Revisiting equivalised incomes for quantifying carbon inequality

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Abstract

Carbon inequality is often quantified based on economic inequality. Therefore it is critical to use appropriate income, wealth or consumption concepts to measure carbon inequality. Equivalence scales of income is a concept from welfare economics that is frequently applied to carbon footprint accounting and carbon inequality assessments. Here we argue that this is a mistake based on a methodological misunderstanding that overestimates carbon footprints, particularly in lower-income groups and low-income countries, and underestimates carbon inequalities - which in turn has implications for climate justice. We also quantify empirical differences between methods across a range of countries and suggest alternative approaches.

1 Introduction

"Who uses how much of a given carbon budget?" is an extremely consequential question in the climate economics and justice discourse. Therefore, calculating carbon footprints and carbon inequality accurately is an important task for climate economists. In this study, we reconsider the concept of equivalised-incomes of households and argue that, while being entirely appropriate to assess the welfare of households from a monetary perspective, it is mistakenly applied to resource footprint accounting. We also present an exemplary comparison across countries to illustrate differences in the estimation of carbon footprints and carbon inequality, when applying equivalised vs. non-equivalised income. Consumption-based accounting has been widely used to estimate how much carbon a given household requires. A popular approach is coupling household expenditure surveys that quantify the consumption of households in monetary terms (that is in $ spent on goods and services) with environmentally extended input-output analysis of the economy[1,2]. This approach allocates carbon emissions to specific household groups based on their consumption patterns. In these studies, it remains uncertain, however, how much resources are used per person living inside a household. Yet per person is a preferred normalized scale to compare resource use across and within

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countries where household size may vary considerably. In principle, one could divide by the number of people in a household and arrive at per capita accounts, but another method, equivalised scales, applies different weights to each additional person in a household. This is to reflect how resources are shared within households and hence estimate the living standard or welfare of a household more accurately. This approach takes economies of scale within households (as well as lower material requirements for children) into account, but it cannot be translated directly to resource accounting or pollution footprinting, yet plenty of studies do so.[3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18]. This includes international-level studies, although the majority focuses on national and subnational levels.

2 What is an equivalence scale?

An equivalence scale for incomes (or expenditure) takes economies of scale within households into account[19]. "The needs of a household grow with each additional member, but not in a proportional way" - as the OECD documentation summarizes[20]. If two people share a flat, the flat is more efficiently used than in the counterfactual where each person has their own flat. The same logic applies to devices (such as TVs or cooking pans) as well as energy inside a home for heating for example. This means an equivalence scale takes the "sharing" of resources into account. In other words, it estimates an experienced living standard vs. an actual resource input to achieve this living standard. In principle, equivalence scales intend to capture resource *avoidance* instead of additional resource use, which also results in the problem of interest when applied to resource footprint accounting as we will elaborate in section 3. But first, let us illustrate the problem with the help of some concrete calculations, which retain their logic regardless of whether applied to income or expenditure and whether one takes only adults into account or also children. If incomes are equivalised across households, so are expenditures. Let us assume a household of two persons, where the first is an adult, lives at a disposable income of \$2000 a month. Per capita then, each person has an income of \$1000. An equivalence scale now does not count the second person as a "full" person, because whatever goods and services the household purchases with this amount of money, there are economies of scale, giving every person more access to resources than they would achieve alone. Assume the weighting factor for the second person is 1/2, then \$2000 a month are equivalent to $\$2000/(1 + 0.5) = \$1333.3$ per capita. Hence their living standard, expressed in monetary terms, is better than if they live on their own each with \$1000, by pooling their money and resources. Now why is all that a significant problem when estimating resource footprints?

3 Equivalence scales and resource footprints

As explained in the introduction, resource footprint accounts are based on the assumption that resource use is in some way proportional to spending. Then if one estimates a household to live at an equivalised income (or expenditure), one not only arrives at a larger effective income but also at a larger resource footprint. To extend the illustrative calculation from above, say the average carbon intensity per dollar of income of a household is $0.2kgCO_2$ per \$, then at a non-equivalised income of \$2000 the footprint is $400kgCO_2$ - at an equivalised income of $2 * \$1333.33 = \$2666$ the footprint is $533kgCO_2$. Hence the equivalised footprint is higher, despite equivalisation representing a resource avoidance. The problem is that the equivalisation introduces an "imaginary" additional amount of money that captures better their living standards. From a welfare accounting perspective this makes complete sense, more access to goods and services without actually purchasing more of those, but it does not accurately reflect the physical resource requirements associated with this imaginary living standard. Again, this is because the added living standard does not, by definition, come from an added resource but from an avoided resource (through sharing) instead. The fact that the scales are used for carbon footprint assessment is almost paradoxical since it is indeed known that economies of scale in households should lead to resource savings and hence lower footprints[21], whereas the equivalised income scale, as it is currently applied, has the opposite effect. In part, the confusion probably comes from the fact that, recently, physical quantities, predominantly energy use, have been used as a proxy for living standard as well[22,23]. While both approaches by themselves make sense, they are not commensurable and the welfare gain in monetary terms cannot be directly translated into additional resource use. Using equivalised scales for footprinting consequently introduces a systematic bias of estimating higher resource use, while there is only an improvement in living standards rather than resource use. This is amplified by the generally accepted observation that higher economic wealth is associated with lower fertility rates[24]. Consequently, applying the method should not only lead to overestimates in carbon footprints but also an underestimate of carbon inequality across income groups. In the following, we illustrate how large the differences are across high-income and low-income countries.

4 International empirical comparison

We now test the hypothesis that employing equivalised expenditure leads to higher footprints overall and lower carbon inequality estimates. To do this we apply data from the Luxembourg Income Survey (LIS) across 51 nations[25] and data from the World Bank for three low-income countries[26]. This selection totals 34 high-income nations and 20 low- to middle-income countries. The data is structured into household income deciles. We combined these surveys with the GTAP multi-regional input-output model to calculate footprints for 2017 with equivalised and without equivalised expenditure (see supplementary note for details). We specifically apply the popular OECD equivalisation scale (the overall trends we find are independent of which scale is used).

In line with our expectations, we find that equivalised expenditures lead to substantially higher carbon footprint estimates across countries and deciles, with a more pronounced difference to non-equivalised footprint in lower income deciles (through larger household sizes) and lower-income countries. As shown in Figure 1, panel (A), across all countries the carbon footprints per equivalised person (sometimes called adult-equivalent) are larger for the Bottom 10% as well as the Top 10%. Figure 1 panel (B) illustrates that the inequality measured as top decile to bottom decile ratio is lower when taking equivalised expenditures into account compared to when not doing so. In Figure 1 we measured carbon inequality across income groups. One could also sort households into deciles according to the size of the footprint. We have found that using different sorting only marginally changes the results and does not influence the conclusions drawn related to equivalised expenditures.

Figure 2 illustrates that across countries aggregate national footprints are overestimated by between 30% to 100% through equivalised income scales. This magnitude can be considered substantial. We only include four low-income countries but here the overestimation seems particularly pronounced. For Mali, for example, the estimated national footprint is twice as large as without equivalised incomes. Figure 2 also shows that the bias grows the lower the income of a country. Some papers have resorted to rescaling of total national footprints after overestimation through equivalised incomes[5].

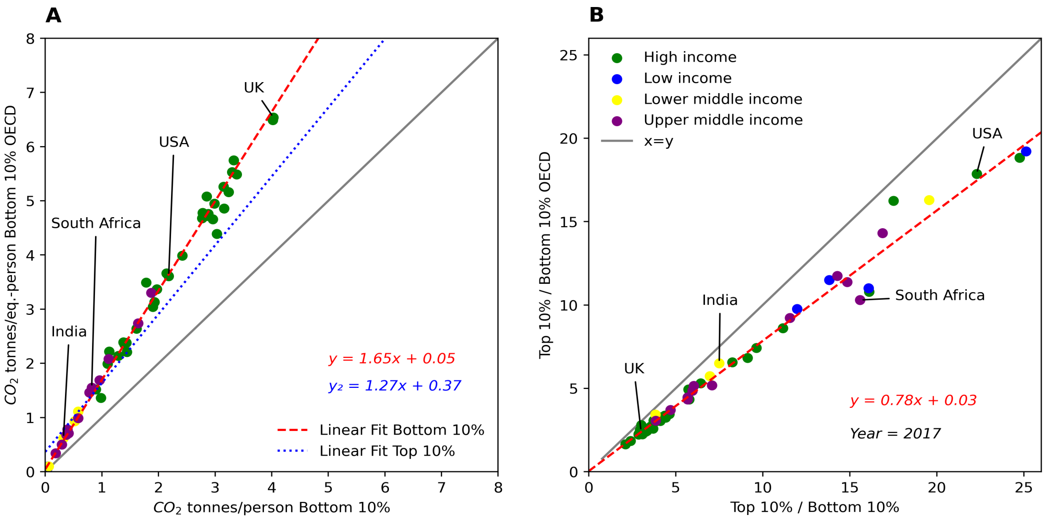

Figure 1: Comparison of equivalised and non-equivalised footprints across LIS database

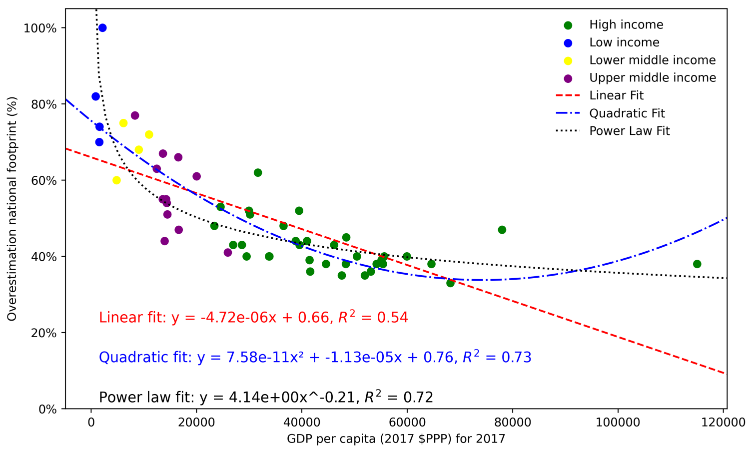

Figure 2: National carbon footprint bias diminishes with income

5 Discussion and recommendations

In summary, we have found that employing equivalised expenditure for carbon footprint estimation introduces systematic biases in three ways: (i) household and per person footprints are overestimated and in turn therefore also footprints across income or carbon deciles (because expenditure is proportional to income and carbon); (ii) due to those biases the aggregate national footprints are overestimated too, and increasingly so for low-income countries which is due to the aforementioned higher fertility in those countries; (iii) there is a systematic underestimation of carbon inequality between and within countries. This is because the footprints of low-income groups within countries are relatively overestimated and the footprints of low-income countries, among the set of all countries, are relatively overestimated (all groups are overestimated but lower-income deciles or countries more so). Table 1 summarizes those findings and the affected metrics.

Table 1: Effect of equivalised incomes/expenditure on carbon footprint metrics

Unit/Level	**Metric**	**Effect**
Individual	Carbon footprint per person/household	Increase +
Subnational	Carbon footprint per income decile	Increase +
National	National carbon footprint	Increase +
	National carbon inequality across incomes	Decrease -
	National carbon inequality sorted by carbon footprint per capita	Decrease -
International	Between country carbon inequality	Decrease -

Therefore, concerning policy-making, we suggest not to employ equivalised incomes for carbon footprinting as it leads to wrong conclusions about climate change responsibility. We have seen, by the example of Mali, that a national footprint might be estimated to be twice as high, and hence produces an inaccurate picture of Mali's contribution to climate change. Even if studies rescale total national footprints to non-equivalised values, the problem of climate change responsibility within countries persists. Lower-income groups are then systematically assigned more responsibility than they should be - which has major implications for climate policy and the required national decarbonization pathways. It has been emphasized in past studies that high-income countries bear the highest responsibility for rapid decarbonization[27]. It also has been argued that within-country carbon inequality is larger than between-country inequality[28] but on the basis of dramatic *wealth* inequality and with conservative assumptions about within-country carbon-expenditure elasticities, partly stemming from the fact that studies apply equivalised-incomes or expenditure. Our empirical results instead show that non-equivalised consumption inequality supports less restrictive assumptions about within-country carbon-expenditure elasticities - which in turn emphasizes the importance of climate policies aimed at reducing consumption-induced carbon inequality[29].

With respect to methodological considerations, we suggest the following course of action based on our findings: 1) There needs to be a systematic reevaluation of how to take household size into account for resource footprinting. While equivalised income and expenditure scales introduce a bias, it is not clear whether other methods such as per capita measures for instance used by Oswald, Owen, and Steinberger[30] are better, especially if, like here, household size is not taken into account when translating household groupings to per capita scales. 2) It might be useful to assess which sectors and products are subject to economies of scale within households and start differentiating equivalization factors between sectors. Heating at home for three people might exhibit more economies of scale than transport services that the three people make use of outside of their home (at least if they do not participate in ride sharing). 3) Given that equivalisation scales are about economies of scale, and hence resource savings, instead of resource addition, it might be worth enquiring whether an inverse-equivalisation can be applied, that is, an adjustment factor that scales down actual expenditure and therewith physical consumption per person, say from \$1000 per household to \$500 for heating, for the purpose of resource footprinting (not for the purpose of measuring monetary welfare of course). However, we want to advise caution, any such methodological adjustment should be developed in collaboration between welfare economists and resource economists before deciding what approach to pursue. 4) We did not discuss biases and limitations stemming from other sources. As the literature illustrates, resource inequalities are usually much lower when applying item-based household surveys rather than expenditure ones[31] but these studies are very rare. Therefore, just because the equivalisation scales introduce a bias toward a reduction in inequality compared to non-equivalised income, we do not claim that non-equivalised income or expenditure-based studies are closer to reality. However, it is important that we clarify where the equivalisation bias comes from - it clearly reduces inequality for the wrong reasons and thus should not be applied any longer. If however, inequality turns out to be much lower because of other reasons such as lower resource use than expected among rich households then this is an entirely different point. 5) Hence, lastly, we suggest to systematically clarify where and when, and for what reasons resource household surveys introduce biases into resource footprinting.

Author contribution

Conceptualization: Y.O.; Data Curation: D.M., X.C.; Formal Analysis D.M., X.C.; Funding Acquisition: D.M., K.F., K.H.; Investigation: D.M., X.C.; Methodology: Y.O., D.M., X.C., K.F., K.H.; Project Administration: K.F., K.H.; Resources: D.M., K.F., K.H.; Software: D.M., X.C.; Supervision K.F., K.H.; Validation Y.O., D.M., X.C., K.F., K.H.; Visualization: Y.O., D.M., X.C.; Writing Original Draft: Y.O.; Review, Editing: Y.O., D.M., X.C., K.F., K.H.

Code and data availability

Code and data to reproduce the figures and empirical analysis can be found at
https://github.com/yloswald/Equivalised-incomes-and-carbon-footprints.

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