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Who decarbonizes? Effects of uniform and differentiated carbon pricing on carbon inequality

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Effects of uniform and differentiated carbon pricing on carbon inequality

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Who decarbonizes?
Effects of uniform and differentiated carbon pricing on carbon inequality

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Abstract

In many countries, consumption-based emissions are increasingly concentrated at the top of the distribution, and there are growing calls in public debate for climate policy to target emission-intensive luxury consumption more strongly. Yet while financial distributional effects of carbon pricing are well studied, its impact on the distribution of emissions across households remains less well understood. This paper first characterizes the demand-side conditions under which uniform carbon pricing increases or decreases consumption-based carbon inequality within countries in a simple partial-equilibrium setting with heterogeneous households. Applying the main result to Germany suggests that uniform carbon pricing would slightly reduce carbon inequality, while a stylized approximation of carbon pricing in Germany increases it. The paper then compares differentiated carbon pricing, where luxury goods are priced at a higher rate than necessities, with the standard benchmark of uniform carbon pricing. While the latter is attractive in terms of efficiency, it does not necessarily outperform differentiated pricing, both regarding financial and emissions-based distributional effects.

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1 Introduction

Carbon inequality, meaning the unequal distribution of household emissions or carbon footprints, is at a high level—this is true both within countries as well as globally, where the bottom half of carbon emitters were responsible for only 10% of global CO_2 emissions while almost half of global emissions were caused by the consumption of the top 10% emitters (Bruckner et al., 2022). Furthermore, while the carbon footprints of the bottom half of emitters in the US and several European countries are already in line with the national emissions reduction commitments under the Paris Agreement for 2030, the top 10% would need to substantially reduce their per-capita emissions to comply with these targets (e.g. by 86% in the US; Chancel, 2022). Looking at the development of carbon inequality in recent decades, it is notable that while emissions differences between countries have narrowed, carbon inequality within countries has increased (Chancel, 2022; Chancel & Piketty, 2015). Between 1990 and 2019, per-capita emissions of low- and middle-income groups of rich countries declined by about 5-15% while the global top 1% emitters increased emissions by 26% and the top 0.01% even by 80% (Chancel, 2022). In the context of a rapidly diminishing carbon budget compatible with limiting global warming to at least 2°C (IPCC, 2023), this high and rising concentration of emissions among the richest households implies that a small share of the population contributes disproportionately to the depletion of the remaining budget and has substantial mitigation potential. As a result, carbon inequality is not only a distributional concern, but also directly relevant for the pace and feasibility of climate change mitigation.

Carbon pricing is widely advocated by economists as the central instrument for climate policy due to its cost-effectiveness and its ability to internalize the social costs of carbon. While financial distributional impacts of carbon pricing have rightly received extensive attention (e.g., Dorband et al., 2019; Klenert et al., 2016; Ohlendorf et al., 2020; Steckel et al., 2021), how carbon pricing affects the distribution of emissions themselves remains less well understood. Yet, within-country carbon inequality is not merely a secondary concern but essential to both fairness considerations and political feasibility of climate policies. A large literature shows that

perceived unfairness in the distribution of climate policy burdens undermines public support for those policies and weakens political feasibility (e.g., Carattini et al., 2017; Kallbekken & Sælen, 2011; Maestre-Andrés et al., 2019). Carbon inequality may therefore undermine the legitimacy of carbon pricing if people perceive it as unfair that lower- and middle-income households bear a disproportionate share of emissions reductions. Furthermore, there is evidence for a pronounced carbon inequality aversion: Surveys by Köchling et al. (2025) and du Marais (2026) suggests that people desire a more equal distribution of carbon footprints. Köchling et al. (2025) show that these preferences are also expressed by wealthy individuals themselves. du Marais (2026) finds that respondents support reducing carbon inequality even when total emissions and the income distribution remain unchanged. Against this background, the first research question this paper examines is: (i) How does uniform carbon pricing affect the distribution of emissions across households and under which conditions does it increase or decrease within-country carbon inequality?[1]

Public debates about carbon inequality raise the question of whether climate policy should target emission-intensive luxury consumption more strongly, such as frequent flying, private jets, large cars, or other affluent consumption practices (Dabi et al., 2025; France 24, 2025; Harvey, 2023; The Guardian, 2023). A common argument is that these types of consumption appropriate a disproportionate share of the remaining carbon budget, while the high-income households consuming them often have more resources or a lower marginal effort to reduce their emissions than low-income households, whose emissions stem mainly from necessity consumption that is less easily avoidable (Kukowski & Garnett, 2023). Some authors suggested that differentiated carbon pricing schemes or luxury-focused carbon prices may al-

[1]Note that this paper focuses on consumption-based carbon emissions and footprints, as the analysis examines the impact of carbon pricing through changes in consumer prices and household consumption decisions, regardless of the specific institutional design of carbon pricing. While e.g. Bruckner et al. (2022) also focuses on consumption-based emissions—similar to many other household-level carbon inequality studies—, Chancel (2022) belongs to a smaller set of recent papers which measure carbon inequality using either an ownership-based approach, where production emissions are attributed to firm owners, or a mixed footprint approach, where emissions related to investment or capital formation are attributed to firm owners (for details see Chancel & Rehm, 2025).

low to target high-emission consumption more effectively by imposing a higher carbon price rate on luxury goods than on necessities (Dietsch, 2024; Oswald et al., 2023). However, from an efficiency perspective, uniform carbon pricing is the cost-effective option since it equalizes marginal abatement costs across sources and thereby achieves a given level of emissions reduction at the lowest possible cost. There is, to the best of current knowledge, no economic analysis that compares differentiated carbon pricing with the standard benchmark of uniform carbon pricing regarding their implications for carbon inequality and financial distributional effects. This leads to the second research question: (ii) Under which conditions does differentiated carbon pricing perform better or worse than uniform carbon pricing with regard to financial and emissions-based distributional effects?

To address these questions, this paper isolates the mechanisms through which carbon pricing affects carbon inequality descriptively in a simple partial-equilibrium setting with heterogeneous households based on a first-order approximation. Focusing on short-term demand-side responses to a carbon price using local elasticities, it shows that whether carbon pricing increases or decreases consumption-based carbon inequality depends on the relative emissions responses of income groups, determined by the composition of their carbon footprints across consumption categories, their price elasticities, and the carbon intensities of their consumed goods. Applying the theoretical result to Germany with an order-of-magnitude estimate suggests that uniform carbon pricing would reduce consumption-based carbon inequality slightly whereas a stylized approximation of 2023 carbon pricing in Germany would increase it. The paper also characterizes the conditions under which differentiated pricing reduces carbon inequality more and is more progressive than uniform pricing. While the latter is attractive in terms of efficiency, interestingly, it does not necessarily outperform differentiated pricing, both regarding financial and emissions-based distributional effects.

The remainder of the paper is organized as follows. Section 2 provides a concise literature review. Section 3 analyzes the effects of uniform and differentiated carbon pricing on carbon inequality, i.e., the emissions-based incidence, as well as the financial incidence under these schemes. Section 4 provides an order-of-magnitude numerical illustration of the mechanism using German data. Section 5 concludes.

2 Literature review

An extensive literature on the incidence of carbon pricing shows how the distributional effects vary across households, depending mainly on expenditure patterns, income effects, and revenue recycling designs (e.g., Dorband et al., 2019; Klenert et al., 2016; Ohlendorf et al., 2020; Steckel et al., 2021). While it deals with the financial implications of carbon pricing, this literature emphasizes that distributional aspects are of central relevance for the design of climate policies.

A related strand of literature in public finance focuses on optimal commodity taxation, which studies how to find the best set of taxes to balance different policy objectives (e.g., Atkinson & Stiglitz, 1976; Cremer et al., 2001; Saez, 2002). These insights have been extended to environmental externalities and taxes, showing that optimal pollution taxes may deviate from Pigouvian benchmarks in second-best settings and with redistributive objectives (e.g., Cremer et al., 1998, 2003; Jacobs & van der Ploeg, 2019; Sandmo, 1975).

Several studies analyze uniform versus differentiated carbon pricing of various designs. Many are primarily concerned with differentiation by sector or fuel and focus on efficiency aspects (e.g. Boeters, 2014; Böhringer et al., 2014; Hoel, 1996; Landis et al., 2017). Abrell et al. (2018) focus on a welfare-optimal tax design and show that uniform pricing is optimal when social concerns relate only to distributional effects from carbon pricing, whereas differentiated pollution taxes across sectors are optimal when social concerns also relate to existing inequality or when revenues cannot be optimally redistributed. Recent contributions have begun to discuss forms of differentiated carbon pricing, also referred to as progressive or non-linear carbon pricing, in which higher carbon prices apply to high-emissions consumption or consumers: Dietsch (2024) proposes differentiating prices between individuals based on their carbon footprints, du Marais (2026) suggests increasing carbon tax rates with individual footprints ("footprint-progressive") or incomes ("income-progressive"), and Oswald et al. (2023) propose differentiation across goods by taxing luxury goods at higher rates than necessities. du Marais (2026) finds substantial support for footprint- and income-progressive carbon taxes that exceeds support for uniform pricing with lump-sum revenue recycling and shows

that this support is linked to carbon inequality aversion. The conditions under which uniform and differentiated carbon pricing increase or decrease consumption-based carbon inequality and are financially progressive have, however, not been examined.

3 Theoretical analysis

3.1 Setup

Consider a partial equilibrium setting in which households $i = 1, ..., I$ differ in income y_i. There are J consumption goods $j = 1, \ldots, J$ that cause greenhouse gas emissions and have pre-policy prices p_j. The demand of household i for good j is given by (Marshallian) demand functions $q_{ij}(p_j, y_i)$ where cross-price effects are ignored for simplicity. The analysis does not rely on a specific preference or demand specification. Instead, it is assumed that demand functions are differentiable and that own-price and income elasticities of demand are well-defined at the pre-policy baseline. Demand and emissions responses to carbon pricing can thus be characterized simply based on local elasticities evaluated at the baseline.

Carbon pricing

In the following, three carbon-pricing schemes are introduced, which are indexed by the superscript S. Specifically, $S \in \{U, D, UL\}$ with U referring to uniform carbon pricing, D to differentiated carbon pricing, and UL to uniform carbon pricing with a lump-sum transfer.

Uniform carbon price

With emission factors $\alpha_j > 0$ of each good, total (consumption-based) emissions of household i are $e_i = \sum_{j=1}^{J} \alpha_j q_{ij}$. A uniform per-ton carbon price $\tau > 0$ increases the price of each good according to

$$\tilde{p}_j{}^U = p_j\big(1 + \kappa_j^U(p_j)\big), \qquad \kappa_j^U(p_j) = \frac{\tau \alpha_j}{p_j} (> 0), \tag{1}$$

where carbon price burden share or proportional price increase $\kappa_j^U(p_j)$ measures how strongly the carbon price increases the price of good j relative to its base price. $t_j^U = \tau\alpha_j$ is the share of the carbon price that is passed-through to consumers.

Differentiated carbon price

Let η_j denote income elasticities of demand which can be defined in the usual way as $\eta_j = \frac{\partial \ln q_j}{\partial \ln y}$.[2] Oswald et al. (2023) analyze a luxury carbon price using income elasticities of demand and the simple carbon pricing rate $t_j^D = A\tau\alpha_j\eta_j$ (translated to my notation) where A is a normalization factor. I suggest a more general version of a differentiated carbon price using a function depending on income elasticities of demand. Differentiating necessities and luxury goods changes the price of each good according to

$$\tilde{p}_j{}^D = p_j\big(1+\kappa_j^D(p_j)\big), \qquad \kappa_j^D(p_j) = \frac{\tau\alpha_j x(\eta_j)}{p_j}, \tag{2}$$

where $x(\eta_j)$ is a strictly increasing and positive weight function of the income elasticities η_j (normalized such that $x(1) = 1$), so that the carbon pricing rate is $t_j^D = \tau\alpha_j x(\eta_j)$. The choice of a specific function $x(\eta_j)$ is a policy choice, depending on how strongly income elasticity should be weighted. Two alternative specifications or options of the differentiation scaling function $x(\eta_j)$ are considered here.

Option A: $x(\eta_j;\gamma) = \eta_j^\gamma$

Under Option A, the level of differentiation can be controlled by choosing the differentiation parameter $\gamma \geq 0$, with $\gamma = 0$ yielding a uniform carbon price, $\gamma = 1$ mirroring the version in Oswald et al. (2023) and $\gamma > 1$ would be strong progressive carbon pricing.

Option B: $x(\eta_j;\gamma) = \begin{cases} \eta_j^\gamma & \text{if } j \in \mathscr{L} \text{ (luxury goods)} \\ 1 & \text{if } j \in \mathscr{N} \text{ (necessities)} \end{cases}$

Under Option B, luxury goods are treated as in Option A and necessities as with a uniform carbon price. In the following, I will first focus on Option A with $\gamma = 1$.

[2] $\eta_j \in (0,1)$ for basic goods (necessities), while luxury or inferior goods may exhibit $\eta_j > 1$ or $\eta_j < 0$.

Uniform carbon price with lump-sum transfer

A uniform carbon price with lump-sum transfer corresponds to a uniform carbon price as defined by Eq. (1) but additionally, the resulting total revenue $R = \sum_i \sum_j \tau \alpha_j p_j q_{ij}$ is redistributed equally among households via a lump-sum transfer, amounting to $\frac{R}{I}$ per household, where I is the number of households.[3]

3.2 Carbon inequality and emissions-based incidence

In the following, the demand response to any carbon price scheme S with proportional price increase $\kappa^S > 0$ is first characterized using a local approximation, before the corresponding change in household emissions and then the change in carbon inequality are derived from this.

Let $\varepsilon_{ij} > 0$ be own-price elasticities of demand. Holding income and other prices fixed, they are defined as $\varepsilon_{ij} = -\frac{dq_{ij}/q_{ij}}{dp_j/p_j}$. It then directly follows that **the first-order change in quantities** for a small proportional price change due to a carbon price $\kappa_j^S = \frac{dp_j}{p_j}$ is

$$\frac{dq_{ij}}{q_{ij}} \approx -\varepsilon_{ij} \kappa_j^S. \tag{3}$$

Note again that total emissions of household i (or the carbon footprint of i) are $e_i = \sum_{j=1}^J \alpha_j q_{ij}$. Hence the share of household i's total emissions coming from good j is

$$w_{ij} = \frac{\alpha_j q_{ij}}{e_i}, \qquad \sum_j w_{ij} = 1. \tag{4}$$

Totally differentiating household emissions e_i yields $de_i = \sum_{j=1}^J \alpha_j dq_{ij}$. Dividing by e_i and multiplying by $\frac{q_{ij}}{q_{ij}}$ gives

$$\frac{de_i}{e_i} = \sum_{j=1}^J \frac{\alpha_j q_{ij}}{e_i} \frac{dq_{ij}}{q_{ij}} = \sum_{j=1}^J w_{ij} \frac{dq_{ij}}{q_{ij}}. \tag{5}$$

[3] Other uses of revenues, e.g. public investments, subsidies or reducing distortionary taxes, are not modeled here as the goal is to compare the effects of differentiated price signals with the standard benchmark of uniform carbon pricing with lump-sum transfers.

Using Eq. (3) yields the **percentage change in total emissions** of household i:

$$\frac{de_i}{e_i} \approx -\sum_{j=1}^{J} w_{ij}\varepsilon_{ij}\kappa_j^S. \tag{6}$$

With J consumption goods $j = 1,\ldots,J$, rearranging Eq. (6) gives **post-policy household emissions** of household i:

$$\tilde{e}_i \approx e_i\left(1-\sum_{j=1}^{J} w_{ij}\varepsilon_{ij}\kappa_j^S\right). \tag{7}$$

In the following, two representative households or income groups are considered, one with high income (H) and one with low income (L) and the ratio of their household emissions $\frac{e_H}{e_L}$ will be used as a measure of carbon inequality. This simple, scale-independent metric reflects the relative emission difference between the two groups and allows for easy interpretation of the analytical conditions. The analysis is limited to cases in which the first-order approximation implies post-policy household emissions to remain positive, i.e. $\tilde{e}_i > 0$ and hence, following Eq. (7), $1-\sum_{j=1}^{J} w_{ij}\varepsilon_{ij}\kappa_j^S > 0$. Then the **change in carbon inequality** due to carbon pricing scheme S is

$$\frac{\tilde{e}_H}{\tilde{e}_L}\Big/\frac{e_H}{e_L} \approx \frac{1-\sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^S}{1-\sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^S}. \tag{8}$$

Due to $1-\sum_{j=1}^{J} w_{ij}\varepsilon_{ij}\kappa_j^S > 0$, it holds that $\frac{\tilde{e}_H}{\tilde{e}_L}\Big/\frac{e_H}{e_L} \lesseqgtr 1 \iff -\sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^S \lesseqgtr -\sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^S$ and hence the following Proposition can be derived.

Proposition 1. *Suppose $e_H > e_L$ initially. The carbon price on a given good j contributes to an increase in carbon inequality if it leads to a larger proportional emissions reduction for the low-income group L than for the high-income group H, i.e. if $w_{Lj}\varepsilon_{Lj} > w_{Hj}\varepsilon_{Hj}$. Conversely, it contributes to a decrease in carbon inequality if the high-income group H reduces emissions more strongly, i.e. if $w_{Hj}\varepsilon_{Hj} > w_{Lj}\varepsilon_{Lj}$. The contribution of each good to the total effect is larger the higher the proportional*

price increase for that good (κ_j^S). Hence,

$$\frac{\tilde{e}_H}{\tilde{e}_L} \Big/ \frac{e_H}{e_L} \lesseqgtr 1 \Longleftrightarrow \sum_j \kappa_j^S \left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj} \right) \lesseqgtr 0. \tag{9}$$

Intuitively, the carbon price on a given good j therefore contributes to an increase in carbon inequality if low-income households cut their carbon footprints more strongly than high-income households because they have higher emissions shares w_{Lj} for this good and/or are more price elastic (ε_{Lj} higher) than high-income households, weighted by the proportional price increase for that good under scheme S, κ_j^S. Inversely, a carbon price on a good j contributes to a decrease in carbon inequality if high-income households cut their carbon footprints more strongly due to their higher emissions shares (w_{Hj}) and/or price elasticities (ε_{Hj}).

The qualitative result can be transferred to any standard scale-invariant inequality index that is monotonic in the group-specific emissions ratio. As shown as an example in the Appendix, the Theil index is a strictly increasing function of the emissions ratio $\frac{e_H}{e_L}$ for $e_H > e_L$.

Comparison of the carbon inequality effect of different carbon pricing schemes

Based on this, it is possible to compare the carbon inequality impact of different carbon pricing schemes S and S' that differ in their proportional price increases κ_j^S and $\kappa_j^{S'}$ for each good j. Using (8), the alternative pricing scheme S' is reducing carbon inequality more strongly than scheme S if $\frac{1-\sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^{S'}}{1-\sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^{S'}} < \frac{1-\sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^{S}}{1-\sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^{S}}$, i.e. if the ratio of the remaining post-policy emissions is smaller with scheme S' than with scheme S.

Let $A_S \equiv \sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^S$ and $B_S \equiv \sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^S$, then the condition becomes $\frac{1-A_{S'}}{1-B_{S'}} < \frac{1-A_S}{1-B_S}$. Cross-multiplying gives $(1-A_{S'})(1-B_S) < (1-A_S)(1-B_{S'})$. Defining $\Delta A = A_{S'} - A_S$ and $\Delta B = B_{S'} - B_S$, this can be rearranged to

$\Delta A - \Delta B + A_S(B_S + \Delta B) - (A_S + \Delta A)B_S > 0$ and as the $A_S B_S$ terms cancel, this yields $\Delta A - \Delta B + A_S \Delta B - B_S \Delta A > 0$. Factoring out gives $(1-B_S)\Delta A - (1-A_S)\Delta B > 0$ and since $1 - \sum_{j=1}^J w_{ij}\varepsilon_{ij}\kappa_j^S > 0$ this can be rearranged to $\frac{\Delta A}{1-A_S} > \frac{\Delta B}{1-B_S}$. Hence, the following general result can be derived.

Proposition 2. *Let* $\mathscr{I}(\kappa_j^S) = \frac{\tilde{e}_H(\kappa_j^S)}{\tilde{e}_L(\kappa_j^S)} \Big/ \frac{e_H}{e_L}$ *be the change in carbon inequality due to a carbon pricing scheme S with proportional price increases* κ_j^S*. For any two carbon pricing schemes* $S, S' \in \{U, D, UL\}$*, scheme* S' *reduces carbon inequality more than scheme S if and only if*

$$\mathscr{I}(\kappa_j^{S'}) < \mathscr{I}(\kappa_j^S) \Longleftrightarrow \frac{\sum_j \left(\kappa_j^{S'} - \kappa_j^S\right)\left(w_{Hj}\varepsilon_{Hj}\right)}{1 - \sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^S} > \frac{\sum_j \left(\kappa_j^{S'} - \kappa_j^S\right)\left(w_{Lj}\varepsilon_{Lj}\right)}{1 - \sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^S}. \quad (10)$$

Hence, scheme S' reduces carbon inequality more than scheme S if moving from scheme S to S' leads to a larger increase in emissions reduction for high-income households than for low-income households, relative to their post-policy emissions under S. This change in emissions can be negative if scheme S' leads to lower emissions reductions than scheme S. Therefore, another interpretation is that the change from S to S' has to reduce emissions of high-income households more or increase them less than the emissions of the low-income household, relative to their emissions under S.

Differentiated vs. uniform carbon pricing

For deriving the condition when differentiated carbon pricing reduces carbon inequality more than uniform carbon pricing[4], $\kappa_j^D = \frac{\tau\alpha_j x(\eta_j)}{p_j}$ and $\kappa_j^U = \frac{\tau\alpha_j}{p_j}$ are inserted into Eq. (10) with $S' = D$ and $S = U$. Dividing by $\tau > 0$ and factoring out gives the following result.

Corollary 1. *The relative carbon inequality effect of differentiated and uniform carbon pricing depends on whether differentiation shifts the carbon price burden towards goods for which high-income households have a larger emissions response term* ($w_{Hj}\varepsilon_{Hj} > w_{Lj}\varepsilon_{Lj}$)*:*

$$\mathscr{I}(\kappa_j^D) \lesseqgtr \mathscr{I}(\kappa_j^U) \Longleftrightarrow \sum_j \left(\frac{\alpha_j\left(x(\eta_j) - 1\right)}{p_j}\right)\left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right) \lesseqgtr 0. \quad (11)$$

[4]The comparison does not consider uniform carbon pricing with lump-sum transfer because the potential additional demand effect induced by the transfer is likely small and would require additional assumptions.

Hence, differentiated carbon pricing reduces carbon inequality more if the goods that have a higher carbon price under differentiation ($\alpha_j \left(x(\eta_j) - 1\right) > 0$) are the goods where high-income households have a stronger emissions response ($w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj} < 0$) and if the low-$\eta$ goods that have a lower carbon price under differentiation ($\alpha_j \left(x(\eta_j) - 1\right) < 0$) are the goods where low-income households have a higher emissions response ($w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj} > 0$). The sign of $\alpha_j \left(x(\eta_j) - 1\right)$ depends on whether the differentiation function $x(\eta_j)$ increases or decreases the tax rate of a specific good j relative to uniform pricing, where the magnitude is larger the higher the carbon intensity of that good α_j. This means that differentiated carbon pricing reduces carbon inequality more if it shifts the carbon price burden sufficiently towards goods where high-income households adjust their demand and hence their carbon footprint more due to a higher price elasticity and/or higher emissions shares.

Considering a case where uniform carbon pricing increases carbon inequality, it can be asked under which conditions differentiated pricing would reverse this and decrease carbon inequality. As is shown in detail in the Appendix ("When changing to differentiated carbon pricing can flip the sign"), this can be the case if the goods where high-income households adjust their demand more in response to a price change (in emissions-weighted terms, i.e. $w_{Hj}\varepsilon_{Hj} > w_{Lj}\varepsilon_{Lj}$) are sufficiently income-elastic and goods where low-income households respond more ($w_{Lj}\varepsilon_{Lj} > w_{Hj}\varepsilon_{Hj}$) are less income-elastic.

3.3 Financial incidence

Let B_i be the absolute financial carbon price burden or payment of household i and $b_i = \frac{B_i}{y_i}$ be its relative burden relative to income or total expenditure. A carbon pricing scheme is progressive if $\frac{\partial b_i}{\partial y_i} > 0$, i.e. if the relative burden increases with income, which implies $b_L < b_H$ in the simple two household or income group case. Continuing with this case, a simple progressivity index can be defined as $P^S = b_H^S - b_L^S$. A positive P^S indicates a progressive and a negative P^S a regressive effect of the respective scheme.

The general absolute burden of household i in case of carbon pricing scheme S

with proportional price increases κ_j^S, fixed quantities or demand and no revenue recycling is $B_i^S = \sum_j \kappa_j^S p_j q_{ij}$. Hence in case of uniform carbon pricing the absolute burden is $B_i^U = \sum_j \tau \alpha_j q_{ij}$, in case of differentiated pricing $B_i^D = \sum_j \tau \alpha_j x(\eta_j) q_{ij}$, and in case of uniform carbon pricing with a lump-sum transfer $B_i^{UL} = \sum_j \tau \alpha_j q_{ij} - \frac{R}{I}$ where $\frac{R}{I}$ is the lump-sum transfer amount per household.

Accounting for demand adjustments via price elasticities gives the adjusted carbon price payments $B_i^{S,adj} = \sum_j \kappa_j^S p_j q_{ij}(1 - \varepsilon_{ij}\kappa_j^S)$ following Eq. (3). The difference relative to the fixed demand burden is the term $-\sum_j \varepsilon_{ij}(\kappa_j^S)^2 p_j q_{ij}$, which is of second order. Therefore, for small price changes, the first-order burden B_i^S yields an approximation of the immediate burden. A robustness check in the numerical illustration shows that the second-order term is indeed small (see Subsection 4.2.4), which is why the first-order burden is used in the following.

Carbon pricing scheme S' is more progressive than carbon pricing scheme S if $P^{S'} > P^S$, i.e. $b_H^{S'} - b_L^{S'} > b_H^S - b_L^S$ or

$$P^{S'} > P^S \iff \frac{B_H^{S'} - B_H^S}{y_H} > \frac{B_L^{S'} - B_L^S}{y_L}. \tag{12}$$

Inserting $B_i^S = \sum_j \kappa_j^S p_j q_{ij}$ gives $\frac{\sum_j (\kappa_j^{S'} - \kappa_j^S) p_j q_{Hj}}{y_H} > \frac{\sum_j (\kappa_j^{S'} - \kappa_j^S) p_j q_{Lj}}{y_L}$. The following Proposition provides the condition for comparing carbon pricing schemes without revenue recycling regarding their financial incidence or progressivity.

Proposition 3. *For any two carbon pricing schemes $S, S' \in \{U, D\}$ with proportional price increases κ_j^S and no revenue recycling, scheme S' is more progressive than scheme S if and only if*

$$P^{S'} > P^S \iff \sum_j (\kappa_j^{S'} - \kappa_j^S) p_j \left(\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} \right) > 0. \tag{13}$$

Hence, scheme S' is more progressive than scheme S if the additional net burden imposed by S' compared to scheme S is larger for high-income households than for low-income households, relative to their (pre-policy) income.

Uniform carbon pricing with a lump-sum transfer is always more progressive than uniform carbon pricing without revenue recycling. Since $B_i^{UL} = B_i^U - \frac{R}{I}$ with $\frac{R}{I} > 0$,

inserting this in Eq. (12) with $S' = UL$ and $S = U$ yields $P^{UL} > P^U \iff \frac{B_H^U - \frac{R}{I} - B_H^U}{y_H} > \frac{B_L^U - \frac{R}{I} - B_L^U}{y_L} \iff \frac{\frac{R}{I}}{y_L} > \frac{\frac{R}{I}}{y_H}$, which holds since $y_L < y_H$. In the following, the differentiated pricing will be compared to both uniform pricing with and without lump-sum recycling.

Differentiated vs. uniform carbon pricing

For deriving the condition when differentiated carbon pricing has more progressive effects than uniform carbon pricing, $\kappa_j^D = \frac{\tau \alpha_j x(\eta_j)}{p_j}$ and $\kappa_j^U = \frac{\tau \alpha_j}{p_j}$ are inserted into Eq. (13) with $S' = D$ and $S = U$, which gives $\sum_j (\tau \alpha_j x(\eta_j) - \tau \alpha_j) \left(\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} \right) > 0$. Dividing by $\tau > 0$ and factoring out yields the following insight.

Corollary 2. *The relative progressivity of differentiated and uniform carbon pricing depends on whether differentiation sufficiently raises the carbon price on goods consumed more intensively by high-income households relative to income, and sufficiently lowers the carbon price on goods consumed more by low-income households relative to income:*

$$P^D - P^U \lesseqgtr 0 \iff \sum_j \alpha_j \left(x(\eta_j) - 1 \right) \left(\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} \right) \lesseqgtr 0. \tag{14}$$

Each good j's contribution to this condition depends both on the term $\alpha_j \left(x(\eta_j) - 1 \right)$, which indicates whether differentiated pricing increases or reduces the tax rate on good j compared to uniform pricing, and the term $\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L}$, which indicates if good j is consumed more by high- or low-income households relative to their income. Hence, differentiated carbon pricing is more progressive if the goods that have a higher carbon price under differentiation ($\alpha_j \left(x(\eta_j) - 1 \right) > 0$ because of their high income elasticity η_j), are the goods which high-income households consume more relative to income ($\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} > 0$) and the low-$\eta$ goods that have a lower carbon price under differentiation ($\alpha_j \left(x(\eta_j) - 1 \right) < 0$) are the goods which low-income households consume more ($\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} < 0$). Or put differently: Differentiated carbon pricing is more progressive if it shifts the carbon price burden sufficiently towards goods which are consumed more intensively by high-income households relative to income.

Differentiated vs. uniform carbon pricing with lump-sum recycling

Using $S' = UL$ and $S = D$ and hence inserting $B_i^{UL} = \sum_j \tau\alpha_j q_{ij} - \frac{R}{I}$ and $B_i^D = \sum_j \tau\alpha_j x(\eta_j) q_{ij}$ into Eq. (12) and rearranging yields

$$\frac{\sum_j \tau\alpha_j q_{Hj}\left(x(\eta_j)-1\right)+\frac{R}{I}}{y_H} - \frac{\sum_j \tau\alpha_j q_{Lj}\left(x(\eta_j)-1\right)+\frac{R}{I}}{y_L} < 0.$$

Dividing by $\tau > 0$, moving y_H and y_L into the sum, factoring out and rearranging gives the following result.

Corollary 3. *The relative progressivity of differentiated and uniform carbon pricing with lump-sum transfer depends on which progressivity gain prevails:*

$$P^{UL} - P^D \lesseqgtr 0 \iff \frac{R}{I\tau}\left(\frac{1}{y_L}-\frac{1}{y_H}\right) \lesseqgtr \sum_j \alpha_j\left(x(\eta_j)-1\right)\left(\frac{q_{Hj}}{y_H}-\frac{q_{Lj}}{y_L}\right). \tag{15}$$

Because $y_H > y_L$ and hence $\frac{1}{y_L} - \frac{1}{y_H} > 0$, the left hand side term is positive and represents the progressivity gain from the lump-sum transfer. The right hand side shows the progressivity gain from differentiation relative to uniform pricing (as in Eq. (14)). Hence the condition has a straightforward interpretation: Uniform carbon pricing with lump-sum transfers is more progressive than differentiated carbon pricing if the progressivity gain from the transfer dominates the one from differentiation, where the carbon price for luxuries is upscaled and the one for necessities downscaled. Vice versa, differentiated carbon pricing would be more progressive if its progressivity gain would outweigh the one from the lump-sum transfer.

While differentiated pricing changes the structure of the carbon price payments across goods, i.e. works on the expenditure side, lump-sum transfers constitute an additional income and hence change the net balance of households. This shows that a progressive effect of carbon pricing can be achieved either through the redistribution of revenues or through differentiation of tax rates, where the ranking depends on which effect is more pronounced.

3.4 Connecting emissions-based and financial incidence

For differentiated carbon pricing to be both more financially progressive as well as more carbon inequality reducing than the uniform carbon pricing benchmark, the respective conditions derived in Corollaries 1 and 2 must both hold:
$\sum_j \left(\frac{\alpha_j \left(x(\eta_j) - 1 \right)}{p_j} \right) \left(w_{Lj} \varepsilon_{Lj} - w_{Hj} \varepsilon_{Hj} \right) < 0, \ \sum_j \alpha_j \left(x(\eta_j) - 1 \right) \left(\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} \right) > 0.$
This implies that goods subject to a higher carbon price under differentiation ($\alpha_j \left(x(\eta_j) - 1 \right) > 0$) must be goods which are more important in high-income households' budgets, i.e. which they consume more relative to income than low-income households ($\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} > 0$), and where they have a stronger emissions response ($w_{Lj} \varepsilon_{Lj} - w_{Hj} \varepsilon_{Hj} < 0$). This holds vice versa for goods subject to a lower carbon price under differentiation.

When will $\frac{q_{Hj}}{y_H} - \frac{q_{Lj}}{y_L} > 0$ and $w_{Lj} \varepsilon_{Lj} - w_{Hj} \varepsilon_{Hj} < 0$ be true for the same goods, namely luxury goods with $x(\eta_j) > 1$? Rearranging the first condition gives $\frac{q_{Hj}}{q_{Lj}} > \frac{y_H}{y_L}$ and after using $w_{ij} = \frac{\alpha_j q_{ij}}{e_i}$, rearranging and canceling α_j the second becomes $\frac{q_{Hj}}{q_{Lj}} > \frac{e_H}{e_L} \frac{\varepsilon_{Lj}}{\varepsilon_{Hj}}$ so that both conditions hold if $\frac{q_{Hj}}{q_{Lj}} > \max \left\{ \frac{y_H}{y_L}, \frac{e_H}{e_L} \frac{\varepsilon_{Lj}}{\varepsilon_{Hj}} \right\}$. Hence both conditions will hold for a luxury good j if the consumption ratio between high- and low-income households exceeds the income ratio and the carbon footprint ratio, taking into account differences in price elasticity.

4 Numerical illustration

4.1 Data and parametrization

To provide a numerical illustration of the three Propositions, the expressions are estimated for different carbon pricing schemes in Germany. To do so, multi-regional input-output (MRIO) data are combined with German household consumption data. The data required for the illustration include *(i)* household carbon intensities derived from the Global Trade Analysis Project (GTAP) 12 database for the year 2023 (Aguiar et al., 2025), *(ii)* household consumption expenditure for different income groups for 2023 from the German income and expenditure survey ("Einkommens-

und Verbrauchsstichprobe", EVS) (Statistisches Bundesamt, 2026), *(iii)* price elasticities of demand from Többen et al. (2023), who estimate them based on the EVS waves from 1998 to 2018 for the carbon-intensive categories heating, electricity and fuel, *(iv)* price elasticities of demand from Schulte and Heindl (2017) who base their estimation on the EVS waves from 1993 to 2008 for the remaining categories, as well as *(v)* income elasticities from the GTAP 12 database (Aguiar et al., 2025). Apart from the price elasticities, all data stem from 2023, which is therefore taken as the year of analysis. Since the German carbon price in 2023 was 30EUR/tCO_2, this carbon price level is used. As a robustness check regarding the income elasticities, the expenditure elasticities from Schulte and Heindl (2017) are used. Note that as the German national emissions trading system was introduced in 2021 and the numerical illustration uses observed expenditure data from 2023 as a reference point, the results should be interpreted as comparative-static counterfactuals where alternative carbon pricing designs are applied to 2023 expenditure patterns, rather than as changes from a pre-policy state.

Because of missing or uncertain values, the EVS categories "Repair, Rental, and Leasing of Household Appliances", "Larger Durable Goods for Leisure", "Tutoring" and "Insurance Services" are excluded. The reported uncertain values are small and hence unlikely to have substantial effect on the results. Results are presented for the 13 upper categories for which results from the underlying 65 EVS categories used for calculation have been aggregated.

Mapping of categories and income groups

The 65 EVS consumption categories are mapped to the GTAP sectors as shown in Appendix Table 8, where the mapping is limited to sectors directly related to goods and services consumed by households and upstream input sectors (e.g. forestry, warehousing, other extraction) are not included. Where several GTAP sectors are relevant for more than one EVS category, aggregated carbon intensities are calculated.

The categories of the price and expenditure elasticities by Többen et al. (2023) and Schulte and Heindl (2017) are mapped to the EVS consumption categories as shown

in Appendix Table 8. The categories "Electricity" and "Heating" are combined to match the EVS "Energy" category.

As the EVS expenditure data were available for eight household-net-income groups with different population shares and the own-price elasticities were available by decile, each EVS income group is assigned to the closest decile (see Appendix Table 7). The results of a robustness check using an alternative mapping are reported in Appendix Table 13. The first two income groups representing 4.5% and 5.5% of households are aggregated to approximate the lowest decile or the Bottom 10% of households (B10). The first six income groups are aggregated to approximate the Bottom 50% of households (B50). All parameters for these groups are hence aggregated using the reported population shares.

MRIO calculation of household carbon intensities

Household carbon intensities (see Table 1) are derived from the environmental satellite data from GTAP which includes CO_2 emissions from the combustion of fossil fuels in 65 sectors and direct CO_2 emissions from households (emissions from land use, land-use change and forestry (LULUCF) and non-CO_2 greenhouse gases are excluded). To calculate category-specific household carbon intensities from GTAP, first embedded CO_2 emissions for household consumption are calculated using a simple MRIO model, as applied for example in Böhringer et al. (2017), and Böhringer et al. (2021). The total CO_2 emission intensity of final consumption (C) of good i in Germany, called cc_i^C, is calculated as the sum of direct household CO_2 emissions and indirect consumption CO_2 emissions divided by the total expenditures of households for good i. The indirect CO_2 emissions from consumption of good i are derived from (i) the CO_2 emissions directly emitted in the production due to fossil fuel combustion, together with (ii) the CO_2 emissions from the production of intermediate inputs, and (iii) the CO_2 emissions from international transport services. Hence, apart from domestic CO_2 emissions, also emissions embodied in imports and international transport are taken into account. Details of the MRIO calculation can be found in the Appendix.

Since GTAP reports expenditures in USD, intensities are initially calculated in

USD/tCO$_2$ and then converted to EUR/tCO$_2$ using the 2023 annual average nominal exchange rate of 1EUR = 1.08USD (European Central Bank, 2026). See Table 1 for the determined carbon intensities of households in Germany for the different consumption categories.

Household emissions and emissions shares

The baseline household emissions or carbon footprints are calculated by multiplying the carbon intensities with the expenditures and summing over all categories (see Figure 1). From this, for each income group i and consumption category j, the respective emissions share w_{ij} is easily calculated according to Eq. (4) (see Table 1).

Price and expenditure elasticities of demand

Own-price elasticities are drawn from Többen et al. (2023) for heating, electricity and fuel and from Schulte and Heindl (2017) for the remaining categories (see Table 2). Household-specific price elasticities from the synthetic population of Többen et al. (2023, supplementary material) are aggregated to expenditure deciles using the share of represented households as weights.

For the other categories, the quartile-specific price elasticities reported by Schulte and Heindl (2017) are used, who estimate demand responses for expenditure quartiles and different household types (singles, couples, with and without children) in ten consumption categories. Elasticities are aggregated across household types using the overall sample population shares reported in Schulte and Heindl (2017), thereby it is assumed that household-type composition does not vary substantially across expenditure quartiles. Then the quartile-specific price elasticities were linearly interpolated to the decile midpoints and linearly extrapolated to the first and tenth deciles.

For the robustness check regarding the income elasticities, expenditure elasticities from Schulte and Heindl (2017) are used as proxies for income elasticities. Schulte and Heindl (2017) show that differences between income and expenditure elasticities are small. The expenditure elasticities are aggregated in the same way as the

price elasticities and then further aggregated to good-specific expenditure elasticity by aggregating the quartile-specific elasticities using population weights.

Calculation of carbon inequality and financial incidence effects

Assuming a carbon price level of τ = 30EUR/tCO_2, the proportional price change for category j, $\kappa_j = \frac{\tau \alpha_j \eta_j^{\gamma}}{p_j}$ (from Eqs. (1) and (2)), is calculated from the category-specific carbon intensity. For uniform pricing, this is $\kappa_j^U = \tau I_j^{€}$ while for differentiated pricing it is $\kappa_j^D = \tau x(\eta_j) I_j^{€}$ because carbon intensities are defined as $I_j = \frac{\alpha_j q_j}{p_j q_j} = \frac{\alpha_j}{p_j}$. Using this, the category-specific contributions to the sum term in Proposition 1, $\sum_j \kappa_j \left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right)$, are computed and summed to obtain the overall carbon inequality effect (see Table 4).

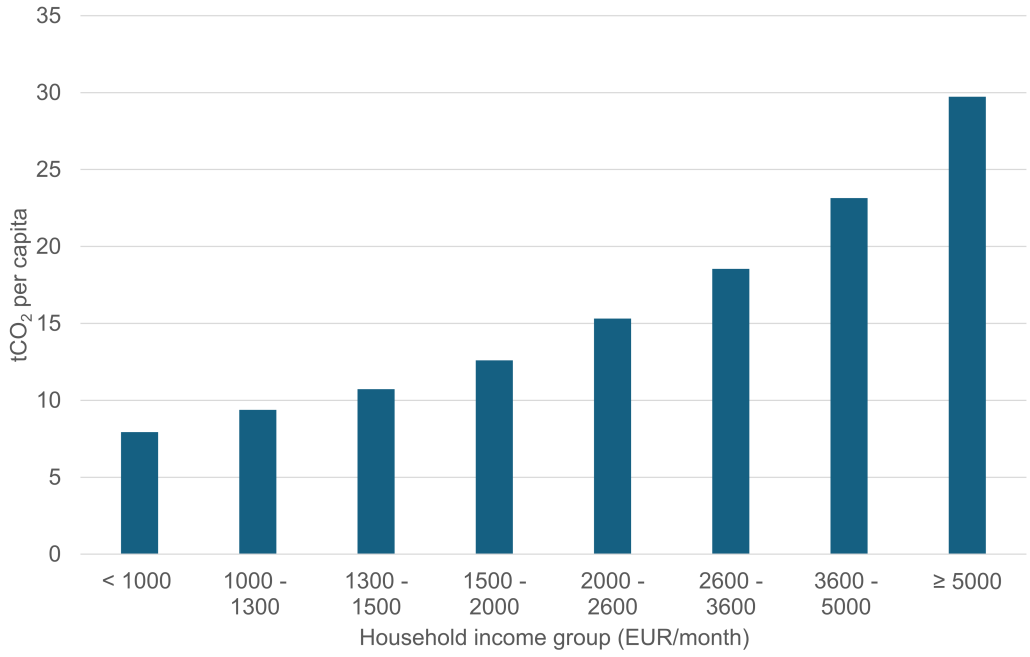
For calculating financial incidence, the same category-specific proportional price changes κ_j and household expenditure $p_j q_{ij}$ are used to derive the annual absolute carbon pricing payment or burden $B_i^S = \sum_j \kappa_j^S p_j q_{ij}$. From this relative burdens can be computed as $b_i = \frac{B_i}{y_i}$ with total household expenditure ($\sum_j p_j q_{ij}$) as a proxy for income y_i.

Inequality measures are calculated from income group means, weighted by their population shares where applicable. Hence, the reported indices capture between-group inequality, but not within-group heterogeneity.

4.2 Results

4.2.1 Baseline results

Figure 1: Household carbon footprints of different income groups



The baseline results based on the 2023 data show that the average German household carbon footprint is roughly 20 tCO_2e per year (see Figure 1). Households in the lowest EVS income group (<1000 EUR/month) emit only 7.9 tCO_2 on average while those in the highest income group ($\geq$5000 EUR/month) emit 29.7 tCO_2.

In the following, the low-income group L corresponds to the bottom 10% households (B10), combining the two lowest EVS income groups (<1000 and 1000-1300 EUR/month) and the high-income group H to the top 30% (T30, $\geq$5000 EUR/month) based on the available EVS income group structure. While these groups differ in population size since the highest income group cannot be further disaggregated, using them ensures a clear contrast between low and high income, and allows the low-income group to be accurately matched to the price elasticities defined by deciles. Robustness tests are conducted using broader definitions of the

low-income group.

The average household in the low-income group B10 emits 8.7 tCO_2 so that the resulting T30-B10 emissions ratio is 3.4. Hence, average household emissions in the top 30% are more than three times higher than those in the bottom 10%. In the following, the T30-B10 emissions ratio is used as the primary carbon inequality measure, before comparing the results using alternative measures at the end of the section.

As Table 1 indicates, the Energy category (electricity, gas and heating fuels) exhibits by far the highest carbon intensity, followed by Transport, while all remaining categories show substantially lower intensities. It also shows that the largest emissions shares of household carbon footprints come from Energy (B10: 62%; T30: 42%), followed by Transportation and Vehicles (B10: 19%; T30: 36%). These sectors therefore play a central role in determining distributional effects.

Table 2 shows the price of demand as derived from Többen et al. (2023) (for Energy and Transport) and Schulte and Heindl (2017) (for all other categories) and income elasticities aggregated from GTAP. Regarding behavioral responses, households in the top 30% have larger own-price elasticities in eight out of 13 categories while households in the bottom 10% show slightly higher price elasticities for the categories Energy, Restaurants & Hotels, Furnishings, Financial Services and Other. With respect to income elasticities, six out of the 13 upper categories can be called necessity categories as their expenditure-weighted average income elasticities are smaller than one, namely Food & Beverages, Energy, Clothing, Transport, Communication and Furnishings.

Table 1: Carbon intensities and emissions shares

Categories	Carbon intensity α_j	Emissions shares w_{ij}	
	in tCO_2/EUR (GTAP)	Bottom 10%	Top 30%
Energy	0.03353	61.6%	42.1%
Transport	0.01490	19.0%	35.9%
Clothing	0.00253	1.3%	2.2%
Furnishings	0.00246	1.4%	2.5%
Food & Beverages	0.00207	6.8%	5.8%
Other	0.00183	1.1%	1.4%
Recreation	0.00150	1.6%	2.7%
Restaurants & Hotels	0.00113	0.9%	1.9%
Communication	0.00104	1.2%	1.1%
Health	0.00104	0.4%	0.7%
Education	0.00057	0.1%	0.1%
Financial Services	0.00044	0.0%	0.0%
Housing	0.00020	1.2%	1.4%

Table 2: Price and income elasticities of demand

Categories	Price elasticities ε_{ij}		Income elasticities η_j
	Bottom 10%	Top 30%	
Housing	0.30	0.80	1.15
Food & Beverages	0.45	0.93	0.58
Energy	0.79	0.64	0.96
Education	0.89	1.28	1.16
Clothing	0.99	1.40	0.56
Recreation	1.09	1.35	1.07
Transport	1.28	1.53	0.98
Health	1.50	1.74	1.09
Communication	1.67	1.80	0.92
Other	2.16	1.54	1.08
Restaurants & Hotels	2.18	1.54	1.20
Furnishings	2.18	1.54	0.96
Financial Services	2.18	1.54	1.22

Notes: Own-price elasticities are reported in absolute values, consistent with the definition in the theoretical analysis ($\varepsilon_{ij} > 0$).

4.2.2 Uniform carbon pricing

Table 3: Overview footprint reductions and carbon inequality change across scenarios

		Footprint reduction			Carbon inequality change			
	Scenario	**Average**	**Bottom 10%**	**Top 30%**	**T30/B10**	**T30/B50**	**Gini**	**Theil**
	Uniform pricing	-6.7%	-6.3%	-6.6%	-0.31%	-0.02%	-0.15%	-0.39%
	Uniform S&H	-5.5%	-2.3%	-7.1%	-4.90%	-3.58%	-4.30%	-8.34%
	Energy & Transport	-6.5%	-6.2%	-6.4%	-0.22%	0.06%	-0.06%	-0.22%
	2023 policy	-8.8%	-9.7%	-8.3%	1.50%	0.98%	1.10%	2.16%
Differentiated pricing GTAP elasticities	Option A, eq. abatem.	-6.7%	-6.5%	-6.6%	-0.06%	0.11%	0.02%	-0.05%
	Option A, $\gamma = 0.5$	-6.4%	-6.2%	-6.3%	-0.17%	0.04%	-0.06%	-0.21%
	Option A, $\gamma = 1.0$	-6.1%	-6.0%	-6.1%	-0.05%	0.10%	0.02%	-0.05%
	Option A, $\gamma = 1.5$	-5.9%	-5.9%	-5.8%	0.06%	0.15%	0.09%	0.10%
	Option A, $\gamma = 2.0$	-5.7%	-5.7%	-5.6%	0.15%	0.19%	0.15%	0.24%
	Option B, eq. abatem.	-6.7%	-6.3%	-6.6%	-0.31%	-0.02%	-0.15%	-0.39%
	Option B, $\gamma = 0.5$	-6.7%	-6.3%	-6.6%	-0.31%	-0.02%	-0.15%	-0.39%
	Option B, $\gamma = 1.0$	-6.7%	-6.3%	-6.6%	-0.31%	-0.02%	-0.15%	-0.40%
	Option B, $\gamma = 1.5$	-6.7%	-6.3%	-6.6%	-0.31%	-0.02%	-0.15%	-0.40%
	Option B, $\gamma = 2.0$	-6.7%	-6.3%	-6.6%	-0.31%	-0.02%	-0.15%	-0.40%
Differentiated pricing S&H elasticities	Option A, $\gamma = 0.5$	-4.7%	-4.1%	-4.8%	-0.68%	-0.27%	-0.43%	-0.94%
	Option A, $\gamma = 1.0$	-3.4%	-2.7%	-3.5%	-0.81%	-0.38%	-0.54%	-1.15%
	Option A, $\gamma = 1.5$	-2.6%	-1.9%	-2.7%	-0.83%	-0.42%	-0.58%	-1.20%
	Option A, $\gamma = 2.0$	-2.1%	-1.5%	-2.3%	-0.80%	-0.44%	-0.57%	-1.17%
	Option B, $\gamma = 0.5$	-6.7%	-6.3%	-6.6%	-0.32%	-0.03%	-0.16%	-0.42%
	Option B, $\gamma = 1.0$	-6.7%	-6.4%	-6.7%	-0.34%	-0.05%	-0.18%	-0.45%
	Option B, $\gamma = 1.5$	-6.8%	-6.4%	-6.8%	-0.36%	-0.07%	-0.20%	-0.49%
	Option B, $\gamma = 2.0$	-6.9%	-6.5%	-6.9%	-0.39%	-0.10%	-0.23%	-0.55%

Notes: S&H refers to the expenditure elasticities from Schulte & Heindl (2017). γ is the differentiation parameter, governing the degree of differentiation. "Average" corresponds to the population-weighted average footprint reduction. The Gini and the Theil index quantify carbon inequality among all EVS income groups using the group-specific average household carbon footprints.

Table 3 provides an overview of the main numerical results across the different carbon pricing scenarios, showing carbon footprint reductions for the average household, B10 and T30 households as well as the carbon inequality change as measured by different metrics. As the average footprint reduction shows, the different carbon pricing scenarios lead to different emissions reduction outcomes. This and the

subsequent subsections discuss these results in detail.

For uniform pricing, a numerical order-of-magnitude illustration of the mechanism identified in Proposition 1 is provided by evaluating the expression for short-term effects of a uniform carbon price of 30EUR/tCO_2 in all sectors using German data. This price level corresponds to the fixed price of the German national emissions trading system (nEHS) in 2023 (German Emissions Trading Authority, 2026). Under this carbon price level, Table 4 shows that the implied category-specific price increases (κ_j) would range from 0.1% to 11.2%, depending on the carbon intensity (see Table 1). While the price increases are modest in most categories, such as Food & Beverages (0.7%), they are most pronounced for Energy (11.2%) as well as Transport (4.6%).

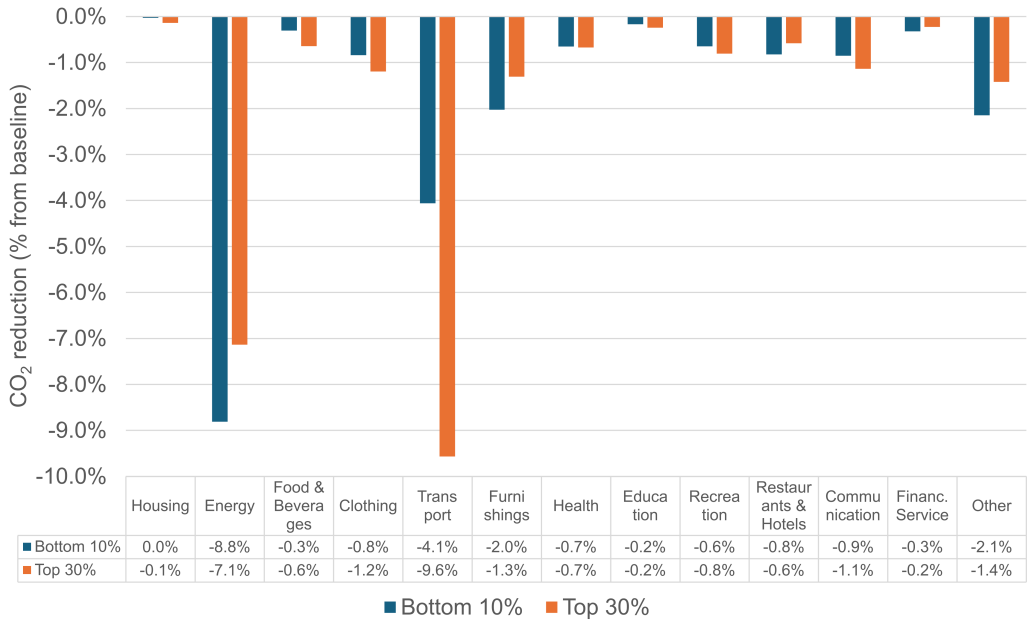
In response, households in the bottom 10% (B10) reduce their carbon footprints by 6.3% while households in the top 30% (T30) reduce theirs slightly more, by 6.6%. As Fig. 2 shows, the largest emissions reductions occur in the categories Energy and the Transport. In the latter, T30 households reduce their emissions substantially more, namely by 10% while B10 households reduce their emissions there by only 4%. In the Energy category, the difference between the two groups is smaller but B10 households reduce slightly more (9% vs. 7%).

As a result, the emissions ratio between high- and low-income households remains nearly unchanged or declines only slightly: For a uniform carbon price of 30EUR/tCO2 carbon inequality decreases by about 0.3%. Table 4 decomposes the overall effect into category-level contributions $\kappa_j \left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right)$ and indicates that all but three categories, namely Energy, Financial Services and Other, contribute to the decline in carbon inequality.

Three factors explain this result. First, Energy and Transport are the most carbon-intensive categories (see Table 1) and hence show the largest price increases, with the increase for Energy being more than twice that for Transport (see κ_j in Table 4). Second, B10 households show higher emissions shares for Energy (B10: 62%, T30: 42%) while T30 households emit more in the Transport category (B10: 19%, T30: 36%, see Table 1). Third, B10 households have a higher absolute Energy price elasticity than T30 households (see Table 2), meaning that they respond more strongly to price changes in this category. Conversely, T30 households show a

higher price elasticity for Transport. With B10 households having both a higher emissions share and a higher price elasticity for Energy than T30 households, Energy contributes more strongly to their carbon footprint reduction, while for T30 households with the opposite pattern, Transport contributes more to their footprint reduction. Taken together, this implies a carbon-inequality-increasing contribution from Energy (0.024) and a carbon-inequality-decreasing contribution from Transport (-0.027, see Table 4). These effects nearly offset each other, with only a small overall reduction effect of 0.3% remaining.

Figure 2: CO_2 emissions reductions with uniform carbon pricing



	Housing	Energy	Food & Beverages	Clothing	Transport	Furnishings	Health	Education	Recreation	Restaurants & Hotels	Communication	Financ. Service	Other
Bottom 10%	0.0%	-8.8%	-0.3%	-0.8%	-4.1%	-2.0%	-0.7%	-0.2%	-0.6%	-0.8%	-0.9%	-0.3%	-2.1%
Top 30%	-0.1%	-7.1%	-0.6%	-1.2%	-9.6%	-1.3%	-0.7%	-0.2%	-0.8%	-0.6%	-1.1%	-0.2%	-1.4%

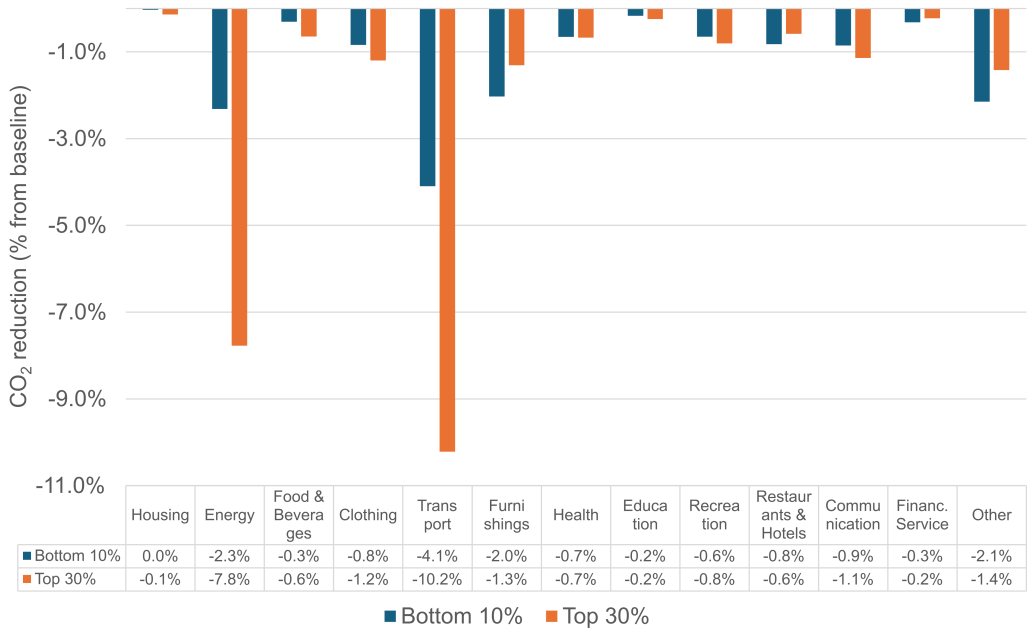
Table 4: Category contributions to the carbon-inequality effect with a 30EUR/tCO_2 uniform carbon price

Category j	κ_j	$w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}$	$\kappa_j\left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right)$
Energy	11.2%	0.217164	0.024271
Other	0.6%	0.003449	0.000047
Financial Services	0.1%	0.000167	0.000000
Education	0.2%	-0.000988	-0.000002
Housing	0.1%	-0.006319	-0.000015
Communication	0.4%	0.001386	-0.000017
Health	0.3%	-0.006201	-0.000021
Restaurants & Hotels	0.4%	-0.010421	-0.000039
Furnishings	0.8%	-0.008130	-0.000046
Recreation	0.5%	-0.020313	-0.000118
Clothing	0.8%	-0.017707	-0.000152
Food & Beverages	0.7%	-0.023990	-0.000165
Transport	4.6%	-0.218137	-0.026604
SUM $\sum_j \kappa_j\left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right)$			-0.002861

Notes: The table reports category-specific contributions to the sign term in Proposition 1, $\sum_j \kappa_j\left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right)$. κ_j denotes the percentage price change of category j, w_{ij} the emissions share of category j of total household emissions of income group i, and ε_{ij} the own-price elasticity. A negative (positive) contribution implies that the respective category decreases (increases) carbon inequality. Categories are ordered by descending absolute contribution (last column).

Using alternative own-price elasticities by Schulte and Heindl (2017) for the important category Energy and Fuel as part of the Transport category (see Appendix Table 11) as a robustness check shows that the results depend strongly on the price elasticities. While the differences of the price elasticities for fuel are rather small, there are more pronounced for Energy, where Schulte and Heindl (2017) report substantially lower price elasticities for low-income groups than Többen et al. (2023) (about 0.6 lower for B10). As Fig. 3 shows, this implies that B10 households show much lower emissions reductions in the Energy category (-2.3% vs. -8.8% baseline) and hence also a much lower total carbon footprint reduction (-2.3% vs. -6.3% baseline). T30 households reduce their Energy emissions slightly more and hence have a slightly higher footprint reduction (7.1% vs. 6.6% baseline). This leads carbon inequality to decrease by 4.9%, substantially more than in the baseline case (-0.3%).

Figure 3: Robustness: CO_2 emissions reductions with alternative price elasticities



	Housing	Energy	Food & Beverages	Clothing	Transport	Furnishings	Health	Education	Recreation	Restaurants & Hotels	Communication	Financ. Service	Other
Bottom 10%	0.0%	-2.3%	-0.3%	-0.8%	-4.1%	-2.0%	-0.7%	-0.2%	-0.6%	-0.8%	-0.9%	-0.3%	-2.1%
Top 30%	-0.1%	-7.8%	-0.6%	-1.2%	-10.2%	-1.3%	-0.7%	-0.2%	-0.8%	-0.6%	-1.1%	-0.2%	-1.4%

As a robustness check, the coverage of carbon pricing is restricted to Energy and Transport, as this aligns more closely with the reality of carbon pricing in Germany. In 2023, the national carbon pricing scheme covered heating and transport fuels at a fixed price of 30EUR/tCO_2 (German Emissions Trading Authority, 2026), while the EU ETS covered electricity generation, carbon-intensive manufacturing, and aviation with an average allowance price of 83.60EUR/tCO_2 in 2023 (European Commission, 2024). Two scenarios are analyzed to distinguish the effect of restricted coverage from that of the different price levels: In the first scenario, called "Energy & Transport", a common price of 30EUR/tCO_2 is applied only to Energy and Transport fuels (other goods and services from the Transport category like cars, bikes, repairs or public transport are not covered). In the second scenario, called "2023 policy", the higher EU ETS carbon price is applied to electricity (as a part of Energy) and the national carbon price to heating and transport fuels, reflecting a stylized approximation of the 2023 carbon pricing in Germany[5].

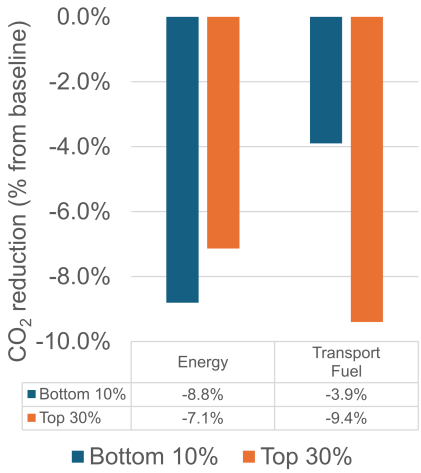
[5]This scenario is called stylized as the EU ETS coverage of carbon-intensive manufacturing and aviation cannot be separately represented with the available EVS categories.

The same pattern in both scenarios is the same as under uniform pricing: B10 households reduce Energy emissions more strongly than T30 households, while the latter reduce Transport emissions more strongly. Moving from uniform to the Energy & Transport scenario, there is a slightly lower reduction in the Transport category (as only transport fuels are covered), leading to slightly lower total footprint reductions (B10: -6.2%, T30: -6.4%). This implies again a nearly stable carbon inequality level with only a slight decrease by -0.2%.

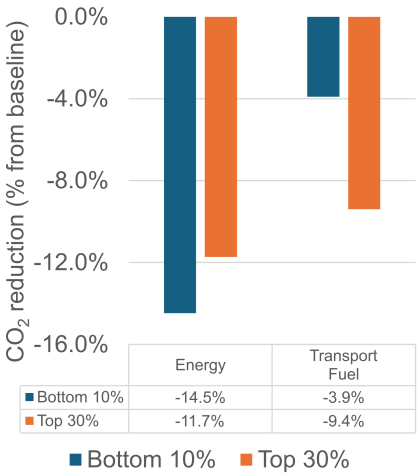
In the stylized 2023 policy scenario, Energy emissions reductions are substantially larger for both income groups due to the higher carbon price on electricity, while transport reductions remain unchanged. B10 households reduce their Energy emissions proportionally more than T30 households, leading to a higher total footprint reduction of B10 households (-9.7% vs. -8.3% for T30). Hence, the carbon-inequality-decreasing effect of Transport is outweighed by the opposing effect of Energy, implying an increase in carbon inequality of 1.5%.

Figure 4: Robustness: CO_2 emissions reductions under carbon pricing of Energy and Transport

(a) Restricted coverage (30EUR/tCO_2)



(b) Stylized 2023 carbon pricing (30EUR/tCO_2 national, 83.60EUR/tCO_2 EU ETS)



Furthermore, the results are robust to the alternative mapping of price elasticity

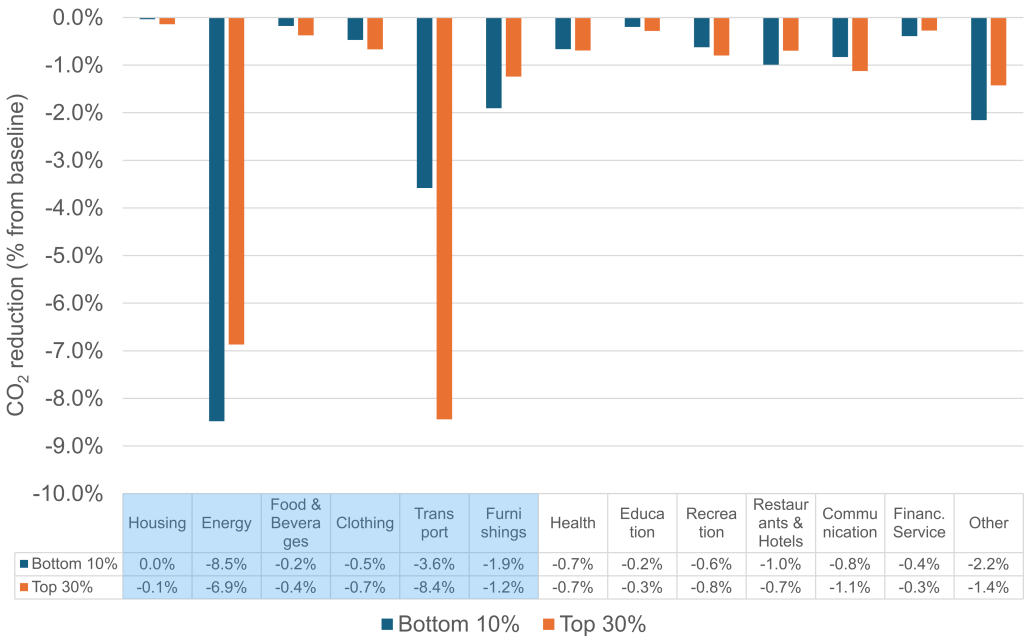
deciles to EVS income groups. Assigning the highest EVS income group Top 30% to decile 10 instead of decile 9 changes the magnitudes only slightly (see Appendix Table 13).

4.2.3 Differentiated carbon pricing

Turning to the evaluation of differentiated carbon pricing with both Option A and B as defined in Section **3.1,** the effects on carbon inequality differ from those under uniform pricing.

In **Option A**, the category-specific price increases due to the carbon price are multiplied with the respective income elasticity (see Table 2) which implies a downscaled price increase for basic goods (categories Housing, Energy, Food & Beverages, Clothing, Transport, Furnishings) and an upscaled price increase for luxury goods (all other categories). However, the effects are quite small using the baseline GTAP income elasticities, as nearly all of them are close to one, especially the carbon-intensive categories Energy and Transport (see Table 2). In response, both income groups would reduce their footprints slightly less than under uniform pricing (B10: -6.0%, T30: -6.1%) since both Energy and Transport are basic goods and hence their price increases under Option A are slightly lower, leading to slightly lower demand and hence footprint reductions in these categories compared to uniform pricing, as shown in Figure 5. The higher price increases in other categories cannot counterbalance the lower reductions in the carbon-intensive basic good categories. Therefore, interestingly, carbon inequality remains nearly unchanged, with an even smaller reduction than under uniform pricing (-0.05%), which is largely due to the lower carbon price in Transport compared to uniform, where T30 households are more price-sensitive (see Table 2). Hence they reduce less in Transport, implying a lower carbon inequality reduction.

Figure 5: CO_2 emissions reductions with differentiated pricing - Option A



	Housing	Energy	Food & Beverages	Clothing	Transport	Furnishings	Health	Education	Recreation	Restaurants & Hotels	Communication	Financ. Service	Other
Bottom 10%	0.0%	-8.5%	-0.2%	-0.5%	-3.6%	-1.9%	-0.7%	-0.2%	-0.6%	-1.0%	-0.8%	-0.4%	-2.2%
Top 30%	-0.1%	-6.9%	-0.4%	-0.7%	-8.4%	-1.2%	-0.7%	-0.3%	-0.8%	-0.7%	-1.1%	-0.3%	-1.4%

Notes: The categories highlighted in blue are basic good categories, the others are luxury categories following the expenditure-weighted average GTAP income elasticity for the respective upper category.

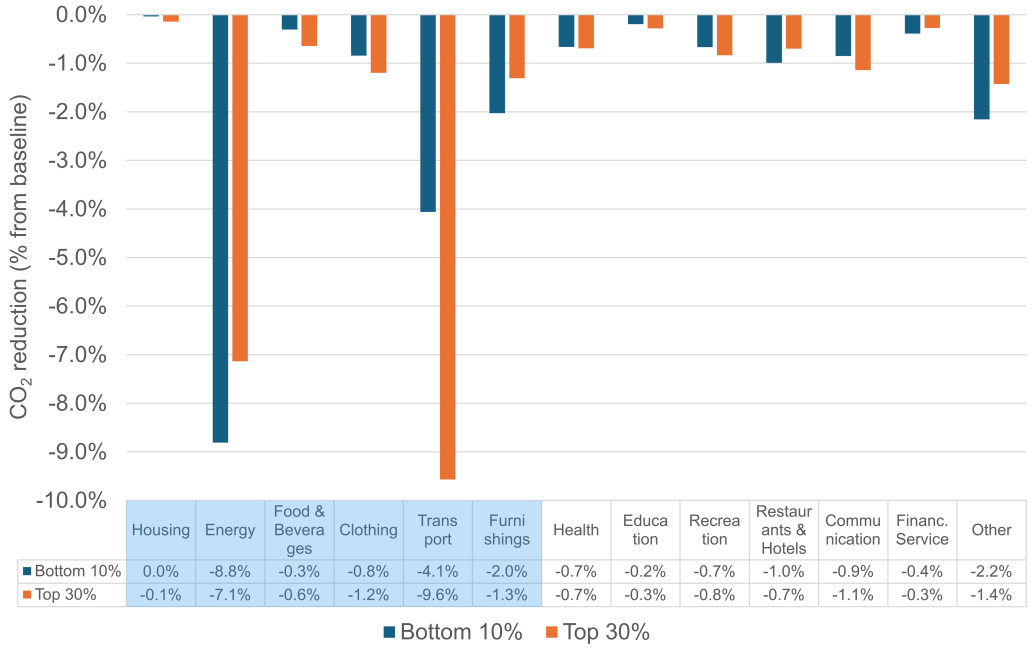
As the limited differentiation in this scenario reflects the near-unity income elasticities of GTAP, the expenditure elasticities with greater variation reported by Schulte and Heindl (2017) are used as a robustness check. The results show lower emissions reductions in Energy and Transport and higher reductions in some other categories like Furnishings, with both groups reducing less in total but a larger difference between them (B10: -2.7%, T30: -3.5%, Table 3). This implies a larger reduction in carbon inequality (-0.8%), demonstrating that the effects under differentiated pricing depend largely on the income or expenditure elasticities.

In **Option B**, luxury goods are treated as under Option A and necessities as under uniform pricing. Hence, compared to uniform pricing, price increases and emissions reductions for luxury categories are stronger and the effects for necessities do not change. Compared to Option A, reductions for necessities are more pronounced as the respective price increases are not downscaled. This is illustrated by Figure 6 and implies higher demand and footprint reductions of both households compared to Option A. B10 households would reduce their footprints by 6.3% and

T30 households by 6.6%. As a result, carbon inequality would decrease by 0.3%. This is nearly the same effect as under uniform pricing, since the effects for basic goods stay the same and the price increases for luxury goods are just slightly higher.

This result is robust to changes in the income or expenditure elasticities, the total footprint reductions and the carbon inequality change is nearly identical. This is not surprising as the income or expenditure elasticities in this scenario are only relevant for the luxury categories where carbon intensities and hence price increases and reductions are relatively low.

Figure 6: CO_2 reduction with differentiated pricing - Option B



	Housing	Energy	Food & Beverages	Clothing	Transport	Furnishings	Health	Education	Recreation	Restaurants & Hotels	Communication	Financ. Service	Other
Bottom 10%	0.0%	-8.8%	-0.3%	-0.8%	-4.1%	-2.0%	-0.7%	-0.2%	-0.7%	-1.0%	-0.9%	-0.4%	-2.2%
Top 30%	-0.1%	-7.1%	-0.6%	-1.2%	-9.6%	-1.3%	-0.7%	-0.3%	-0.8%	-0.7%	-1.1%	-0.3%	-1.4%

Notes: The categories highlighted in blue are basic good categories, the others are luxury categories following the expenditure-weighted average GTAP income elasticity for the respective upper category.

As Table 3 indicates, varying the level of differentiation via the differentiation parameter $\gamma \geq 0$ yields only small or no differences to the uniform result using the GTAP income elasticities. With the expenditure elasticities from Schulte and Heindl (2017), however, the reductions in carbon inequality are stronger and increasing with the level of differentiation (under Option A there is a peak at $\gamma = 1.5$), indicating again that the effects under differentiated pricing depend strongly on the

income or expenditure elasticities. Furthermore, as an additional numerical comparability check, proportional price increases (κ_j) of differentiated pricing can be scaled to achieve the same aggregate abatement as uniform pricing ("eq. abatem."). Under Option A, B10 households reduce their footprints slightly more, hence carbon inequality decreases less or even increases slightly, depending on the measure. Under Option B, footprint reductions and carbon inequality changes are nearly identical to those under uniform pricing which is not surprising given that Option B results are already very close to uniform pricing without this scaling.

To illustrate Proposition 2 that states the condition when a carbon pricing scheme S' reduces carbon inequality more than another scheme S, this condition term is also computed and shown in Appendix Table 10 for each differentiated pricing scenario relative to uniform pricing. According to Proposition 2, when the condition term is positive, the respective scenario reduces carbon inequality more than uniform pricing. The results are consistent with the carbon inequality changes reported before and show that all differentiated pricing cases (option A and B with different income or expenditure elasticities) except Option A using GTAP income elasticities reduce carbon inequality slightly more than uniform pricing.

Until now the T30-B10 emissions ratio has been used as the primary carbon inequality measure. Comparing the results across different carbon inequality measures, as shown in Table 3, indicates that the qualitative findings are generally robust across measures. This is particularly evident for scenarios with relatively large carbon inequality effects. For scenarios with small changes, estimates fluctuate around zero and the sign can hence be sensitive to the chosen measure. However, the direction of changes when moving from one scenario to another remains consistent.

4.2.4 Financial incidence

Table 5: Overview relative burden and progressivity across scenarios

		Relative burden (b_i)		Inequality relative burden		Progressivity gain ($P^D - P^U$ from Cor. 2, $\times 10^{-5}$)	
	Scenario	**Bottom 10%**	**Top 30%**	**T30-B10**	**Gini**	***H*=T30, *L*=B10**	***H*=T30, *L*=B50**
	Uniform pricing	1.8%	1.6%	-0.002	0.034		
	Uniform demand adj.	1.7%	1.5%	-0.002	0.034		
	Energy & Transport	1.4%	1.2%	-0.003	0.047		
	2023 policy	2.1%	1.6%	-0.006	0.062		
Differentiated pricing GTAP elasticities	Option A, $\gamma = 0.5$	1.7%	1.5%	-0.002	0.034	0.2	0.3
	Option A, $\gamma = 1.0$	1.7%	1.4%	-0.002	0.034	0.3	0.5
	Option A, $\gamma = 1.5$	1.6%	1.4%	-0.002	0.035	0.5	0.8
	Option A, $\gamma = 2.0$	1.6%	1.3%	-0.002	0.035	0.6	1.0
	Option B, $\gamma = 0.5$	1.8%	1.6%	-0.002	0.033	0.1	0.0
	Option B, $\gamma = 1.0$	1.8%	1.6%	-0.002	0.033	0.2	0.1
	Option B, $\gamma = 1.5$	1.8%	1.6%	-0.002	0.033	0.3	0.2
	Option B, $\gamma = 2.0$	1.8%	1.6%	-0.002	0.032	0.4	0.2
Differentiated pricing S&H elasticities	Option A, $\gamma = 0.5$	1.0%	1.1%	0.001	0.017	6.3	4.7
	Option A, $\gamma = 1.0$	0.9%	1.0%	0.002	0.025	10.2	7.7
	Option A, $\gamma = 1.5$	0.9%	1.1%	0.002	0.041	13.2	10.1
	Option A, $\gamma = 2.0$	1.3%	1.2%	-0.001	0.021	16.3	12.2
	Option B, $\gamma = 0.5$	1.8%	1.6%	-0.002	0.029	1.7	1.0
	Option B, $\gamma = 1.0$	1.8%	1.7%	-0.002	0.026	2.9	1.7
	Option B, $\gamma = 1.5$	1.9%	1.8%	-0.001	0.021	4.5	2.7
	Option B, $\gamma = 2.0$	2.0%	1.9%	0.000	0.018	6.8	4.0

Notes: "S&H" refers to the expenditure elasticities from Schulte & Heindl (2017). γ is the differentiation parameter, governing the degree of differentiation. The Gini index quantifies carbon inequality among all EVS income groups using the group-specific average household carbon footprint. "T30-B10" refers to the difference between the relative burden of the Top 30% and the relative burden of the Bottom 10%, i.e. $P^S = b_H^S - b_L^S$, where *H*=T30, *L*=B10.

In the following, a numerical illustration of the mechanism identified in Proposition 3 regarding financial distributional effects of different carbon pricing schemes is provided. As revenue recycling cannot be implemented with the available data, the illustration of the theoretical financial incidence results of Section 3.3 focuses on the carbon price payments or burdens or the comparison between uniform and differentiated pricing. Table 5 provides an overview of the financial incidence results

across the different carbon pricing scenarios, showing the relative carbon pricing burdens for B10 and T30 households (i.e. the share of their absolute carbon pricing payment in total expenditure), the inequality in relative burdens, as well as the progressivity gain from Cor. 2.

As the table shows, when considering the relative burdens of income groups B10 and T30 and the difference between their relative burdens (fourth column T30-B10), most scenarios are regressive, including uniform carbon pricing. Accounting for demand adjustments via price elasticities ("Uniform demand adj.") yields only slightly lower relative burdens. The Energy & Transport scenario and the 2023 policy scenario are even more regressive than uniform pricing. Only Option A of differentiated pricing with expenditure elasticities from Schulte and Heindl (2017) and $\gamma \in \{0.5, 1.0, 1.5\}$ is progressive. Turning to inequality in relative burdens across all income groups, the Gini index is highest for the 2023 policy scenario, i.e. it shows the most unequal distribution of relative burdens. Differentiated pricing with Option B and $\gamma = 2.0$ and Option A and $\gamma = 0.5$ using the Schulte and Heindl (2017) elasticities show the lowest Gini index, i.e. the most equal distribution of relative burdens across income groups.

The last two columns of the table illustrate the progressivity gain defined in Cor. 2, which is used to estimate the relative progressivity of differentiated and uniform carbon pricing. According to Cor. 2, differentiated pricing is more progressive than uniform pricing if differentiation sufficiently raises the carbon price on goods consumed more intensively by high-income households relative to income, and sufficiently lowers the carbon price on goods consumed more intensively by low-income households relative to income, which is the case if the progressivity gain term (Eq. (11)) is positive. As the table shows, this is the case for all differentiated pricing scenarios because the basic good categories with a lower carbon price than under uniform account for a greater share of the expenditure of B10 households (77% vs. 70% T30) and the luxury good categories with higher carbon prices make up a greater share for higher-income groups. However, it is important to note that a positive progressivity gain does not indicate that differentiated pricing is progressive overall, instead it implies that it is more progressive than uniform pricing. Moreover, with the GTAP income elasticities being close to unity, it is evident that the

progressivity gain values are small in the scenarios using the GTAP elasticities, indicating that the financial distributional effects are close to those under uniform pricing. By contrast, progressivity gains are larger in the cases using Schulte and Heindl (2017) expenditure elasticities, suggesting that the differentiated scenarios lead to more progressive results.

5 Conclusion

At a time where carbon inequality is at high levels and emissions are increasingly concentrated at the top of the distribution in many countries, the effects of carbon pricing as the central climate policy instrument on the distribution of emissions across households have so far been unexplored. This paper examined how carbon pricing affects carbon inequality within countries. Using a simple analytical partial-equilibrium setting with heterogeneous households and demand responses, the paper linked carbon pricing to changes in the distribution of household emissions to analyze how uniform and differentiated carbon prices differ in their effects.

It shows that uniform carbon pricing can either increase or decrease consumption-based carbon inequality, depending on how emissions shares and price elasticities differ across income groups and interact with carbon intensities and the good-specific carbon price levels. Intuitively, the carbon price on a given good contributes to an increase in carbon inequality if in response low-income households cut their demand and hence related emissions more strongly than high-income households, which is the case if the respective product of emissions shares and price elasticity is higher for low-income households. Differentiated carbon pricing reduces carbon inequality more if it shifts the carbon price burden sufficiently towards goods where high-income households adjust their demand and hence their carbon footprint more due to a higher price elasticity and/or higher emissions shares.

Applying the main analytical result to Germany with an order-of-magnitude estimation suggests that uniform carbon pricing slightly reduces consumption-based carbon inequality because the carbon-inequality-increasing contribution from the Energy category and the carbon-inequality-decreasing contribution from Transport

nearly offset each other. In the stylized 2023 policy scenario, the Energy reductions are stronger due to the EU ETS price being higher for electricity, implying an increase in carbon inequality. A differentiated carbon price where the carbon price burden is increased for luxury goods (Option B) leads to a slightly higher carbon inequality reduction than under uniform pricing and is also more progressive.

When interpreting these results, some limitations should be noted. First, the analysis is based on a first-order approximation and uses locally estimated elasticities. Hence, nonlinear demand responses may become relevant in case of larger price changes. Second, the analysis abstracts from general equilibrium effects, income feedback effects, cross-price effects, long-run technological adjustments, and non-standard behavioral responses. Third, by assuming stable preferences and constant price elasticities, status-oriented or price-dependent demand effects are excluded. Fourth, the numerical illustration should be interpreted as an order-of-magnitude estimation that depends on sectoral aggregation, available elasticity estimates, carbon intensities and expenditure data. The latter may be affected by underreporting, especially concerning the high-income groups, which could imply underestimating their carbon footprints and carbon price burdens. Finally, the analysis focuses on consumption-based carbon inequality. The ownership-based dimension of carbon inequality, i.e. emissions linked to asset ownership, investments or production decisions, is outside the scope of this paper.

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Appendix

Further theoretical insights

Theil index

To see that the Theil index is strictly increasing in the emissions ratio $r \equiv \frac{e_H}{e_L}$, let high-income households H have population share π and low-income households population share $1-\pi$. Normalizing $e_L = 1$ gives $e_H = r$. Then the average household emissions level is $\mu(r) = \pi r + (1-\pi)$.

For two groups, the **Theil index** (Theil, 1967) corresponds to

$$T(r) = \pi \frac{r}{\mu(r)} \ln\left(\frac{r}{\mu(r)}\right) + (1-\pi)\frac{1}{\mu(r)} \ln\left(\frac{1}{\mu(r)}\right).$$

Using the rules of logarithms gives $T(r) = \pi \frac{r}{\mu(r)} (\ln r - \ln \mu(r)) + (1-\pi)\frac{1}{\mu(r)} (-\ln \mu(r))$, and factoring out $\ln \mu(r)$ yields $T(r) = \frac{\pi r \ln r}{\mu(r)} - \left[\frac{\pi r}{\mu(r)} + \frac{1-\pi}{\mu(r)}\right] \ln \mu(r)$. Since $\frac{\pi r + (1-\pi)}{\mu(r)} = 1$, this can be simplified to

$$T(r) = \frac{\pi r \ln r}{\mu(r)} - \ln \mu(r).$$

Differentiating with respect to r gives $T'(r) = \pi \frac{(\ln r + 1)\mu(r) - r \ln r \pi}{\mu(r)^2} - \frac{\pi}{\mu(r)}$. Expressing the second term with the common denominator $\mu(r)^2$, canceling and factoring out $\pi \ln r$ yields $T'(r) = \frac{\pi \ln r (\mu(r) - \pi r)}{\mu(r)^2}$. Using $\mu(r) - \pi r = 1 - \pi$ gives

$$T'(r) = \frac{\pi(1-\pi)\ln r}{\mu(r)^2}.$$

For $r > 1$, $\ln r > 0$ holds and from $\pi(1-\pi) > 0$ and $\mu(r)^2 > 0$ it follows that $T'(r) > 0$, i.e. the Theil index is strictly increasing in r for $r > 1$ or $e_H > e_L$. Hence, $T(r^S) \lesseqgtr T(r^{S'}) \iff r^S \lesseqgtr r^{S'}$ and the conditions of Propositions 1 and 2 are qualitatively the same for the emissions ratio and the Theil index.

When changing to differentiated carbon pricing can flip the sign

Considering a case where uniform carbon pricing increases carbon inequality, it is interesting to ask under which conditions differentiated pricing (Option A) would reverse this and decrease carbon inequality. Defining the contribution of each good j to the sum term of Proposition 1 as $A_j \coloneqq \frac{\alpha_j}{p_j}\left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right)$ since $\kappa_j^U = \frac{\tau\alpha_j}{p_j}$ in the uniform pricing case, a carbon inequality increase due to uniform pricing means that $\sum_j A_j > 0$ holds. The conditions when $\sum_j \eta_j^\gamma A_j < 0$ holds in the differentiated pricing case are investigated.

In both cases there can be goods j with a positive contribution to the sum or inequality-increasing effect $A_j > 0$, and goods with a negative contribution $A_j < 0$. Let $P = \left\{j : A_j > 0\right\}$ denote the set of goods with a positive contribution for which it holds that $w_{Lj}\varepsilon_{Lj} > w_{Hj}\varepsilon_{Hj}$ and $N = \left\{j : A_j < 0\right\}$ the set of goods with a negative contribution for which it holds that $w_{Lj}\varepsilon_{Lj} < w_{Hj}\varepsilon_{Hj}$. Hence, in the uniform pricing case, the P-goods outweigh the N-goods in the sum, $\sum_{j\in N}\left|A_j\right| < \sum_{j\in P} A_j$. In the differentiated pricing case, the sign of the sum can flip, i.e. $\sum_j \eta_j^\gamma A_j < 0$ holds, when the differentiation scaling factor η_j^γ weigh the goods with negative A_j sufficiently more and the goods with positive A_j less so that consequently the η_j^γ-weighted N-goods outweigh the η_j^γ-weighted P-goods, $\sum_{j\in N}\eta_j^\gamma\left|A_j\right| > \sum_{j\in P}\eta_j^\gamma A_j$. This means that if ($N$-)goods with $w_{Lj}\varepsilon_{Lj} < w_{Hj}\varepsilon_{Hj}$ predominantly have a higher η_j, so differentiated pricing places relatively more weight on them, and (P-)goods with $w_{Lj}\varepsilon_{Lj} > w_{Hj}\varepsilon_{Hj}$ tend to have lower η_j, so they are weighted less, then there exists a differentiation parameter $\gamma > 0$ such that $\sum_{j\in N}\eta_j^\gamma\left|A_j\right| > \sum_{j\in P}\eta_j^\gamma A_j$ implying $\sum_j \eta_j^\gamma A_j < 0$ and hence differentiated pricing "flips the sign" and decreases carbon inequality. This insight follows directly from Proposition 1.

Corollary 4. *Under differentiated carbon pricing with* $\kappa_j^D = \eta_j^\gamma\frac{\tau\alpha_j}{p_j}$ *and* $\eta_j > 0$*, carbon inequality decreases if and only if*

$$\sum_j \eta_j^\gamma A_j < 0, \qquad A_j \coloneqq \frac{\alpha_j}{p_j}\left(w_{Lj}\varepsilon_{Lj} - w_{Hj}\varepsilon_{Hj}\right).$$

In particular, if goods for which $A_j < 0$ *are predominantly luxury goods (high* η_j*) while goods for which* $A_j > 0$ *are predominantly necessities (low* η_j*), then there*

exists a $\gamma > 0$ *for which differentiated pricing can reverse a carbon-inequality-increasing effect of uniform pricing.*

Put differently, differentiated carbon pricing can reverse a carbon-inequality-increasing effect of uniform pricing if the goods where high-income households adjust their demand more in response to a price change (in emissions-weighted terms, i.e. $w_{Hj}\varepsilon_{Hj} > w_{Lj}\varepsilon_{Lj}$) are sufficiently income-elastic and goods where low-income households respond more ($w_{Lj}\varepsilon_{Lj} > w_{Hj}\varepsilon_{Hj}$) are less income-elastic.

MRIO calculation

Household carbon intensities (see Table 1) are derived from the environmental satellite data from GTAP which includes CO_2 emissions from the combustion of fossil fuels in 65 sectors and direct CO_2 emissions from households. To calculate category-specific household carbon intensities from GTAP, first embedded CO_2 emissions for household consumption are calculated using a simple MRIO model, as applied for example in Böhringer et al. (2017), and Böhringer et al. (2021). The total CO_2 emission intensity of final consumption (C) of good i in Germany, called cc_i^C, is calculated as the sum of direct household CO_2 emissions and indirect consumption CO_2 emissions divided by the total expenditures of households for good i. The indirect CO_2 emissions from consumption of good i are derived from (i) the CO_2 emissions directly emitted in the production due to fossil fuel combustion, together with (ii) the CO_2 emissions from the production of intermediate inputs, and (iii) the CO_2 emissions from international transport services.

The MRIO accounting identities in Eqs. (16)-(18) are used to derive the total carbon content or the embedded CO_2 emissions. The GTAPinGAMS notation by Lanz and Rutherford (2016) is applied and slightly expanded by including a set of the individual German households as well as some variables for the calculations as listed in Table 6. Index r and the alias s indicate regions.

Equation (16) defines the total CO_2 emissions embodied in the output ($cc_{gr}^{Y} vom_{gr}$) of activity g in region r as the sum of direct CO_2 emissions (CO_2e_{gr}), CO_2 emissions embodied in domestic intermediate inputs ($\sum_i cc_{gr}^{Y} vdfm_{igr}$), and CO_2 emissions embodied in imported intermediate inputs ($\sum_i cc_{ir}^{M} vifm_{igr}$). Equation (17) shows that CO_2 emissions embodied in imports of good i in region r ($cc_{ir}^{M} vim_{ir}$) are the sum of emissions embodied in exports from all other regions s to region r ($\sum_s cc_{is}^{Y} vxmd_{isr}$) and those embodied in international transport services ($\sum_s \sum_j cc_j^{T} vtwr_{jisr}$). Equation (18) specifies the CO_2 emissions embodied in international transport service j ($cc_j^{T} vtw_j$) as the sum of embodied CO_2 emissions required to provide international transport service j in all countries r.

Table 6: Denotations

Sets	
R	Set of regions (r)
I	Set of production sectors / set of commodities (i)
G	Set of activities (g), covering production sectors (i), as well as final consumption ("C"), public spending ("G"), and investment ("I")
J	Set of international transport services (j)
H	Set of individual German households in the household survey
Parameters	
vom_{gr}	Production output, including final consumption ("C"), government spending ("G"), investment ("I") in region r
vim_{ir}	Imports of commodity i in region r
$vxmd_{isr}$	Exports of commodity i from region s to region r
$vdfm_{igr}$	Domestic intermediate inputs of commodity i in activity g in region r
$vifm_{igr}$	Imported intermediate inputs of commodity i in activity g in region r
vst_{jr}	International transport service j produced in region r
$vtwr_{jisr}$	Input of transport service j to imports in sector i directed from region s to region r
CO_2e_{gr}	Direct CO_2 emissions in activity g in region r
Variables	
cc^Y_{gr}	Carbon content / CO_2 emission intensity in activity g in region r
cc^M_{ir}	CO_2 emission intensity of imported good i in region r
cc^T_j	CO_2 emission intensity of international transport service j
cc^C_{ir}	CO_2 emission intensity of final consumption of good i in region r
$tCO_2e^C_{ir}$	Total CO_2 emissions in final consumption of good i in region r
ex_{hi}	Expenditures of individual German household h for good i
cf_h	Carbon footprint / embedded carbon emissions of household consumption of individual household h

$$\forall g \in G \qquad \forall r \in R \qquad cc^Y_{gr} vom_{gr} = CO_2e_{gr} + \sum_i cc^Y_{gr} vdfm_{igr} + \sum_i cc^M_{ir} vifm_{igr} \tag{16}$$

$$\forall i \in I \qquad \forall r \in R \qquad cc^M_{ir} vim_{ir} = \sum_s \left(cc^Y_{is} vxmd_{isr} + \sum_j cc^T_j vtwr_{jisr} \right) \tag{17}$$

$$\forall j \in J \qquad cc^T_j vtw_j = \sum_r cc^Y_{jr} vst_{jr} \tag{18}$$

The resulting system comprises $[card(G) + card(I)] \times card(R) + card(J)$ unknowns and linear equations. It can be solved recursively using a diagonalization algorithm

to obtain the CO_2 emission intensity in activity g in region r, cc^Y_{gr}. Based on these intensities, total CO_2 emissions embodied in household consumption, $tCO_2e^C_{ir}$, are calculated as the sum of direct and indirect CO_2 emissions:

$$\forall i \in I \qquad \forall r \in R \qquad tCO_2e^C_{ir} = CO_2e_{ir} + cc^Y_{ir} vdfm_{icr} + cc^M_{ir} vifm_{icr} \tag{19}$$

To link the GTAP carbon intensities to household consumption, GTAP sectors are mapped to the consumption categories defined by (Statistisches Bundesamt, 2026), Schulte and Heindl (2017), and Többen et al. (2023) as shown in Appendix Table 8. Then the CO_2 emission intensity of household consumption, cc^C_{ir}, expressed in tCO_2 per US$ of household expenditure, is calculated by dividing the total CO_2 emissions of household consumption by the total household expenditure in the aggregated sector i in region r. In the application considered here, r refers to Germany:

$$\forall i \in I \qquad \forall r \in R \qquad cc^C_{ir} = \frac{tCO_2e^C_{ir}}{vdfm_{icr} + vifm_{icr}} \tag{20}$$

In the notation used for the analytical considerations in Section 3, this is equivalent to $I_j = \frac{\alpha_j q_j}{p_j q_j}$ with I_j denoting the carbon intensity in sector or consumption category j.

Mapping tables for numerical illustration

Table 7: Mapping of EVS income groups to elasticity deciles

EVS household income group (EUR/month)	Population share	Assigned elasticity decile
< 1000	4.5%	1
1000 - 1300	5.5%	1
1300 - 1500	3.7%	2
1500 - 2000	10.0%	2
2000 - 2600	11.9%	3
2600 - 3600	17.2%	5
3600 - 5000	17.2%	7
$\geq$ 5000	30.0%	9

Table 8: Mapping EVS categories to GTAP, Többen et al. (2023) and Schulte and Heindl (2017) categories

EVS categories (translated)	**GTAP sector**	**Többen et al. (2023) and Schulte and Heindl (2017) categories**
Food, beverages, tobacco and similar products		
- Food and non-alcoholic beverages	pdr, wht, gro, v_f, osd, c_b, ocr, ctl, oap, rmk, fsh, cmt, omt, vol, mil, pcr, sgr, ofd	food
- Alcoholic beverages, tobacco and similar products	b_t	food
Clothing and footwear		
- Men's clothing (aged 14 and up)	wap	cloths
- Women's clothing (aged 14 and up)	wap	cloths
- Children's clothing (under 14 years)	wap	cloths
- Other clothing and accessories, clothing not clearly assignable	wap	cloths
- Footwear and footwear accessories	wap, lea	cloths
- Repairs, cleaning, rental	ros	cloths
Housing, energy and dwelling maintenance		
- Housing rents and similar payments	dwe	housing
- **Energy**	ely, gasgdt, p_c, coa	*electricity, heating*
- Dwelling maintenance	cns	housing
Furnishings, household appliances and household equipment		
- Furniture, furnishings and loose carpets	lum, omf	
- Major household appliances (electric and other)	eeq	others
- Small household appliances (electric and other)	eeq	others
- Repair, rental and leasing of household appliances	ros	others

EVS categories (translated)	**GTAP sector**	**Többen et al. (2023) and Schulte and Heindl (2017) categories**
Food, beverages, tobacco and similar products		
- Household textiles	tex	others
- Other durable goods and tools for household and garden	fmp	others
- Consumable household goods	chm	others
- Services of domestic helpers and domestic services	ros	others
Health		others
- Medical aids and health-related assistive devices	bph	
- Pharmaceuticals and medical products	bph	health
- Health services (outpatient and inpatient)	hht	health
Transport		health
- Passenger cars (including leasing)	mvh	
- Motorcycles and bicycles, including e-bikes and pedelecs (including leasing)	otn	mobility
- Spare parts and accessories	mvh	mobility
- Fuels and lubricants	p_c	mobility
- Maintenance and repairs of private vehicles	ros	*fuel*
- Other services	ros	mobility
- Passenger transport services	otp	mobility
- Transport services for goods (including letters and parcels)	otp	mobility
Information and **Communication**		mobility
- Telephones and other devices (landline and mobile; without contract, without SIM card)	ele	
- Computers, laptops and tablets (excluding software)	ele	mobility
- Peripheral equipment and accessories for IT devices	ele	mobility
- Audio and video receiving, recording and playback equipment	ele	mobility
- Blank recording media (e.g. CDs, Blu-rays, memory sticks)	ele	
- Other devices (e.g. smartwatches, e-book readers or non-assignable devices/accessories)	ele	mobility
- Other accessories (e.g. processors, memory, cases, mounts)	ele	mobility
- Software (excluding games)	obs	mobility
- Services for landline, mobile communications and internet	cmn	mobility
- Repair and rental of devices	ros	mobility
- Other services and fees	cmn	mobility
Recreation, sport and culture		mobility
- Photographic and film equipment, optical instruments and accessories	ele	mobility
- Major durable goods for recreation	ome	
- Equipment and gear for sport and camping	omf	education
- Musical instruments and audiovisual media	omf	education
- Toys and hobbies	omf	education
- Flowers and gardens	ocr	education
- Pets and products for pets	oap	education
- Recreational services (including rental and repair)	ros	education
- Cultural services	ros	education
- Books (including CD-ROMs and e-book downloads)	ppp	education
- Newspapers, magazines and similar products	ppp	education
- Stationery and drawing materials	ppp	education
- Package holidays	afs	education
Educational services		education

EVS categories (translated)	**GTAP sector**	**Többen et al. (2023) and Schulte and Heindl (2017) categories**
Food, beverages, tobacco and similar products		
- Private tutoring	edu	others
- Fees for educational institutions and childcare (excluding meals)	edu	
Catering and accommodation services		education
- Catering services	afs	education
- Accommodation services	afs	
Insurance and **Financial services**		others
- Insurance services	ins	others
- Financial services	ofi	
Other goods and services		others
- Jewellery and watches	omf	others
- Other personal effects	omf	
- Personal care services	ros	others
- Personal care products and appliances	chm	others
- Other services	ros	others

Notes: The EVS categories were translated from the original German category names. The bold labels correspond to the short category names used in the Results Section. A "-" before a category name indicates that it is a subcategory. The categories "electricity," "heating," and "fuel," which are shown in italics, appear in both Többen et al. (2023) and Schulte and Heindl (2017).

Proposition 2 term

According to Prop. 2, scheme S' reduces carbon inequality more than scheme S if and only if

$$\frac{\sum_j \left(\kappa_j^{S'} - \kappa_j^S\right)\left(w_{Hj}\varepsilon_{Hj}\right)}{1-\sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^S} > \frac{\sum_j \left(\kappa_j^{S'} - \kappa_j^S\right)\left(w_{Lj}\varepsilon_{Lj}\right)}{1-\sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^S}. \tag{21}$$

Hence, this is the case when the term $C^{S',S} = \frac{\sum_j \left(\kappa_j^{S'} - \kappa_j^S\right)\left(w_{Hj}\varepsilon_{Hj}\right)}{1-\sum_j w_{Hj}\varepsilon_{Hj}\kappa_j^S} - \frac{\sum_j \left(\kappa_j^{S'} - \kappa_j^S\right)\left(w_{Lj}\varepsilon_{Lj}\right)}{1-\sum_j w_{Lj}\varepsilon_{Lj}\kappa_j^S}$ is positive. Table 10 shows this term for comparing the carbon inequality effect under different differentiated pricing scenarios to the effect under uniform pricing.

Table 10: Comparison carbon inequality effect

	Scenario	Carbon inequality change T30/B10	Proposition 2 term $C^{S',\text{uniform}}$
	Uniform pricing	-0.305%	
Differentiated pricing GTAP elasticities	Option A, $\gamma = 0.5$	-0.173%	-0.001327
	Option A, $\gamma = 1.0$	-0.054%	-0.002535
	Option A, $\gamma = 1.5$	0.055%	-0.003634
	Option A, $\gamma = 2.0$	0.154%	-0.004635
	Option B, $\gamma = 0.5$	-0.306%	0.000008
	Option B, $\gamma = 1.0$	-0.307%	0.000018
	Option B, $\gamma = 1.5$	-0.308%	0.000028
	Option B, $\gamma = 2.0$	-0.309%	0.000038
Differentiated pricing S&H elasticities	Option A, $\gamma = 0.5$	-0.680%	0.003850
	Option A, $\gamma = 1.0$	-0.814%	0.005292
	Option A, $\gamma = 1.5$	-0.829%	0.005501
	Option A, $\gamma = 2.0$	-0.795%	0.005162
	Option B, $\gamma = 0.5$	-0.319%	0.000133
	Option B, $\gamma = 1.0$	-0.336%	0.000304
	Option B, $\gamma = 1.5$	-0.358%	0.000527
	Option B, $\gamma = 2.0$	-0.387%	0.000817

Notes: S&H refers to the expenditure elasticities from Schulte & Heindl (2017). γ is the differentiation parameter, governing the degree of differentiation.

Robustness checks

Alternative price elasticities

Table 11: Comparison price elasticities of demand

Categories	Price elasticities		Price elasticities	
	Baseline		**Schulte & Heindl (2017)**	
	Bottom 10%	Top 30%	Bottom 10%	Top 30%
Housing	0.30	0.80	0.30	0.80
Food & Beverages	0.45	0.93	0.45	0.93
Energy	**0.79**	**0.64**	**0.21**	**0.70**
Education	0.89	1.28	0.89	1.28
Clothing	0.99	1.40	0.99	1.40
Recreation	1.09	1.35	1.09	1.35
Transport	1.28	**1.53**	1.28	**1.55**
Health	1.50	1.74	1.50	1.74
Communication	1.67	1.80	1.67	1.80
Other	2.16	1.54	2.16	1.54
Restaurants & Hotels	2.18	1.54	2.18	1.54
Furnishings	2.18	1.54	2.18	1.54
Financial Services	2.18	1.54	2.18	1.54

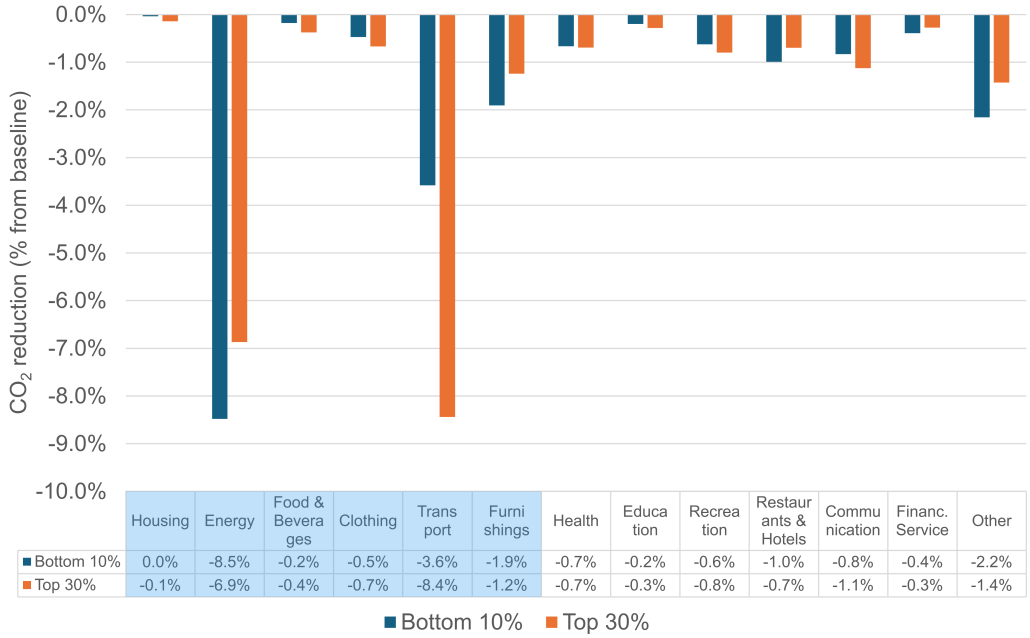
Notes: Own-price elasticities are reported in absolute values, consistent with the definition in the theoretical analyis ($\varepsilon_{ij} > 0$). "Baseline" refers to elasticities from Többen et al. (2023) for heating, electricity and fuel and from Schulte & Heindl (2017) for the remaining categories. Bold numbers highlight differences between the baseline and the alternative price elasticities.

Alternative expenditure elasticities

Table 12: Comparison income and expenditure elasticities of demand

Categories	income elasticities (GTAP)	expenditure elasticities (Schulte & Heindl, 2017)
Housing	1.15	0.68
Food & Beverages	0.58	0.64
Energy	0.96	0.38
Education	1.16	1.21
Clothing	0.56	1.24
Recreation	1.07	1.47
Transport	0.98	1.29
Health	1.09	1.47
Communication	0.92	1.56
Other	1.08	2.13
Restaurants & Hotels	1.20	2.13
Furnishings	0.96	2.13
Financial Services	1.22	2.13

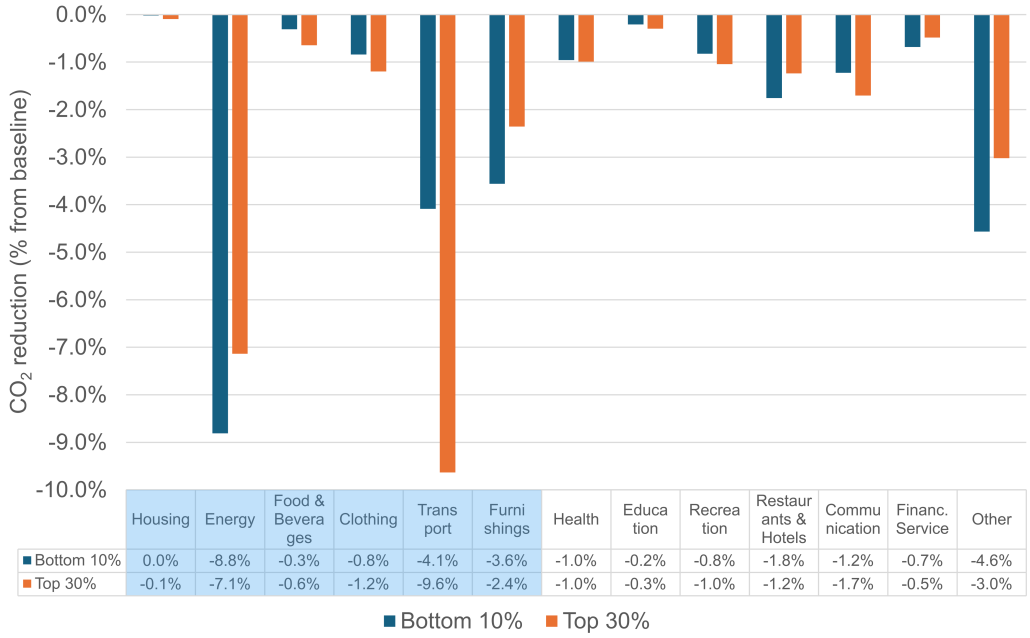
Figure 7: CO_2 emissions reductions with differentiated pricing Option A and alternative expenditure elasticities



	Housing	Energy	Food & Beverages	Clothing	Transport	Furnishings	Health	Education	Recreation	Restaurants & Hotels	Communication	Financ. Service	Other
Bottom 10%	0.0%	-8.5%	-0.2%	-0.5%	-3.6%	-1.9%	-0.7%	-0.2%	-0.6%	-1.0%	-0.8%	-0.4%	-2.2%
Top 30%	-0.1%	-6.9%	-0.4%	-0.7%	-8.4%	-1.2%	-0.7%	-0.3%	-0.8%	-0.7%	-1.1%	-0.3%	-1.4%

Notes: The categories highlighted in blue are basic good categories, the others are luxury categories following the expenditure-weighted average GTAP income elasticity for the respective upper category.

Figure 8: CO_2 emissions reductions with differentiated pricing Option B and alternative expenditure elasticities



	Housing	Energy	Food & Beverages	Clothing	Transport	Furnishings	Health	Education	Recreation	Restaurants & Hotels	Communication	Financ. Service	Other
Bottom 10%	0.0%	-8.8%	-0.3%	-0.8%	-4.1%	-3.6%	-1.0%	-0.2%	-0.8%	-1.8%	-1.2%	-0.7%	-4.6%
Top 30%	-0.1%	-7.1%	-0.6%	-1.2%	-9.6%	-2.4%	-1.0%	-0.3%	-1.0%	-1.2%	-1.7%	-0.5%	-3.0%

Notes: The categories highlighted in blue are basic good categories, the others are luxury categories following the expenditure-weighted average GTAP income elasticity for the respective upper category.

Alternative OPE deciles to EVS income groups mapping

Table 13: Overview footprint reductions and carbon inequality change across scenarios with alternative OPE to EVS income groups mapping

For this robusness check, the highest EVS income group (Top 30%, household net income $\geq$ 5000 EUR/month) is assigned to the highest decile (D10, baseline: D9).

		Footprint reduction		**Carbon inequality change**			
	Scenario	**Bottom 10%**	**Top 30%**	**T30/B10**	**T30/B50**	**Gini**	**Theil**
	Uniform pricing	-6.3%	-6.6%	-0.28%	0.00%	-0.12%	-0.35%
	Uniform S&H	-2.3%	-8.0%	-5.79%	-4.49%	-5.33%	-10.07%
	Energy & Transport	-6.2%	-6.3%	-0.18%	0.10%	-0.02%	-0.15%
	2023 policy	-9.7%	-8.4%	1.44%	0.91%	1.03%	2.03%
Differentiated pricing GTAP elasticities	Option A, $\gamma = 0.5$	-6.2%	-6.3%	-0.16%	0.06%	-0.05%	-0.18%
	Option A, $\gamma = 1.0$	-6.0%	-6.1%	-0.04%	0.11%	0.02%	-0.03%
	Option A, $\gamma = 1.5$	-5.9%	-5.8%	0.06%	0.15%	0.09%	0.11%
	Option A, $\gamma = 2.0$	-5.7%	-5.6%	0.15%	0.19%	0.14%	0.23%
	Option B, $\gamma = 0.5$	-6.3%	-6.6%	-0.28%	0.00%	-0.13%	-0.35%
	Option B, $\gamma = 1.0$	-6.3%	-6.6%	-0.28%	0.00%	-0.13%	-0.35%
	Option B, $\gamma = 1.5$	-6.3%	-6.6%	-0.28%	0.00%	-0.13%	-0.35%
	Option B, $\gamma = 2.0$	-6.3%	-6.6%	-0.29%	0.00%	-0.13%	-0.35%
Differentiated pricing S&H elasticities	Option A, $\gamma = 0.5$	-4.1%	-4.7%	-0.64%	-0.23%	-0.39%	-0.86%
	Option A, $\gamma = 1.0$	-2.7%	-3.5%	-0.77%	-0.33%	-0.50%	-1.07%
	Option A, $\gamma = 1.5$	-1.9%	-2.7%	-0.79%	-0.38%	-0.53%	-1.12%
	Option A, $\gamma = 2.0$	-1.5%	-2.2%	-0.76%	-0.40%	-0.54%	-1.11%
	Option B, $\gamma = 0.5$	-6.3%	-6.6%	-0.30%	-0.01%	-0.14%	-0.37%
	Option B, $\gamma = 1.0$	-6.4%	-6.7%	-0.31%	-0.03%	-0.16%	-0.41%
	Option B, $\gamma = 1.5$	-6.4%	-6.8%	-0.34%	-0.05%	-0.18%	-0.45%
	Option B, $\gamma = 2.0$	-6.5%	-6.9%	-0.37%	-0.08%	-0.21%	-0.51%

Notes: S&H refers to the expenditure elasticities from Schulte & Heindl (2017). γ is the differentiation parameter, governing the degree of differentiation. The Gini and the Theil index quantify carbon inequality among all EVS income groups using the group-specific average household carbon footprints.

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