Global carbon inequality over 1990-2019

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Abstract

All humans contribute to climate change but not equally. Here I estimate the global inequality of individual greenhouse gas (GHG) emissions between 1990 and 2019, using a newly assembled data set of income and wealth inequality, Environmental Input-Output tables and a framework differentiating emissions from consumption and investments. In my benchmark set of estimates, I find that the bottom 50% of the world population emitted 12% of global emissions in 2019, whereas the top 10% emitted 48% of the total. Since 1990, the bottom 50% of the world population has been responsible for only 16% of all emissions whereas the top 1% for 23% of the total. While per capita emissions of the global top 1% increased since 1990, emissions from low and middle income groups within rich countries declined. Contrary to the situation in 1990, 63% of the global inequality in individual emissions is now due to a gap between low and high emitters within countries rather than between countries. Finally, the bulk of total emissions from the global top 1% of the world population comes from their investments rather than from their consumption. These findings have implications for contemporary debates on fair climate policies and stress the need for governments to develop better data on individual emissions to monitor progress towards sustainable lifestyles: a lot remains to be learned about the relationship between emissions and wealth.

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I Introduction

Climate change and economic inequalities are among the most pressing challenges of our times, and they are interrelated: failure to contain climate change is likely to exacerbate inequalities within and between countries [1, 2, 3, 4] and economic inequalities within countries tend to slow the implementation of climate policies [5, 6]. In order to properly understand the relationship between economic inequality and climate change, sound and timely data is needed about 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 even basic facts about which groups of the population contributes to emissions growth, or mitigation. This jeopardize any efforts towards sustainable lifestyles.

This paper seeks to address these issues by harnessing recent conceptual and empirical progress in the measurement of income, wealth and GHG emissions. Compared with previous work on global carbon inequality [7, 8, 9, 7, 10], this paper presents three major developments in terms of data, methods and scope.

First, the paper uses novel income and wealth inequality data from the World Inequality Database [11] to track inequality from the bottom to the top of the distribution. This economic inequality data is combined with GHG footprints from Input-Output models thanks to a newly assembled set of country-level information on the link between individual emissions, consumption and income in more than 100 countries. The methodology therefore makes it possible to track individual GHG emission levels with more precision than previous longitudinal carbon inequality estimates[9]. Second, the method developed allows to distinguish explicitly between emissions from private consumption and investments, making it possible to better understand the drivers of emissions among wealthy groups. Third, the paper focuses on the distribution of emissions over the 1990-2019 period, that is from the first Intergovernmental Panel on Climate Change (IPCC) report to the eve of the Covid-19 pandemic. The three decades saw critical shifts in the distribution of world economic growth [12], which have not been systematically studied from the point of view of GHG emissions inequality.

There are two broad approaches to the measurement of global carbon inequality. *Bottom-up* approaches use household-level micro data to produce macro estimates. This is the approach taken by [8, 13, 14], who mobilize the large set of consumption surveys available from the World Bank Global Consumption Database, as well as additional consumer expenditure surveys done in rich countries. These surveys are linked to Environmental Multi Regional Input Output models (EMRIOs) to provide estimates of energy consumption or emissions per consumption group. To the extent that micro-level data is available, this method is the best way to measure global carbon inequality associated with individual *consumption*. Given the data-intensive process, this approach has not looked at the evolution of global emissions. Another limitation is that this approach tends to underestimate the consumption levels of the richest groups, due to well documented misreporting and sampling errors [15]. *Top-down* approaches to the measurement of global carbon inequality use the regularities observed in micro-level data to provide modeled estimates based on elasticity parameters and income or consumption inequality distributions. This is the approach taken by [7, 9, 10, 16]. These studies typically use one single elasticity for all countries, which limits the precision country-level estimates. Another limitation of both top-down and the bottom-up approaches is that they do not treat investment-related emissions particularly well.

The present paper builds on the strengths of top-down and bottom-up approaches and offers novel developments. By mobilizing country-level elasticities from over a hundred countries, the paper departs from previous top-down approaches. By focusing on the 1990-2019 period, the paper adds historical depth to single year *bottom-up* studies and by distinguishing between emissions from personal consumption and from investments, it is possible to shed new light on the dynamics of emissions in particular among top groups.

The general approach followed here can be summarized as follows: using EMRIOs, I obtain country-level GHG emissions for the household sector, the investment sector and the government sector across countries (emissions are net of imports and exports embedded in goods and services traded with the rest of the world). These emissions are distributed to individuals in each country using country-level data on the elasticity of emissions and consumption, income and wealth. A variety of alternative estimation strategies are tested and it appears that the key results are robust to a large range of parametric assumptions on the relationship between emissions, income, consumption and wealth. To be clear, a lot remains to be learned and debated about the link between individual emissions and wealth. As in any exercise of this sort, the statistical reconstructions presented below should be analyzed with caution.

II Results

Carbon emission inequalities within regions

Global average per capita emissions reached about 6tCO_2e in 2019. To have high chances of staying below +1.5°C global temperature increase, average per capita emissions should be 1.9tCO_2e between now and 2050 (that is the equivalent of an economy-class round-trip flight between London and New-York) and zero afterwards (see **SI** section 3).

Inequality in average per capita emissions *between* world regions remain large, as shown in Extended Data Figure 1. On top of these gaps, significant inequalities in carbon footprints are observed within regions. Figure 1 presents the carbon footprints of the bottom 50% of emitters, the middle 40% and the top 10% of the population within regions according to my benchmark estimates. Emission levels and shares for other groups are presented in the **SI** (section 7).

In East Asia, it is found that the poorest 50% emit on average 2.9 tCO_2e 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% around 69 tCO_2e. This in turn can be contrasted with the emissions in Europe, where the bottom 50% emit five tonnes, the middle 40% around 10.5 tCO_2e, and the top 10% around 30 tCO_2e. Emissions levels in South and Southeast Asia are significantly lower than in the these regions, from around 1 tCO_2e for the bottom 50% to 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 as this group in purchasing power parity terms [17]. Conversely, the top 10% of the population in East Asia emits significantly more than its European counterpart (40tCO_2e vs. 29tCO_2e, respectively). It also appears that Russia & Central Asia have an emissions distribution broadly similar to that of Europe, but with higher top 10% emissions (due to higher income and wealth inequalities in Russia & Central Asia) and lower bottom 50% emissions. Sub-Saharan Africa lags behind, with the bottom 50% emitting around 0.5 tonnes per capita and per year, and the top 10% emitting around 7.5 tonnes.

Global carbon inequality between individuals

Figure 2 presents the inequality of carbon emissions between individuals at the world level. The global bottom 50% emit on average 1.4 tCO_2e per year and contribute to 11.5% of the total. The middle 40% emit 6.1 tonnes on average, making up 40.5% of the total. The top 10% emit 28.7 tonnes (48% of the total). The top 1% emits 101 tonnes (16.9% of the total). Global carbon emissions inequality thus appears to be great: close to half of all emissions are released by 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).

The evolution of individual carbon emissions inequalities

How has global emissions inequality changed over the past few decades? In Figure 3A, global polluters are ranked from the least emitting to the highest on the X axis, and their per capita emissions growth rate between 1990 and 2019 is presented on the Y axis. (Figure 4B shows where each global percentile of emitters live as discussed below.) Since 1990, average global emissions per capita grew by 2.3% (and overall emissions grew by about 50%, see SI Table 6.1). The per capita emissions of the bottom 50% grew faster than the average (26%), while those of the middle 40% as a whole was negative (-1.2%), and some percentiles of the global distribution actually saw a reduction in their emissions of between 5 and 25%. Per capita emissions of the top 1% emissions grew by 26% and top 0.01% emissions by

80%.

Per capita emissions matter, but understanding the contribution of each group to the overall share of total emissions growth is also crucial. The bottom half of the global population actually contributed only 16% of the growth in emissions observed since then, while the top 1% (77 million individuals in 2019) was responsible for 23% of total emissions growth. The top 0.1% (7.7 million individuals in 2019) contributed two nearly three-quarters of the entire growth in emissions associated to the poorest half of the global population (3855 million individuals in 2019). **SI** Table 7.1 presents the evolution of the Theil and Gini indexes of global emissions inequality and Figure 4A presents the evolution of top 1% and bottom 50% shares in global emissions.

One striking results shown in Figure 3A is the reduction in the emissions of about 5-15% for percentiles p75 to p95. This segment of the world population largely corresponds to the lower and middle income groups of the rich countries and contrast with the emissions of the top 1%, which have significantly increased.

Global carbon inequality dynamics are governed by two forces: the evolution of average emission levels *between* countries and the evolution of emission inequalities *within* countries. Which one of these two forces has been driving the dynamics of global carbon inequality over the past few decades? Figure 3B compares the share of global emissions due to within-country differences with the between-country differences, using a Theil-index decomposition. In 1990, most global carbon inequality (62%) was due to differences between countries in my benchmark estimates: then, the average citizen of a rich country polluted unequivocally more than the rest of the world, and income inequalities within countries were on average lower across the globe than today. The situation has entirely reversed in 30 years. Within-country emissions inequalities now account for nearly two thirds of global emissions inequality. To be clear: this does not mean that significant inequalities in emissions between countries and regions have disappeared. On the contrary, it means that on top of the great inter-national inequality in carbon emissions, there are also even greater emissions inequalities between individuals.

Investments and the carbon footprints of wealthy individuals

What is behind this rise in emissions at the top of the distribution presented above? This is due to the increase in income and wealth inequalities within countries as well as to the rising share of emissions generated by wealthy individuals' investments. Individual carbon footprints can indeed be split into emissions generated by private consumption, investments and government spending. Consumption-related emissions come from the carbon released by the direct use of energy (e.g. fuel in a car) or its indirect use (e.g. energy embedded in the production of goods and services consumed by individuals). Investment-related emissions are emissions associated with choices made by capital owners about investments in the production process (i.e. emissions involved in the construction of machines, factories, etc.).

Focusing on the breakdown between consumption and investment emissions, I find that the bulk of the emissions generated by the global top 1% comes from their investments rather than their consumption (Figure 4B) (over 70% in 2019 in the benchmark scenario). It also appears that the weight of investments in the per capita footprint of the top groups has been rising significantly since the 1990s. This is due to the rise in wealth inequality (wealth and investments are more concentrated today than they were in 1990), as well as the rise in overall emissions associated with investments over the period (see **SI** Table 1.1.).

III Discussion

The results presented above reveal the very highly skewed concentration of individual carbon emissions that characterizes the contemporary global economy: while one tenth of the global population is responsible for nearly half of all emissions, half of the population emits less than 12% of it. Seen in perspective, carbon inequalities are lower than income and wealth inequalities (the global top 10% of earners captures 52% of total income and the global top 10% of wealth owners owns three quarters of total wealth [18]). Global carbon inequalities nonetheless remain very significant.

The increased emissions by top global emitters since 1990 is particularly striking when compared with the emission trajectories of other population groups. Indeed, the emissions of the poorest 50% in Europe and the US have dropped by approximately 15%-20% since 1990. These reductions are the result of the combined effect of compressed wages and consumption and a reduced national per capita footprint in most rich countries, driven by climate and energy policies and efficiency gains in industrial processes. As a consequence, a large part of the population in rich countries already appears to be near 2030 national climate targets, when these are expressed in per capita terms. Nationally Determined Contributions (NDCs) established under the rubric of the Paris Agreement imply a per capita target of around 10 tonnes of CO_2e in the US in 2030 and around five tonnes for European countries in my benchmark estimates. In the US and in some European countries, I find that the bottom 50% of the population is relatively close or may even meet these 2030 targets (Figure 6). This is not the case for the middle 40% and top 10% of the income distribution in these countries. In the US, the top 10% would have to reduce its average per capita emissions (from consumption and investments) by 86% to reach the 2030 target, the value is 81% in France.

In emerging and developing countries, 2030 climate targets imply an increase in average per capita emissions rather than a reduction. But there, too, inequality matters a lot: in China and India, emissions of the bottom 90% of the population are below the target, while those of the wealthiest 10% are already well above it. In China, the richest 10% of the population would have to reduce its emissions by more than 70% to reach the 2030 target, and the figure is over 50% for India (Figure 6 and **SI** Section 8).

To be clear, no country currently envisages the enforcement of strict per capita targets in order to meet its 2030 objectives. Nonetheless, the gaps between individual emissions levels and the implied national target raise important questions about the design of climate and sustainability policies in the years to come: how do we ensure that regulations, tax instruments and other climate policies effectively address the emissions of the high emitters?

There is no straightforward answer to such questions, but it appears that climate policies over the past decades have often targeted low-income and low-emitter groups disproportionately, while leaving high emitters relatively unaffected. The trends documented in this paper support this view. In fact, key climate policy instruments (such as carbon taxes, for instance) have done little to address the vast inequalities in carbon footprints - and may have exacerbated them in some countries. Carbon taxes have been found to place a disproportionate burden on low-income and low-emitter groups [19, 20, 21] while the carbon price signal for high and wealthy emitters may be too low to force changes in consumption (or investment) patterns among wealthy individuals.

Extended Data Figure 2 presents several options to better integrate inequality in the design of climate policies. Focusing on the specific issue of the carbon content of investments, it appears that progressive carbon tax systems could be helpful to accelerate decarbonization. To design progressive carbon tax systems, one option is to combine carbon pricing with cash transfers for certain categories of the population, as has been done in British Columbia (Canada) [5]. Another option is to make carbon tax rates increase with emissions levels. This could potentially be achieved via a combination of tax instruments, focusing on consumers as well as on investors in carbon intensive activities. Today, states typically do not impose taxes or regulations on the basis of the pollution content of asset-portfolios or of investments. This can be seen as paradoxical given that investors have a variety of options for investing their wealth, and it stands in stark contrast with low-income consumers who do not always have alternatives, in the short run, to using fossil fuels, but who must pay carbon taxes.

Using the data constructed for this paper, it appears that the global top 1% would contribute to about 40% of total revenues from an additional carbon tax focusing on investments and the top 10% three quarters of the total. With a tax rate r equal to 0 for annual investments with a carbon content below 5tCO_2e per capita and $r > 0$ for investments with a carbon content above this threshold, close to 100% of the tax would fall on the top 10% of the global population. Under this schedule, the bottom 77% of the US population, the bottom 90% of the European population and the bottom 99.5% of the Sub-Saharan African population would not pay the tax at all (see **SI** Table 8.3). Such a tax could therefore be used as a top-up mechanism, to make overall carbon tax systems more progressive and to raise additional revenues to invest in low-carbon infrastructures, or to compensate losers of the transition. The technical and economic conditions under which policies targeting the carbon content of investments are developed is a matter for further research. In any case, more transparency and more systematic data released by governments on individual carbon footprints will be paramount to guarantee a just transition.

METHODS

Environmental input-output data. The most straightforward way to obtain internationally comparable direct and indirect emission levels of individuals is the Input-Output (IO) framework applied to the environment framework developed by [22]. The benchmark IO data source used in this paper is the Global Carbon Project (GCP) [23]. The paper also relied on the EORA dataset [24]. For details on the construction of I-O carbon aggregate series used in this study, see **SI** Section 1 and [25].

Income and wealth inequality data. The past two decades were marked by breakthroughs in our capacities to monitor income and wealth inequality within countries [26, 18], which the paper builds upon. The standard source of information for tracking inequality within countries is household surveys, which typically fail to properly measure incomes and wealth at the top of the distribution, and are usually not consistent with macroeconomic totals [27, 28], making cross-country comparisons difficult. The Distributional National Accounts (DINA) methodology [29, 11] addresses these issues by systematically combining household surveys with additional sources of information (including, in particular, administrative tax data and national accounts).

This study relies on the DINA project, which provided detailed income and wealth inequality series for 174 countries for the 1990-2019 period, i.e. for more than 97% of the world population and 97% of global Gross Domestic Product. The general guidelines and methods underlying these data series are described in the Distributional National Accounts Guidelines [11] (see also **SI** Section 4).

Elasticity between carbon emissions and consumption or income. Data on individual emissions inequalities have been produced for several countries and years by researchers using input-output analysis applied to the environment and household surveys. Available literature typically finds that carbon emissions associated with individual consumption depend on several factors, including income, household location, energy conversion technologies, occupation status, habits, age, national regulations, and energy mixes [30, 31, 32, 33, 34, 35, 36, 37, 38, 14]. While non-income factors play a role in determining individual emissions levels, income retain an overarching role in explaining variance in emissions between households.

Studies measuring the *elasticity* of individual carbon emissions (or the strength of the relationship between rising individual income and CO_2 emissions) are presented in **SI** section 5. These studies find that the elasticity of household consumption to emissions (in a model of the form $e = k \times y^{\alpha}$, where e is the level of emissions, c consumption, α the elasticity and k a constant), typically falls in the 0.9-1.1 range, while the elasticity of household income to emissions typically falls in the 0.5-0.7 range (see **SI** Table 5.1). This paper mobilizes these country-level elasticities, now available for most countries, to produce fine grained modeled estimates of the distribution of emissions.

Distributing emissions among individuals. National-level distributions (of income, wealth or carbon emitters) are broken down in 99 percentile groups and 28 smaller fractiles within the top percentile. 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 with household consumption, private investment and public spending, respectively. More precisely:

$$E_p^{cons} = f(E^{cons}, y_p, \alpha) \tag{2}$$

$$E_p^{inv} = f(E^{inv}, w_p, \gamma) \tag{3}$$

$$E_p^{gov} = f(E^{gov}, y_p, \delta) \tag{4}$$

Where E^{cons} is the average carbon footprint associated with a unit of 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 $E_p^{cons} = kE^{cons} \times y_p^{\alpha}$); E^{inv} is the average emissions level associated with fixed capital formation, w_p the average wealth level of individuals in percentile p, γ the elasticity of wealth to investment emissions; E^{gov} is the average emission level of the government sector (associated with in-kind redistribution) and δ, is the elasticity of government emissions to individual income.

The benchmark results presented above are based on α values available from country-level studies based on micro-data. I also test a variety of α values for each country from **SI** Table 5.1.

Fitting the model with observed γ is a challenging task given how few studies of the matter exist. Limited available evidence suggests that the distribution of emissions associated with wealth ownership is close to proportional to the distribution of wealth ownership (see also **SI** section 5). The elasticity of emissions to asset ownership reported by [39] is near unity and this finding tends to be corroborated by the estimates produced by [40].

The benchmark scenario is based on $\delta = 0$. This amounts to distributing government collective consumption expenditure equally to individuals, as a lump-sum. This is a rather conservative choice, which tends to minimize inequality in carbon emissions between income groups. In alternative scenarios, I distribute emissions in proportion to individuals' private consumption.

Besides the benchmark scenario, I produce results for the following set of parameters: $\alpha = \{0.4; 0.5; 0.6; 0.7; 0.8\}$; $\gamma = \{0.9; 1; 1.1\}$; $\delta = \{0; 1\}$. Extreme scenario bounds presented in the Figures are based on extreme bounds observed in available country-level data, that is $\alpha = [0.4; 0.8]$ and $\gamma = [0.9; 1.1]$. In all countries, I assume that emissions are split equally within households.

Robustness checks. The **SI** section 7 provides additional results for different parametric assumptions at the global, regional and country levels. The main results of this paper appear to be robust to a wide set of different assumptions. In an extreme lower-bound scenario (in which all countries would have the lowest empirically observed α value), I find that the global top 10% share of emissions nears 45% in 2019 (vs. 48% in the benchmark scenario). In an extreme upper-bound scenario (in which all countries would have the highest empirically observed α value), I find that the global top 10% share is 51%. Setting different γ parameters affects results at the top of the distribution, although in a moderate way: with γ=0.9 (and using empirically observed α values), the global top 10% share is equal to 46% in 2019. With γ=1.1 the global top 10% share is equal to 50% in 2019. Opting for $\delta = 1$ yields a global top 10% of around 50% and a bottom 50% share near 10%. It also appears that setting $\delta = 1$ has a fairly limited impact on bottom and top groups' overall emissions, as can be seen in **SI** Table 7.2, given that overall government emissions remain relatively low as compared with private consumption and investments.

Global dynamics between 1990 and 2019 also appear to be robust across these different scenarios and are not particularly sensitive to changes in parameter values within plausible bounds, as presented in Figures 1, 2 or 3. Changes in α values over time also seem to have little impact on global results, as illustrated on Figure 3B: if α had decrease in all countries from 0.8 to 0.4 between 1990 and 2019 (that is, if the wealthy had done much more decarbonization efforts than the rest of the population, per dollar spent), global emissions inequality we would still be essentially driven by within-country dynamics today.

Let me stress at the outset that, given the nature of the reconstruction exercise presented above, within-country estimates should be interpreted with care: a lot remains to be done by governments to improve the quality of distributional and environmental statistics. This novel set of estimates is as much a progress in our understanding of global carbon inequalities as a mapping of the many data and conceptual gaps which will have to be addressed in further research.

Data availability The data gathered for this study is available at https://lucaschancel.com/global-carbon-inequality-1990-2019/ and on demand.

Code availability The code used to produce key results of this study is available at https://lucaschancel.com/global-carbon-inequality-1990-2019/ and on demand.

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Author contributions statement

LC conceived and conducted the research, analysed the results, and reviewed the manuscript.

Additional information

The author declares no conflict of interest.

Figures

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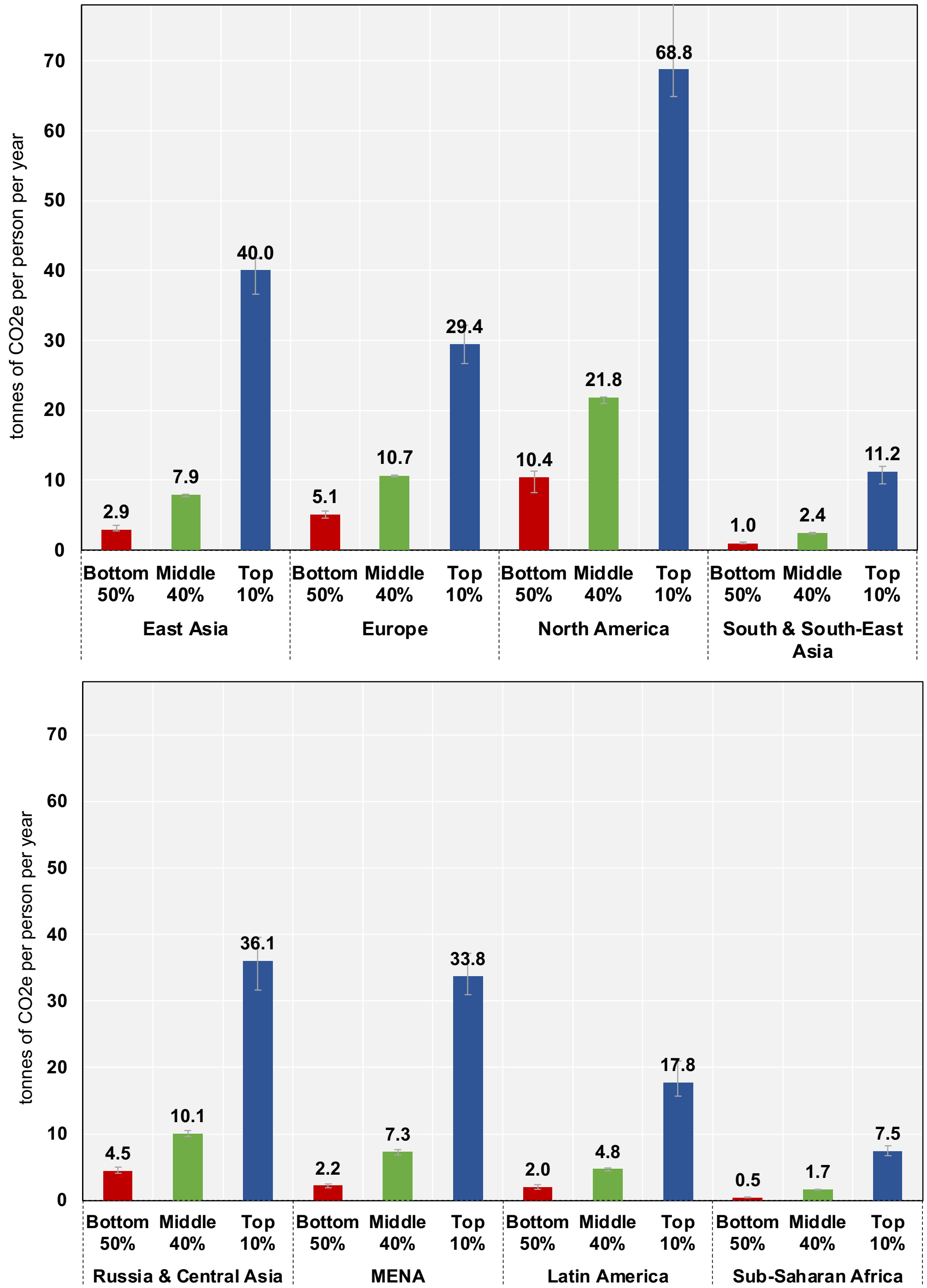


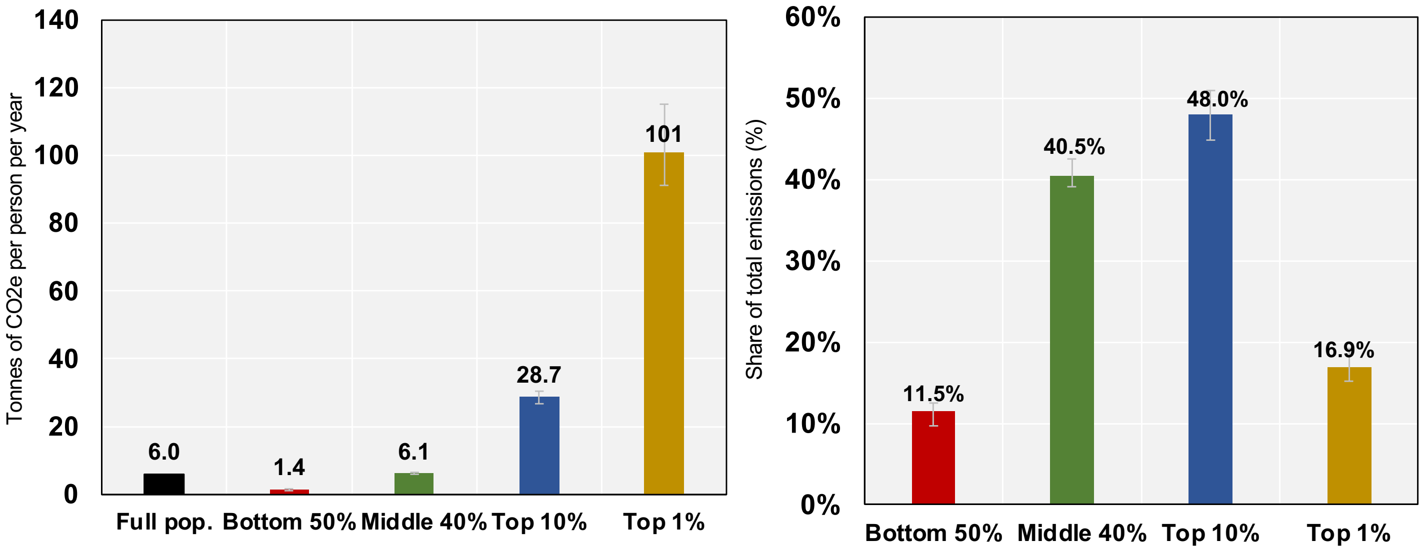
Figure I

Per capita emissions by group in 2019 (tCO_2e / capita)

Notes: Per capita emissions include emissions from domestic consumption, public and private investments, and imports and exports of carbon embedded in goods and services traded with the rest of the world. Benchmark scenario with modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Error bars show estimates for extreme scenarios (with $\alpha = 0.4$ and $\alpha = 0.8$ in the other). **Source and series**: Author, see Methods and **SI** sections 5-7.

A. Global emissions by group in 2019 (tCO2e/capita)

B. Group emissions share in world total in 2019 (%)



C. Global emissions inequality in 2019: summary table

	Number of individuals (million)	Average (tonne CO2 per capita)	Threshold (tonne CO2 per capita)	Share (% total)
Full population	**7710**	**6**	**<0.1**	**100%**
Bottom 50%	**3855**	**1.4**	**<0.1**	**11.5%**
incl. Bottom 20%	*1542*	*0.7*	*<0.1*	*2.3%*
incl. Next 30%	*2315*	*1.8*	*1.1*	*9.2%*
Middle 40%	**3084**	**6**	**2.8**	**40.5%**
Top 10%	**771**	**29**	**13**	**48%**
incl. Top 1%	*77.1*	*101*	*47*	*16.9%*
incl. Top 0.1%	*7.71*	*425*	*125*	*7.1%*
incl. Top 0.01%	*0.771*	*2332*	*566*	*3.9%*

Figure II
Global emissions by group of emitters in 2019

Notes: Per capita emissions 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 are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. Error bars show estimates for extreme scenarios (with $\alpha = 0.4$ in one case and $\alpha = 0.8$ in the other). Panel A: average emissions by group. Panel B: share of group emissions in total. Panel C: Summary Table. **Source and series**: Author, see Methods and **SI** sections 5-7.

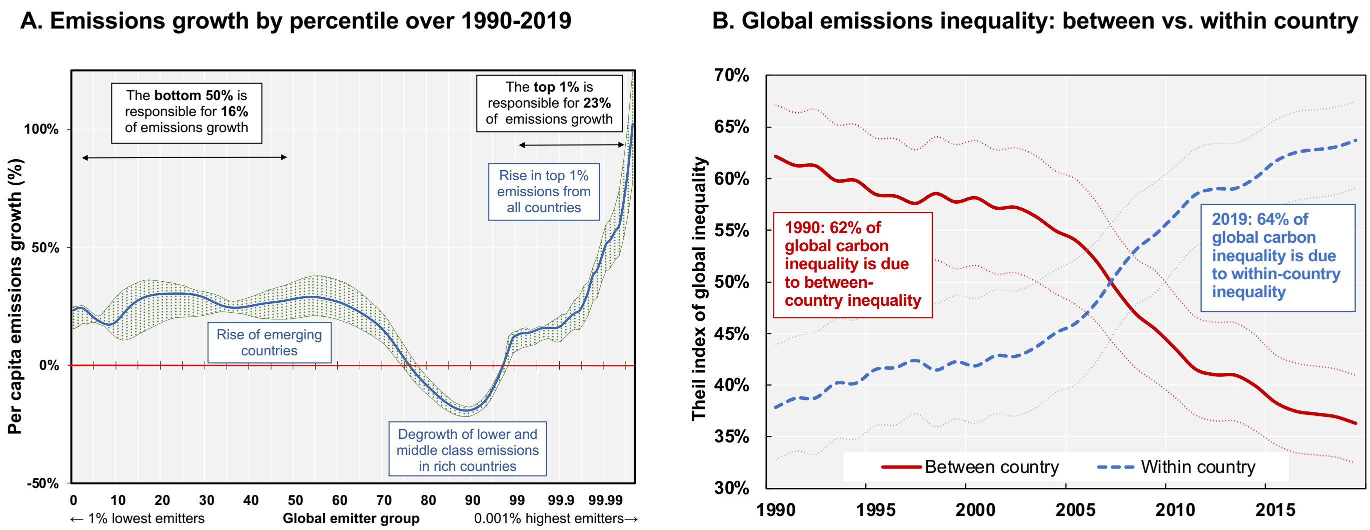


Figure III
Global emissions inequality over 1990-2019

Notes: 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 on the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. Panel A: Growth in emissions by global emitter group over 1990-2019. Dotted area represents upper and lower bounds from our range of extreme scenarios. Panel B: Dotted lines represent scenarios with $\alpha = 0.4$ and $\alpha = 0.8$. **Source and series**: Author, see Methods and **SI** sections 5-7.

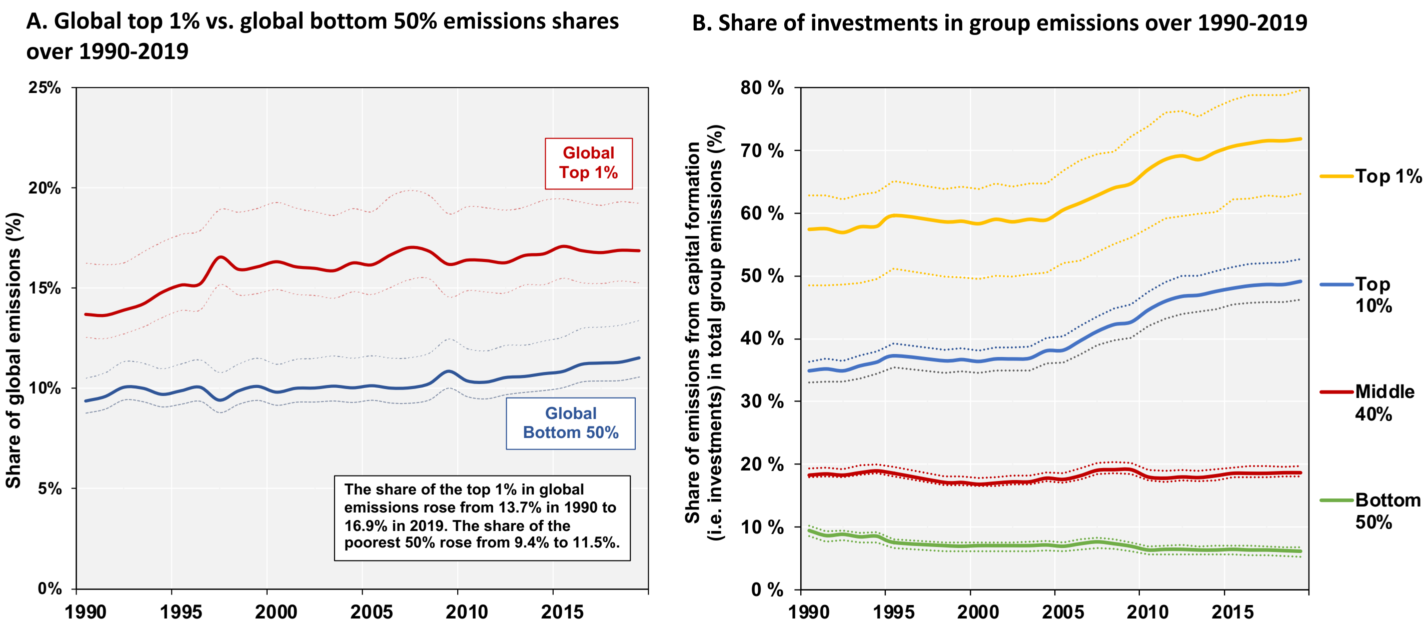


Figure IV

Top 1% vs. Bot. 50% shares and emissions from investments over 1990-2019

Notes: 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 on the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario with values from extreme scenarios (with $\alpha = 0.4$ and $\alpha = 0.8$). Emissions split equally within households. Panel A. Group shares in world totals. Panel B. Share of GHG emissions by different groups of emitters that can be traced to their investments, rather than to their consumption. **Source and series**: Author, see Methods and **SI** sections 5-7.

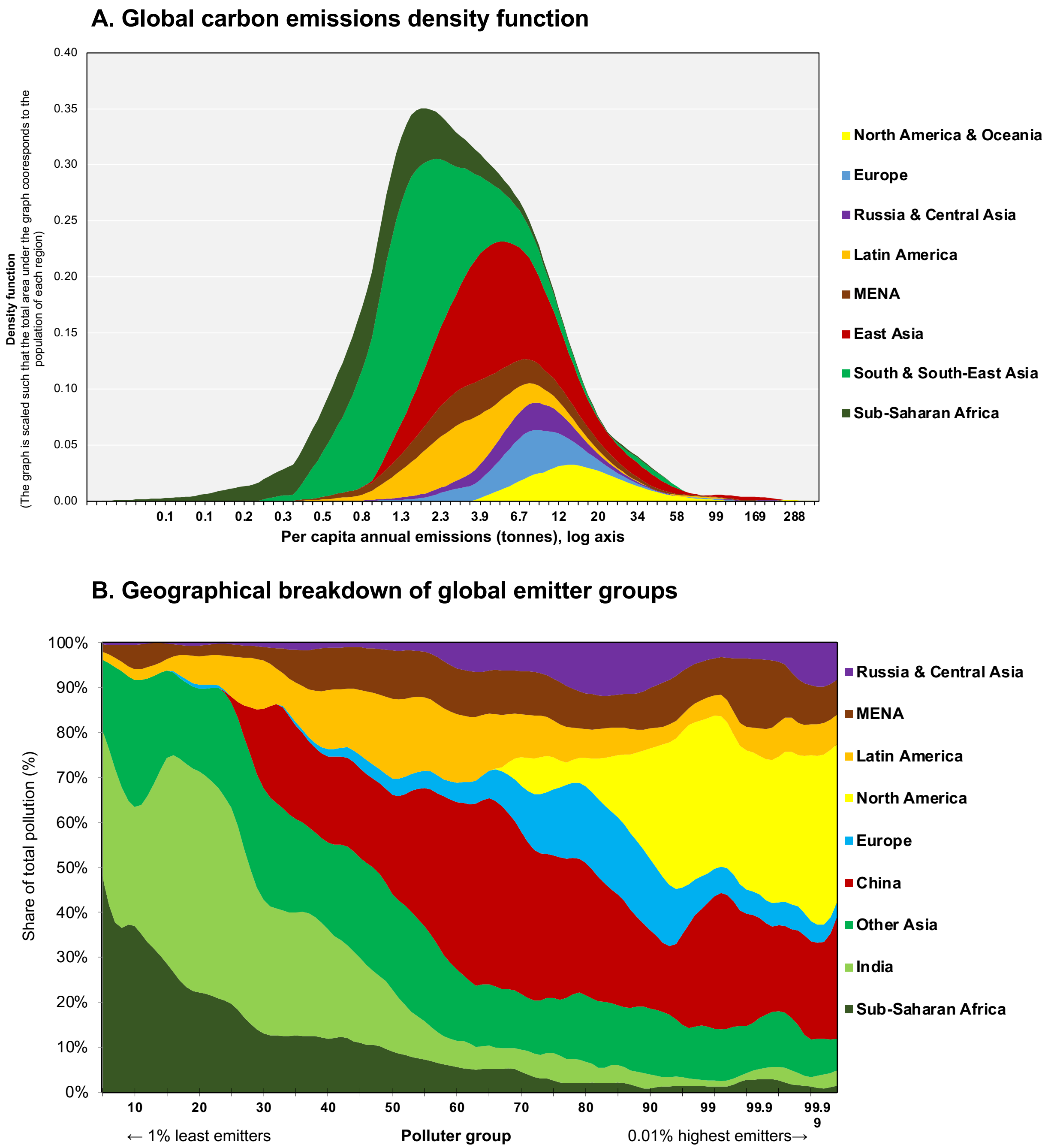


Figure V

Geographical breakdown of global emitters in 2019

Notes: Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Benchmark scenario. Emissions split equally within households. Panel A. Number of emitters from each world region across the per-capita emissions scale. The Y axis is scaled such that the colored areas are proportional to the population share of each region in total world population. The X axis is log-scaled. Panel B. Share of each region's population within each global emitter group. Among the lowest emitter groups, about 30-40% of the population lives in Sub-Saharan Africa. GHG emissions measured correspond to individual footprints, i.e. they include indirect emissions produced abroad and embedded in individual consumption. **Sources and series**: Author, see Methods and Supplementary Information.

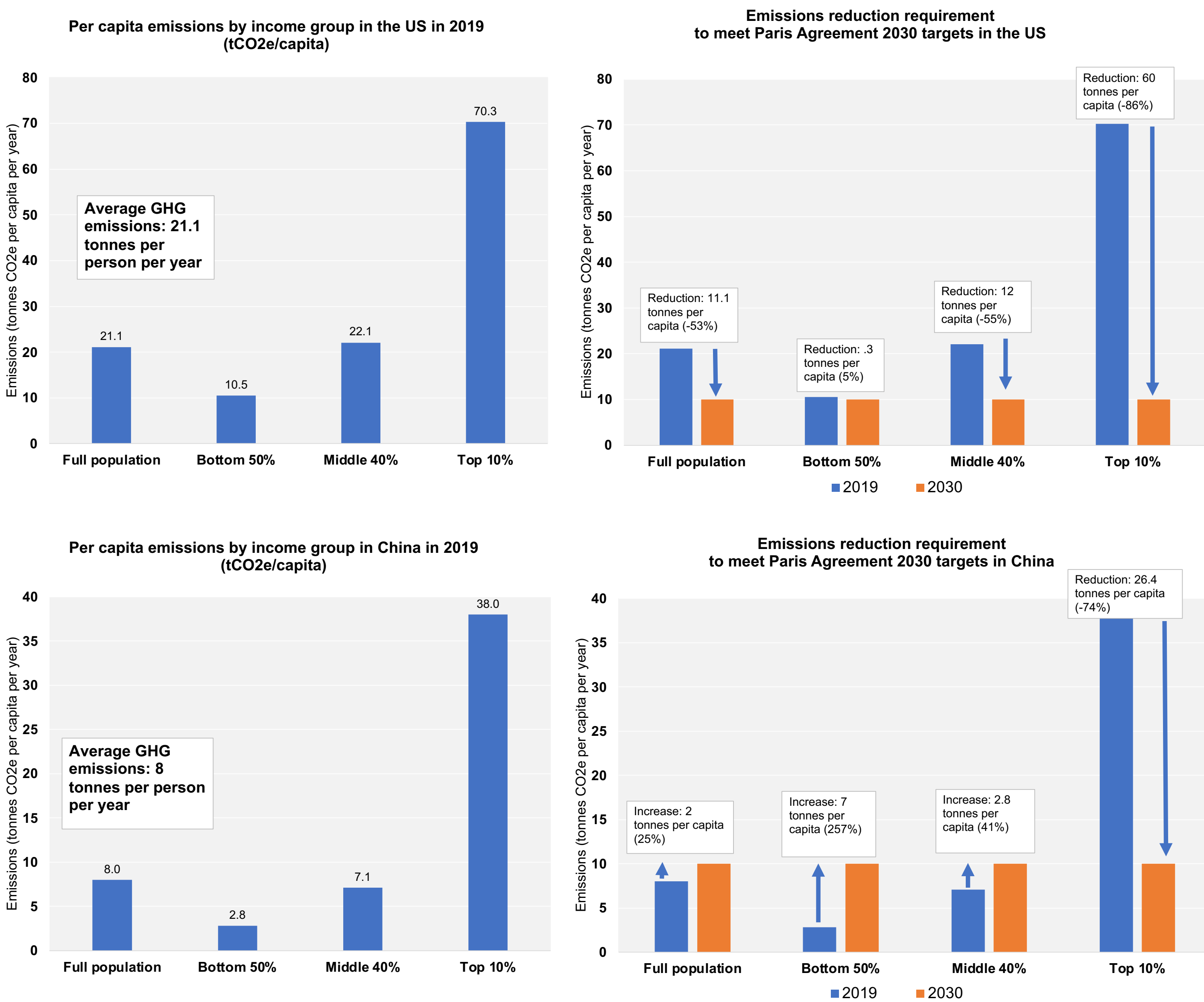
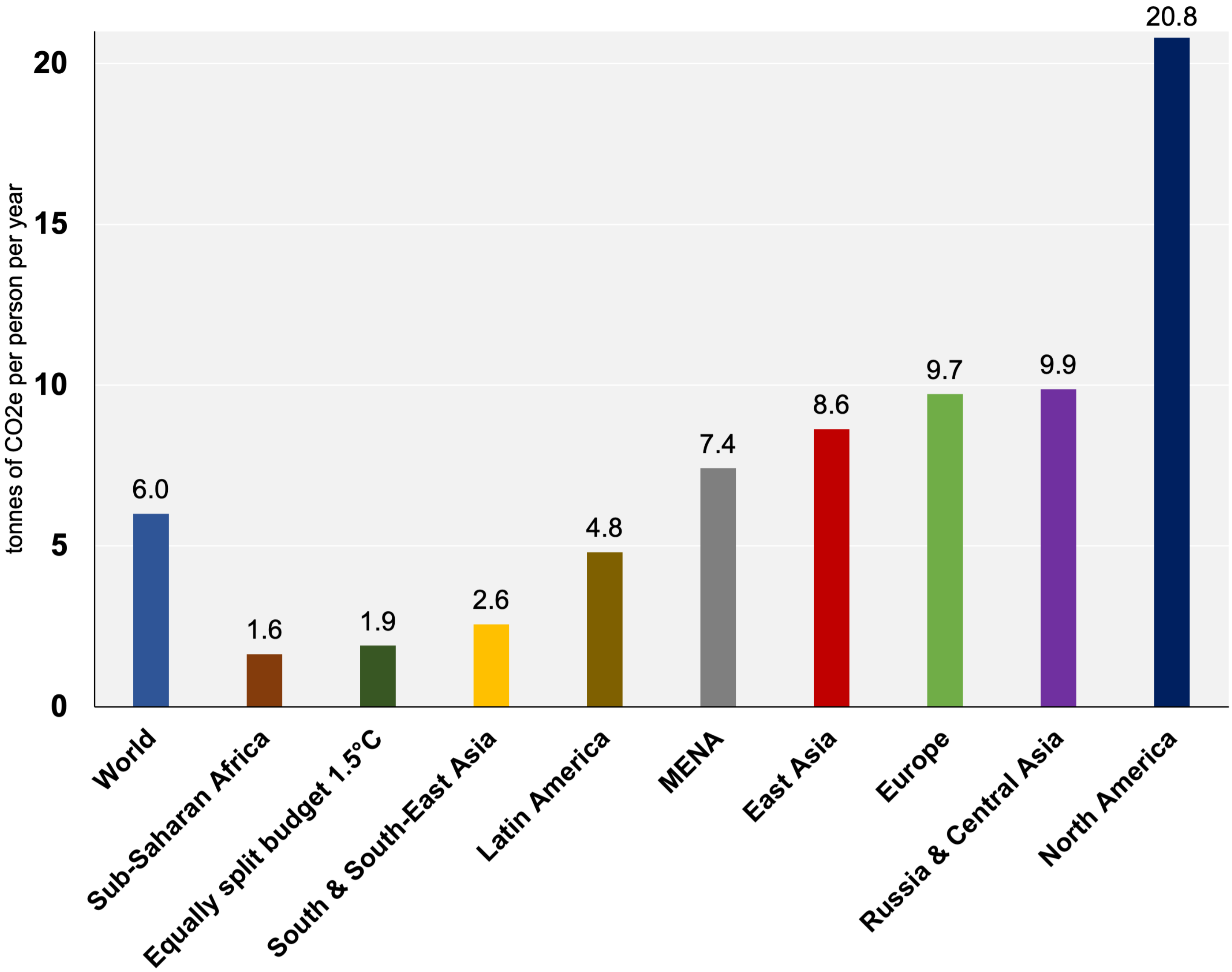


Figure VI
Emissions inequality and climate targets

Notes: Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. The graph shows national emissions targets (NDCs) expressed in per capita terms, and compares these with current emission levels of different income groups in the US and in China. **Sources and series**: Author, see Methods and **SI** section 8.



Extended Data Figure 1. Average GHG emissions by world region in 2019

Notes: Sharing the remaining carbon budget to have 83% chances to stay below 1.5°C global temperature increase implies an estimated annual GHG per capita emissions near 1.9 tonnes per person per year between 2021 and 2050 (and zero CO2 emissions afterwards). Emission levels present regional per capita emissions and include all 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 (LULUCF emissions are excluded). **Sources and series**: Author, see Methods and **SI** section 3.

		What kind of climate policy?		
		Increase green energy supply	Increase green energy access	Switch in energy end-uses (building, transport, industry)
Which social group is targetted?	Bottom 50%	Industrial policy: public investments in renewables (off or on-gridd); Social protection: increase transfers to workers in industries affected by the transition	Public investments in green energy access (e.g. clean cookstoves; construction of new zero carbon social housing)	Develop public transport systems: low-carbon bus, rail, car-sharing strategies; energy retrofitting in social housing; cash-transfers to compensate increase in fossil energy prices
	Middle 40%	Same as above + Financial incentives to encourage middle-class investments in green energy. Bans on new fossil investments	Subsidies for green housing construction; Buildings regulations; penalty and bans on sales of inefficient housing	Same as above; Stricter regulations & taxes on polluting purchases (SUVs, air tickets); Subsidies on green alternatives (elec. vehicles)
	Top 10 % & Top 1%	Wealth or corporate taxes with pollution top-up to finance the above & accelerate divestment from fossils; Bans on new fossil investments	Wealth or corporate taxes with pollution top-up (see left); Fossil fuel subsidy removal*	Strict regulations on polluting purchases (SUVs, air tickets); Wealth or corporate taxes with pollution top-up (see left); Carbon cards to track high personal carbon footprints & cap them

Extended Data Figure 2. Inequality check for climate policies

Notes: The table presents a non-exhaustive list of different types of climate policies and of their potential impacts on social groups. *Fossil fuel subsidies typically benefit wealthy groups more than poorer groups in rich and developing countries. **Sources and series**: Author. See also SI section 8.2.