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Is There a Green Dividend of National Redistribution?

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Is There a Green Dividend of National Redistribution?

Abstract

CO₂ emissions are disproportionately caused by more affluent consumers. In the political debate, this fact has triggered the demand for income redistribution and wealth taxes not only to reduce inequality but also to reduce CO₂ emissions. This paper calculates the possible size of such a green dividend of redistribution in 26 countries and concludes that, for most EU countries, it is negative if the redistribution is efficient, in the sense that it keeps average incomes constant. If the redistribution introduces inefficiencies that lead to total income losses, the negative green dividend, otherwise associated with additional redistribution, may be avoided.

JEL-Codes: Q560, D120, D300.

Keywords: environment, redistribution, CO₂ emissions, inequality, green dividend.

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1 Introduction

There is growing awareness that CO₂ emissions are disproportionately caused by the most affluent consumers. Chancel and Piketty (2015) estimate that 10% of the world's population are responsible for approximately 45% of global CO₂ emissions. Oxfam (2020) reckons that the richest five percent of the world's population account for 37% of global CO₂ emissions.

When it comes to the responsibility for CO₂ emissions, considerable attention recently has been given to the rich and super-rich. Barros and Wilk (2021) take stock of the emissions by 20 billionaires and suggest shaming as a measure to reduce their enormous CO₂ footprints, which are driven by yachts, private jets and heating of multiple estates. For the EU, Ivanova and Wood (2020) calculate that the average carbon footprint of the top 1% of households amounts to 55 tons of CO₂-equivalent emissions per person, while in most EU countries the median polluter has a footprint of less than 10 tons. In the political debate, these asymmetric emissions trigger the demand for income redistribution and wealth taxes to reduce emissions by decreasing inequality. The claim has been made that less unequal countries may produce less CO₂ emissions (see Kenner, 2015; Dorling, 2010).

Concurrently, in the academic literature, the question whether redistribution from rich to poor within a country could reduce CO₂ emissions, and in that way could provide a green dividend, has received only limited attention. Brännlund and Ghalwash (2008) provide information based on Swedish household data on non-durable goods consumption. Using estimates of a non-linear demand system and pollution intensities of different consumption goods, they show that the income-pollution relationship is positive, but concave, which means that a more equal income distribution would increase, rather than decrease, the amount of three pollutants (CO₂, NO_x, SO₂). This suggests that, contrary to what underlies the popular demand, no green dividend of redistribution would result. There is also scattered evidence from other countries. A working paper by Castelucci et al. (2010) applies the Brännlund and Ghalwash (2008) method to Italian data and also suggests a negative green dividend of redistribution. Sørheim (2021) finds

that the carbon intensity of consumption of Norwegian households increases with income. A similar finding for urban China derives from Golley and Meng (2012). Duarte et al. (2012) find the opposite for Spain, where the pollution intensity of consumption seems to be lower for high incomes. Levinson and O'Brien (2019) identify concave Engel curves in the U.S. Unlike the present paper, they look at five different more local pollutants, omitting CO₂.

Apart from the studies based on micro data of consumption expenditure, several studies attempt to infer the relationship between income distribution and emissions via times series or panel data with macroeconomic variables. Often, these studies regress the log of national CO₂ emissions on a lag structure of the Gini index and other variables. For the U.S., Beck and Gweisah (2013) find a positive short and long-term association of the Gini index with the level of CO₂ emissions. Demir et al. (2019) find a negative long run association for Turkey, while Uzar and Eyuboglu (2019) empirically claim a positive association.¹ Chen et al. (2020) provide a related macro study using historical data on not just one country, but for the G20 group; Ghazouani and Beldi (2022) look at seven Asian economies. For OECD countries, Hailemariam et al. (2020) focus on the top income inequality in a macro-econometric approach. Hübner (2017) derives mixed results dependent on the specific panel data model. Knight et al. (2017) suggest an empirical association of wealth inequality and national CO₂ emissions in high-income countries.

A problem of macro studies that exploit the time dimension is that interactions between income and technical progress, as well as potentially important omitted variables (such as regulation, international commitments, political upheavals), are not included in the analysis. A causal interpretation of these regressions is therefore difficult. Redistribution via tax-transfer schemes may have a different impact on emissions than empirically observed distributional variation that,

¹ Bae (2018) looks at the interaction between mitigation instruments and the income distribution. Bruckner et al. (2022) evaluate the effect of possible further initiatives of international poverty reduction on CO₂ emissions. The results suggest a modest positive impact of poverty reduction on global CO₂ emissions. The connection between inequality and local air quality is studied in Kasuga and Tokaya (2017).

among other factors, may derive from changes in trade patterns, innovation, or unionization.

The present study avoids these issues by following a microeconomic approach. It resembles Brännlund and Ghalwash (2008) in using household budget surveys to study the link between income distribution and CO₂ emissions. Our study differs from existing studies in several ways. First, unlike Brännlund and Ghalwash (2008) and other papers that consider specific countries, we investigate 26 European countries simultaneously thanks to harmonized datasets. Second, we have access to kgCO₂-equivalent emissions of 200 products (direct plus indirect emission products), a considerably higher number than analyzed in previous studies. Brännlund and Ghalwash (2008) use eight products, Castelucci et al. (2010) exploit three direct emission products. Sørheim (2021), Golley and Meng (2021), Duarte et al. (2012) respectively study emission intensities of 61 products, 42 sectors, and 27 economic activities. Third, emission intensities utilized in this study are derived from a multi-regional input-output model. Hence, we do not have to impose the assumption that imported products have the same environmental impact as domestically produced products, a limitation acknowledged by Brännlund and Ghalwash (2008), Golley and Meng (2021) and Duarte et al. (2012).² This limitation may be important if production locations of goods consumed by rich vs. poor systematically differ.

For 26 European countries, we simulate a redistributive tax-transfer policy which comes on top of existing policies. It adds a flat tax of ten percent to finance a lump sum payment for every household. We derive that, for 22 countries, such an income redistribution would result in a negative green dividend, i.e., CO₂ emissions would increase. Only four countries would have a reduced level of CO₂ emissions. Even for those, the green dividend is limited. For example, the redistribution might be expected to reduce the UK emissions by some 40 kg of CO₂ equivalent emissions per capita, which amounts to a mere 0.47% of per capita emissions in the year 2010.

² Castelucci et al. (2010) study direct emission products and, hence, imports are not relevant. An exception is Sørheim (2021), which also derives emission intensities from a multi-regional model.

We also explore scenarios when the tax-transfer system is costly and therefore shrinks average income. A vast literature on the deadweight loss of taxation (excess burden) suggests that a transfer system may resemble a leaky bucket: increased taxes could lead to distorted incentives and behavioral effects on labor markets may shrink output. On top of losses due to behavioral changes, taxes imply losses because of compliance and administrative costs. We address these losses in a stylized way by asking how growth-adverse a tax system must be to overturn the results derived under the assumption of a neutral tax-transfer system. We find that if slightly more than 15% of the tax revenues are assumed to be wasted, then this would be enough to generate a green dividend in all countries. This means that, in most countries, only a costly, wasteful redistribution system may carry a green dividend, i.e., lower CO₂ emissions; however a costless system does not.

The reminder of the paper is organized as follows. The next section introduces our methodology and data. Section 3 contains the main analysis, Section 4 concludes. Technical details are described in the Appendix.

2 Methodology and Data

Simulating how households' CO₂ emissions would change with income may be done in a variety of ways. One approach is to estimate individual demand curves for various goods categories using a structural model. With these demand curves, it is possible to derive a counterfactual demand after some redistribution is applied. In a second step, CO₂ intensities of final output goods are used to calculate CO₂ emission changes from the income effects on demand. This approach is used by Brännlund and Ghalwash (2008). Several assumptions must be imposed for its implementation. For example, some functional form of demand must be specified. In addition, the estimation assumes differently affluent households face the same prices, which has been empirically contested by the literature on shopping behavior (e.g., Aguiar and Hurst, 2007).

A simpler approach, utilized in the present paper, is to regress the actual, observed CO₂ emissions of households over some explanatory variables that

include a proxy of their permanent incomes, household type and size. After altering households' net incomes with, e.g., a redistributive policy, counterfactual CO₂ emissions can be predicted using the previous regression's coefficients. See Appendix Section B for a more detailed presentation of our methodology. While this method requires no assumption on the homogeneity of prices and no specific functional form of demand, it also comes with caveats. An implicit assumption in using this approach is that consumers' goods demand, and hence CO₂ emissions, are changed in the same way irrespective of the source of income changes (e.g., market influences on income vs. tax changes). The same assumption, however, is made for approaches that exploit demand estimates through structural modeling.

Our data comes from two sources.³ Information on households' good demands is taken from the 2010 European Union Household Budget Surveys (EU HBSs) provided by Eurostat. For most of our 26 European countries, we facilitate 63 different product baskets (51 for Germany and 59 for Sweden). In a next step, the goods demands need to be transformed into the direct and indirect CO₂ emissions that go with these product baskets.⁴ For this, we use the 2010 wave of EXIOBASE v3.8.2 database, which relies on country-specific input-output matrices and technical coefficients to yield CO₂ emissions of 200 different product categories in each country. More specifically, EXIOBASE gives kgCO₂-equivalent emissions per euro spent on these 200 product categories.⁵ Because of national differences in transport costs, input-output matrices, and production processes these data differ between countries.

As the product categories between the EU HBSs and EXIOBASE3 differ, a rule on how to assign the 63 HBS groups into the 200 EXIOBASE3 groups is required. To achieve this, we rely on a concordance table provided by Ivanova and Wood (2020).

³ The datasets and data preparation procedures are described in more detail in Appendix Section A.

⁴ A direct CO₂ emission occurs in the use phase of a product (e.g., when a household buys gasoline and burns it while driving). An indirect emission occurs when a consumer purchase leads to emissions in the production chain.

⁵ EXIOBASE reports CO₂ content of goods in per euro expenditure in basic prices (excluding trade & transport margins and taxes). EU HBSs provide expenditures in purchaser prices. We follow Ivanova and Wood (2020) and convert HBS expenditures in purchaser prices into basic prices by removing taxes and allocating trade & transport margins into associated products.

In the HBSs, reported expenditures by households may be too large or too small to match country-wide levels despite the representative nature of the EU HBSs. We follow Ivanova and Wood (2020) in scaling HBS expenditures of each household proportionately to match country level expenditures reported in EXIOBASE (national accounts). On average, this leads to a scaling factor of 1.37.

Scaling of expenditures for specific goods comes at a cost as it may alter total household level expenditures in asymmetric and slightly arbitrary ways: a household's expenditure for motor vehicles may be scaled up if it bought a car, whereas for another household that did not buy a car, expenditure cannot be scaled up. We identify four product categories that reduce the correlation between total raw expenditures and total scaled expenditures in a visible way and exempt them from scaling if under reported:

- Motor vehicles, trailers and semi-trailers (25 out of 26 countries under report)
- Kerosene (5 out of 26 countries under report)
- Financial intermediation services, except insurance and pension funding services (26 out of 26 countries under report)
- Other business services (26 out of 26 countries under report)

The first two categories frequently have zero expenditures for households, as car purchases and holiday flights clearly may not occur each year.⁶ Many households with zero reported expenditure for the last two categories may simply not be aware of having those expenditures.

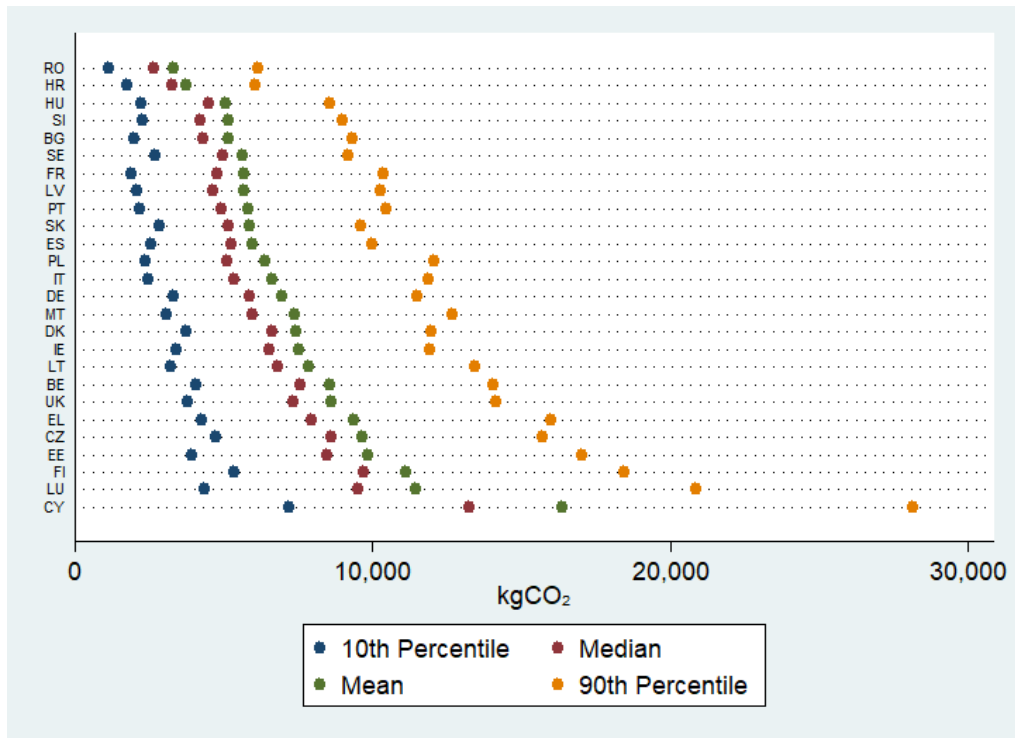
Outliers exist in every country, both in terms of CO₂-equivalent consumption and total household expenditure. We drop households that constitute the top 0.1% of household CO₂ consumption and the top 0.1% of household total expenditure. The total number of dropped observations amounts to 425 out of 274.396 (the remaining sample size after performing other cleaning procedures is further described in Appendix Section A).

While it is widely accepted that, in general, the climate effect of CO₂ emissions does not depend on where and in what way CO₂ is emitted, there is one exception:

⁶ Scaling of kerosene consumption from air travel may also be problematic if some of national consumption should be attributed to foreign flight guests.

aviation. The radiative forcing that measures the climate relevance of all side effects to CO₂ emissions is deemed higher for aviation, because high layer contrails and other effects tend to aggravate aviation induced global warming. This was emphasized by the International Panel on Climate Change, IPCC (1999). One way of expressing the climate effect of aviation is to divide the sum of climate effects (radiative forcing) by the radiative forcing that resulted from aviation's CO₂ emissions alone, leading to a frequently used upscaling factor of about three (Wit, et al., 2005, p. 34). While more recent literature seems to suggest a somewhat smaller average factor, a large variation of estimates between 1.9 and 5 still prevails (cf. Jungbluth and Meili, 2019, p. 405). We decided to introduce a factor three for CO₂ emissions from kerosene. Considering the role of inequality for CO₂ emissions, it is important to recognize the role of kerosene in this research, as air travel services are disproportionally consumed by the rich. This weighting has not been done in previous work on the nexus between inequality and CO₂ emissions. However, we argue that ignoring the fact that a ton of CO₂ emitted via air travel has a larger climate impact than a ton emitted by public buses would systematically distort our calculations that are concerned about distributional issues. Because air travel is consumed disproportionately by the more affluent, the weighting of kerosene tends to produce a higher green dividend compared to using no weight.

Figure 1. CO₂ footprints across countries.



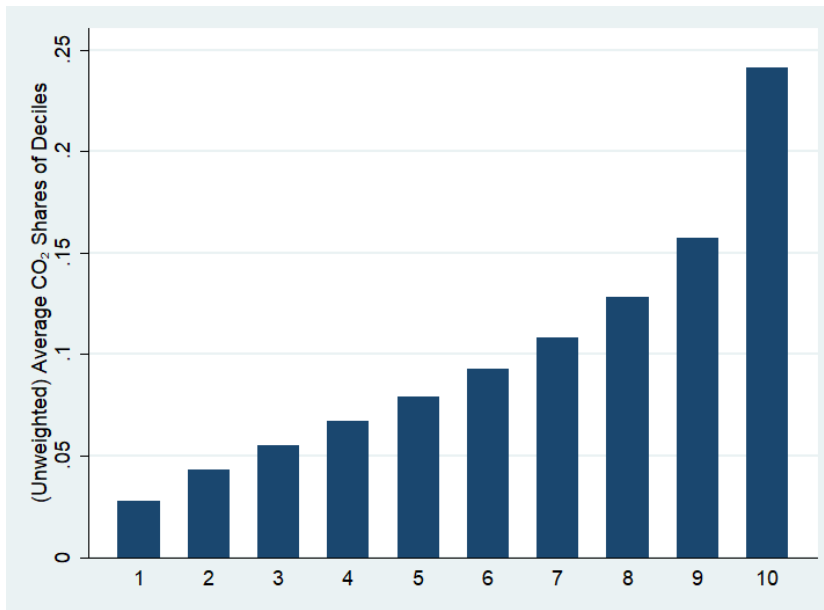
Note: Belgium (BE), Bulgaria (BG), Czech Republic (CZ), Cyprus (CY), Denmark (DK), Germany (DE), Estonia (EE), Finland (FI), Greece (EL), Spain (ES), France (FR), Croatia (HR), Hungary (HU), Italy (IT), Ireland (IE), Lithuania (LT), Latvia (LV), Luxembourg (LU), Malta (MT), Poland (PL), Portugal (PT), Romania (RO), Slovenia (SI), Slovakia (SK), Sweden (SE), United Kingdom (UK).

While EU HBSs contain self-reported household income, we found this variable to be fraught with considerable noise, including negative values. For example, CO₂ consumption vs. reported net incomes curve exhibits a second peak at the bottom of the distribution. This may reflect a temporary income shock such as capital losses. We therefore decided to take scaled reported household expenditure as a measure of permanent income as in Brännlund and Ghalwash (2008).

Figure 1 reports our calculations of the CO₂ footprint for four different household types in each country. The ranking of countries is based on mean (per-capita) kgCO₂-equivalent consumption (green dots); in each country, the footprint of the 10th and 90th percentiles and the median are also reported.⁷

⁷ Unexpectedly, Cyprus ranks highest in mean CO₂ footprint, which is not due to a single expenditure category, but based on several CO₂-intensive consumption categories.

Figure 2. Distribution of CO₂ across consumption expenditure deciles



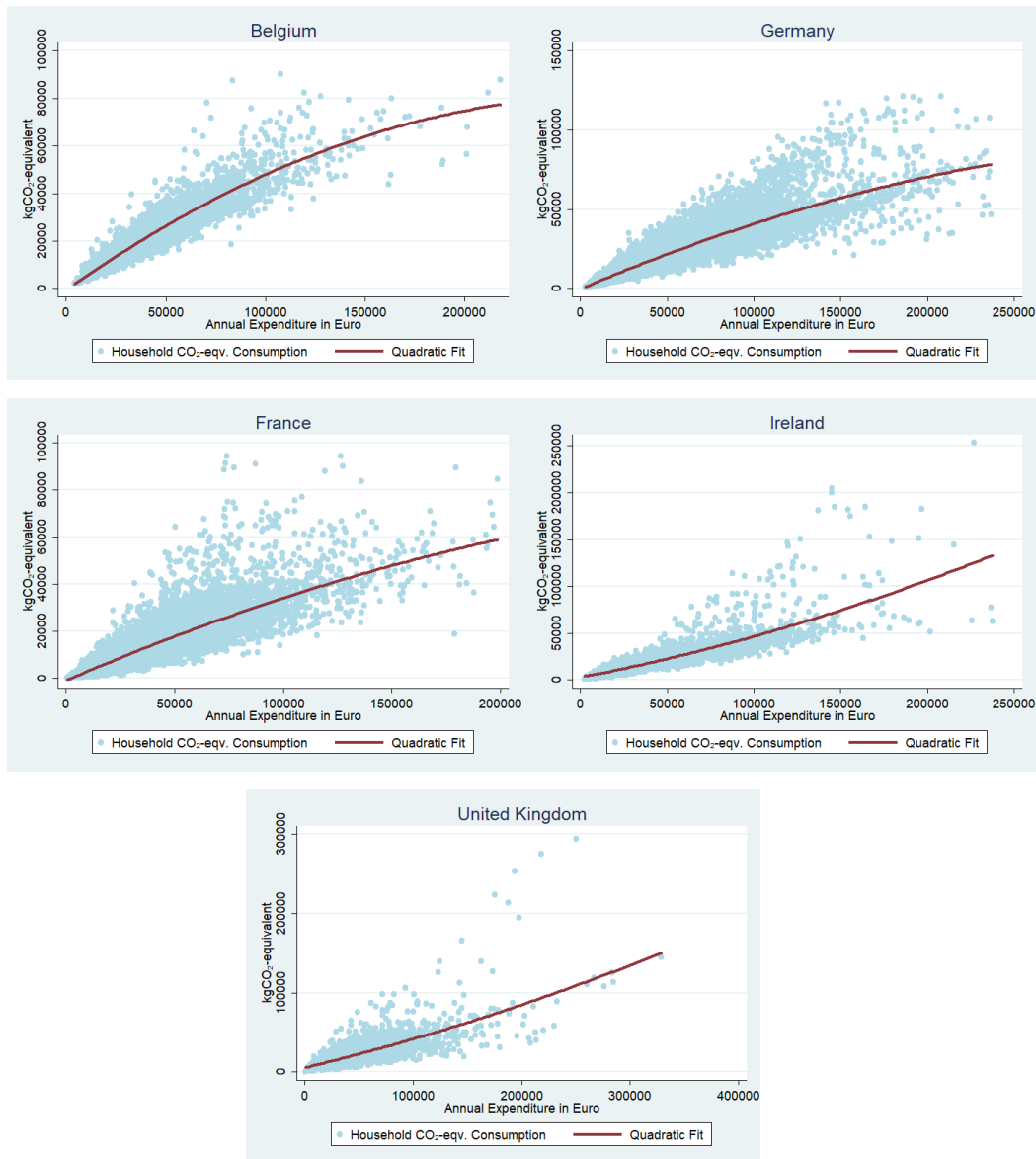
Note: The length of the bar for decile 1 (and analogous for the other bars) is derived by calculating the CO₂ consumption share of those 10 percent of the population with the smallest total expenditure in each country and then taking the unweighted average across the 26 countries.

Figure 2 illustrates the unweighted average of CO₂-equivalent consumption shares for each consumption expenditure decile. Across countries, the top 30 percent, in terms of consumption expenditure, is responsible for more than 50% of CO₂.

3 Redistribution and CO₂ emissions

It is recognized that convexity or concavity of the Engel curves for carbon intensive consumption is decisive for the role of redistribution on carbon emissions (Brännlund and Ghalwash, 2008). In the case of a concave relationship, redistribution, which puts more households from the ends of the income distribution to the middle, should tend to increase total emissions. The opposite should be the case if the Engel curve is convex. The five panels in Figure 3 illustrate Engel curves for CO₂ consumption for five selected countries. We find concave curves for the vast majority of countries, exemplified in Figure 3 by Germany, France and Belgium. Convex curves, on the other hand, are depicted in Figure 3 for Ireland and the UK; they are also found in Luxemburg and Cyprus.

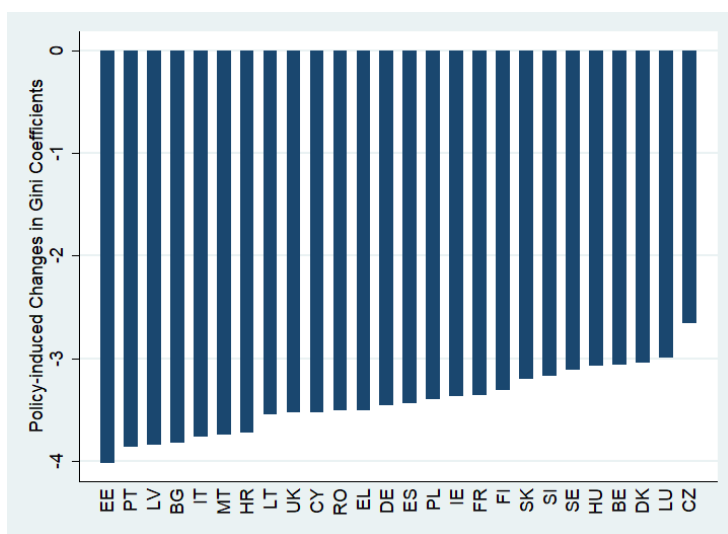
Figure 3. CO₂ emissions vs. total expenditures



While the role of the Engel curve's shape is recognized in the literature, it is unclear how large the changes of CO₂ emissions from redistribution are. In this section, we therefore simulate a policy measure that reduces national inequality. This policy measure, which is added to the existing system in each country, collects from each household 10 percent of total expenditure (our proxy of permanent income) and uses the revenues to pay a limited, universal demogrant to each household. Neither the tax, nor the demogrant is conditioned on household size. This policy measure would not affect all countries in the same way. If a country exhibits a rather equal distribution to begin with, then our measure

has a modest impact compared to a pre-existing situation of a very unequal distribution. Figure 4 illustrates the impact of our policy measure on the Gini coefficient, measured in percentage points (ppt.), in all 26 countries. For most countries, a flat tax of 10% plus a lump sum grant would reduce the Gini coefficient between three and four ppt., where three ppt., for example, equals the difference in the Gini coefficient for disposable income between Portugal and Sweden in 2019.⁸

Figure 4. A policy measure and its impact on the Gini coefficient



Note: The bars illustrate the differences in Gini coefficients that represent inequalities in total annual household expenditure observed in the data vs. after the policy experiment (10% tax over total expenditures plus equally distributed demogrants). Gini coefficients are calculated using the “fastgini” command of Stata. For country codes, see Figure 1.

As mentioned in Section 2, we assume that the CO₂ emission of a household is a function of the total expenditure (permanent incomes) up to its fifth order⁹, household type and size. Thus, after altering the total expenditures of households via our experiment, we can predict a household’s post-redistribution emissions using the coefficients estimated in the initial regressions. Hence, the new CO₂ consumption of a household is calculated by using the behavior of households of comparable size and type, which also had the same total expenditure/permanent

⁸ Based on data from the OECD inequality database (<https://data.oecd.org/inequality/income-inequality.htm>).

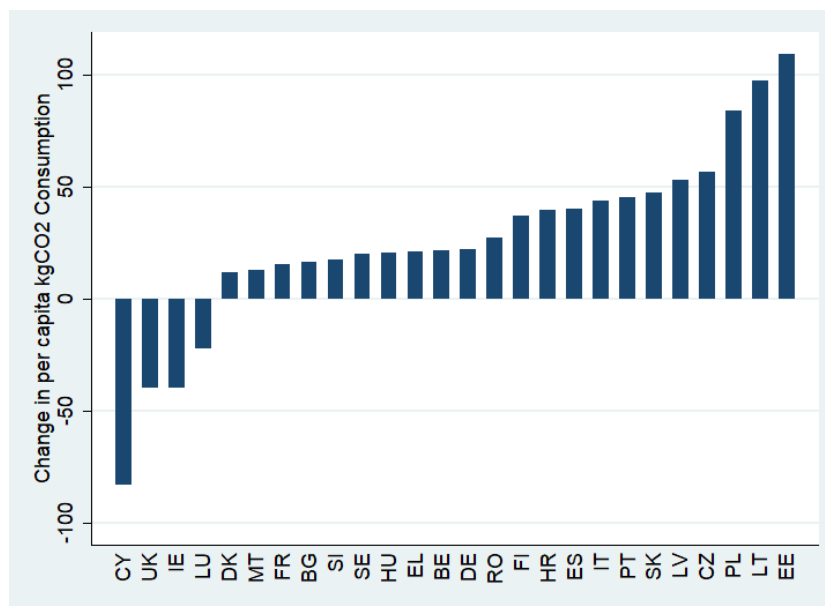
⁹ Akaike Information Criterion (AIC) scores favor regression models with the fifth order of total expenditure over simpler models. We stopped at the fifth order for simplicity.

income before introducing the measure. Further details are provided in Appendix Section B.

Figure 5 presents our main results. For most countries, the green dividend is negative: implementing the additional redistribution increases CO₂ emissions. Except in three states (Poland, Lithuania and Estonia), the annual redistribution-induced emissions are approximately 50 kg or below per-capita . Of the four countries that show a green dividend, the three largest dividends are found on islands: Cyprus, the UK and Ireland.

The calculations behind Figure 5 assume that the 10 percent tax on permanent income and the lump sum transfer have no behavioral effects. This assumption is overoptimistic. First, as most income taxes fall on labor, there is a tax-induced reduction in the net wage that can have effects on labor supply and the number of hours worked. Second, the payment of a lump sum transfer to all households can also affect labor supply via an income effect.

Figure 5. The effect on emissions from a 10 percent flat-tax experiment



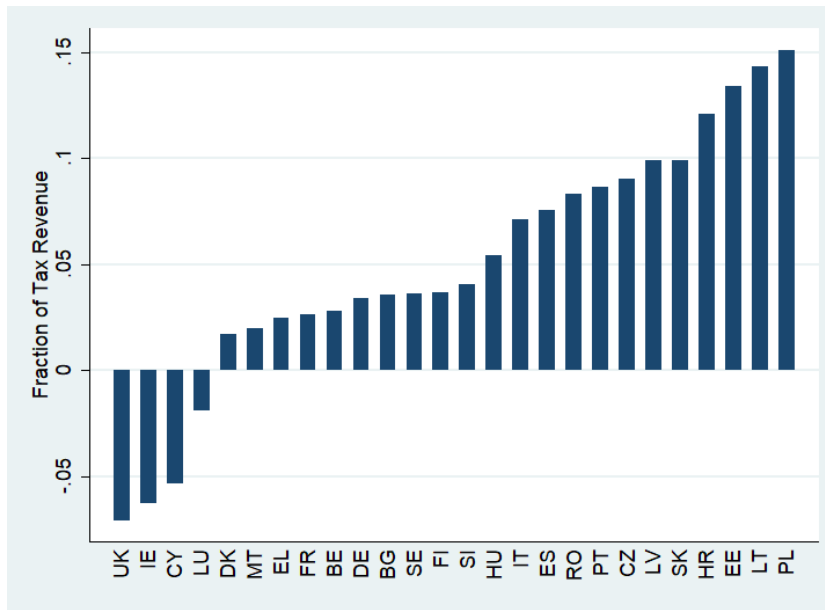
Note: See Appendix Section B for the calculation of the emission effects represented in the bars. For country codes see Figure 1.

From a theoretical point of view, the labor supply reaction of such a reform is uncertain. Individuals facing a higher tax on their labor income may feel poorer

and may therefore be willing to trade in leisure for additional hours of work. Typically, however, empirical studies of national labor markets find a negligible income effect on labor supply, but a statistically significant, positive effect of the net wage (e.g., Bargain et al., 2014). This implies that we can expect to have a negative effect on hours worked from a tax increase plus lump sum transfer, which tends to shrink total income and expenditures. If we use a cross-country average of the elasticity of hours worked from Bargain et al., we may expect that a 10% reduction of the effective wage leads to a 2.7% reduction of hours worked. Although labor productivity may react somewhat to this reduction in hours worked, this figure gives a rough magnitude of the possible output loss. Further losses may arise from additional administration and compliance costs of implementing the additional tax.

How large must output losses (and losses in consumption expenditure) be in order to turn a negative green dividend into a positive one? Figure 6 addresses this issue. For each country, Figure 6 depicts the proportional cut in permanent income and expenditures that would be necessary to eliminate the (mostly negative) green dividend of redistribution. Indeed, for roughly a third of the 26 countries analyzed, an expenditure reduction amounting to approximately three percent of tax revenues (triggered by inefficiencies of the tax-transfer system) would eliminate a negative green dividend. A loss of slightly more than 15 percent of the tax revenues would eliminate the negative green dividend for all countries.

Figure 6. Required tax revenue losses to overturn green dividend effect



Note: The bar for each country is calculated as follows. Let TR denote the tax revenue of a country after imposing a 10% tax on total annual household expenditures/permanent incomes. In the redistributive policy experiment, TR is equally distributed to all the households within a country. Bars in this figure represent a factor x , which neutralizes the environmental effect of redistribution after altering the tax revenue as $TR(1 - x)$.

4 Conclusion and limitations

Households with high income are responsible for a disproportionately large share of CO₂ emissions. In the political arena, this has led to calls for more redistribution, not only to benefit the lower income groups, but also to reduce emissions.

The present paper analyzes possible environmental effects of redistribution and the resulting magnitudes in a large set of European countries. Because in most countries there is a concave relationship between households' CO₂ consumption and their total expenditures, a redistribution from rich to poor is expected to increase CO₂ emissions rather than reduce them. For those countries, our simulations suggest that a ten percent income tax (on top of existing taxes), which is used for a lump sum transfer to all households, may increase per capita CO₂ consumption between 10 and 110 kg, implying a negative green dividend of redistribution. In four countries, mostly islands, we find the opposite effect, a positive green dividend.

If the extension of the tax-transfer system is inefficient and wasteful to a certain extent, the negative green dividend can be averted via lower incomes and reduced total expenditures.

Our study shows only small and often counter-productive effects of a redistribution on emissions, even with a quite pronounced tax hike. This suggests that policies to reduce CO₂ emissions should target emission reduction more directly. An example of such policies is the Swedish carbon tax; it seems to have a more significant positive effect than the green dividend of redistribution found in this study, even among the four countries where the green is positive.¹⁰

An important limitation as well as an opportunity for future research should be mentioned. Our study, in line with previous literature on income distribution and CO₂ emissions, does not take into account the effects of the EU emissions trading system. So far, only some part of all CO₂ emissions falls under this system - emissions from residential heating and car traffic are not included. A bias in the calculations may arise when differently affluent households have diverse consumption patterns. If the sum of total tradable permits is fixed, then the CO₂ emissions triggered by some consumption purchases needs to be neutralized elsewhere in the economy. This is not the case if the emissions triggered are not subject to the EU emissions trading system. In a hypothetical world in which the rich are predominantly responsible for CO₂ emissions that are capped via the trading system, but the less affluent are responsible for emissions that do not fall under this system, a redistribution of income towards the poor could have a more negative green dividend compared to a world without a trading system. Accounting for the EU carbon trading system would require a more sophisticated accounting of CO₂ emissions, because for each production step a distinction between capped and uncapped CO₂ emissions would be necessary to calculate the size of a green dividend.

A further concern may be that household surveys miss the super-rich. Recently, Barros and Wilk (2021) provided estimates for 20 billionaires and concluded that, on average, these individuals seem to be responsible for some 36 thousand tons

¹⁰ For a detailed analysis of the CO₂ reduction due to the Swedish carbon tax, see Andersson (2019).

of CO₂ equivalent emissions in 2018. This finding, as impressive as it may be, does not rule out that taxation of these billionaires and giving the money to poorer households would increase emissions. While the CO₂ budgets of billionaires are stunningly high, their emissions per dollar of income are quite small: assuming that permanent incomes of the super-rich can be approximated by a 7% return to their wealth as reported in Barros and Wilk (2021), we find that they consume 3 grams of CO₂-equivalent emissions per dollar of income. This compares to an unweighted average of the median household's emissions across 26 countries in our 2010 data of 831 grams. The value is lower for richer countries, e.g., 440 grams in Germany and 341 grams in France. While the figure of 3 grams¹¹ relies on Barros and Wilk's (2021) analysis of highly visible consumption (yachts, flights, heating and air-conditioning of multiple estates) and does not incorporate daily, regular expenses of super-rich, the calculations are instructive. It shows that, even for the super-rich, the CO₂ intensity of permanent income may well fall far below the equivalent of the much less affluent. Consequently, redistribution from these super-rich to poorer households could still be expected to increase CO₂ emissions.

Overall, our analysis suggests that redistribution and CO₂ reduction are distinct goals. Therefore, in general, they seem best addressed by distinct instruments.

Appendix

A. Data Appendix

This study mainly relies on two datasets. Consumption structure data of European households are obtained from European Union Household Budget Surveys (EU HBSs). Emission coefficients of per euro expenditure on various consumption categories are gathered from EXIOBASE v3.8.2 (EXIOBASE3).

European Union Household Budget Surveys

¹¹ This figure would be 11 grams if we assume a 2% return on wealth and be even lower for returns bigger than 7%.

EU HBSs are conducted by individual European countries once in every five years since 1988. Their purpose is to derive weights for national consumer price indices and for Eurostat’s official price index, Harmonized Index of Consumer Prices. Classification of consumption categories follow United Nation’s “classification of individual consumption by purpose (COICOP)” structure. Along with the detailed information on monetary expenditure on various consumption categories, EU HBSs collect information on several demographic characteristics of households such as household type, family size, etc. This study relies on the 2010 wave of EU HBSs.

COICOP structure reports consumption expenditure on various levels of aggregation. For example, EUR_HE01 is a one-digit category that reports annual household expenditure on “Food and Non-Alcoholic Beverages”. Two-digit categories EUR_HE011 and EUR_HE012 respectively and separately report expenditure on “Food” and “Non-alcoholic Beverages”. Three-digit categories from EUR_HE0111 to EUR_HE0119 provide further details on consumption structure by reporting expenditures on, e.g., “Bread and Cereals”, “Meat” etc. Following Ivanova and Wood (2020), this study by a combination of one-to three-digit levels, employs 63 categories, except for Germany (51) and Sweden (59) for which data on some of those 63 categories is missing. These 63 categories are reported in Table 1. In the interest of space, we do not report the categories employed for Germany and Sweden but they can be found in the supplementary material of Ivanova and Wood (2020).

Table 1. Definitions of 63 HBS categories utilized.

COICOP Code	Category Name
EUR_HE0111	Bread and cereals
EUR_HE0112	Meat
EUR_HE0113	Fish
EUR_HE0114	Milk, cheese and eggs
EUR_HE0115	Oils and fats
EUR_HE0116	Fruit
EUR_HE0117	Vegetables

EUR_HE0118	Sugar, jam, honey, chocolate and confectionery
EUR_HE0119	Food products n.e.c.
EUR_HE012	Non-alcoholic beverages
EUR_HE021	Alcoholic beverages
EUR_HE022	Tobacco
EUR_HE031	Clothing
EUR_HE032	Footwear
EUR_HE041	Actual rentals for housing
EUR_HE042	Imputed rentals for housing
EUR_HE043	Maintenance and repair of the dwelling
EUR_HE044	Water supply and miscellaneous services relating to the dwelling
EUR_HE0451	Electricity
EUR_HE0452	Gas
EUR_HE0453	Liquid fuels
EUR_HE0454	Solid fuels
EUR_HE0455	Heat energy
EUR_HE0511	Furniture and furnishings
EUR_HE0512	Carpets and other floor coverings
EUR_HE0513	Repair of furniture, furnishings and floor coverings
EUR_HE052	Household textiles
EUR_HE053	Household appliances
EUR_HE054	Glassware, tableware and household utensils
EUR_HE055	Tools and equipment for house and garden
EUR_HE0561	Non-durable household goods
EUR_HE0562	Domestic services and household services
EUR_HE061	Medical products, appliances and equipment
EUR_HE062	Out-patient services
EUR_HE063	Hospital services
EUR_HE071	Purchase of vehicles
EUR_HE0721	Spare parts and accessories for personal transport equipment
EUR_HE0722	Fuels and lubricants for personal transport equipment

EUR_HE0723	Maintenance and repair of personal transport equipment
EUR_HE0724	Other services in respect of personal transport equipment
EUR_HE0731	Passenger transport by railway
EUR_HE0732	Passenger transport by road
EUR_HE0733	Passenger transport by air
EUR_HE0734	Passenger transport by sea and inland waterway
EUR_HE0735	Combined passenger transport
EUR_HE0736	Other purchased transport services
EUR_HE08	Communication
EUR_HE091	Audio-visual, photographic and information processing equipment
EUR_HE092	Other major durables for recreation and culture
EUR_HE093	Other recreational items and equipment, gardens and pets
EUR_HE094	Recreational and cultural services
EUR_HE095	Newspapers, books and stationery
EUR_HE096	Package holidays
EUR_HE10	Education
EUR_HE111	Catering services
EUR_HE112	Accommodation services
EUR_HE121	Personal care
EUR_HE1231	Jewelry, clocks and watches
EUR_HE1232	Other personal effects
EUR_HE124	Social protection
EUR_HE125	Insurance
EUR_HE126	Other financial services n.e.c.
EUR_HE127	Other services n.e.c.

Ideally, three-digit categories should add up to their two-digit aggregates, two-digit categories should add up to their one-digit aggregates and one-digit categories should add up to total annual household expenditure. Unfortunately, this is not always the case in EU HBSs. We assume that the total annual household expenditure is truthfully reported and scale one-digit categories such that they

add up to total annual expenditure. Next, we scale the relevant combinations of two- and three-digit categories such that they add up to their one-digit aggregate.

Initially, EU HBSs 2010 has a sample size of 275,247 from 25 EU countries (Austria and the Netherlands are missing) plus the UK. Upon the data cleaning procedures, most of which are also outlined in the main text, we end up with 273,971 observations. Observations with negative or missing income or expenditure on any categories employed in this study are dropped. As mentioned above, we assume that total annual expenditure is accurate and scale lower level categories accordingly. Therefore, we drop those observations where any one-digit category reports positive expenditure but lower level categories report zero expenditure because, in these cases, there is insufficient information to perform scaling. The main text mentions that 63 HBS categories are converted into 200 EXIOBASE3 products following the concordance table of Ivanova and Wood (2020) and then scaled once again such that per-capita expenditures on those 200 products will match that of EXIOBASE (national accounts). We further drop the top 0.1% of this scaled total expenditure distribution as well as the top 0.1% of kgCO₂-equivalent consumption distribution. Overall, the fraction of dropped observations is $(275,247 - 273,971) / 275,247 = 0.46\%$. A country-by-country breakdown of our effective sample size is provided in Table 2.

Table 2. Effective sample size by country.

Country	Sample Size	Country	Sample Size
Belgium	7,159	Ireland	5,882
Bulgaria	2,980	Italy	22,179
Cyprus	2,703	Lithuania	6,093
Czechia	2,914	Luxembourg	3,446
Germany	53,818	Latvia	3,783
Denmark	2,351	Malta	3,713
Estonia	3,494	Poland	37,178
Greece	3,508	Portugal	9,475
Spain	22,165	Romania	31,314

Finland	3,538	Sweden	1,930
France	15,714	Slovenia	3,910
Croatia	3,456	Slovakia	6,133
Hungary	9,922	United Kingdom	5,213

EXIOBASE3

EXIOBASE (Stadler et al., 2021) is a publicly available Environmentally Extended Multi-Regional Input-Output Database (EE-MRIO) developed mainly by earth scientists with the purpose of conducting environmental research. Built upon the previous versions, the third version, EXIOBASE3, is a part of European Commission's "Development of a System of Indicators for a Resource Efficient Europe (DESIRE)" project. EXIOBASE3 reports the trades of 200 products (as well as the trades between 163 industries) among 27 EU countries plus 17 other countries (including the UK) and 5 rest-of-the-world regions. The definitions of 200 products are not provided here but can be found in the (publicly available) dataset (Stadler et al., 2021). Environmental accounts of EXIOBASE3 includes various metrics of environmental pressure generated by 200 products. In the rest of this section, we present a brief summary of the data within EXIOBASE3 utilized in this study. Further information on EXIOBASE3 can be found in Stadler et al. (2018).

EXIOBASE3 provides individual country Monetary Supply-Use Tables (MSUTs). MSUTs incorporate data on total monetary expenditure in basic prices by households on 200 EXIOBASE products as well as the total trade margin expenditure, the total transport margin expenditure and the total tax expenditure due to purchasing these products. Summing up all four, one can arrive at the total money spent on these 200 products in purchaser prices. This data is useful for two purposes. First, it allows us to scale household expenditure observed in EU HBSs such that per capita expenditure on any of these products equals per capita expenditure in EXIOBASE 3 (national accounts). Second, we can convert household expenditure in EU HBSs, which is reported in purchaser prices, into expenditure in basic prices. We do so by assigning trade and transport margins

into related products and removing taxes from household expenditure. Hence, we ensure that the mere tax margins of household expenditure are not associated with an environmental impact.

Emission coefficients for all 200 products are available in EXIOBASE3. The emission coefficients utilized in this study measure kgCO₂-equivalent of CO₂, CH₄, N₂O and SF₆ emitted via a one euro expenditure on any product. This combination of different types of emissions is based on Global Warming Potential 100 metric (Solomon et al., 2007). Whereas EE-MRIO approach of deriving these coefficients is documented elsewhere, (e.g., Peters and Hertwich (2004) or Stadler (2021)), we outline the procedure below.

The input-output tables incorporate two matrices: Z and Y . Each element of Z is a sub-matrix, $Z_{k,l}$. Sub-matrix $Z_{k,l}$ incorporates the flow of any product produced in country k to be used in the production of all other products in country l . Sub-matrix $Z_{k,k}$ provides the same cross-product trades within country k . Matrix Y contains data on the final demand by diverse final consumers (e.g., households, governments etc.) for each product group.

Total gross output (x) equals the output used as the intermediate good plus the output used by the final consumers. Thus,

$$x = Z\sigma + Y\sigma \quad (1)$$

where σ represents a summation vector. The following formula reiterates that the gross output equals intermediate consumption plus the final consumption:

$$x = Ax + y. \quad (2)$$

In equation (2) matrix A incorporates the fraction of a product's gross output in one country that is traded to any other country (including the same country) for the production of any other good. Parameter y denotes any demand by final consumers. Rearranging (2) yields:

$$x = (I - A)^{-1}y = Ly \quad (3)$$

where I represents an identity matrix. Assuming Leontief demand, that is a unit increase in final demand leads to a proportional increase in the production, matrix

L incorporates the changes in the gross outputs of every product in each country in response to a change in the demand by final consumers of a country for a product (a change in y).

The environmental accounts of EXIOBASE 3 provide a matrix F that incorporates the total environmental impact, e.g., kgCO₂-equivalent emissions, in every country induced by the demand of any product. Further information on the environmental accounts of EXIOBASE3 is provided in Stadler et al. (2018). One can calculate the emission per output in every country for each product (matrix S) by dividing F element-wise by x :

$$S = F\hat{x}^{-1} \quad (4)$$

Our interest is to calculate the change in emissions if final demand goes up by one unit. Thus, we need to recover the increases in gross outputs of all the products in response to an increase in the final demand. Subsequently, any increase in final demand should be multiplied by emissions per gross output of the products in every country. Thus, our final emission coefficients (M) are given by:

$$M = SL \quad (5)$$

B. Estimation Appendix

Let c_i^{pre} denote kgCO₂-equivalent consumption of household i residing in any country (for brevity country indices are suppressed) directly observed in the data at 2010. Note that c^{pre} represents the household's kgCO₂-equivalent consumption before the redistributive policy experiment. Our regression specification that predicts CO₂ consumption reads:

$$\begin{aligned}
c_i^{pre} = & \alpha + \sum_{k=1}^7 \lambda_k p_{k,i} + \sum_{k=1}^7 \beta_k^1 p_{k,i} * e_i^{pre} + \sum_{k=1}^7 \beta_k^2 p_{k,i} * (e_i^{pre})^2 + \sum_{k=1}^7 \beta_k^3 p_{k,i} \\
& * (e_i^{pre})^3 + \sum_{k=1}^7 \beta_k^4 p_{k,i} * (e_i^{pre})^4 + \sum_{k=1}^7 \beta_k^5 p_{k,i} * (e_i^{pre})^5 + \delta s_i \\
& + \varepsilon_i
\end{aligned} \tag{6}$$

where $p_{k,i}$ denotes a set of household-type dummies with $k \in \{1, 2, \dots, 7\}$ indicating whether household i belongs to household-type group k . Household-type classification is as follows: 1- one adult, 2- two adults, 3- more than two adults, 4- one adult with dependent children, 5- two adults with dependent children, 6- more than two adults with dependent children, 7- others. Note that there are only 22 observations of group 7 in Spain. Parameter e_i^{pre} represents the total annual expenditure (permanent income) of household i before redistribution (observed in the data after performing previously mentioned scalings) and s_i indicates household size. Variables $\beta_k^1, \dots, \beta_k^5$ are the regression coefficients associated with the terms that include different orders of total expenditure. It should be noted that household-type information is missing in Sweden. Thus, explanatory variables in the regressions of Sweden are e_i^{pre} , \dots , $(e_i^{pre})^5$ and s_i .

We run the regression specification given in (5) separately for each country and collect the predicted values $\hat{\alpha}, \hat{\lambda}_k, \hat{\beta}_k^1, \dots, \hat{\beta}_k^5, \hat{\delta}$ and $\hat{\varepsilon}_i$ with $k \in \{1, 2, \dots, 7\}$. In the next step, we perform the redistributive policy experiment by taxing the 10% of e_i^{pre} and redistributing the resulting tax revenue equally to every household country-by-country. Let e_i^{post} denote the total expenditure (permanent income) of household i located in any country after redistribution. Resulting kgCO₂-equivalent consumption of any household can be predicted by:

$$\begin{aligned}
c_i^{post} = & \hat{\alpha} + \sum_{k=1}^7 \widehat{\lambda}_k p_{k,i} + \sum_{k=1}^7 \widehat{\beta}_k^1 p_{k,i} * e_i^{post} + \sum_{k=1}^7 \widehat{\beta}_k^2 p_{k,i} * (e_i^{post})^2 + \sum_{k=1}^7 \widehat{\beta}_k^3 p_{k,i} \\
& * (e_i^{post})^3 + \sum_{k=1}^7 \widehat{\beta}_k^4 p_{k,i} * (e_i^{post})^4 + \sum_{k=1}^7 \widehat{\beta}_k^5 p_{k,i} * (e_i^{post})^5 + \hat{\delta} s_i \\
& + \widehat{\varepsilon}_i
\end{aligned} \tag{7}$$

Hereafter, one can calculate kgCO₂-equivalent consumption per-capita, \bar{c}^{post} , in every country. Country-by-country differences, $\bar{c}^{pre} - \bar{c}^{post}$, yield the bars in Figure 5.

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