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Potential pension fund losses should not deter high-income countries from bold climate action

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Main Text

Shutting down fossil-fuel production sites before available reserves are depleted or the useful life of the capital equipment exhausted, is a necessary consequence of ambitious climate policy.[1,2] Yet, if unanticipated by the investors in these assets, it also leads to a loss on their investment, so-called stranded assets.[3] Governments in rich, Western countries may water down their climate policies for fear of the social repercussions of such asset stranding as these policies hurt oil and gas companies. In particular, pension plans invested in capital markets that are already underfunded could be at risk of falling even shorter of meeting their present and future pay-out obligations.[4] The current push to expand fossil-fuel investments in both Europe and the United States as a result of the reduced gas supplies from Russia, following Russia's invasion of Ukraine, only serves to underscore the worry of diluted climate ambition. As the valuations of oil and gas companies soar, their importance for the health of pension savings only grows.

However, it is unclear how socially relevant such asset stranding would really be. Are most people invested through their pension or is interest in excessive fossil-fuel production concentrated among a small group of affluent investors? While there is good evidence that the richest few percent of individuals and households account for the bulk of carbon emissions through their consumption and investments[5,6], the distribution of ownership of fossil-fuel assets and infrastructure at risk of stranding is much less analysed.

We argue that governments should not be deterred by the risk of stranded fossil-fuel assets because any resulting wealth loss that causes economic hardship can be compensated at low cost. For an exploration of the distribution of stranded assets, we combine for the first time detailed macroeconomic and financial network modelling data on the value and location of financial ownership of oil and gas stranded assets[7] with estimates of the financial asset and overall wealth distributions[8] for the United States and European countries. Stranded assets are modelled as the present value of potentially lost profits from over 40,000 oil and gas fields as investor expectations realign to a lower-carbon future. Losses are traced to ultimate owners, i.e., the persons and governments that own stocks in oil and gas companies through shares and funds. Losses for persons living in the United States and Europe exceed $500 billion (US-dollar) in a 'medium' expectations realignment to a world of about 2°C warming (Fig. 1). The financial asset size distribution is assembled from income tax records, wealth surveys and national accounts data, and made comparable across countries by following Distributional National Accounts guidelines.[9,10] As a first approximation, we assume that each wealth fractile is allocated stranded assets to non-government ultimate owners in proportion to its share in the national distribution of financial assets, a wealth elasticity of stranded assets equal to one. That is, $1 invested by the bottom 50% of persons by wealth has the same probability of stranding as $1 invested by the top 1%. This certainly does not mean that the bottom 50% owns the same absolute amount of stranded assets as the top 1% (Fig. 1), because of very large inequalities in financial asset ownership and savings between groups. For instance, the top 1% in the United States owns 39% of all financial assets, while the bottom 50% owns barely more than 3% of them (Supplementary Table 1). For robustness we consider three alternative expectation realignments that lead to different totals and distributions of stranded assets as well as different elasticities of stranded asset reflecting potential biases in investment portfolios across the wealth distribution (Fig. 2, see also Supplementary Note 1-2 and Supplementary Table 2).

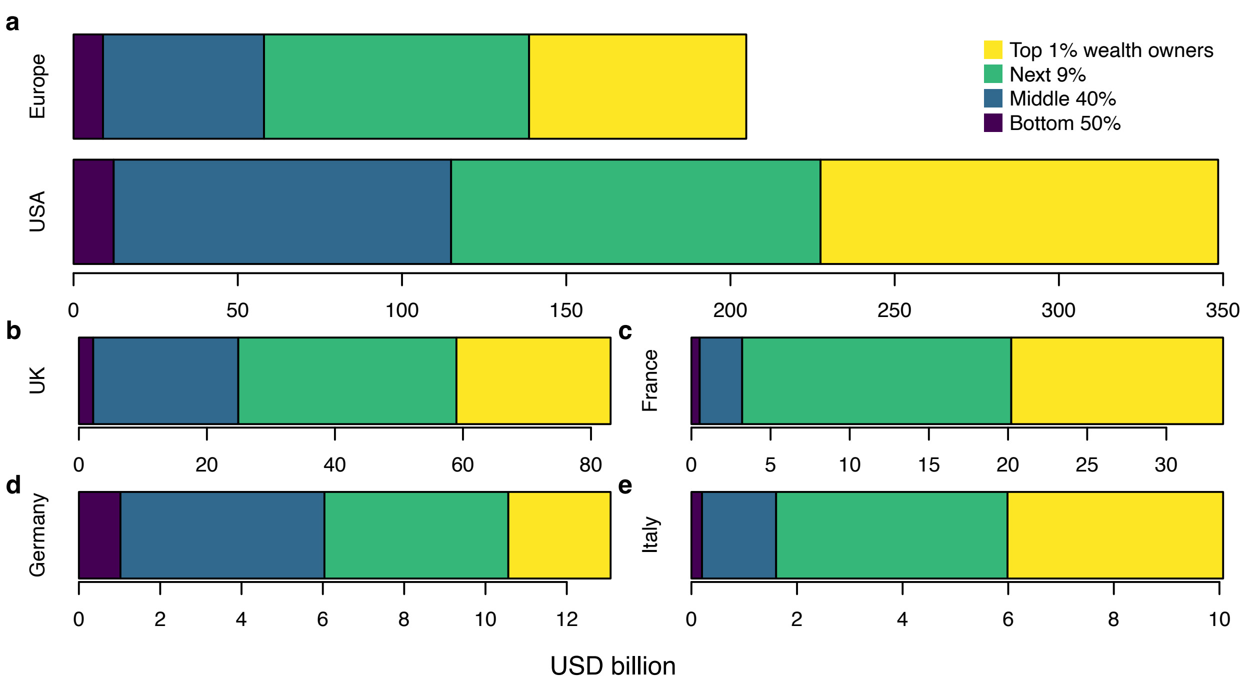

Figure 1. Partition of country or regional stranded assets by wealth fractile for **(a)** Europe as a whole and the United States, and **(b)-(e)** four major European countries. Middle 40% corresponds to the group of the population between the bottom 50% and the top 10% of the population. Next 9% corresponds to the group between percentiles 90 and 99.

Unequal losses

In the United States, of an estimated $350 billion in stranded assets, only 3.5% of the total hits the poorest half of the population and one third the bottom 90%. The remaining two thirds split roughly equally between the top 1% of wealth holders and the next 9% (Fig. 1a, Supplementary Fig. 1). Overall losses in Europe are estimated at around $200 billion and are similarly skewed. Given the extremely high level of concentration of financial assets at the top of the distribution (apart from Germany, the top 10% hold 70-90% of the total depending on countries, i.e., much more concentrated than incomes, or than real estate), one would need to make extreme assumptions on the relative weight of stranded assets in lower income groups' portfolios to counterbalance this first-order effect. Even when introducing a strong fossil fuel and by extension stranded asset portfolio bias to lower wealth groups, the top 10% typically still hold most losses (Supplementary Figs. 2 & 3).

Although affluent persons own most losses in absolute terms, these are small compared to their wealth. Stranded assets in Fig. 1 amount to less than one percent of the top 1% of individual net wealth (Fig. 2, right panel, green disks). This group corresponds to adults each owning on average several million US-dollars (Fig. 2, bottom). Even under the most severe asset stranding scenario, consistent with oil and gas demand in a world limiting global warming to 1.5°C, and a portfolio bias of affluent persons towards fossil fuels, their losses would be less than 2% of their wealth (Fig. 2, right panel, dark blue squares). Stranded assets as a share of net wealth tend to be even lower for the next 9% and the middle 40% of wealth owners because financial assets make up a smaller share of their wealth, which is largely composed of housing assets.

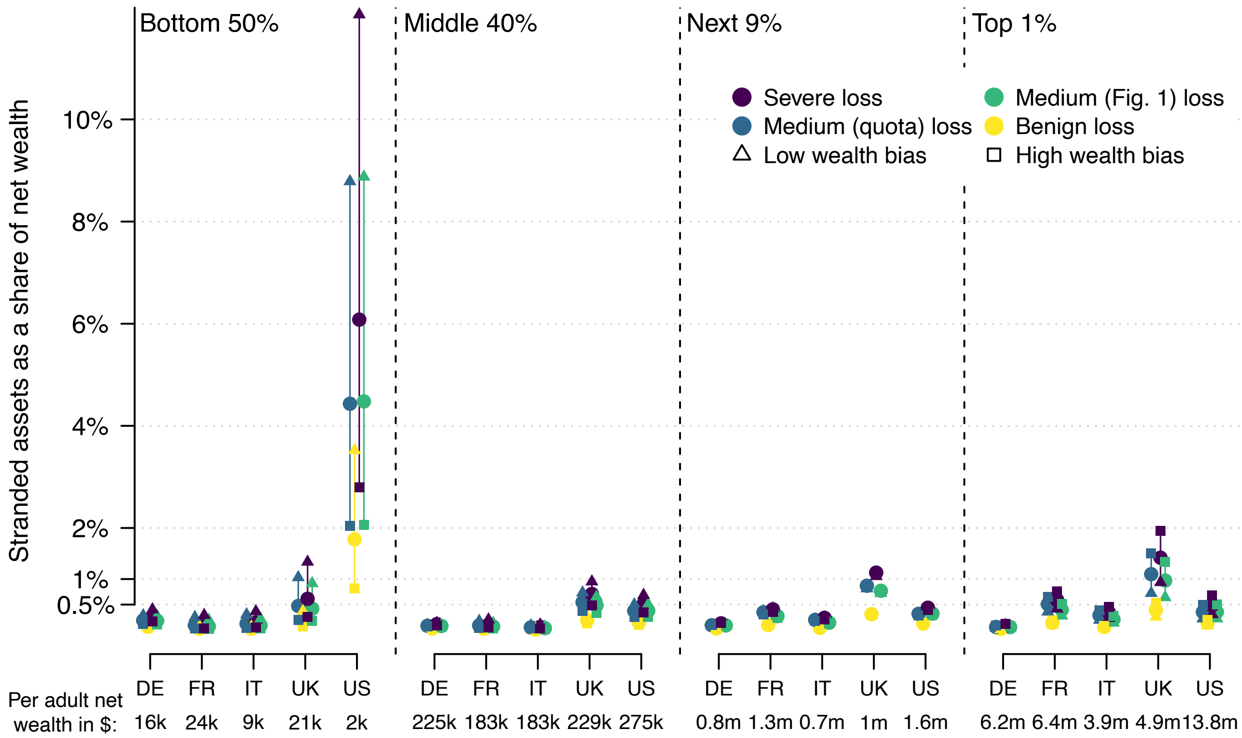

Figure 2. Stranded assets as share of total net wealth by fractile for five large countries and for different scenarios. Each country-fractile shows four colours that reflect different totals and international distributions of asset stranding. Each colour shows three shapes, with the disk showing losses proportional to financial assets, triangles a higher fossil-fuel portfolio exposure of the bottom 90% and squares a higher exposure by the top 10%. The bottom row of numbers reports average net wealth by an adult person in the country-fractile observation (ref[8] discusses international comparisons of wealth distributions). Supplementary Fig. 3 on a log scale distinguishes detail for low losses and Supplementary Table 4 reports the data points. Supplementary Figure 5 compares US losses reported here with those calculated from the Federal Reserve's Distributional Financial Accounts.

Turning to the bottom 50%, we find losses ranging from 0.05%-1% in continental European countries, to 4-5% of total net wealth in the US, and even higher under some portfolio bias scenarios. We stress that one of the main takeaways is that the bottom 50% own little net wealth to start with, independently of any potential stranded assets losses. Therefore, even small absolute losses can be substantial as a share of net wealth. Relatively high losses as a share of net wealth in the United States and the United Kingdom can be explained by low levels of bottom 50% bank deposits as compared to other countries (deposits are not exposed to stranded asset losses in our framework). Conversely, in these two countries the bottom 50% have substantial assets as pension contributions in capital market relative to deposits, and such pension investments are exposed to asset stranding (Supplementary Table 1). This contrasts with French, German, and Italian pension systems, which are mostly independent of capital market valuations.

Social repercussions and compensation

Our results reveal two distinct social outcomes of asset stranding. First, top wealth groups own most of the losses yet appear to be protected by their considerable overall wealth. Stranded assets might extend beyond upstream fossil fuels, but fossil fuels are the most directly affected industrial sectors. Neglected losses in sectors that use fossil fuels as inputs, rather than outputs, could be of comparable magnitude according to one study[11] (for comparison with other stranded fossil-fuel estimates see Supplementary Note 3). Moreover, other sectors that use fossil fuels as an input, rather than as their output, have more substitution opportunities (from internal combustion engine to electric vehicle manufacturing for instance). As such, aggregate stranded asset losses in those sectors could be counterbalanced by an increase in the value of other portfolio positions.

Second, less affluent groups, particularly in the United States and United Kingdom, could be tipped (deeper) into net negative wealth, increasing risks of personal bankruptcy, and suffer pay-out reductions from defined contribution pension schemes. Since adults are unequally exposed, e.g. 9% of British pension funds have completely divested from fossil fuels,[12] the losses for those who do sustain them exceed the averages in Fig. 2. In continental European countries, current high inflation rates arguably pose a bigger threat to the value of financial assets. Still, those groups who are most exposed to stranded assets and have little capital could experience economic hardship.

These two outcomes generate a key insight for ambitious climate change mitigation: governments could compensate socially relevant asset devaluation at low cost. For instance, compensating all stranded assets of the bottom 50% under ‘medium’ losses (Fig. 1), would cost $9 billion in Europe and $12 billion in the United States. These amounts are lower than the recent German government bailout of the utility Uniper for $15 billion,[13] or anticipated compensation to investors insured under the Energy Charter Treaty against losses caused by climate policy of up to $20 billion.[14] Even doubling compensation figures to extend equal protection to all groups would keep compensation figures modest. Fig 3 & 4 present what fully compensating each group would cost, expressed as a share of national income and national wealth. Compensating all losses incurred by the least affluent 90% of adults would cost between 0.1% and 1.2% of national income and 0.02% and 0.3% of national wealth of the countries shown separately in Fig. 1.

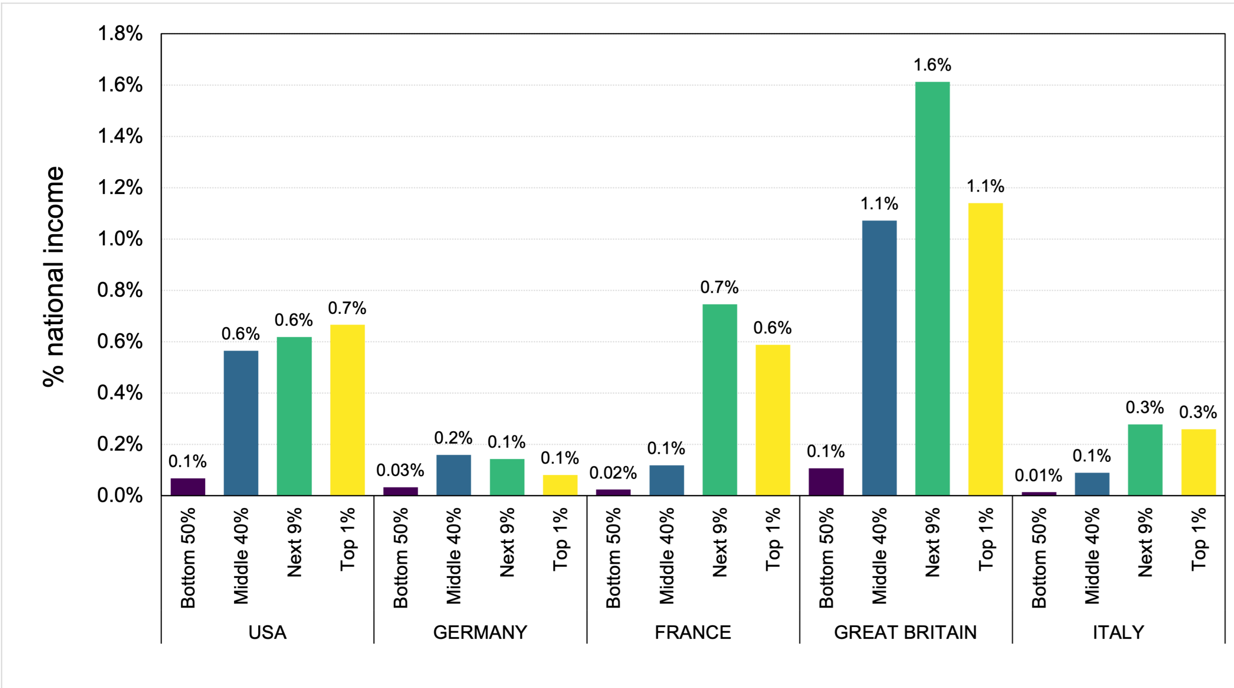

Figure 3. Stranded asset losses by wealth group as a share of national income in 2019. National income data from WID.world. [10] Benchmark scenario as in Fig. 1

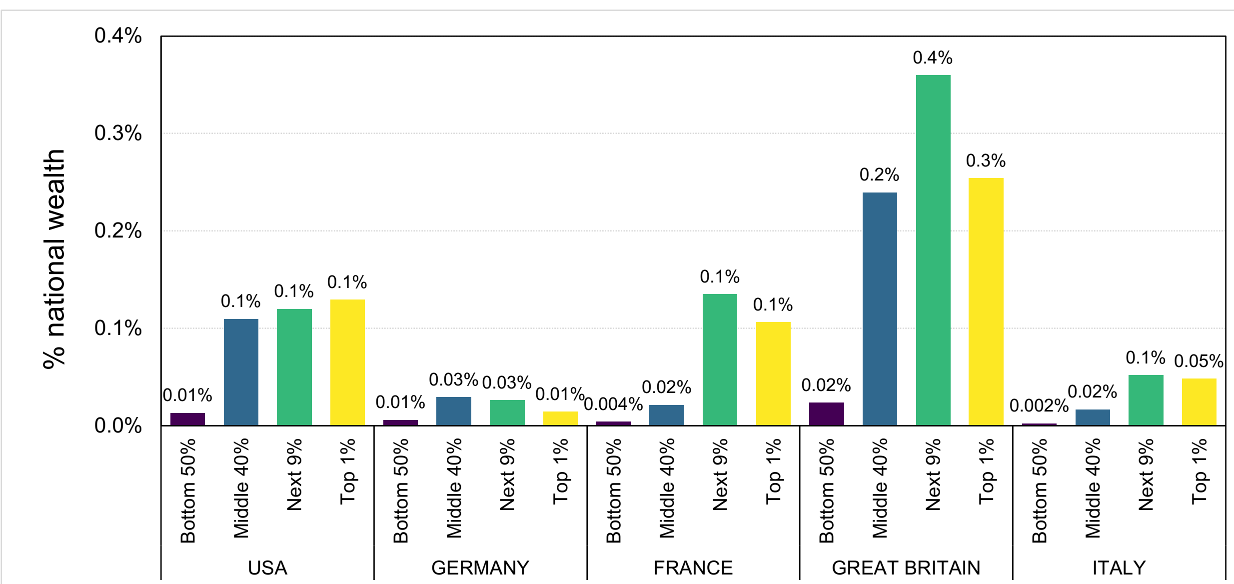

Figure S7. Stranded asset losses by wealth group as a share of national wealth in 2019. National wealth data from WID.world.[10] Benchmark scenario as in Fig. 1.

Funding options

Funding for compensation could be procured in several ways. A modest price of $13/MTCO_2e on US carbon emissions would raise about $74 billion per year over the next decade;[15] compensating the bottom 50% would only use one sixth of one year's revenue and thus leave enough funds to also avoid regressive redistribution from the pricing via, e.g., a carbon dividend.[16] In some countries, financing could also result from pushback against investor treaties, such as the Energy Charter. If some of these treaties were abolished, a portion of the savings could be redistributed. Finally financing could also be done directly by redistributing wealth. A modest progressive wealth tax on the top 0.005% of the population (2% on the net wealth of persons owning over $100m and 3% on persons owning over $1bn) could compensate the totality of stranded asset losses in about 2 years in the United States and less than 3 years in Europe[8] (Supplementary Table 3).

High-income country governments are expected take bold climate action. The prospect of stranded assets, and their potential impacts on low and middle-class capital owners, is no credible deterrent to doing so. Stranded assets appear to be disproportionately concentrated among the very well-off and losses can be compensated at relatively low cost among the poor. Our results remain limited by little data transparency and availability on these important matters. We stress that increasing governments' statistical capacity to better track stranded asset ownership will be important for implementing fair decarbonization policies. If such compensation can be carried out, the main political economic challenge to be overcome is lobbying by affluent fossil-fuel interests to protect their wealth at risk. In principle, these investors should be able to hedge their portfolios against excessive exposure to stranded fossil-fuel assets. We stress that this analysis focuses solely on financial capital ownership and its distribution in affluent countries – that is, we leave aside the important question of loss of labour incomes as well as that of other macroeconomic impacts, which could be analysed in future work. Analyses of macroeconomic impacts in less affluent, oil-exporting countries find that those countries can face greater macroeconomic challenges associated with stranded assets, even if these are smaller in absolute numbers.[17] We also note that it would be important to investigate more precise portfolio holdings across the wealth distribution with more granular data. Given the limited variation in shares of wealth lost even under strong portfolio bias, we suggest that our results here provide a robust first-order approximation over possible outcomes.

Supplementary Information Description

Supplementary Notes 1-3

Supplementary Tables 1-5
Supplementary Figures 1-3

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Author Contributions: All authors conceptualized the research. GS, LC and ES curated and analysed the data, and drew the figures. GS, LC, PH and NE wrote the paper. GS and LC contributed equally.

Declaration of Interests
The authors declare no competing interests. G.S. is affiliated with the University of Sussex, University College London and SOAS University of London. L.C. is affiliated with Harvard University and the London School of Economics. J.F.M. is affiliated with the University of Exeter and University of Cambridge. N.R.E. is affiliated with the University of Cambridge.

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Supplementary Information:

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Contents

Note S1: Methods

We calculate the numbers in Fig. 1&2 by combining estimates from two different sources.

We define stranded assets as the reduction in discounted future expected profits from extracting oil and gas when investor expectations realign to lower future oil and gas demand. Demand with initial and realigned expectations is modelled in previous research with the E3ME-FTT-GENIE integrated assessment model, and reduced demand passed to those oil and gas fields with the least favourable economics using Rystad's ucube and the asset loss to ultimate owners of these fields using Bureau van Dijk's ORBIS database[1]. E3ME is a highly disaggregated, demand-led, macro-econometric and dynamic input-output model resolving global economic output of goods and services into 43 consumption categories, 70 sectors, 61 countries and regions, 23 fuel user types and 12 fuel types. Technological change dynamics are represented in greater detail for the most carbon-intensive sectors (energy, transport, heat, and steel) by the FTT model, and climate dynamics by the intermediate complexity three-dimensional Earth system model GENIE. Expectation realignments are based on 4 global demand scenarios, supplied by the most economically competitive oil and gas sites: (1) IEA 2019 Stated Policies, (2) as for scenario (1) but with faster diffusion of low-carbon technologies using the FTT model, (3) Europe and East Asia reach 20150/60 net zero greenhouse gas/CO_2 emissions targets, consistent with 2C global warming, (4) the world reaches net zero CO_2 emissions by 2050, consistent with 1.5C warming. The medium realignment calculates stranded assets when demand expectations realign from scenario (1) to (3), the benign realignment from (2) to (3), and the severe realignment from (1) to (4). The medium quota realignment also realigns from (1) to (3) but alters which sites are supplying by assuming OPEC member countries stick to current global production shares, which lowers their production relative to a medium realignment. Here we analyse the portion of the losses ultimately owned by persons as opposed to governments in each of the countries considered.

Net personal wealth is equal to the sum of all personal assets, net of debts, and can be decomposed into financial and non-financial wealth. Financial wealth includes equity, bonds, and loans (owed to others as an asset or owing others as a liability). Non-financial wealth includes physical assets such as real estate. Various data sources are based on the systematic combination of inheritance and income tax records, wealth surveys and national accounts, following the Distributional National Accounts guidelines [2,3]. Data are expressed in equal-split adult (i.e., wealth is shared equally among spouses). This database contains the distributions of wealth, financial and non-financial asset ownership among 127 generalized percentiles (i.e., the 99 bottom percentiles, the top 1% split into 10 fractiles of equal population size, the top 0.1% again split into ten fractiles of equal population size, and so forth up to the top 0.001%).

To allocate stranded assets we use financial assets minus deposits, i.e., financial ownership without subtracting liabilities. We do subtract deposits (an asset) as these are typically not directly invested in financial markets and are guaranteed up to a significant amount by governments. We compute distributive shares as follows. For percentile $p = 1, \ldots, 100$ in country c and asset stranding scenario i, we calculate its stranded assets, S_{pci}, as proportional to its financial assets minus deposits, A_{cp} relative to the country's total financial assets minus deposits, A_c, times total country and scenario-specific stranded assets S_{ci}

$$S_{pci} = \frac{A_{pc}}{\sum_p A_{pc}} S_{ci} = \frac{A_{pc}}{A_c} S_{ci} \quad . \qquad (1)$$

Stranded assets for the four groups in figure 1 can simply be computed by summing across the percentile in each of the four fractiles, $q_{bottom50} = \{p \mid p \in \{1, \ldots, 50\}\}$ etc. In symbols

$$S_{qci} = \frac{\sum_{p \in q} A_{pc}}{A_c} S_{ci} \quad .$$

The share of a percentile's net wealth lost n_{cpi} is:

$$n_{pci} = \frac{S_{pci}}{W_{pc}} \quad , \qquad (2)$$

where W_{cp} is the net wealth (all assets minus liabilities) of percentile p in country c. Again, for group q, the share of net wealth lost amounts to

$$n_{qci} = \frac{\sum_{p \in q} S_{pci}}{\sum_{p \in q} W_{pc}} \quad .$$

The distribution of losses in stranded assets between the population groups is determined in equation (1) in proportion to non-deposit financial assets: $1 invested by the bottom 50% has the same probability of stranding as $1 invested by the top 1%. This can be expressed as an elasticity of asset stranding with respect to financial assets of one.

To allow for a biased distribution of fossil-fuels assets in low/high wealth portfolios, we define an alternative within-country stranded asset allocation using lower and higher elasticities. We apply the model of the form $\log(s_{pci}) = \log(k_{ci}) + e_i \times \log(a_{pc})$, where s_{pci} represents average per person stranded assets in percentile p of country c for scenario i, and a_{cp} the average per person financial assets minus deposits in percentile p of country c , e_i is the elasticity of stranded assets with respect to total financial assets minus deposits in scenario *i*, and k_{ci} a constant depending on country and scenario.

To obtain s_{pci}, we proceed in the following way. We first normalize the per person financial assets (minus deposits) of all percentiles in a given country and year, such that the distribution in this country and year has an average of 1. Normalized financial wealth (minus deposits) at percentile *p* is given by

$$\dot{a}_{cp} = \frac{a_{cp}}{\overline{a_c}} \quad ,$$

with $\overline{a_c}$ the mean per person financial assets (minus deposits) of the entire population in the country. We then raise $\dot{a}_{cp}$ to the power of e, the elasticity of stranded asset ownership with respect to financial wealth (minus deposits) ownership to calculate weights

$$b_{pci} = \left(\dot{a}_{pc}\right)^{e} \quad .$$

The share of stranded assets possessed by percentile *p* under scenario *i* is given by

$$\widehat{s_{pci}} = \frac{b_{pci}}{\sum_p b_{pci}} \quad . \qquad (3)$$

Total stranded assets of percentile *p* are then:

$$S_{pci} = \widehat{s_{pci}}\, S_{ci}$$

which can be summed to larger fractiles. In our benchmarks estimations *e* takes values in the set {0.8; 0.9; 1; 1.1; 1.2}. Results for the share of stranded assets for all wealth percentiles under each elasticity are depicted in Table S2.

As a further note on the data, the total for Europe sums over 24 countries and accounts for 96.2% of stranded assets from a 'medium' expectations realignment in Europe including Turkey the Caucasian countries, and excluding Russia. The precise list of countries and their stranded assets are in Table S5. Countries that are missing do not have the detailed information on financial asset distribution (as opposed to total wealth distribution) used in this research. Additional sources for the wealth distribution for European countries are from ref.[4] For some countries, for which the breakdown of assets by wealth group (e.g. equity vs. deposits vs. housing assets) was not available, we estimated the distribution of assets by wealth group based on what is observed in neighbouring countries.

Source code and data for the figures will be available at Zenodo (https://doi.org/10.5281/zenodo.7008065) upon publication.

Note S2: Portfolio bias

Our baseline assumption about the distribution of stranded fossil-fuel asset portfolio holdings across the wealth distribution is that these assets are in a fractile's portfolio in proportion to its share in overall asset holdings. To our knowledge, there are no studies that investigate the sectoral asset holdings across the wealth distribution. To test the sensitivity of our assumption absent such studies, we contrast our baseline with the alternative of an elasticity of stranded assets with respect to wealth of 0.8 (low wealth bias), and of 1.2 (high wealth bias). This means that for a doubling of wealth, stranded assets increase by 80% and by 120% respectively. It is important to understand that these scenarios provide extreme bounds on possible biases. Of course, individuals (such as business owners) might have a very unbalanced portfolio of assets. But given the basic investment advice of a diversified portfolio, it is highly unlikely that an entire fractile has a highly unbalanced portfolio. The proliferation of index funds has made it even more likely that any sectoral differences in investment portfolios across fractiles have become minimal. One candidate explanation for why there might be some bias in portfolios anyway, and in particular a high elasticity, could be the aforementioned business owners. If business owners in oil and gas tend to belong to the most affluent groups in society (as opposed to, say, restaurants, personal services or farms), affluent fractiles may hold a disproportionate share of stranded assets. Another is that ESG investing might have had different impacts across wealth fractiles, although the direction of this bias is not clear a priori. An explanation for a low elasticity could be that shortly before assets strand, sophisticated investors in high wealth fractiles manage to sell part of their holdings to fund managers of less affluent persons. This may be, for instance, because of superior investment skills or inside information. In any event, given these considerations we consider our low and high wealth biases to be extreme bounds for bias in portfolios at the fractile level. Table S2 reports losses for each fractile and geography for elasticities of 0.8, 09, 1.1, 1.2 as well as the benchmark elasticity of 1.

Note S3: Comparison with other stranded asset estimates

The levels of global stranded assets on which our analysis for European countries and United States bases ($1.4 trillion in the medium alignment, ranging from $700 billion in the benign realignment to $2.6 trillion in the severe one) reported here are lower than some of the estimates in the literature. Other studies reported upwards of $10 or even $20 trillion, and there are even estimates of $100 trillion.[5] Such numbers would of course drastically increase the losses as a share of total wealth. The reason for the difference is that our results are restricted to losses that can reasonably be expected to be already priced into current valuations of fossil fuel companies, i.e. the present value of expected profits over a 15-year time horizon. Such valuations are also considered by financial investors and reflected in financial asset values that make up the net worth of individuals. The much larger numbers elsewhere come from first considering all current reserves, which are much more than would be extracted in the next 15 years even without climate policies, and then asking what part of these reserves cannot be extracted over a longer horizon such as until 2050 or 2100 (following e.g. the Welsby et al. method[6]). These are then secondly multiplied by a (discounted) price or profit factor to arrive at much larger numbers. However, from an investor perspective the risk of mispricing assets is not related to the total amount of reserves. It is only those reserves that are at risk of not being extracted in the next several years and the capital stock built to extract them that can affect the financial wealth of individuals. Of course, different assumptions about model parameter and scope of asset classes considered can lead to higher estimates even with a method similar to ours as e.g. done by Hansen[5].

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Table S1. Asset categories and net wealth by wealth percentile group.

Country	Fractile	Shares in in %						
		Net wealth	Financial Assets					Nonfinancial assets
			All	Deposits	Non-deposits	Pensions	Other	
DEU	Bottom 50	3.5	9.8	12.7	7.8	9.7	4.2	1.6
	Middle 40	38.8	40.5	43.7	38.4	44.1	27.4	38.0
	Next 9	31.1	32.7	30.0	34.6	33.5	36.6	29.9
	Top 1	26.6	17.0	13.6	19.2	12.7	31.8	30.6
FRA	Bottom 50	4.5	4.4	23.5	1.6	3.8	0.4	8.3
	Middle 40	27.3	12.9	46.3	8.0	17.3	3.0	43.2
	Next 9	44.2	47.5	26.5	50.6	54.7	48.4	38.0
	Top 1	24.0	35.2	3.7	39.8	24.2	48.3	10.5
GBR	Bottom 50	4.4	3.7	6.7	2.7	2.6	2.9	17.1
	Middle 40	38.6	31.4	43.6	27.3	28.4	23.8	48.3
	Next 9	36.5	39.9	36.5	41.0	42.4	36.8	25.4
	Top 1	20.5	25.0	13.2	29.0	26.5	36.5	9.2
USA	Bottom 50	0.3	3.1	1.8	3.5	5.4	0.4	7.5
	Middle 40	28.2	25.6	13.7	29.5	43.0	7.0	40.8
	Next 9	36.2	32.3	32.4	32.3	38.4	22.1	34.5
	Top 1	35.3	39.0	52.1	34.7	13.2	70.5	17.2

Note: Shares sum to 100% for each country and asset category. For instance, the bottom 50% wealth owners in Germany own 12.7% of German deposits. Non-deposits used for stranded asset partitions (see also Fig. S1). Asset category data for Italy not shown. Italian non-deposit assets are simulated from France and Spain, based on the similarities in pension systems.

Table S2. Share of each wealth fractile in total stranded assets under different elasticities, e.

	Group	Benchmark scenario	Robustness checks (e values)			
			e=0.8	e=0.9	e=1.1	e=1.2
Germany	Bottom 50%	8%	12%	10%	6%	5%
	Middle 40%	38%	45%	42%	35%	31%
	Next 9%	35%	31%	33%	36%	37%
	Top 1%	19%	13%	16%	23%	28%
Europe	Bottom 50%	4%	8%	5%	2%	1%
	Middle 40%	20%	30%	25%	15%	12%
	Next 9%	41%	39%	41%	40%	39%
	Top 1%	36%	23%	29%	42%	48%
France	Bottom 50%	1%	4%	2%	1%	0%
	Middle 40%	8%	16%	12%	6%	4%
	Next 9%	51%	52%	52%	48%	45%
	Top 1%	40%	28%	34%	46%	51%
GB	Bottom 50%	3%	6%	4%	2%	1%
	Middle 40%	27%	37%	32%	23%	19%
	Next 9%	41%	38%	40%	41%	40%
	Top 1%	29%	19%	24%	34%	40%
Italy	Bottom 50%	2%	5%	3%	1%	1%
	Middle 40%	14%	23%	18%	10%	8%
	Next 9%	44%	44%	45%	41%	38%

	Top 1%	41%	27%	34%	47%	53%
USA	Bottom 50%	4%	7%	5%	2%	2%
	Middle 40%	29%	39%	34%	25%	20%
	Next 9%	32%	32%	32%	31%	29%
	Top 1%	35%	22%	28%	42%	49%

Table S3. Wealth tax revenues in Europe and North America

Europe

Wealth group	Rate (%)	Total wealth ($ bn)	Number of adults	Revenues (% of regional income)	Effective wealth tax rate (%)	Revenues ($bn)
All above 100m	NA	4968	8788	0.44	1.51	75
100m-1b	2	2562	8290	0.16	1.05	27
Above 1b	3	2406	498	0.28	2.01	48

North America

Wealth group	Rate (%)	Total wealth ($ bn)	Number of adults	Revenues (% of regional income)	Effective wealth tax rate (%)	Revenues ($bn)
All above 100m	NA	11844	30130	0.88	1.38	163
100m-1b	2	7022	29300	0.35	0.93	65
Above 1b	3	4822	834	0.53	2.03	98

Table S4. Datapoints underlying Fig. 2.

	Quantile:	Bottom 50%			Middle 40%			Next 9%			Top 1%		
Scenario	Elasticity:	0.8	1	1.2	0.8	1	1.2	0.8	1	1.2	0.8	1	1.2
Benign	Germany	0.10%	0.07%	0.04%	0.04%	0.03%	0.02%	0.03%	0.03%	0.04%	0.01%	0.02%	0.03%
	France	0.07%	0.03%	0.01%	0.05%	0.03%	0.01%	0.10%	0.10%	0.09%	0.10%	0.14%	0.19%
	Italy	0.07%	0.03%	0.01%	0.02%	0.01%	0.01%	0.04%	0.04%	0.04%	0.04%	0.06%	0.08%
	United Kingdom	0.37%	0.17%	0.07%	0.26%	0.20%	0.14%	0.29%	0.31%	0.30%	0.26%	0.39%	0.54%
	United States	3.52%	1.78%	0.82%	0.20%	0.15%	0.10%	0.13%	0.13%	0.12%	0.09%	0.14%	0.20%
Medium	Germany	0.28%	0.18%	0.12%	0.09%	0.08%	0.07%	0.08%	0.09%	0.10%	0.04%	0.06%	0.08%
	France	0.20%	0.07%	0.02%	0.14%	0.07%	0.03%	0.28%	0.27%	0.24%	0.28%	0.40%	0.51%
	Italy	0.22%	0.09%	0.03%	0.06%	0.04%	0.02%	0.15%	0.15%	0.13%	0.14%	0.21%	0.28%
	United Kingdom	0.91%	0.42%	0.18%	0.65%	0.49%	0.33%	0.72%	0.77%	0.76%	0.64%	0.97%	1.33%
	United States	8.88%	4.48%	2.06%	0.51%	0.38%	0.26%	0.32%	0.32%	0.29%	0.23%	0.36%	0.50%
Quota	Germany	0.29%	0.19%	0.12%	0.10%	0.08%	0.07%	0.08%	0.10%	0.10%	0.04%	0.06%	0.09%
	France	0.25%	0.09%	0.03%	0.18%	0.09%	0.04%	0.36%	0.35%	0.31%	0.36%	0.51%	0.65%
	Italy	0.31%	0.13%	0.05%	0.09%	0.05%	0.03%	0.21%	0.20%	0.18%	0.20%	0.29%	0.38%
	United Kingdom	1.03%	0.47%	0.20%	0.73%	0.55%	0.38%	0.81%	0.87%	0.85%	0.72%	1.09%	1.50%
	United States	8.79%	4.43%	2.04%	0.50%	0.38%	0.26%	0.31%	0.32%	0.29%	0.22%	0.35%	0.50%
Severe	Germany	0.40%	0.27%	0.17%	0.14%	0.12%	0.10%	0.12%	0.13%	0.14%	0.06%	0.09%	0.12%
	France	0.29%	0.11%	0.04%	0.21%	0.11%	0.05%	0.42%	0.41%	0.36%	0.42%	0.59%	0.76%
	Italy	0.37%	0.15%	0.06%	0.11%	0.06%	0.03%	0.25%	0.24%	0.21%	0.24%	0.35%	0.46%
	United Kingdom	1.34%	0.61%	0.26%	0.95%	0.71%	0.49%	1.05%	1.13%	1.10%	0.94%	1.42%	1.95%
	United States	12.05%	6.08%	2.79%	0.69%	0.52%	0.35%	0.43%	0.44%	0.40%	0.31%	0.48%	0.68%

For details see Zenodo repository with figure data and code.

Table S5. Ultimately owned stranded assets by private persons by country in USD billion.

Country	Medium	Severe	Benign
AUT	2.18	3.47	0.97
BEL	6.83	12.1	0.41
CHE	8.77	11.77	4.37
CYP	13.34	19.1	5.94
DEU	13.08	19.13	4.87
DNK	1.9	2.98	0.51
EST	0.02	0.02	0.01
FIN	0.38	0.54	0.17
FRA	33.59	49.96	12.25
GBR	83.06	121.27	33.49
GRC	0.14	0.19	0.06
HUN	0.14	0.23	0.07
IRL	0.2	0.27	0.09
ISL	0.02	0.02	0.01
ITA	10.07	16.63	2.97
LTU	0.02	0.02	0.01
LUX	6.36	6.84	5.89
LVA	0.01	0.02	0.01
NLD	6.16	9.23	2.29
NOR	16.76	27.04	7.64
POL	1	1.44	0.44
PRT	0.72	1.09	0.37
SVK	0.05	0.06	0.02
SVN	0.03	0.04	0.01
USA	348.48	473.22	138.25

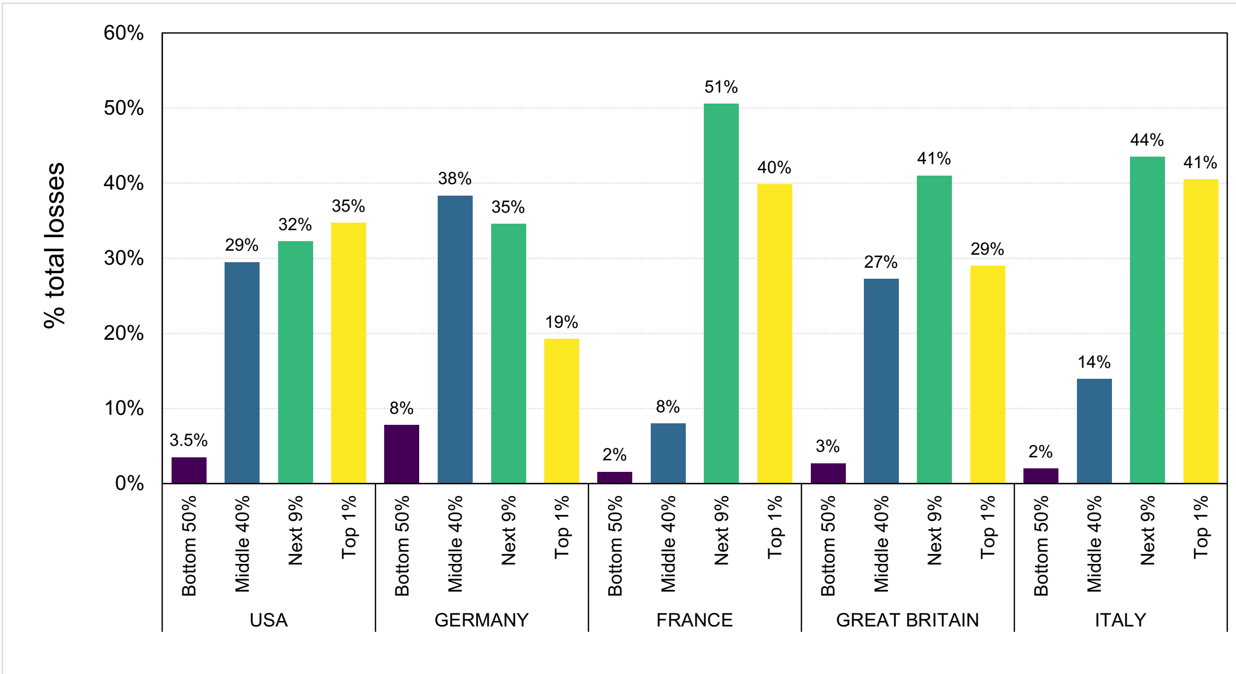

Figure S1. Share of losses by group as % of total national losses in 2019.

Stranded asset losses based on Semieniuk et al.[1] Distributional National Accounts data from WID.world.[2] Benchmark scenario as in Fig. 1.

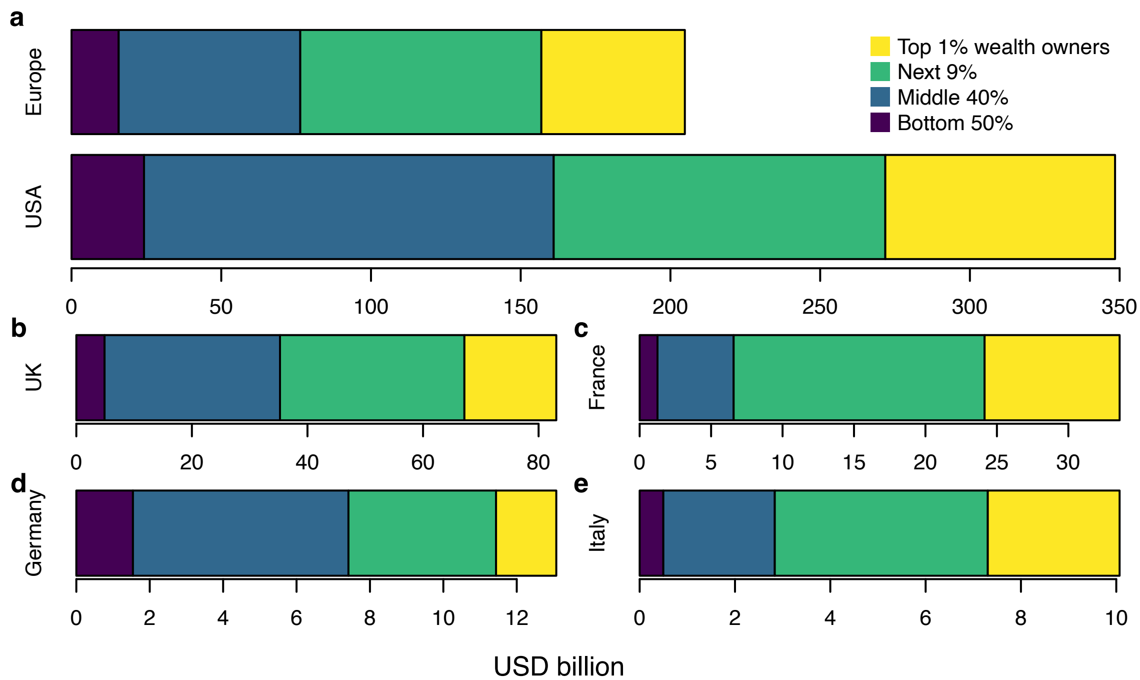

Figure S2. Distribution of stranded assets across the wealth distribution with a bias toward low wealth quantiles.

Partition of country or regional stranded assets with low-wealth portfolio bias of stranded assets (wealth elasticity of stranded assets of 0.8) by wealth fractile for **(a)** Europe as a whole and the United States, and **(b)-(e)** four major European countries. Middle 40% corresponds the group of the population between the bottom 50% and the top 10% of the population. Next 9% corresponds to the group between percentiles 90 and 99.

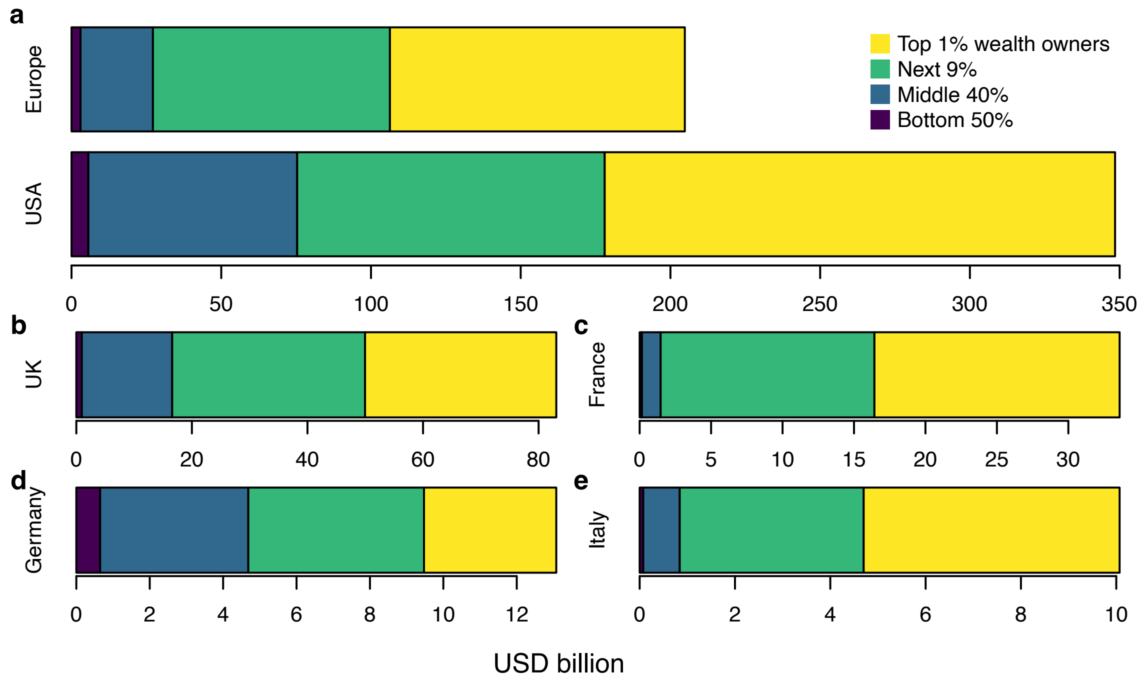

Figure S3. Distribution of stranded assets across the wealth distribution with a bias toward high wealth quantiles.

Partition of country or regional stranded assets with high-wealth portfolio bias of stranded assets (wealth elasticity of stranded assets of 1.2) by wealth fractile for **(a)** Europe as a whole and the United States, and **(b)-(e)** four major European countries. Middle 40% corresponds the group of the population between the bottom 50% and the top 10% of the population. Next 9% corresponds to the group between percentiles 90 and 99.

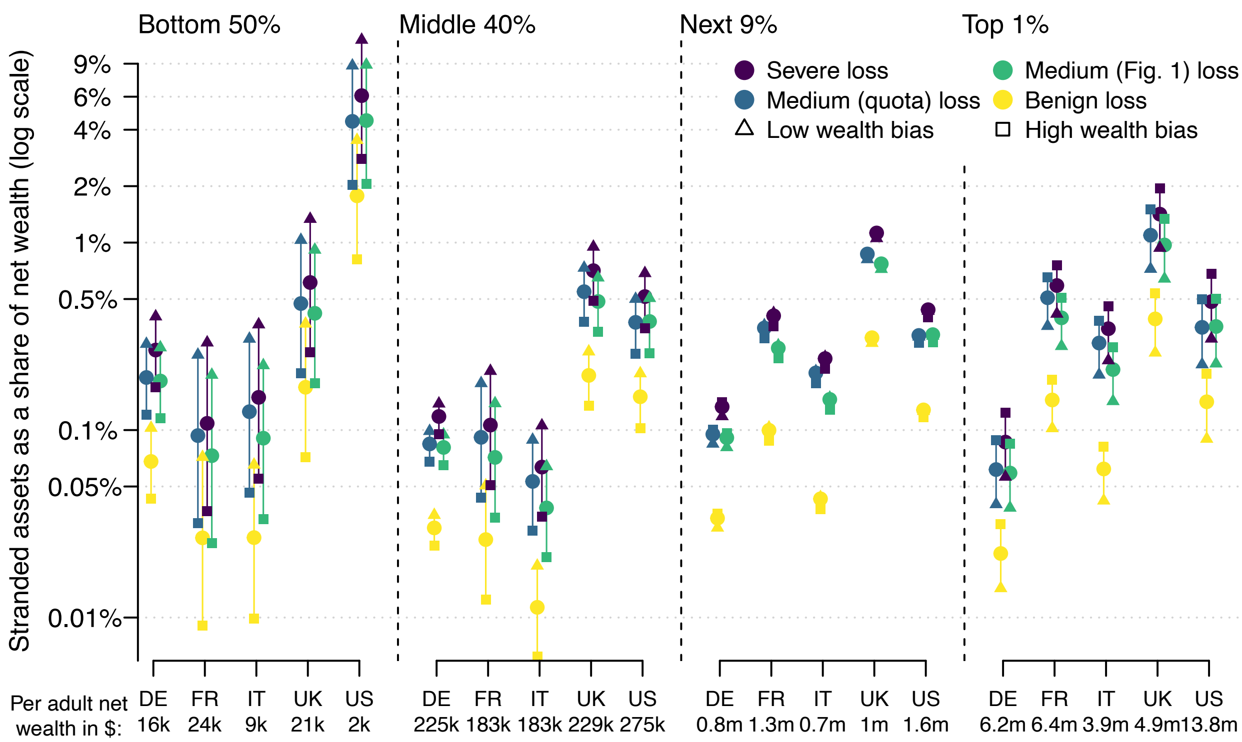

Figure S4. Stranded assets as a share of net wealth for different scenarios on a log scale. Stranded assets as share of total net wealth by fractile for five large countries and for different scenarios on a log scale. Each country-fractile shows four colors that reflect different totals and international distributions of asset stranding. Each color shows three shapes, with the disk showing losses proportional to financial assets, triangles a higher fossil-fuel portfolio exposure of the bottom 90% and squares a higher exposure by the top 10%. The bottom row of numbers reports average net wealth by an adult person in the country-fractile observation.

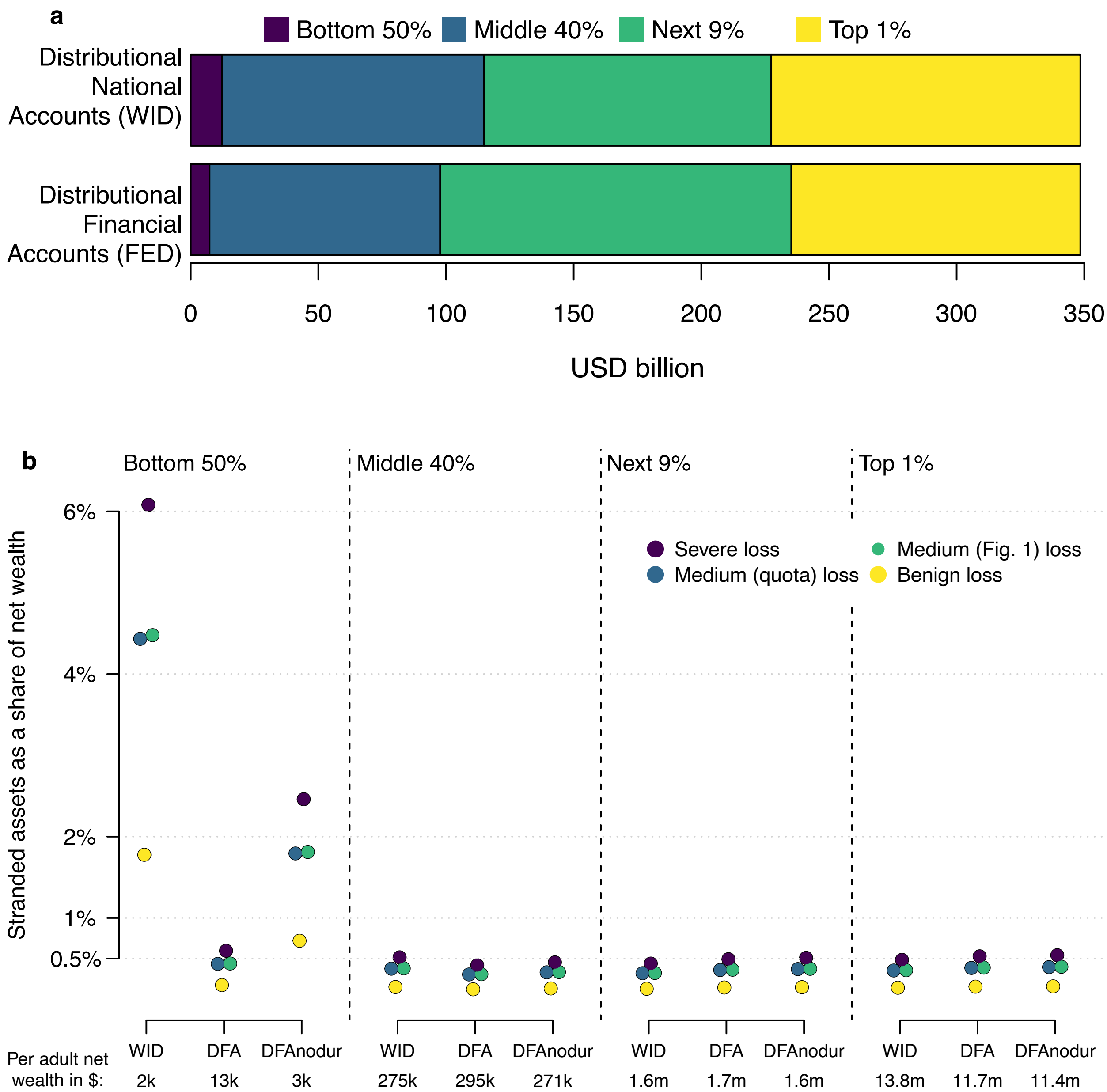

Figure S5: US stranded assets comparing two sources for assets and wealth estimates. **(a)** Partition of US stranded assets by wealth fractile as in Fig 1. Using WID data as elsewhere in this article, and using the Federal Reserve's (FED) Distributional Financial Accounts (DFA),[7] which use a different method for estimating household wealth and financial assets that is less comparable across countries than Distributional National Accounts from WID. **(b)** Stranded assets as a share of net wealth for the US using wealth estimates from WID and from the DFA. One DFA net wealth estimate includes consumer durables as assets, such as cars and appliances. Another (DFAnodur) excludes durables. The estimates in Fig. 2 relying on WID also exclude durable goods.