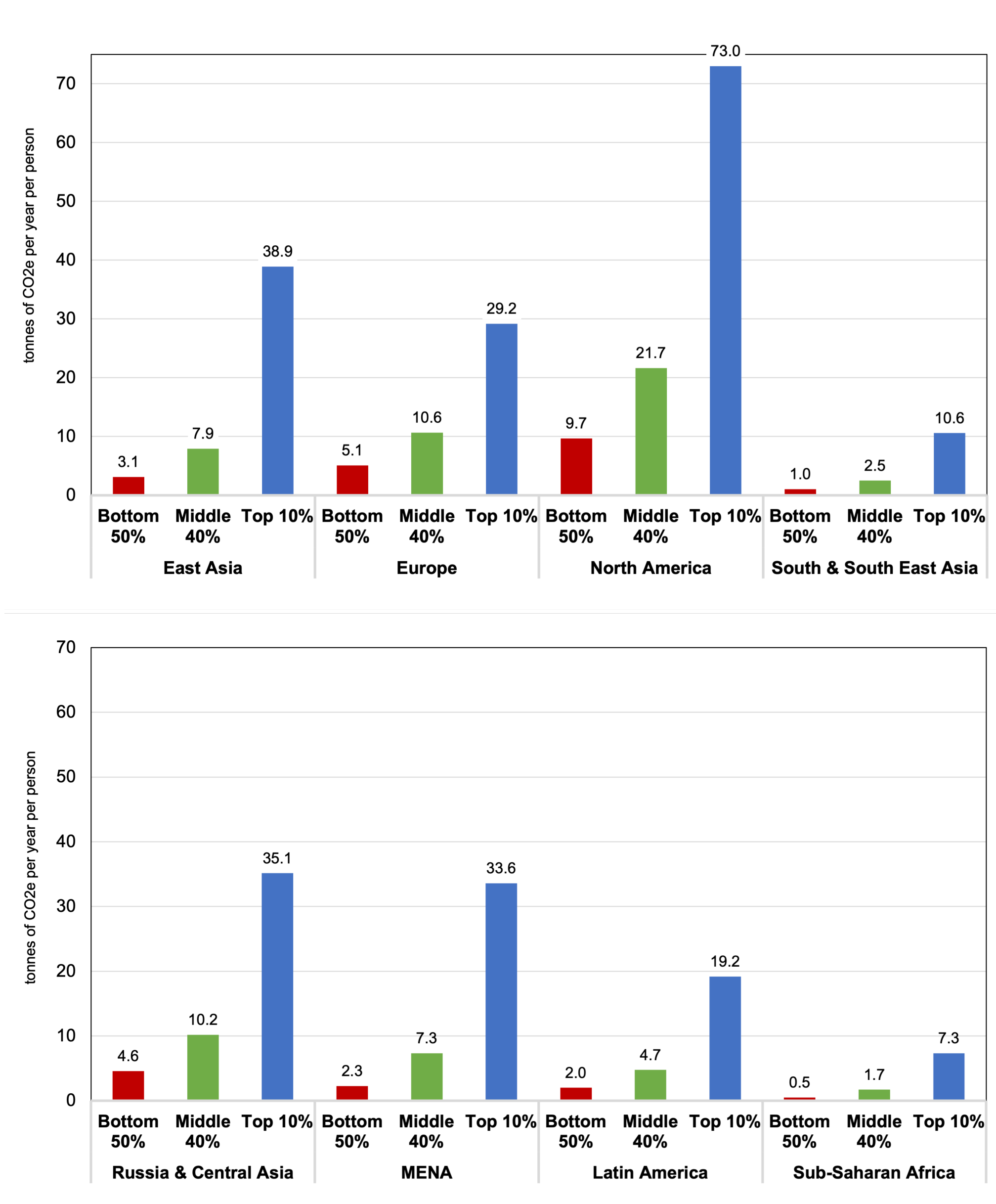


Interpretation: Values include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Sustainable level correspond to an egalitarian distribution of the remaining carbon budget until 2050. *Source and series*: See Supplementary Information, Chancel (2022).

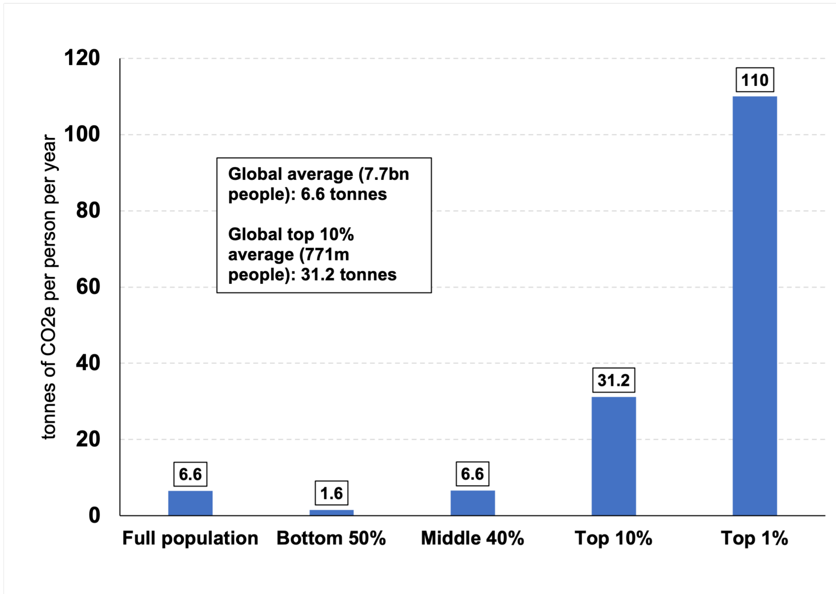
Figure I
Per capita emissions (incl. imports) by world region (tCO2/year), 2019



Interpretation: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. **Source and series**: See Supplementary Information, Chancel (2022).

Figure II
Carbon footprints by income group across the world, 2019

(a) Per capita emissions by group (tCO2 / year)



(b) Group share (%) in world total emissions

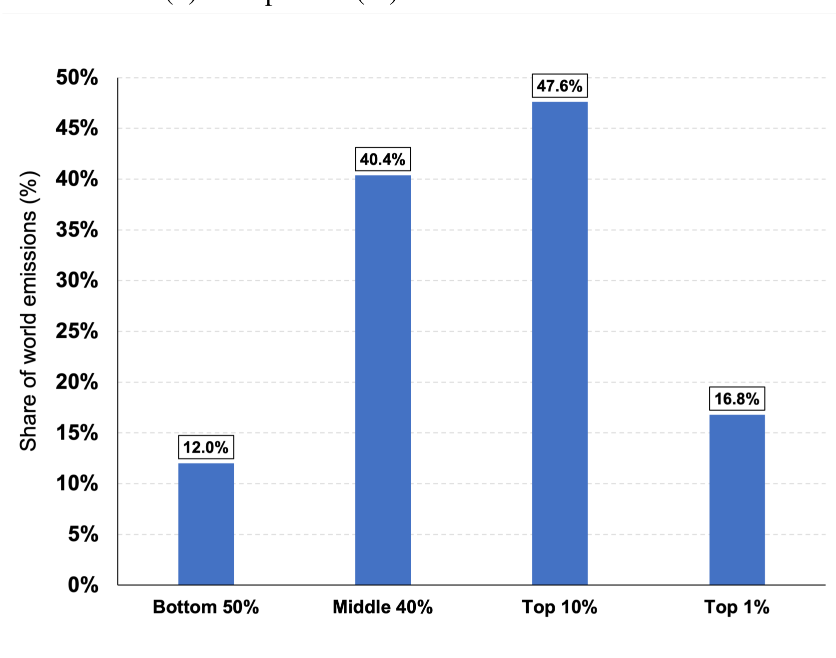
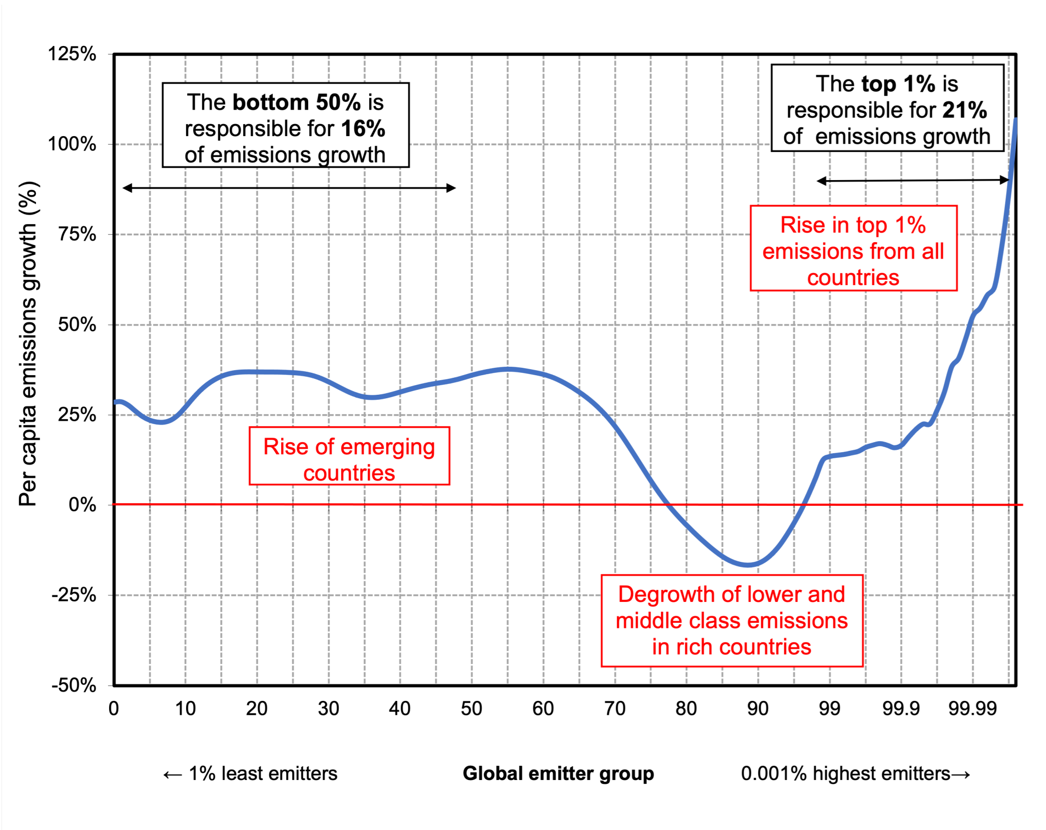


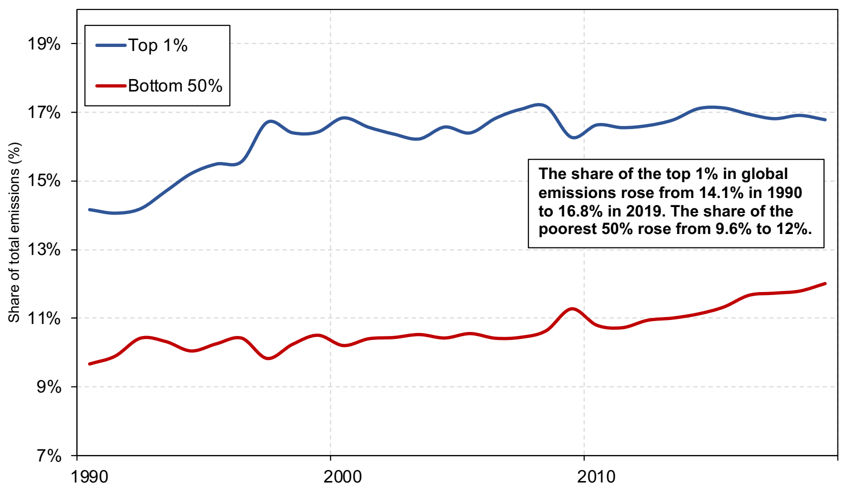
Figure III
Global inequality in individual carbon emissions, 2019

Interpretation: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. **Source and series**: See Supplementary Information, Chancel (2022).



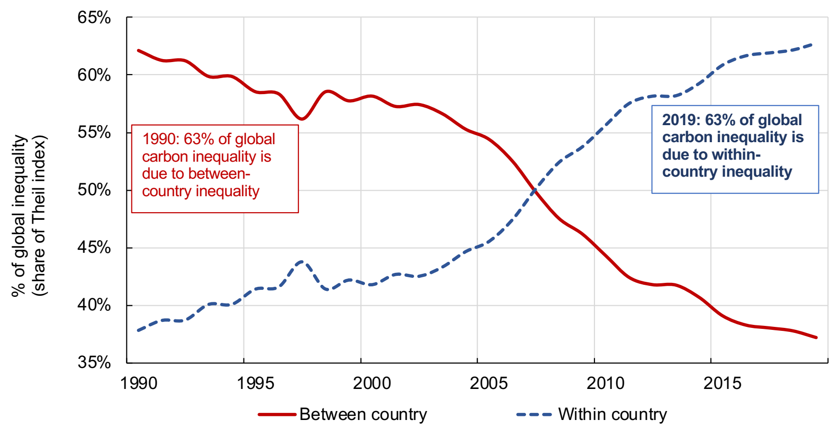
Interpretation: Emissions of the global bottom 50% rose by around 20-40% between 1990 and 2019. Emissions notably declined among groups above the bottom 80% and below the top 5% of the global distribution, these groups mainly correspond to lower and middle income groups in rich countries. Emissions of the global top 1% and richer groups rose substantially. Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. *Source and series*: See Supplementary Information, Chancel (2022).

Figure IV
Global inequality and carbon emissions, 1990-2019



Interpretation: This figure presents the share of global GHG emissions by the top 1% and bottom 50% of the global population between 1990 and 2019. GHG emissions measured correspond to individual footprints, i.e. they include indirect emissions produced abroad and embedded in individual consumption. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households.*Source and series*: See Supplementary Information, Chancel (2022).

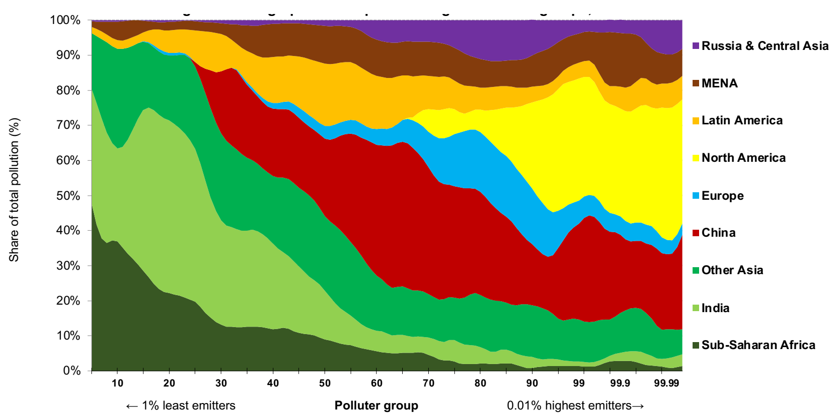
Figure V
Top 1% and bottom 50% shares in global carbon emissions, 1990-2019



Interpretation: 37% of global carbon inequality between individuals is due differences in emissions levels between countries while 63% is explained by inequality within countries in 2019. *Source and series*: See Supplementary Information, Chancel (2022).

Figure VI
Theil index decomposition of global carbon inequality

(a) Per capita emissions by group (tCO2 / year)



(b) Group share (%) in world total emissions

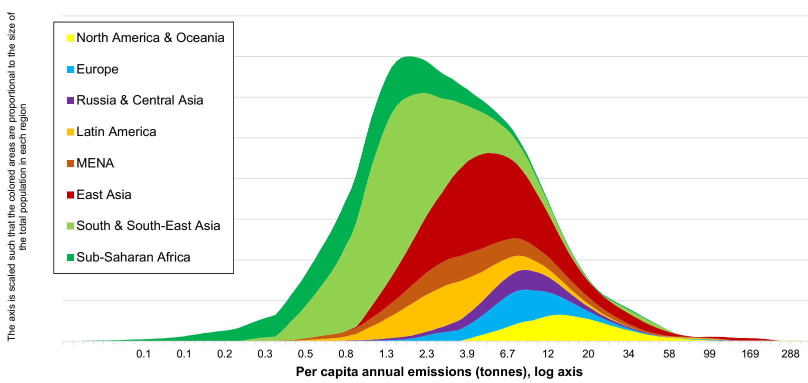
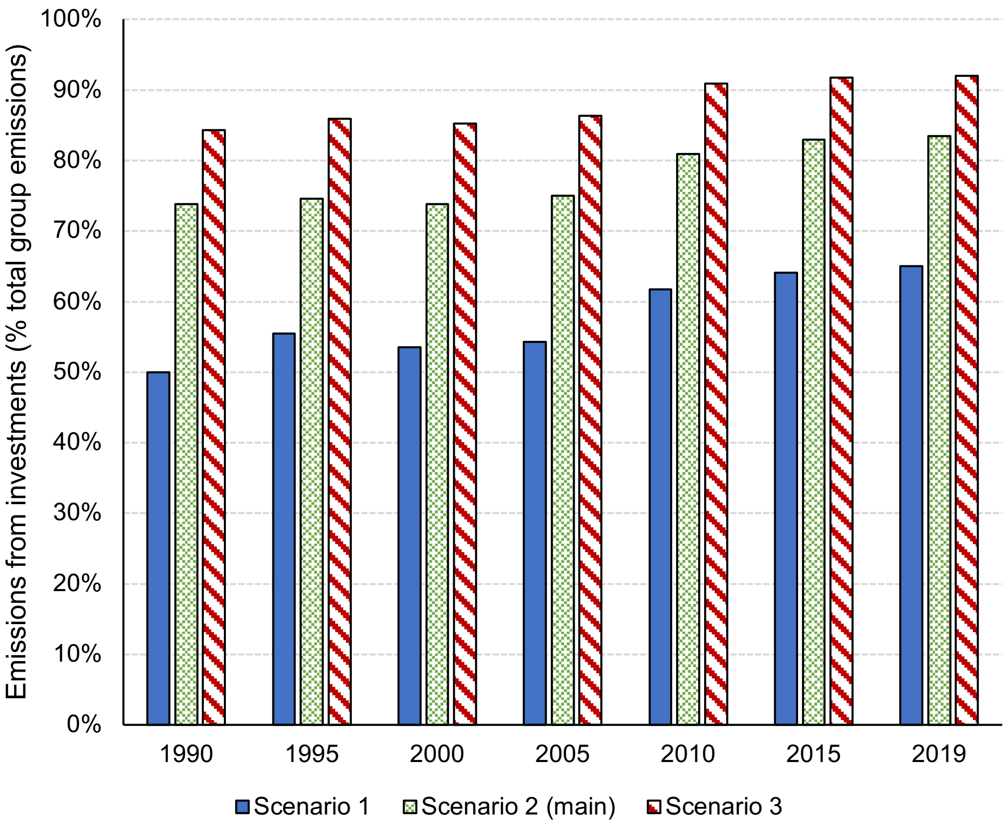


Figure VII
Global inequality in individual carbon emissions, 2019

Interpretation:Panel A The graph shows the share of world regions in each group of global emitters, from the lowest 1% to the highest 0.1%. Panel B shows the global distribution (density) of individual emitters in 2019. GHG emissions measured correspond to individual footprints, i.e. they include indirect emissions produced abroad and embedded in individual consumption. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. **Sources and series**: See Supplementary Information, Chancel (2022).



Interpretation: This figure presents the share of global GHG emissions by the top 1% that can be traced to their investments (rather than to their consumption). This share has been rising since 1990. Scenario 1 corresponds to α=1, γ=1; Scenario 2: α=0.6, γ=1; Scenario 3: α=0.6, γ=1.2 (See Methods). *Source and series*: See also Supplementary Information, Chancel (2022).

Figure VIII
The share of investments in global top 0.1% emissions, 1990-2019

	Number of individuals (million)	Average (tonne CO2 per capita)	Threshold (tonne CO2 per capita)	Share (% total)
Full population	**7710**	**6.6**	**<0.1**	**100%**
Bottom 50%	**3855**	**1.6**	**<0.1**	**12.0%**
incl. Bottom 20%	*1542*	*0.8*	*<0.1*	*2.5%*
incl. Bottom 30%	*2313*	*2.1*	*1.8*	*9.5%*
Middle 40%	**3084**	**6.6**	**3.1**	**40.4%**
Top 10%	**771**	**31**	**13**	**47.6%**
incl. Top 1%	*77.1*	*110*	*46*	*16.8%*
incl. Top 0.1%	*7.71*	*467*	*130*	*7.1%*
incl. Top 0.01%	*0.771*	*2531*	*569*	*3.9%*

Table I

Global inequality of individual carbon emissions, 2019

Interpretation: Individual carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. *Source and series*: See Supplementary Information, Chancel (2022).

	Per capita emissions (tonnes CO2e per capita)		Total emissions (billion tonnes CO2e)		Growth in per capita emissions (1990-2019)	Growth in total emissions (1990-2019)	Share in emissions growth (1990-2019)
	1990	2019	1990	2019			
Full population	6.2	6.6	32.0	50.5	7%	58%	100%
Bottom 50%	1.2	1.6	3.1	6.1	32%	96%	16%
Middle 40%	6	6.6	13.3	20.4	4%	54%	39%
Top 10%	30	31	15.7	24.0	4%	54%	45%
Top 1%	87	110	4.5	8.5	26%	87%	21%
Top 0.1%	323	467	1.7	3.6	45%	114%	10%
Top 0.01%	1397	2531	0.7	2.0	81%	168%	7%

Table II

Emissions growth and inequality, 1990-2019

Interpretation: Individual carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. *Source and series*: See Supplementary Information, Chancel (2022).