# Carbon taxes on consumption: distributional implications for a just transition in the EU

*JRC Working Papers on Taxation and Structural Reforms No 9/2024*

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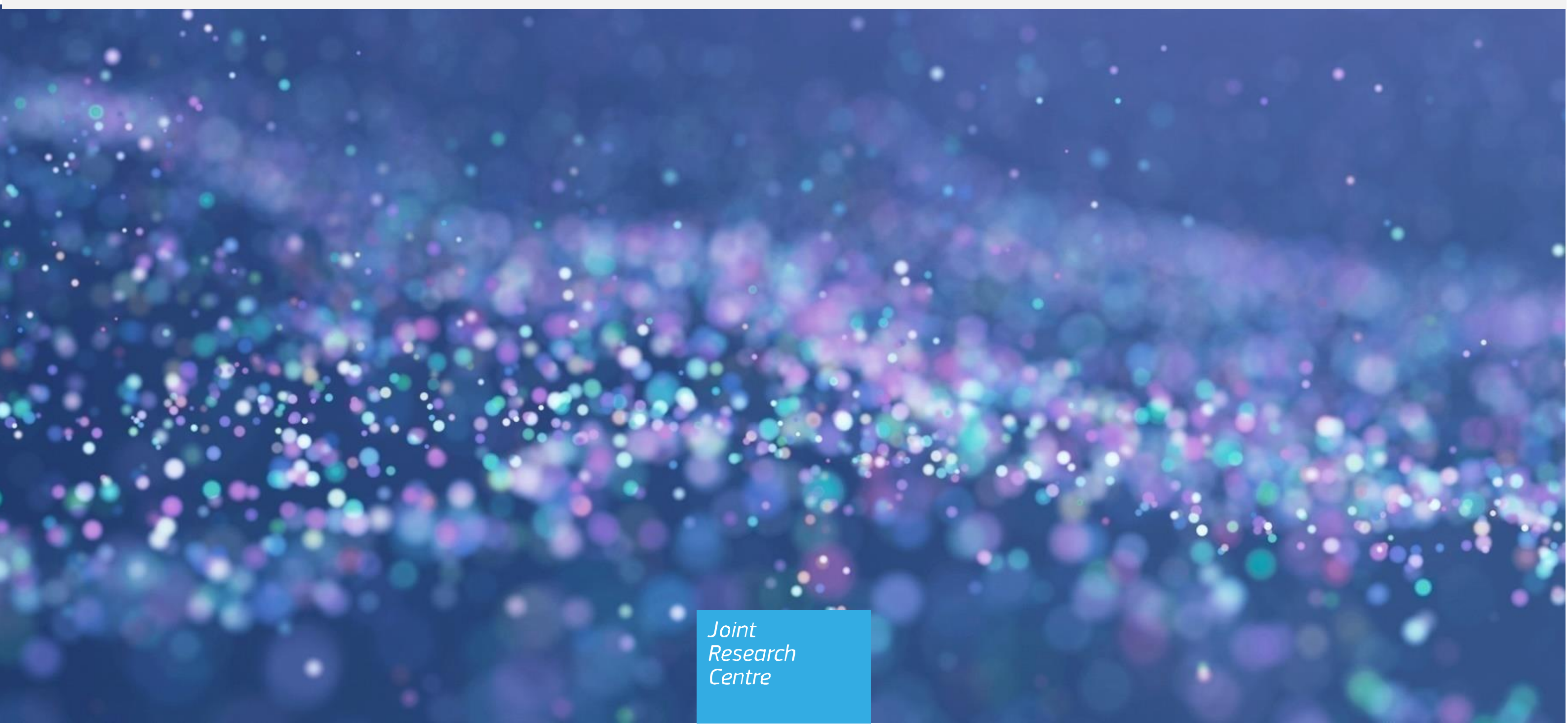
2024



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JRC138420

Sevilla: European Commission, 2024



How to cite this report: European Commission, Joint Research Centre, Maier, S., De Poli, S. and Amores, A.F., *Carbon taxes on consumption: distributional implications for a just transition in the EU*, European Commission, Sevilla, 2024, JRC138420.

## Executive summary

- Over the past years, a consensus has been growing regarding, first, the need to reduce greenhouse gas (GHG) emissions to limit global warming and second, that carbon pricing is a key tool to achieve this. Yet, carbon taxes often face public resistance, as evidenced by the yellow vest movement, due to their regressivity and perceived unfairness.
- This study uses micro-simulations to assess the distributional effects of various hypothetical carbon taxes on household consumption across the 27 EU Member States. We build on the conventional literature by simulating more progressive tax structures, aiming for improved distributional outcomes without relying on compensatory transfers, which are often of limited practical feasibility.
- For this purpose, we extend the EUROMOD tax-benefit model with household's GHG footprints, covering both direct (from fuel use, such as heating or driving) and indirect (from production and trade) emissions from the EXIOBASE multi-regional input-output model. This Green EUROMOD extension allows us to evaluate alternative carbon tax reforms (e.g., with progressive tax designs) within a coherent and standardized framework using EU-HBS and EU-SILC data across all 27 EU Member States.
- Our estimates show that household GHG emissions vary significantly across countries and income groups. Notably, only the lowest-income 10% of the EU population exhibits consumption patterns that align with what the literature considers sustainable and consistent with the goals of the Paris Agreement, with per capita emissions averaging approximately 2.5 tonnes of $CO_2$ equivalent ($tCO_2e$) per year.
- Simulations of a flat carbon tax set at EUR 80 per $tCO_2e$ suggest that this measure would exacerbate inequality across all 27 EU Member States. The tax's regressive pattern arises from the greater tax burden on lower-income households, who allocate a larger proportion of their income to GHG-intensive goods such as food and energy. The extent of this inequality increase varies by country, largely due to the varying tax burdens, which would range from 2% of household disposable income in France and Sweden to up to 9% in Hungary, Poland, and Greece.
- This flat carbon tax could generate revenues of up to EUR 208 billion annually. In line with previous studies, redistributing this revenue via lump-sum cash transfers would completely offset the tax's inequality effects.
- Notably, we also show that a carbon tax with allowances (i.e., where the first 2.2 tons of $tCO_2e$ are tax exempted), and to a lesser extent, a carbon tax with rate differentiation (across product groups, such as with VAT), perform relatively well in preventing large inequality-increasing effects, without relying on compensatory measures. As such, these alternative tax designs could enhance public acceptability and policy feasibility of taxing household carbon footprints for a just transition.

# Carbon taxes on consumption: distributional implications for a just transition in the EU

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September 16, 2024

**Abstract**

Carbon taxes on household consumption can simultaneously increase public funding and promote greener consumption habits, an appealing combination for the just transition plans of the European Union (EU). However, concerns about equity and public support pose challenges. This paper assesses the distributional and budgetary effects of various designs for an EU-wide hypothetical carbon tax on households consumption. To this end, we extend the EU tax-benefit microsimulation model, EUROMOD, with greenhouse gas (GHG) emissions data from input-output tables and estimate households' carbon footprints. We show that a carbon tax on households GHG emissions would be regressive, thereby inequality-increasing. This is primarily due to the low income elasticity of highly GHG-intense necessity goods, such as food and heating, which represent larger shares of income at the bottom of the distribution. Still, we demonstrate that this inequality-increasing impact can be offset with compensatory cash transfers (though these may be challenging to implement), and at least partially reverted with more progressive (and presumably feasible) tax designs, including rate differentiation by products and tax allowances.

***Keywords*: Progressive carbon tax, Just transition, Footprints, Inequality, European Union**

***JEL codes*: H23, Q52, D31, C67**

***Acknowledgements:*** This paper was developed within the AMEDI projects of the Directorate General for Employment and Social Affairs of the European Commission. We extend our sincere gratitude to Salvador Barrios and Richard Wood for their invaluable support to the Green EUROMOD project. We are particularly indebted to Gerlinde Verbist, whose presentation at the JRC Fiscal Policy Workshop in 2020 inspired us to pursue this research, and for her feedback on the final draft. Special thanks are due to José Antonio Ordoñez, David Klenert and Salvador Barrios for their insightful feedback. We would also like to thank the EUROMOD community for their ongoing development of this powerful micro-simulation tool and its underlying harmonized micro-datasets. We are grateful to Matthias Weitzel for providing information from JRC-GEM-E3 on scenarios for the new 2040 targets. Finally, we would also like to thank the participants of the 2023 EUROMOD Annual Workshop in Seville for their valuable contributions. We also want to thank Ilda Dreoni and Hannes Serruys for their work on statistical matching.

# 1 Introduction

Over the past years, a consensus has been growing regarding, first, the need to reduce greenhouse gas (GHG) emissions to limit global warming (Stiglitz et al., 2017; Pearce, 1991),[1] and second, that carbon pricing is essential to achieve it (Hepburn et al., 2020). Based on Pigou (1920)'s original idea of incorporating externalities into prices, an entire body of literature has highlighted the theoretical attractiveness of carbon pricing in terms of efficiency (Hepburn et al., 2020; Hassler et al., 2016; Nordhaus, 1991), and provided empirical evidence on their positive causal effects on GHG emissions reduction (see, e.g., Dechezleprêtre et al., 2023; Andersson, 2019; Martin et al., 2016; Lin and Li, 2011).

Carbon pricing can be implemented downstream at the production level, or upstream, directly to consumers.[2] The most common practices follow the first approach, primarily through cap-and-trade schemes known as Emission Trading Systems (ETS) and carbon taxes. According to the World Bank's Carbon Pricing Dashboard, about 23% of global GHG in 2023 were covered by carbon pricing, 18% by ETS and 5% by carbon taxes (World Bank, 2023). ETS set a cap on total GHG emissions and allow firms to trade emission permits, with the price of carbon determined endogenously by the market. In contrast, carbon taxes fix the price and do not guarantee any level of GHG reduction. Unlike ETS or other carbon pricing mechanisms targeting producers, consumption-based carbon taxes do not exert carbon leakages or competitiveness problems (Parry et al., 2022, Nachtigall et al., 2022, Böhringer et al., 2021, Hepburn et al., 2020, Böhringer et al., 2017). More in general, for revenue-raising purposes, environmental taxes are often preferred over other types of taxes, such as those on labour, because they address a market failure and are therefore considered less distortionary (Barrios et al., 2013; Bovenberg, 1999).

In this paper, we offer fresh insights into the distributional (and budgetary) effects of a hypothetical carbon tax on households' carbon footprints across the 27 EU Member States. By combining data from household surveys with and input-output tables, we analyze the progressivity and redistributive effects of various tax designs and compensatory measures. In particular, we discuss whether a progressive tax structure could enable governments to achieve a positive redistributive impact without relying on revenue-recycling compensatory measures, which are often challenging to implement on political and practical grounds.

Carbon taxes are a particularly appealing tool in the current policy context because they can, in principle, simultaneously boost the de-carbonization efforts the European Union (EU) is pursuing to achieve its objective of becoming the first carbon-neutral economy by 2050,[3] while improving public finances to implement other transition-related policies. Despite the strong reduction in per capita GHG emissions of the past decades -dropping from 11 to 7 tons of $CO_2$e, according to the European Environmental Agency),[4] the carbon footprints of EU households are among the top in the world and quite above the

[1] This has led, among others, to the first-ever international binding agreement in Paris 2015, as a result of the Conference of Parties (COP) 21 (see: UNFCCC, 2015).

[2] In the first case (the so-called "producer responsibility approach"), producers are held responsible only for all the GHG emissions generated directly by them. In the second (or "consumer responsibility approach"), based on the footprint concept, consumers are held responsible for all the GHG emissions generated along the value chain to produce what they consume. Figure A.1 in the Appendix presents an overview of these two strategies.

[3] To meet its 2050 climate targets, the EU launched the "Green Deal", which includes carbon-pricing initiatives like the Carbon Border Adjustment Mechanism (CBAM) and the extension of the Emissions Trading System (ETS2). The CBAM, a tax on carbon-intensive imports, will start in 2026, while ETS2, expanding the current ETS to buildings and road transport, begins in 2026/27. Additionally, the Fit-for-55 package, aimed at a 55% GHG emissions reduction by 2030, proposes revising the Energy Taxation Directive (ETD) to update minimum tax rates based on $CO_2$ content, a proposal that is still under discussion.

[4] https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

"sustainable" levels compatible with international agreements related with global warming (Chancel, 2022, Chancel et al., 2022, Gore, 2021, Ivanova et al., 2016, and Girod et al., 2014). Furthermore, while the EU has nearly double the global average of 23% of GHG emissions covered by carbon pricing (European Commission, 2022), more than half of its GHG emissions remain tax-exempt.

Yet, carbon taxes can be quite unpopular, as the yellow vest movement put in clear evidence (Douenne and Fabre, 2022, Rubin and Sengupta, 2018). In part, this acceptability problem relates to the regressivity and the perceived unfairness of these taxes (Köppl and Schratzenstaller, 2023; Andersson, 2019; Klenert and Mattauch, 2016, Wang et al., 2016), on top of the lack of dissemination or information on the actual effect of these policies (Douenne and Fabre, 2022; Klenert et al., 2018; Murray and Rivers, 2015). The European Commission has recognized this challenge, as emphasized by its President during the adoption of the European Green Deal Communication in 2019: "This transition will either be working for all and be just, or it will not work at all".[5] Still, as documented by the meta-analyses of Wang et al. (2016) and Ohlendorf et al. (2021), evidence on the regressivity of carbon taxes is limited and shows mixed results. In this context, our analysis makes two important contributions to the literature, as outlined below.

First, we provide new evidence on the distributional and budgetary effects of a hypothetical EU-wide consumption-based carbon tax, covering all 27 EU Member States. To this end, we extend the EU tax-benefit microsimulation model, EUROMOD,[6] by integrating greenhouse gas (GHG) emissions data derived from input-output tables. With this "Green EUROMOD" extension we estimate households' carbon footprints, accounting for emissions linked to both domestic production and imports, including those generated through trade and transport, at the very detailed product level. While the literature on carbon pricing has grown rapidly in recent years (see overviews by Wang et al., 2016, Ohlendorf et al., 2021 and Döbbeling-Hildebrandt et al., 2024), most studies tend to be country- or product-specific and employ a variety of methodologies, making cross-country comparisons difficult. Our study leverages detailed, harmonized data from multiple sources, addressing gaps in previous research.

Second, while much of the existing literature focuses on compensatory measures like cash transfers or labor tax reductions for households affected by carbon taxes, our study explores alternative tax designs that aim for more progressive outcomes. This approach avoids over-reliance on compensatory measures, which can be costly to administer and may face low uptake, potentially undermining public support for the initiative.

The most related study to ours is Feindt et al. (2021), which reports progressive patterns (at the country-level) from a simulated carbon tax in 23 EU countries. We extend and depart from this paper in several ways, by expanding country coverage, using more updated data, considering all GHG emissions for the tax base and not only $CO_2$; and more fundamentally, varying the type of simulated tax and using incomes from SILC instead of expenditures to assess the tax burden, regressivity and distributional effects. This directly influences the less regressive patterns they identify, as discussed also by Maier and Ricci (2024) and Linden et al. (2024).

We begin by simulating a flat carbon tax of EUR 80 per tonne of $CO_2e$ on household consumption. This tax covers direct GHG emissions from household fuel use as well as emissions embedded throughout the supply chain of goods and services, including those from abroad. The chosen tax rate of 80 EUR per $tCO_2e$ is consistent with the prevailing price under EU ETS and aligns with the emissions reduction

[5] See, e.g., speech at: https://ec.europa.eu/commission/presscorner/detail/fr/speech_19_6749.

[6] EUROMOD is a publicly available model developed by an international community of scientists and policy-makers since the 1990s. The recent extensions to cover consumption taxes and GHG emissions are not yet public, but shall be in the future. More information: https://euromod-web.jrc.ec.europa.eu/.

targets stipulated by the Paris Agreement, as suggested by Stiglitz et al. (2017). We then discuss to what extent revenue-neutral compensatory measures could improve the distributional outcomes. Finally, we simulate two alternative carbon tax regimes, where we try a less regressive design. With this, we avoid relying on a compensatory measure. Specifically, we simulate a scenario with what we call "green allowances" (tax exemptions below a threshold, similar to the global progressive tax proposed by Chancel and Piketty, 2015) and another consisting of different carbon tax rates across product categories, like the different rates of VAT.

To simulate these carbon tax scenarios, we extend the EUROMOD model with carbon footprints, following two main steps. First, we statistically match two EU-level harmonized household surveys, EU-SILC (EU Statistics on Living Conditions) and HBS (Household Budget Surveys), which provide detailed data on household income and consumption, respectively. Second, we impute GHG emissions per euro spent from EXIOBASE at a highly disaggregated product level into our HBS-SILC matched files.[7] This Green EUROMOD extension allows us to simulate various carbon taxes, considering each country's fiscal policies and evaluating their distributional effects based on household disposable income. By using SILC-based incomes, our results can be directly compared to the EU's official figures on income inequality and poverty published by Eurostat. While our analysis does not account for behavioral responses and should be interpreted as "overnight" effects, the literature suggests that demand responses to price changes in necessity goods (e.g., food and energy) are typically small in the short run (Linden et al., 2024; Labandeira et al., 2017). Therefore, we offer a reliable insight into the expected short-term impacts of these tax reforms.

Our results suggest that this simulated carbon tax would represent, on average, 5% of household disposable income, a tax burden that ranges from about 2% in Sweden to almost 9% in Greece. Generally, the burden is more pronounced in lower-income countries, largely due to the higher proportion of income these households allocate to expenditures compared to their wealthier counterparts. This regressive pattern is also evident within countries, where the tax burden disproportionately affects lower-income households. On average, the tax would represent 7.7% of disposable income in the poorest income quintile, more than double the 3.6% tax burden faced by the richest quintile. This pattern leads to a negative distributional effect within all 27 EU countries, with no exceptions. This is particularly pronounced under the flat tax scenario (with no allowances, rate differentiation nor compensatory measures), with the Gini coefficient increasing by up to 0.02 points in some countries.[8]

This flat carbon tax of EUR 80 per $tCO_2e$ could generate up to EUR 208 billion annually for the EU, more than double the projected budget for the Social Climate Fund. Although the increase in inequality driven by the simulated tax can be fully reversed through revenue-neutral cash transfers —whether designed at the national or EU level— the practical feasibility of such transfers remains a significant challenge. Importantly, our findings also show that, even without revenue-recycling cash transfers, the inequality effects can be partially mitigated through alternative, more progressive tax designs, such as implementing tax allowances or varying tax rates across different products.

The rest of the paper is organized as follows. In the next section, we briefly present the EU-level GHG emissions reduction targets and describe the current carbon pricing initiatives to understand where we stand in the baseline. In Section 3, we present the methodology and data, while in Section 4, we present the results from our analysis. In Section 5, we discuss the scope of our results in light of the assumptions

[7]EXIOBASE data is publicly available at their website (`https://www.exiobase.eu/`), and documented by Stadler et al. (2018), Tukker et al. (2013), Wood et al. (2014).

[8]For context, this figure can be compared to the average redistributive effect of consumption taxes in the EU, and it is four times greater than the redistributive effect of current energy taxes (Amores et al., 2023c).

we make, as well as the relative advantages and disadvantages of each of these simulated scenarios. At the end, Section 6 concludes.

## 2 GHG targets and carbon prices in the EU

The policy relevance of the estimated budgetary and distributional consequences of carbon taxes depends on the feasibility of our simulated scenarios. The parameters that we use (e.g., the carbon price that we impose on each $tCO_2e$, as well as the thresholds that we use for tax allowances) have to be consistent with the current context and, in particular, with the carbon pricing practices and EU's climate policy agenda. Therefore, before introducing the data and methodological strategy in Section 3, we provide here a brief overview of the main international and EU-level climate targets related to GHG emissions reduction, as well as the shares of GHG that are currently covered by some carbon pricing.

### GHG targets

The "Paris Agreement", signed in the 2015 Paris Conference of the Parties (COP) 21 of the UNFCCC, was the first-ever internationally binding agreement. It established a long-term goal to limit the increase in global average temperature to well below 2°C above pre-industrial levels by the end of this century and to pursue efforts to limit this increase to 1.5°C (UNFCCC, 2015).

Since then, climate policy agendas have considered and pushed forward several intermediate targets related to GHG emissions reduction. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC), to reach the 1.5°C goal, GHG emissions must peak before 2025 at the latest and decline by 43% by 2030 (with respect to the 1990s). Other studies have estimated the "sustainable levels" of consumption compatible with these targets. For example, Gore (2021) and Ivanova et al. (2016) suggest that per capita GHG emissions should be around 2.2 $tCO_2e$ to be consistent with this 1.5°C goal, similar to the 1.9 $tCO_2e$ estimate of Chancel (2022).

In this context, the EU has committed to becoming the first carbon-neutral economy (i.e., zero net GHG emissions) by 2050. To achieve this, it has set an ambitious climate agenda under the road-map of the Green Deal, launched in 2021, with specific targets towards 2030 (55% net GHG emissions reduction with respect to 1990) and -more recently- also so for 2040 (90% reduction).[9] To be consistent with carbon-neutrality and the new 2040 targets, in-house estimates from the European Commission suggest that per capita GHG emissions have to be reduced to about 1.7 in 2040, starting from 4.9 in 2025.[10]

### GHG emissions covered by carbon pricing

The World Bank provides a publicly accessible dashboard documenting the type of carbon price initiatives implemented worldwide and the share of GHG emissions they cover. According to World Bank (2023), referring to data from 2023, about 23% of global GHG are covered by some form of carbon pricing: 18% by ETS, and 5% by carbon taxes. The carbon price per $tCO_2$ differs widely between countries and carbon price instruments, from US$0.46 to 167. In this context, the EU has one of the largest GHG coverage (about 45%, mostly covered by the EU ETS). Moreover, a few European countries (especially some Scandinavian countries) have among the highest carbon prices in the form of specific carbon taxes.

[9] More information: https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en.

[10] These values were obtained from the JRC-GEM-E3 modelling that informed the impact assessment underlying the European Commission's proposal for a 2040 climate target (European Commission, 2024).

The heterogeneity in carbon pricing initiatives, the main price rate, the sectors and the percentage of GHG covered across EU countries are documented in Table 1.

Table 1: Carbon taxes in the EU

| Starting | Country | Type | Main price | %GHG | Sectors covered |
|---|---|---|---|---|---|
| 1990 | Finland | Carbon tax | $99.99 (€93) | 45 | Industry, Mining & extractives, Transport, Buildings |
| 1990 | Poland | Carbon tax | Not available | 24 | Electricity & Heat, Industry, Mining & extractives, Transport |
| 1991 | Sweden | Carbon tax | $127.3 (SEK1,368) | 40 | Electricity & Heat, Industry, Mining & extractives, Transport |
| 1992 | Denmark | Carbon tax | $28.2 (DKR196) | 48 | Electricity & Heat, Industry, Mining & extractives, Transport |
| 1996 | Slovenia | Carbon tax | $18.60 (€17) | 45.7 | Transport, Buildings |
| 2000 | Estonia | Carbon tax | $2.15 (€2) | 10 | Electricity & Heat, Industry |
| 2004 | Latvia | Carbon tax | $16.12 (€15) | 2 | Electricity & Heat, Industry, Mining & extractives |
| 2005 | EU 27 | ETS | $61.30 (€57) | 38 | Electricity & Heat, Industry, Mining & extractives, Aviation |
| 2010 | Ireland | Carbon tax | $60.19 (€56) | 34 | Electricity Heat, Industry, Mining extractives, Transport |
| 2014 | France | Carbon tax | $47.94 (€45) | 40 | Industry, Transport, Buildings, Agriculture, forestry & fishing fuel |
| 2014 | Spain | Carbon tax | $16.12 (€15) | 1.9 | Industry |
| 2015 | Portugal | Carbon tax | Not available | 40 | Electricity & Heat, Industry, Mining & extractives, Transport |
| 2021 | Netherlands | Carbon tax | $71.48 (€66) | 45 | Electricity & Heat, Industry, Mining & extractives, Waste |
| 2021 | Germany | ETS | $48.37 (€45) | 39 | Electricity & Heat, Industry, Mining & extractives, Transport |
| 2021 | Luxembourg | Carbon tax | $49.91 (€46) | 72 | Industry, Mining & extractives, Transport, Buildings |
| 2022 | Austria | ETS | $48.37 (€45) | 40.3 | Electricity & Heat, Industry, Mining extractives, Transport |
| 2023 | Hungary | Carbon tax | $38.70 (€36) | 32.3 | Electricity & Heat, Aviation |

Source: World Bank ( https://carbonpricingdashboard.worldbank.org/compliance/instrument-detail).

The European ETS in the EU was launched in 2005. It is the world's first major carbon market and remains the largest one, regulating about 40% of total EU GHG and covering about 10,000 power stations and manufacturing plants in the EU.

Some of the flagship policies are directly (or indirectly) related to carbon pricing, such as the Fit-for-55 package proposal for the revision of the Energy Taxation Directive (ETD) and the already approved proposal for a Carbon Border Adjustment Mechanism (CBAM -see European Commission (2021)-) and the extension of the ETS to the ETS2 (European Commission, 2022) targeting $CO_2$ emissions from fuel combustion in buildings, road transport, and additional sectors, focusing primarily on smaller industries not previously covered. The goal of ETS2 is to reduce emissions by 42% by 2030 compared to 2005 levels.

# 3 Empirical strategy and data

In this section, we present the data we use, the carbon tax scenarios we simulate, and the strategy we employ to assess the ex-ante budgetary and distributional effects of the implementation of such taxes across the 27 EU countries.

## 3.1 Data

This paper uses microdata from two household surveys (EU-HBS and EU-SILC)[11] and GHG emission intensities from an environmentally extended input-output model based on EXIOBASE. In what comes next, we explain the main steps we follow to combine all these databases to estimate household carbon footprints, the base for our $CO_2$ tax simulations.

[11] In a few cases, we use national HBS or national SILC instead of the EU versions, depending on data availability.

### 3.1.1 Matching information on expenditures from EU-HBS into EU-SILC

Our main micro-data are the EU Statistics of Income and Living Conditions (SILC) surveys, which contain information on key socio-economic variables, including household composition and incomes.

However, EU-SILC does not have information on expenditures, which are necessary for estimating carbon footprints and simulating carbon tax liabilities. On the contrary, EU-HBS contains both information on income and expenditure. However, as highlighted by Lamarche et al. (2020), a critical issue with the income data gathered in the HBS survey is that this information is derived from a limited set of questions. Therefore, for the distributional analysis, we rely on income from SILC, the official source for calculating inequality and poverty indicators. To get this information, we use household-level expenditure data from the 2015 harmonised Eurostat Household Budget Surveys (EU-HBS).[12] To impute these household consumption expenditures from HBS data (i.e. the source dataset) to SILC data of the same year (i.e. the recipient dataset), we use the two-step semi-parametric procedure developed by Akoğuz et al. (2020). See more details in the Appendix (A).

Since our data on carbon footprints (emissions per EUR) refer to 2019 prices, we need to update income (EU-SILC) and expenditures (EU-HBS) from 2015 to 2019 price level. Using the EUROMOD microsimulation model, we "uprate"[13] market incomes from 2015 to 2019. Then, by applying the tax-benefit rules in place in that year, we estimate the 2019 disposable income of each household. Disposable income simulated in EUROMOD is very similar to the one reported in SILC. An overview of the extension of the EUROMOD is provided in Figure A.2. Expenditures for 2019 are obtained assuming that households consume the same share of their income in every product as in 2015.[14] This means that if a household's income increases by 5% from 2015 to 2019, expenditures will also increase by 5%.

### 3.1.2 Imputing GHG emission intensities (multipliers) from EXIOBASE

To estimate carbon footprints associated with household consumption baskets, we use the emissions intensities derived from EXIOBASE, a global multi-regional environmentally extended input-output (IO) framework.[15]

EXIOBASE contains detailed information on emissions by emitter industry and country. However, there are three key steps to bring this information into our matched EU-SILC-HBS surveys. The first is to calculate the emissions embedded (indirect emissions, henceforth) in the consumption of goods and services from the emissions made by industries in each stage of the supply chain across the world to be able to calculate emissions' intensities per unit of consumption (per EUR). The second is to express those emission intensities in purchasers' prices (those paid by consumers) instead of basic prices (that is the working standard of IO models). The difference between both valuation standards are trade

[12] For data quality or access reasons, for a few countries (Germany, Austria and Italy), we use 2010 HBS. For Austria, we used national data as it was not available at Eurostat.

[13] More information on the uprating factors used in EUROMOD can be found in Sutherland and Figari (2013), De Poli et al. (2023) and, in more detail for each country in the Country Reports, annually updated and published in EUROMOD's website (https://euromod-web.jrc.ec.europa.eu/).

[14] More details on the calculation of the income shares at the Appendix A.

[15] EXIOBASE is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT). It is based on harmonized and detailed supply-use tables for a long list of countries, with emissions and resource extractions by industry. The country supply-use tables are linked via trade, creating an MR-SUT and producing MR-IOTs; that are the basis of the input-output model from which we derived the environmental impacts associated with the final consumption of product groups. Source data is publicly available (https://www.exiobase.eu/).

and transport margins and taxes less subsidies on consumption. The third is to bridge classifications. HBS follows the COICOP[16], while EXIOBASE is based on a different production-oriented classification industry-based, covering about 200 products (Merciai and Schmidt (2018)). More technical details on the bridging matrices are available in the Appendix A. Finally, the intensities per product of direct emissions (those made by consumers when burning fuel domestically for heating or driving) are also calculated using aggregate household consumption and energy prices and emission factors from the International Energy Agency (IEA).

Those intensities contain, for each product, detailed information on equivalent [17] $CO_2$ direct GHG emissions (e.g., from burning fuels for heating a house or driving a car) as well as indirect GHG emissions embedded in consumption (considering those related to, both, domestically produced goods, as well as imports, from other EU countries or from the Rest of the World). Emission intensities are expressed as GHG emissions, in $tCO_2e$ per euro spent.

We apply these intensities to the imputed expenditures to obtain the carbon footprints associated with consumption expenditures at the household level for each EU country.

Let us define $Z_{g_p}$ (see equation 1) as the annual expenditures (in euros) spent by household $g$ on consumption category $p$ (e.g., "rice"). This is calculated as the product between the income share of expenditures on this consumption category imputed from HBS into SILC ($w_{g_p}$) and household disposable income ($Y_g^d$) from the EUROMOD microsimulation model, which is based on SILC.

$$Z_{g_p} = w_{g_p} \cdot Y_g^d \tag{1}$$

Once we have these expenditures at the household level, the carbon footprint of each household $g$ ($FP_{GHG,g}$, equation 2) is calculated as the sum of the cross-product between household expenditures on each consumption category $p$ ($Z_{g_p}$) and the intensities from EXIOBASE ($m_p$), being $m_p^{dir}$ and $m_p^{ind}$, the direct and indirect GHG intensities ($tCO_2e$ of GHG per euro spent).

$$FP_{GHG,g} = \sum_{p=1}^{P} (m_{dir_p} + m_{ind_p}) Z_{g_p} \tag{2}$$

We consider around 200 consumption categories ($P$) in most countries.[18]

By combining household income with expenditures and carbon footprints, we extend the capabilities of the EUROMOD model in what we call Green EUROMOD. Currently, the core policies simulated by this model are direct taxes (e.g., personal income taxes and capital taxes), social insurance contributions and cash benefits (e.g., unemployment benefits, child benefits or social assistance). From Autumn 2024, EUROMOD releases run over the extended datasets, combining HBS-based expenditures and SILC microdata, and the model contains the simulation of consumption taxes. The Green EUROMOD extension

[16] Classification of Individual Consumption by Purpose, developed by the United Nations Statistics Division and adapted by Eurostat to the needs of HBS. It is a classification based on the purpose of which products are consumed, contrary to the classifications of IO tables, based on how products are produced.

[17] We merge all GHG: Carbon dioxide ($CO_2$), Methane ($CH_4$), Nitrous oxide ($N_2O$), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride ($SF_6$), Nitrogen trifluoride ($NF_3$), weighting them by their Global Warming Potential (GWP100) as from the IPCC.

[18] More categories are available for the Netherlands and Austria, while less in Germany due to source data limitations.

allows us to expand the scope of tax reforms by allowing us to simulate carbon taxes on household consumption. For an overview of the main steps to combine our data and the relative modelling tool, please refer to Figure A.2.

By integrating this environmental dimension into EUROMOD, the tool allows for a more comprehensive analysis of the distributional effects of environmental policies, helping policymakers design interventions that are both environmentally effective and socially equitable.

## 3.2 Scenarios

We assess the budgetary and distributional effects of three types of scenarios (as outlined in Table 2), each representing a hypothetical consumption tax design aimed at increasing the tax burden based on GHG emissions embedded in household consumption.

As detailed below, Scenario 1 involves a flat tax, which we evaluate both with and without revenue-recycling compensatory measures. Scenario 2 introduces a flat tax with an allowance, exempting GHG emissions below a specified threshold. Scenario 3 applies tax differentiation across products. The primary objective of Scenarios 2 and 3 is to enhance distributional outcomes by alleviating the regressivity and negative redistributive effects associated with a flat tax. It is important to note that while we often refer to this as a "carbon tax," the tax encompasses all greenhouse gas (GHG) emissions, including not only carbon dioxide ($CO_2$) but also other gases such as methane ($CH_4$) and nitrous oxide ($N_2O$).

Table 2: Simulated scenarios

| Scenario | Name | Description | Budget |
|---|---|---|---|
| S1 | Flat | Tax on GHG emissions | |
| S1.1 | Flat80 | No compensation | Increases |
| S1.2 | ... + cnt compensation | Cnt-compensation | Neutral by cnt |
| S1.3 | ... + EU compensation | EU-compensation | Neutral EU |
| S2 | Green allowances | Tax on GHG emissions with allowances | |
| S2.1 | GA 2.2 | Exempted 2.2 $tCO_2e$ | Increases $<$ S1.1 |
| S2.2 | GA 2.2 - FB | Exempted 2.2 $tCO_2e$ (FB) | Increases $=$ S1.1 |
| S3 | Progressive by different rates | Different GHG tax rates by product | |
| S3.1 | Prog40 | Different tax rates | Increases $=$ S1.1 |

Note: "cnt" = country. "'GA"= Green allowances. "FB" = fixed budget - equivalent to scenario S1.1

### Scenario 1: Flat carbon tax, without and with compensation

The first scenario (1.1) is an EU flat carbon tax that charges EUR 80 per $tCO_2e$ of total GHG emissions, including both direct and indirect ones.

This 80 EUR rate is quite above that one simulated by Feindt et al. (2021) (35 EUR, referring to 2010), but it is more aligned with the current prices negotiated in the EU ETS, and it is still way below what it is expected for the upcoming years and towards the end of this decade. Moreover, this price we impose is also quite in line with the Stiglitz et al. (2017)'s Report of the High-Level Commission on Carbon Prices, where the authors suggest that the appropriate carbon price across the world will need to be USD 40–80 by 2020, and USD 50–100 by 2030, to be consistent with meeting the goals of the Paris Agreement. Moreover, Tol (2023) suggests that, over the past decade, estimates of the social cost of carbon have substantially increased from US$9 per to 40 for a high discount rate and from US$122 to even 525 for a low discount rate.

We complement this scenario with two revenue-recycling compensatory measures: scenario 1.2) a lump-sum cash transfer of an equal amount for each individual within each country, depending on each country's contribution (budget-neutral at the country level), and scenario 1.3) a lump-sum cash transfer of equal amount for all EU inhabitants.

### Scenario 2: Sustainable Green Allowances

In these scenarios, we impose a flat carbon tax but only for those emissions above the 'sustainable levels' of 2.2 $tCO_2e$, which are exempted (what we call "green allowances"). The threshold is based on previous estimates of sustainable levels compatible with the 1.5°C agreements (see, e.g., Gore, 2021, Ivanova et al., 2016). This approach with green allowances is similar to the progressive tax proposed by Chancel and Piketty (2015). They propose a global progressive carbon tax to increase climate adaptation funding. Among other designs, they simulate a funding strategy where all individuals emitting more than the global average emissions level (6.2 $tCO_2e$ per year) would contribute proportionately to their emissions above this threshold.

The motivation is dual: make the system less regressive (or more progressive) by alleviating the tax burden on low-consumption households, while also sending a clear signal on what would be sustainable behaviour. In practical terms, for this, we would need: i) carbon footprints associated with each good and service, ii) an allocation of free "allowances" amounting to 2.2 $tCO_2e$ to each person in each household per year (the carbon price would be only paid once this "allowance" is exhausted).

We distinguish two sub-scenarios here. In scenario 2.1, GHG emissions over this threshold are taxed at the same rate as in scenario 1 (EUR 80 per $tCO_2e$ of GHG emissions). This naturally leads to lower budgetary gains. In contrast, in scenario 2.2, we still exempt the first 2.2 $tCO_2e$ of GHG emissions from taxes, but we increase the flat tax to the GHG emissions above this limit beyond EUR 80 per $tCO_2e$, to ensure we get the same budget as in scenario 1.1. Therefore, GHG emissions above the 2.2 $tCO_2e$ are taxed at a higher level (on average, the carbon tax increases from EUR 80 to 145, with a maximum of 249 in Romania). Table B.5 in the Appendix B shows the specific tax rate in each country.

### Scenario 3: Different tax rates by product

In this scenario, we try to tackle the regressivity of the carbon tax by using three carbon prices, depending on the type of good ($p$). The different tax rates ($t_p$) are selected based on the median level of the concentration index ($C_p$, see equation 3) of GHG emissions for each product category $p$ with respect to equivalised disposable income.[19] With this, we enhance the balance between fairness and sustainability.

The concentration index of GHG emissions of 10 groups of products, $p$, in relation to disposable income $C_{p,y^d}$ is defined in a standard way (see Lambert, 1992) as:

$$C_{p,y^d} = \frac{2}{\mu_{y^d}} \text{Cov}(e_p, r_{y^d}) \tag{3}$$

[19] Considering the standard modified OECD equivalence scales to account for the economies of scale in consumption due to differences in household size and composition when comparing welfare at the individual level (first adult = 1, each other adults = 0.5, each children= 0.3).

where $e_p$ is the total GHG emissions of product $p$, $r$ is the fractional rank of individuals based on equivalised household disposable income, $\mu_{y^d}$ is the mean of disposable income ($y^d$), and $\text{Cov}(e, r)$ represents the covariance between $e$ and $r$. The concentration index is defined as twice the area between the concentration curve and the line of equality (the 45-degree line). If there is no relation between GHG and income (i.e., if 20% poorest would emit 20% of GHG, and for the 40% the same, and so on), the concentration index is zero. The index is negative if the curve lies above the line of equality, indicating a disproportionate concentration of GHG among low-income households, and positive if it lies below.

For each country, we define three rates: a low rate of EUR 40 per tCO2e, which we apply to those consumption categories that have a lower concentration index (i.e. median at EU level, lower than 0.1), a medium-level rate of EUR 80 for those in the middle (i.e. a median concentration index between 0.1 and 0.2), and a high rate that is country-specific - as it is endogenously defined to ensure the same revenue collection of scenarios 1.1 - for those commodities that are consumed more among higher-income households (i.e. with a median concentration index larger than 0.2). More specifically, the high rate ($t_{p_h}$) is calculated as follows:

$$t_{p_h} = \frac{T^{S1} - (80 \times E_m) - (40 \times E_l)}{E_h} \tag{4}$$

where $T^{S1}$ is the total amount of revenues collected in scenario 1.1 (carbon tax without any compensation), while $E_l$, $E_m$ and $E_h$ are the total emissions related to, respectively, low, medium and high concentrated goods in each country. Since $E_l$, $E_m$ and $E_h$ are different in each country, the tax rate is also country-specific. The values of $t_{p_h}$ are represented in table B.5 in the Appendix B.

### 3.3 Micro-simulations, welfare approach and behavioural assumptions

Combining income, direct and consumption taxes, expenditures and GHG emissions within the same framework allows us to simulate carbon taxes and examine the redistributive effects of hypothetical consumption-based carbon taxes in comparison with other tax-benefit policies as well as consider welfare effects based on disposable income. Throughout this paper, we use "distributional" and "redistributive" interchangeably, reflecting the common use of the former in environmental studies and the latter in fiscal policy analysis.

More specifically, we assess the distributional consequences of the simulated carbon taxes with a compensating variation welfare approach. This follows a widely used concept of equivalent income used in public economics at least since King (1983): we estimate the post-tax income that a household would need to keep consuming the same bundle under the new tax rates.

Let $u(z)$ be the utility function, where $z$ is the consumption bundle. Let $E(\rho, u)$ be the expenditure function, where $\rho$ is the price vector and $u$ is the utility level. The compensating variation (CV) can be simply expressed as follows:

$$CV = E(\rho_1, u_0) - E(\rho_0, u_0) \tag{5}$$

where $E(\rho_0, u_0)$ is the expenditure function evaluated at the initial prices $p_0$ and $E(\rho_1, u_0)$ is the expenditure function evaluated at the final prices $\rho_0$ and the initial utility level $u_0$.

In practice, we estimate these welfare effects by simulating an after-tax equivalent income at the household level $g$ ($AY_g^d$). This depends on $\Delta Z_g$, the variation of expenditures with the tax:

$$\Delta Z_g = Z_{ag} - Z_{bg} \tag{6}$$

To estimate the expenditures after the tax under compensating variation ($Z_{ag}$, equation 7), we subtract from baseline expenditures ($Z_{bg}$) total simulated carbon taxes. These taxes are obtained by multiplying the tax rate ($\tau$, defined in EUR per ton) by the household carbon footprint ($FP_{GHG_g}$). In that stage is where we assume a full pass-through (inelastic demand), as the quantities consumed (that enter the tax base, through the carbon footprints) are fixed in the baseline.

$$Z_{ag} = Z_{bg} + \tau FP_{GHG_g} \tag{7}$$

At the end, $AY_g^d$ is obtained by subtracting these simulated tax liabilities from from baseline equivalised household disposable incomes.

$$AY_g^d = Y_g^d - \Delta Z_g = Y_g^d - FP_{GHG_g}\tau \tag{8}$$

To assess the distributional effects under this compensating variation welfare approach we then compare this after-tax income and the distribution of the tax with baseline disposable income with two standard indicators: the Gini coefficient -based on the concentration index- and the S8020 ratio -the difference between the income shares of the top and bottom 20%.

Although this serves to provide a welfare magnitude of the effect in the short run, the main motivation for the implementation of carbon taxes is to reduce demand, especially of carbon-intensive goods and services. Since we do not model it in this paper (see Section 5), our 'overnight' results should be interpreted as short-run effects and probably upper bounds of the overall effect (as the negative demand response should actually reduce both the tax burden on households as well as the revenues from tax collection). Nevertheless, the literature suggests that demand responses to changes in prices of necessity goods (i.e., food and energy, which are precisely among the most carbon intensive) tend to be small, especially in the short-run (Linden et al., 2024; Labandeira et al., 2017).

# 4 Results

In this section, we present the main results of our study. We start, in sub-section 4.1, with a brief descriptive analysis of the distribution of carbon footprints across households and countries. Then, in sub-section 4.2, we present the results from the simulation of alternative carbon tax designs.

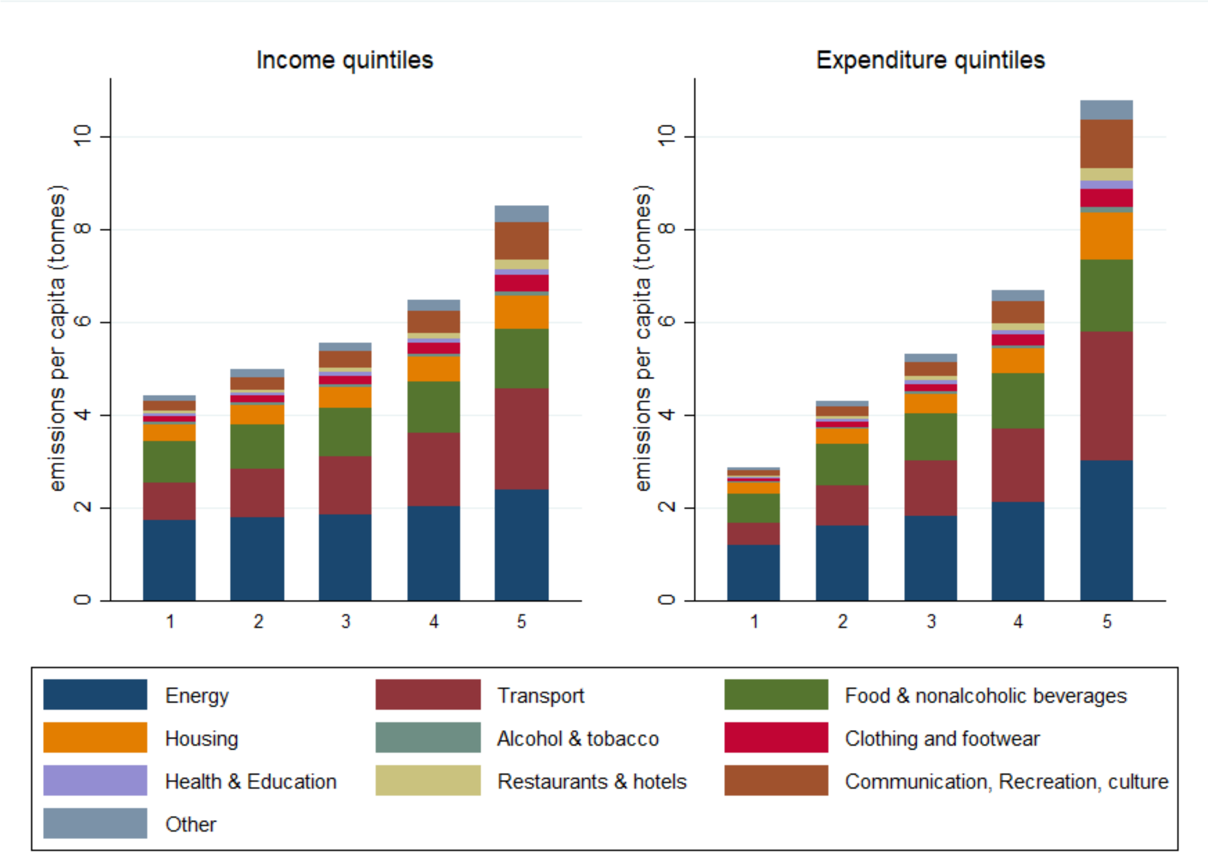
## 4.1 Carbon footprints - EU households

Figure 1 shows the distribution of per capita GHG footprints ($tCO_2e$ per year) across income and expenditure quintiles. These quintiles are based on each country's distribution, with the EU average calculated as a weighted population average.

As illustrated in Figure 1, individuals in high-income households (within countries) have much larger carbon footprints than those in low-income households. On average, our estimates for 2019 suggest that the average GHG embedded in the consumption of the top 20% (fifth quintile, Q5) is slightly above 8 $tCO_2e$, doubling that of the bottom 20% (first quintile, Q1). The Q5/Q1 gap is even larger -almost five times- when individuals are ranked by their equivalised expenditures (expenditures quintiles, right-hand side).

Three consumption categories -residential energy, transport, and food- are responsible for most of the GHG emissions. The predominance of these categories is well-documented in the literature. Not coincidentally, the ETS2 covers the first two groups. This can be explained by the high level of expenditure on these consumption categories and their high GHG intensity. Figures B.1 and B.2 highlight the large heterogeneity across countries in expenditures and GHG emission intensities by type of consumption category. While this pattern holds true across all income and consumption quintiles, emissions from food and energy remain relatively constant, whereas GHG emissions from transport substantially increase among high-income and high-consumption households.

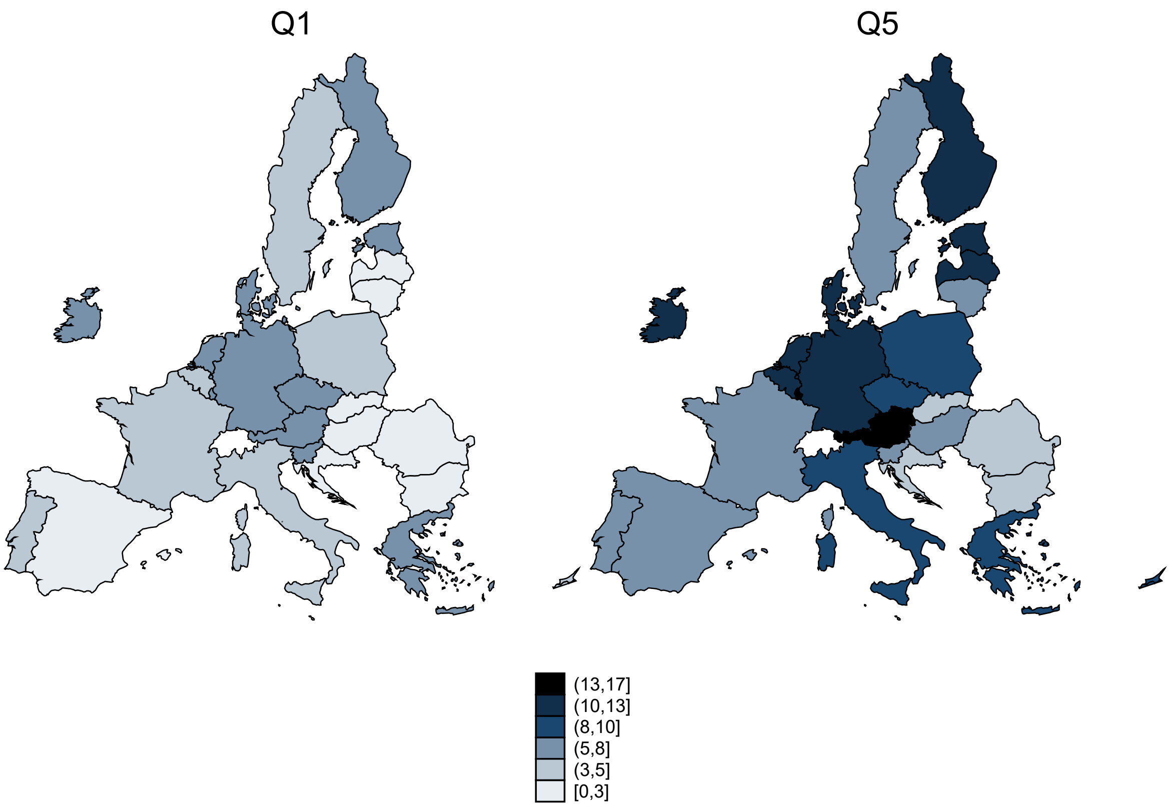
Figure 1: Per capita GHG emissions across income and expenditure quintiles (EU average, 2019)




Note: GHG footprints ($tCO_2e$) based on environmental extensions from EXIOBASE (2019), EU HBS 2015 and SILC 2015 and EUROMOD tax-benefit rules of 2019. EU average: population weighted. Consumption categories at the most aggregate level (COICOP two digits) - for illustrative purposes, we group health with education (COICOP 06 and 10), communication with recreation and culture (COICOP 08 and 09), housing with furnishings, household equipment and routine maintenance of the house (COICOP 04 and 05), excluding energy.

To better visualize the cross-country dispersion of these per capita emissions across the income distribution, Figure 2 presents a map with per capita GHG emissions at the bottom (Q1) and at the top of the income distribution (Q5). The same information per country and type of good is provided in Figure B.3 in the Appendix B. At the bottom of the distribution (left panel of Figure 2), some Eastern Countries and Spain exhibit very low emissions (less than 3 tonnes per capita). In contrast, some Western central countries (Germany, the Netherlands, Luxembourg, Austria) and Ireland have more than 8 tones per capita $CO_2$e of GHG emissions. As expected, in quintile 5 (right panel of Figure 2), per capita GHG emissions are much higher, with about half of the countries showing more than 10 tonnes per capita emissions. Here we can also appreciate that the cross-country dispersion of the carbon footprints of the top 20% income groups is higher than the one of the bottom 20%.

Figure 2: Per capita GHG emissions in quintile 1 (Q1) and quintile 5 (Q5), 2019




Note: GHG footprints (t$CO_2$e) based on environmental extensions from EXIOBASE (2019), EU HBS 2015 and SILC 2015 and EUROMOD tax-benefit rules of 2019.

Overall, we can see that most of the first quintiles across the EU countries have, on average, carbon footprints that are above "sustainable levels" (of 2-2.5 tons a year). In fact, only if we rank households from the poorest to the richest (in terms of incomes) in the EU and look at the first decile (the 10% with the lowest incomes, regardless of the country of residence) We observe a carbon footprint that is aligned with this threshold.

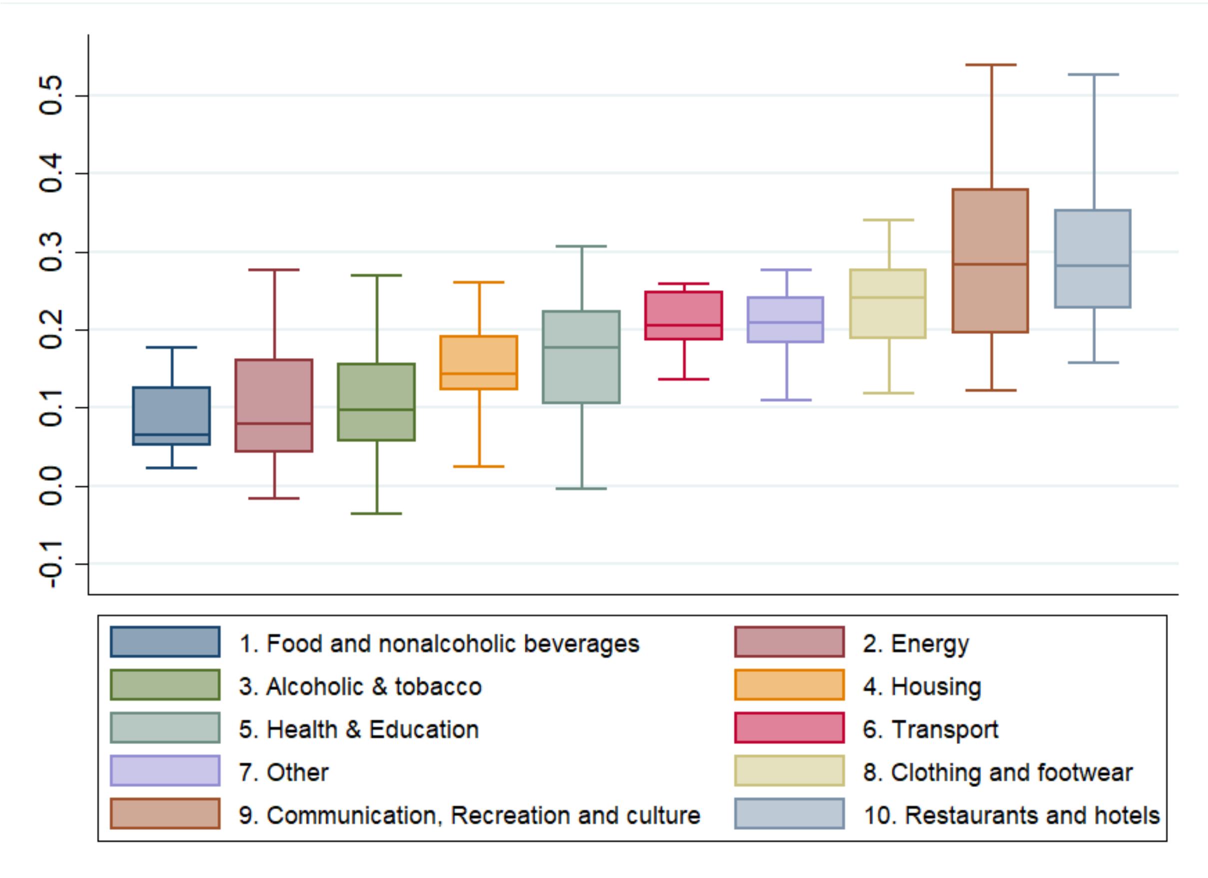
Consumption taxes are generally regressive (Maier and Ricci, 2024, Decoster et al., 2010). Their overall redistributive effect depends on two main features: the average tax rate or tax burden, and how these tax liabilities are distributed across income groups, see, e.g., Kakwani (1977) and Reynolds and Smolensky (1977). We now explore the second dimension (distribution of GHG emissions across income) using concentration indices, as this can help us interpret the results from the simulation and provide inputs for the design of a progressive carbon tax (scenario 3).

Figure 3 presents the distribution of concentration indices -see equation 3- across countries and aggregate consumption categories. These are ranked from left to right by the median concentration index of the

27 EU countries. GHG emissions from food, energy, alcohol and tobacco show the lowest concentration indices, suggesting that they are more equally distributed across income groups than the rest of the consumption categories. Conversely, transport, other, clothing and footwear, communication, recreation and culture, restaurants, and hotels are mostly concentrated at the top of the distribution.

These results feed the design of our third tax scenario, where we look at improving the progressivity of the carbon tax by imposing different rates across consumption categories. To make carbon taxation more progressive with this strategy, tax rates should be higher among those products with higher concentration indices (GHG emissions vs incomes). Still, the improvement of the overall distributional effect (i.e., to minimize the inequality-increasing effects) depends also on whether those products with higher tax rates represent large shares of the total carbon footprints. For instance, in most of the countries, we could expect an improvement in the distributional results driven by transport, which has both a high concentration index (and as such, it will be taxed at higher rates in our simulations) while it also represents a large share of the tax burden.

Figure 3: Concentration index: GHG emissions by consumption category (EU 27 countries, 2019)




Note: GHG footprints (eq-$CO_2$) based on data from EXIOBASE (2019), HBS 2015 and EU-SILC 2015, with values uprated and tax-benefit rules of 2019 applied with EUROMOD. Concentration index of equivalised GHG emissions with respect to equivalised household disposable income. The line within the boxes indicates the median across the 27 EU Countries. The boxes represent the range of the percentiles 25 and 75 (inter-quartile range).

## 4.2 Simulation results

We now present the results from our simulations. We start with the results from scenario 1, where we impose a flat $CO_2$ tax on consumption, and discuss the overnight budgetary and redistributive effects both without and with revenue-recycling compensatory measures. Next, we move to scenarios 2 (green allowances) and 3 (different tax rates by products), where we try to make the carbon tax less regressive by design (without compensatory measures).

Before presenting the distributional effects of our simulated scenarios, Table 3 provides an updated version of Table 2, with an overview of the estimated budgetary effects (aggregate tax revenues). Additionally, it provides the implicit carbon tax for those scenarios where this variable is endogenously determined (scenarios 2.2 and 3.1).

Table 3: Simulated scenarios: price and budget

| Scenario | Name | Description | Carbon price | Budget* |
|---|---|---|---|---|
| | | | (EUR/$tCO_2e$) | (EUR bn) |
| S1 | Flat | Tax on GHG emissions | | |
| S1.1 | Flat80 | No compensation | 80 | 208 |
| S1.2 | ... + cnt compensation | Country specific compensation | 80 | 0 |
| S1.3 | ... + EU compensation | EU compensation | 80 | 0 |
| S2 | Green allowances | Tax on GHG emissions with allowances | | |
| S2.1 | GA 2.2 | Exempted 2.2 $tCO_2e$ | 80 | 135 |
| S2.2 | GA 2.2 - FB | Exempted 2.2 $tCO_2e$ (FB) | 145** | 208 |
| S3 | | Different GHG tax rates by product | | |
| S3.1 | Prog40 | Three rates (40, 80, $t_{p_h}$) | 40-144** | 208 |

Note: FB = fixed budget - equivalent to scenario 1.1. *Budget effect for the whole EU27. Detailed results by country are reported in Table 4 for scenario 1, and in the Appendix B for the rest. EU simple average of the carbon tax (country-specific values in Table B.5).

### 4.2.1 Results from scenario 1: hypothetical 80 EUR $CO_2$ flat tax

Let us start with the simulated flat carbon tax of EUR 80 (per $tCO_2e$) for the 27 EU countries. In the horizontal axis of Figure 4, we plot the average tax rate, or "tax burden" (i.e., total tax liabilities expressed as a share of disposable income). In the vertical axis we plot the redistributive effect, measured as the change in the Gini coefficient before and after the simulated carbon tax.

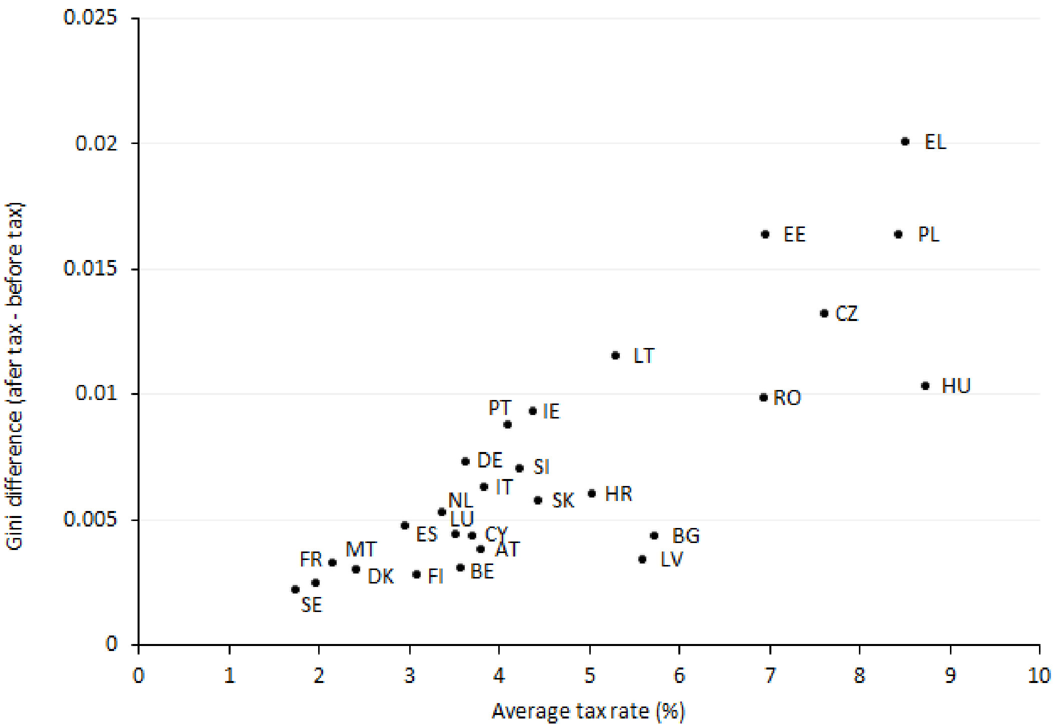
The tax burden ranges from about 2% of household disposable income in Sweden (SE), France (FR) and Denmark (DK) to 9% in Hungary (HU), Greece (EL) and Poland (PL). In general, we observe a larger tax burden in lower-income countries compared to higher-income ones. While, in fact, higher income countries consume more and have larger per capita carbon footprints, (and as such, they end-up paying more in absolute terms), the relative weight of the carbon tax on incomes is smaller. This is primarily because of their lower income shares of consumption expenditures. Additionally, differences in consumption patterns contribute to this variation: lower-income countries tend to have a higher proportion of expenditures allocated to GHG-intensive categories such as food, heating, and transport. These categories also account for a greater share of total GHG emissions in these countries. As illustrated in Figures B.1 and B.2 (Appendix B), food, heating and transport ranges from about one-third of household consumption expenditures in Luxembourg, Netherlands and Finland to almost two-thirds in Estonia, Croatia and Romania.

In the same figure we can observe that the tax leads to negative redistributive effects in all EU 27 countries. We measure it as the change in the Gini coefficient of equivalised disposable income before and after the tax (by "after" we mean incomes that would be needed to purchase the baseline consumption basket with the new prices/taxes, following the compensating variation welfare approach discussed at the end of section 3). A positive value suggests that the Gini coefficient has increased after the tax, which means that the after-tax income distribution is more concentrated than in the baseline (i.e., "inequality increases"). Although this inequality-increasing effect is observed in all EU countries, its magnitude widely varies from around 0.0025 Gini points in Sweden (in general in all Scandinavian countries, as well as in France and Belgium) to 0.02 (in Greece). These results are robust to the use of an alternative indicator to measure income concentration, such as the S8020 ratio, as we show later.

From the well-known Kakwani decomposition (Reynolds and Smolensky, 1977, Kakwani, 1977), that is the difference in Gini coefficient before and after a tax can be decomposed into a progressivity effect (measured with the Kakwani index, capturing how the tax is distributed along pre-tax income), a size effect (the average rate or tax burden) and a re-ranking effect. In Figure 4, we observe a clear positive cross-country correlation between the tax burden and the redistributive effect. This suggests that most of the cross-country disparities are explained by the relative size of the carbon tax with respect to household incomes, rather than by differences in progressivity/regressivity. Nevertheless, the relationship is not perfectly linear.

We can see, for example, that there are countries with very similar average tax burdens (e.g., Estonia and Romania, where the carbon tax would represent on average 7% of household disposable income) with quite different redistributive effects (0.017 vs 0.010, for Estonia and Romania, respectively). In these cases, we do observe substantial differences in regressivity - the simulated carbon tax is more disproportionately affecting lower-income households in Estonia than in Romania. As it can be appreciated in Figure B.3 (Appendix B), per capita GHG emissions in quintile 1 are much higher in Estonia than in Romania.

Figure 4: Distributional effect and average tax rate of a hypothetical 80 EUR flat $CO_2$ tax (S1.1)




Note: Simulated results based on Green EUROMOD. Average tax rate (or tax burden) expressed as % of equivalised household disposable income. GHG footprints ($tCO_2e$) based on environmental extensions from EXIOBASE (2019), HBS 2015, EU-SILC 2015 and EUROMOD tax-benefit rules of 2019.

An advantage of the Green EUROMOD model is that we can simulate not only household disposable income (after direct taxes and cash benefits) but also consumption tax liabilities (VAT and excises), with a high level of precision and cross-country harmonization. This allows us to compare the tax burden and redistributive effect of our simulated carbon tax with the one from consumption taxes.[20] Our estimates suggest that consumption taxes represent approximately 13.5% of household disposable income (in 2019, on the EU-27 average). This means that our hypothetical carbon tax would increase the overall consumption tax burden by about one-third (35%). Unsurprisingly, this EU average also masks substantial cross-country heterogeneity, as this share (carbon tax to total consumption taxes) ranges from 16-19% in Sweden and Denmark to about 70% in Poland (see Figure B.5, Appendix B). Although it is well true that some countries have higher consumption tax rates in the baseline -what *ceteris paribus* makes the relative increase from carbon taxation smaller- differences here are again mainly driven by the heterogeneity in the tax burden of the simulated carbon tax. In terms of the distributional outcomes, the inequality-increasing effect of the simulated carbon tax is about one-third of the inequality-increasing effect of 2019 consumption taxes in the EU. Again, this varies across countries, from about 13% in Sweden and Denmark to more than 100% in Czechia and Poland (see Figure B.5, in Appendix B).

We now explore to what extent a compensatory measure such as a cash transfer to households (recycling the tax revenues from this simulated tax) can offset these inequality-increasing effects. To do so we need first to estimate the total tax revenues. According to our micro-simulations, this EUR 80 flat carbon tax would increase government revenues by EUR 208 billion. Table 3 reports the results for the EU

[20] For more information on simulated carbon taxes in EUROMOD, see, e.g., Maier and Ricci (2024).

aggregates and Table 4 by country.[21] For context, the EUR 208 bn represents more than twice the Social Climate Fund for 2026-2032 (EUR 87 bn).

Table 4: Results from a hypothetical EUR 80 carbon tax by country (scenario 1)

| cnt | Average tax burden % (tax/$y^d$) | Budgetary effect EUR bn | %GDP | Redistributive effect (change in Gini) S1.1 (no comp) | S1.2 (cnt comp) | S1.3 (EU comp) |
|---|---|---|---|---|---|---|
| AT | 3.79 | 6.29 | 1.6% | 0.004 | -0.006 | -0.003 |
| BE | 3.56 | 6.63 | 1.4% | 0.003 | -0.005 | -0.003 |
| BG | 5.71 | 1.48 | 2.4% | 0.004 | -0.017 | -0.042 |
| CY | 3.70 | 0.38 | 1.6% | 0.004 | -0.008 | -0.009 |
| CZ | 7.60 | 6.09 | 2.7% | 0.013 | -0.007 | -0.004 |
| DE | 3.62 | 56.94 | 1.6% | 0.007 | -0.003 | 0.000 |
| DK | 2.40 | 3.19 | 1.0% | 0.003 | -0.003 | -0.002 |
| EE | 6.95 | 0.85 | 3.0% | 0.016 | -0.006 | 0.000 |
| EL | 8.51 | 5.58 | 3.0% | 0.020 | -0.010 | -0.007 |
| ES | 2.95 | 14.34 | 1.2% | 0.005 | -0.006 | -0.011 |
| FI | 3.08 | 3.23 | 1.3% | 0.003 | -0.005 | -0.003 |
| FR | 1.96 | 22.42 | 0.9% | 0.002 | -0.003 | -0.005 |
| HR | 5.02 | 0.97 | 1.7% | 0.006 | -0.009 | -0.024 |
| HU | 8.73 | 3.86 | 2.6% | 0.010 | -0.018 | -0.023 |
| IE | 4.37 | 3.38 | 0.9% | 0.009 | -0.004 | 0.000 |
| IT | 3.82 | 29.64 | 1.6% | 0.006 | -0.006 | -0.006 |
| LT | 5.28 | 0.97 | 2.0% | 0.012 | -0.007 | -0.014 |
| LU | 3.52 | 0.43 | 0.7% | 0.004 | -0.005 | -0.001 |
| LV | 5.58 | 0.92 | 3.0% | 0.003 | -0.016 | -0.016 |
| MT | 4.86 | 0.11 | 0.8% | 0.003 | -0.003 | -0.008 |
| NL | 3.36 | 10.55 | 1.3% | 0.005 | -0.004 | -0.001 |
| PL | 8.44 | 16.76 | 3.1% | 0.016 | -0.010 | -0.012 |
| PT | 4.09 | 3.36 | 1.6% | 0.009 | -0.006 | -0.012 |
| RO | 6.93 | 3.97 | 1.8% | 0.010 | -0.017 | -0.049 |
| SE | 1.74 | 3.35 | 0.7% | 0.002 | -0.002 | -0.004 |
| SI | 4.23 | 0.88 | 1.8% | 0.007 | -0.004 | -0.005 |
| SK | 4.42 | 1.31 | 1.4% | 0.006 | -0.005 | -0.014 |

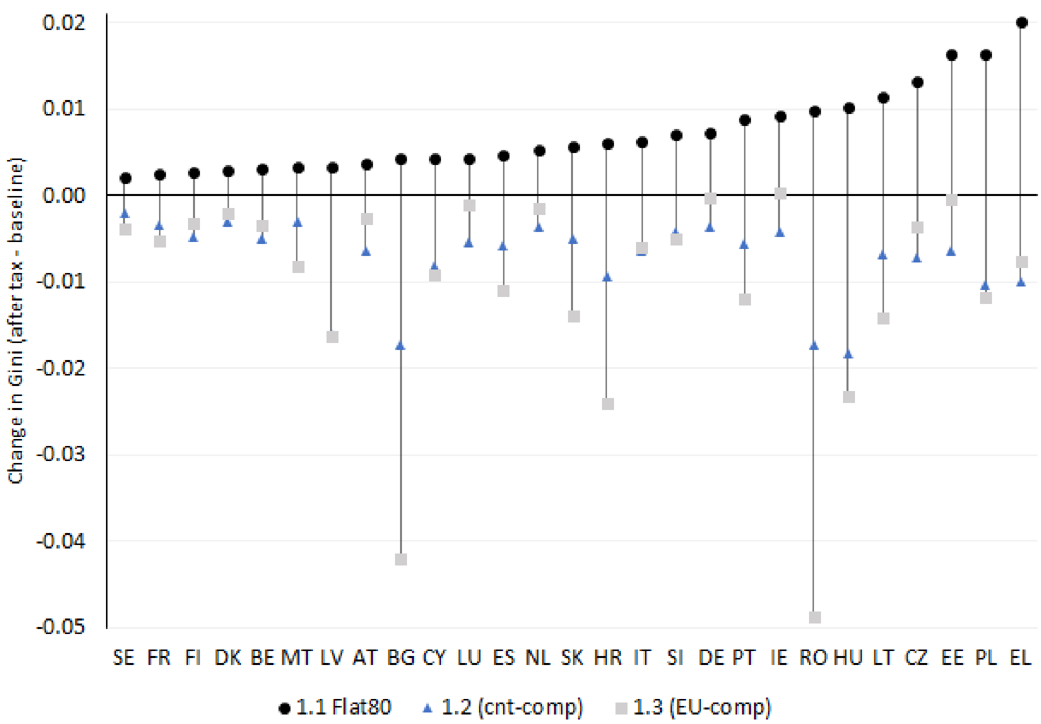
Note: Simulated results based on Green EUROMOD. GHG footprints ($tCO_2e$) based on environmental extensions from EXIOBASE (2019), HBS 2015, EU-SILC 2015 and EUROMOD tax-benefit rules of 2019. "bn": billions, "$y^d$": household disposable income. Change in Gini is calculated as the difference between the Gini coefficient of equivalised household disposable income after the carbon tax (under compensating variation) and the Gini coefficient of baseline equivalised household disposable income.

The absolute size of the budgetary effect depends on each country's per capita GHG emissions and population size and varies from below EUR 0.5 bn in small countries (Malta, Cyprus, Luxembourg) to EUR 57 bn in Germany. On average, it represents about 1.74% of GDP, a share that varies from 0.7% (Sweden or Luxembourg) to around 3% (Latvia, Poland, Estonia or Greece). When the compensatory measure is given in a revenue-neutral way for all EU inhabitants in the same magnitude (scenario 1.3), the cash transfer amounts to EUR 480 per year. In contrast, when the cash transfer is given at the Member State level (scenario 1.2), it varies from EUR 200-250 in Bulgaria, Romania, Croatia, Malta and Slovenia to close to EUR 700-800 in Austria, Germany, Ireland and Luxembourg.

[21] These budgetary estimates are, as well as our distributional estimates, 'overnight' effects (i.e., do not consider potential behavioural responses, nor at the level of consumer demand nor general equilibrium effects related with competitiveness and changes in functional income). We further discuss the implications of this assumption in the Discussion section 5.

To what extent do these compensatory measures offset the negative redistributive consequences of the carbon flat tax? The different redistributive outcomes across countries and scenarios are plotted in Figure 5, where countries are ranked from left to right according to the increase in the Gini coefficient in scenario 1.1 (no compensation). There, we can see that the effect is reverted in all countries: while the tax is inequality-increasing in all EU countries, inequality is reduced in all EU countries with compensatory measures.[22] These values, together with the average tax burden and budgetary effects per country are also reported in Table 4.

Figure 5: Distributional effect: without and with compensatory measures (scenario 1)




Note: Simulated results based on Green EUROMOD. GHG footprints ($tCO_2e$) based on environmental extensions from EXIOBASE (2019), HBS 2015, EU- SILC 2015 and EUROMOD tax-benefit rules of 2019.

Generally, in the budget-neutral scenarios with compensatory measures (1.2 and 1.3), countries in Central and Eastern Europe experience the strongest reductions in inequality. These countries tend to have higher levels of inequality than Western, Northern and Southern European countries. Therefore, scenario 1.1 not only increases inequality everywhere but also broadens divergences across countries, whereas scenarios 1.2 and 1.3 would not only lead to a reduction in within-countries inequality but also to smaller cross-country divergences in this dimension.

In countries where the EU-level transfer is much larger than the national-level one (i.e., in Bulgaria, Romania, Slovakia and Croatia), the positive redistributive effects are stronger in scenario 1.3 than in 1.2. Extreme cases are Bulgaria and Romania, where the redistributive effect in scenario 1.3 (of about 0.04 Gini points) more than doubles that in scenario 1.2 (of slightly less than 0.02). In contrast, in most Western/Northern high-income countries, the inequality-reducing effect after the EU-level transfer (scenario 1.3) is weaker than with the national-level transfer (1.2). This is clearly the case in Germany, Ireland, Austria and Luxembourg.

[22] The only exceptions are Ireland, Germany and Estonia, that in scenario 1.3 (EU-level compensatory transfer) experience an inequality-neutral effect of the combined reform (tax + compensatory measure).

Overall, results from scenario 1 suggest that an EU flat carbon tax can lead to positive redistributive effects only if accompanied by revenue-recycling compensatory measures. We illustrate this with a lump-sum transfer, which turns out to be enough to compensate the increase in the post-tax concentration of income. While compensatory measures -typically in the shape of revenue-recycling cash transfers to households, such as those we have simulated- are widely discussed in the literature (e.g., Feindt et al., 2021; Vandyck et al., 2021), they are not automatic and can be challenging to implement from the point of view of their public and political support. Among other limitations, it is difficult to define how long these transfers would endure, and how to phase them out, and even more to identify eligibility based on potential winners/losers. Moreover, they may also bring undesired rebound effects (e.g., see Murray, 2013).

#### 4.2.2 Results from scenarios 2: green allowances

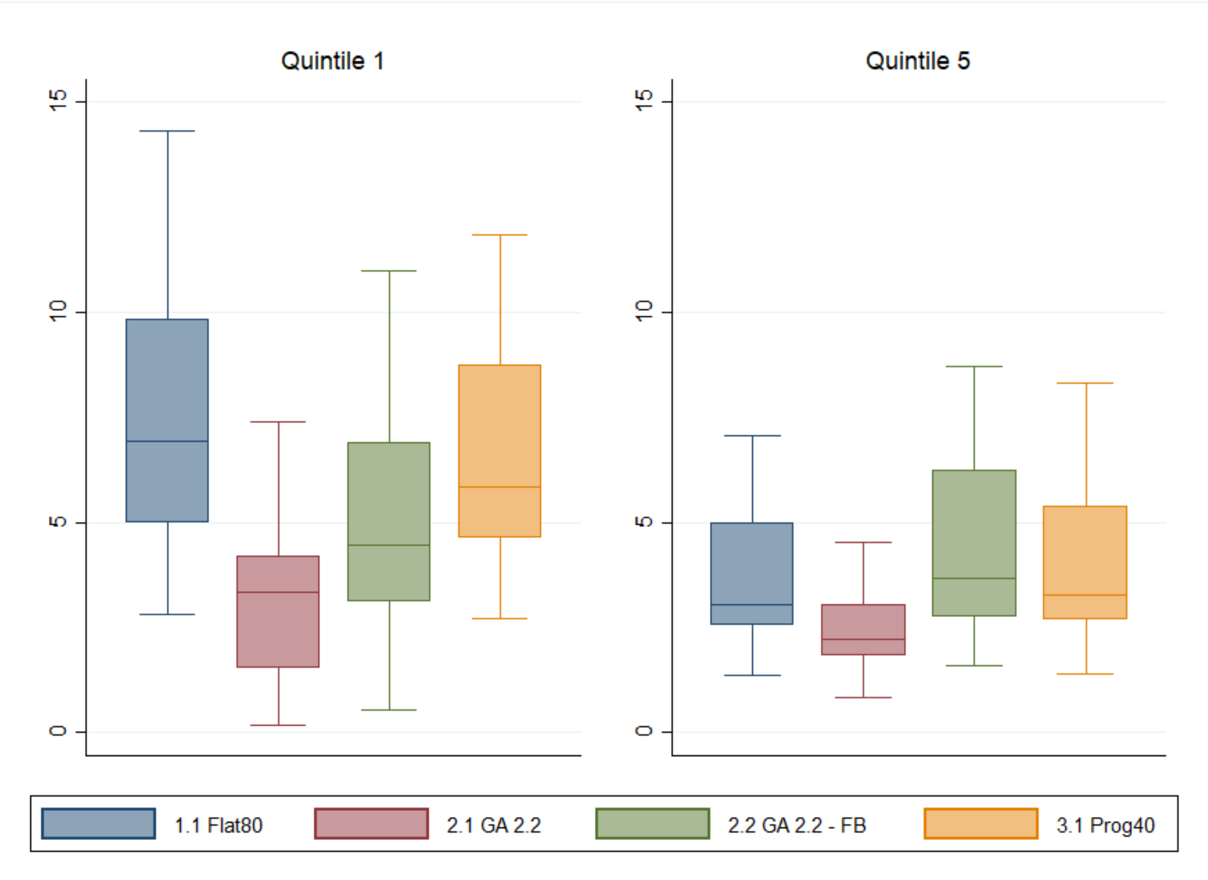
In what comes next, we turn our attention to evaluating the budgetary and distributional impacts of alternative tax designs, specifically scenarios 2 and 3 outlined in Table 2.

We simulate these other scenarios as alternative approaches to enhancing distributional outcomes from this simulated carbon pricing initiative without the need for additional compensatory cash transfers. This is achieved by making the carbon tax more progressive. Moreover, a progressive tax could, in fact, increase public support for this policy, as suggested by Klenert et al. (2018).

We start by comparing scenarios with "green allowances" (S2.1 and S2.2) with the flat tax scenarios, without and with compensation (1), see Section 3.2. If we keep the original carbon price of EUR 80, under the green allowances (S2.1), total tax revenues would be EUR 135 bn (see Table 3) instead of EUR 208 (S1). Alternatively, we simulate a budget-equivalent variant (S2.2) where we endogenously calculate the new carbon tax rate that would be needed to collect the same tax revenues per country as in the flat tax without compensation (S1). This, of course, leads to a larger carbon price on all those GHG emissions that are generated above the 2.2 $tCO_2e$ per year threshold (a price of EUR 145 per $tCO_2e$, on EU average), with wide cross-country variability, as reported in Table B.5.

In Figure 6, we can see that, in general, across scenarios, the bottom 20% (first quintile, based on equivalised disposable income) in each of the 27 EU countries would face a much larger tax burden than their richest counterparts (top 20%, quintile 5), suggesting that these simulated tax reforms are generally regressive. The largest gap between quintiles is observed in the flat tax (scenario 1.1), where, on average, the tax burden of the first quintile is 7.7%, more than doubling that of the fifth (richest) quintile (3.6%). We also identify substantial cross-country dispersion of the average tax burden in the flat tax scenario, which is particularly pronounced at the bottom of the income distribution. Table B.6 reports the country-specific estimates (tax burdens for quintiles 1 and 5 across all simulated scenarios). The simulated tax burden of the bottom quintile in scenario 1.1 ranges from about 2.5% in France and Sweden to almost 20% in Greece. By contrast, the tax burden in the fifth quintile ranges from 1.5% to 6%.

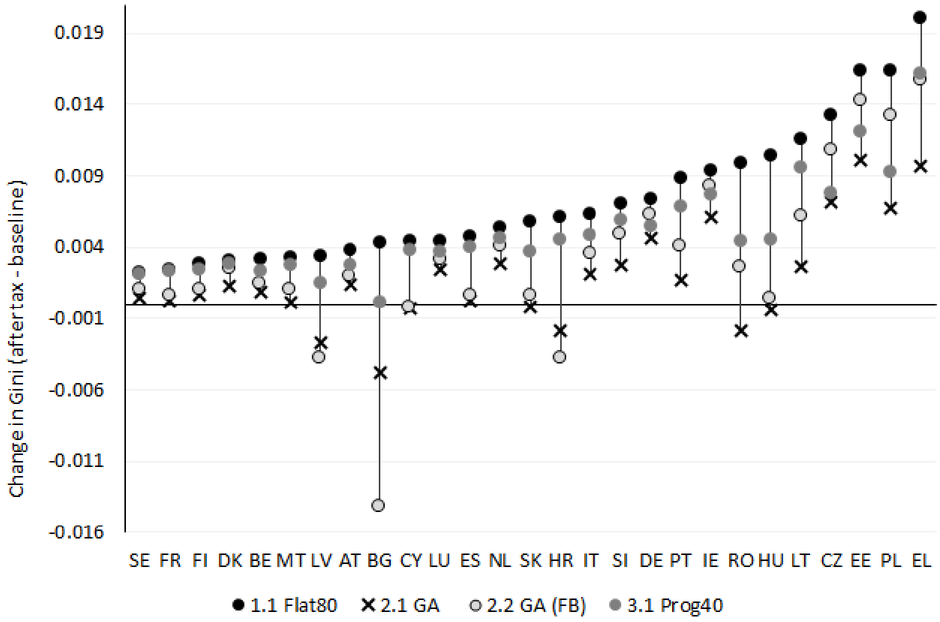
Figure 6: Tax burden (% of disposable income) at the bottom and top of the income distribution




Notes: The vertical axis (%) shows the tax burden, estimated as the share of simulated tax liabilities over baseline equivalised disposable income. Simulated results based on Green EUROMOD. GHG footprints ($tCO_2e$) based on environmental extensions from EXIOBASE 2019, HBS 2015, EU-SILC 2015 and EUROMOD tax-benefit rules of 2019. The line within the boxes indicates the median across the 27 EU Countries. The boxes represent the range of the percentiles 25 and 75 (inter-quartile range).

Results plotted in Figure 6 suggest that the "best" distributional outcomes are observed with the green allowances (S2.1). The gap between the top and the bottom quintiles is, in general, much lower with the allowances than with the flat tax (S1.1) or the different tax rates across products (S3). Still, on average, the first (bottom) quintile faces a higher tax burden (of about 3.5%, on average across countries) than the fifth (of 2.5%), suggesting that the regressivity is not completely reversed.

Figure 7: Redistributive effect: change in the Gini coefficient




Notes: Simulated results based on Green EUROMOD. GHG footprints ($tCO_2e$) based on environmental extensions from EXIOBASE 2019, HBS 2015, EU-SILC 2015 and EUROMOD tax-benefit rules of 2019. Scenario 2.1 (green allowances) is marked with × to distinguish it from the rest of the scenarios, which are all budget equivalent (S1.1, S2.2 and S3.1).

In fact, the increase in the Gini coefficient observed in all scenarios, even in 2.1, confirms our findings. Figure 7 shows the difference between the Gini coefficient after the simulated reform and before it (baseline), and as such, a positive value means that the distribution of income is more unequal after the tax (i.e. inequality increasing effects).[23] The inequality-increasing effect of the carbon tax is attenuated thanks to the green allowances (S2), with respect to the flat carbon tax of (S1.1) in all countries, but only in seven (Bulgaria, Latvia, Romania, Croatia, Hungary, Cyprus and Slovakia) inequality after the tax is reduced respect the baseline (pre-tax). Still, in the rest of the countries, the increase in the Gini coefficient is substantially reduced with the green allowances (S2) with respect to the flat tax (S1.1). On average, the increase in the Gini coefficient is about 36% of the one registered under the flat tax without compensation (S1.1), ranging from about 4% (Malta or Spain) to around 60% (Estonia, Ireland or Germany). This is quite an attractive result. The maximum increase in inequality would be a difference in the Gini coefficient of 0.01 (Estonia or Greece), which is about half the expected increase with the flat tax without compensation (S1.1). On the other hand, under the original green allowances (S2.1) scenario budgets would be lower than in scenario S.1.1.

If we adjusted the carbon price of this scenario (green allowances) to collect the same revenues as in the flat tax scenario without compensation (S1.1), the redistributive effect would not be as good as in S2.1,

[23]Results are consistent, and cross-country patterns very similar, if, alternatively, we use the S8020 ratio (coefficient between the share of income between the top 20% and the bottom 20% income groups) instead of the Gini coefficient, as it can be appreciated in Figure B.4. As a reference, the magnitude of this ratio in the baseline ranged from around 7 in Bulgaria, Romania or Latvia (i.e., those at the top income quintile have a share of the total income of the country that is seven times higher than the share held by the bottom quintile) to around 3 in Slovakia or Belgium. All country-specific estimates of the Gini and S8020 are reported in Table B.7.

but still better than in S1.1. This can be appreciated in Figure 7, where we plot the results from this scenario under the S2.2 GA (FB) label, where "FB" stands for "fixed budget". In line with what could be appreciated in Figure 6, the average tax burden of the bottom and top income quintiles is still better than under the flat tax without compensations (S1.1) but worse than under the green allowances keeping the original carbon price (S2.1) because the new carbon price is higher to ensure the same budget with a reduced tax base due to the allowance.[24] For example, the number of countries experiencing a decrease in inequality is reduced from 7 to 3 (Bulgaria, Latvia and Croatia). Among these, the distributional effect is even better than with the green allowances with the original carbon price (S2.1), and this is because very large shares of the population are responsible for less than 2.2 $tCO_2e$ per year. Only middle and top-income households end up paying the new higher carbon price that is charged above that allowance.

While under the original green allowances (S2.1), the increase in inequality was about 85% lower, on average, than under the flat tax without compensation (S1.1), when increasing the carbon price (S2.2), this offsetting effect is reduced to about half (50%). On top of the worse distributional outcomes, another disadvantage of the increased carbon price (S2.2) with respect to the original green allowances (S2.1) is that to force the budget neutrality condition (with respect to the flat tax without compensation, S1.1), we endogenously estimate the carbon tax, which is not only higher than the EUR 80 of previous scenarios (S1.1 and S2.1) but also end-up varying quite a lot across countries (ranging from EUR 100 in Luxembourg to about 250 in Bulgaria, as reported in Table B.5).

Overall, our simulations suggest that a tax allowance might be an appropriate tool to tackle the regressivity of the flat carbon tax. Keeping the carbon price at EUR 80 (S2.1) is better from a distributional viewpoint than the higher prices that would be needed to ensure the same level of government revenues as in the flat tax scenario. This would imply a reduction in the budget ranging from about 0.15-0.2% GDP in high-income Western and Northern countries to about 0.6% in Southern European middle-income countries, scaling up to almost 2% in Bulgaria. Moreover, with respect to the simulated cash transfer in S1.2 and S1.3, this carbon tax with green allowances would prove more feasible and realistic.

#### 4.2.3 Results from scenario 3: different tax rates across product

Next, we propose enhancing the progressivity of the carbon tax by implementing differential tax rates across various aggregate consumption categories. These rates would be adjusted based on the degree of concentration of consumption within each category relative to the distribution of pre-tax incomes. In other words, the approach involves taxing products that make up a larger portion of low-income households' budgets at a lower rate, while taxing goods and services that are more prevalent among high-income households at a higher rate (see section 3). To ensure comparability from a budgetary perspective with the flat tax without compensation (S1.1) and S2.2, the tax structure is calibrated to achieve the same revenue—EUR 208 billion—both at the individual country level and across the EU as a whole. The estimated high tax rate ranges between EUR 100-110 per $tCO_2e$ in Austria, Cyprus, Denmark, Finland, France, Latvia, Malta and Sweden to close to EUR 250-300 in Estonia, Romania and Poland (country-specific estimates that ensure budget neutrality in scenario 3.1 are reported in Table B.5). As expected, the higher tax rate is larger in countries where energy and food account for a higher share of total emissions (see Figure B.2).

The redistributive effect of the different tax rates (S3.1) can be assessed through the average tax burden by quintiles (Figure 6), as well as with the change in the Gini coefficient (Figure 7). In general, this leads to a redistributive effect, which is not as regressive as the flat tax without compensation (S1.1)

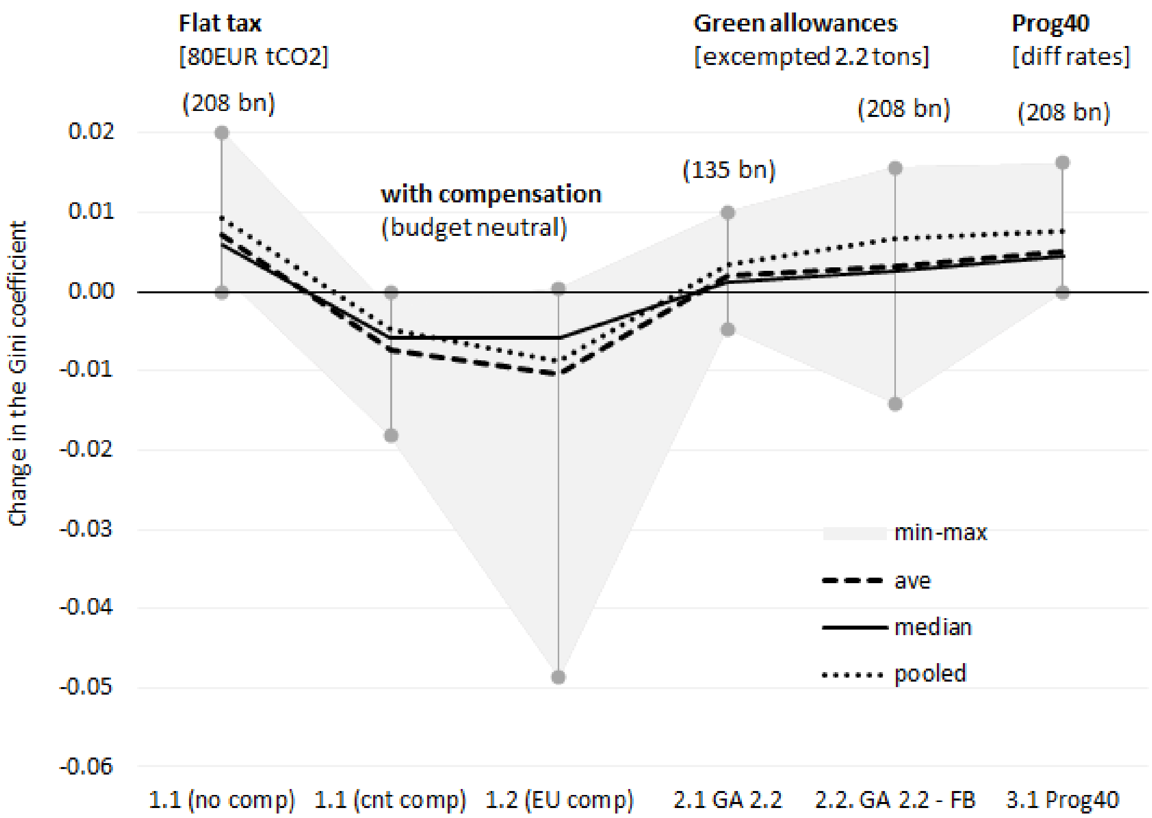
[24]The higher carbon price increases the regressivity.

but more regressive than the green allowances (S2.1 and S2.2). Only in very few cases, this tax design with different tax rates leads to better distributional outcomes than the green allowances with increased carbon price (S2.2): Poland, Estonia, Czechia, Ireland, and Germany. We have checked the robustness of these results to a number of sensitive tests by, for example, setting the three rates as EUR 40-80-120 or 60-80-100 instead of adjusting the highest rate for budget neutrality, and results are quite similar in terms of distributive effects, with some variation in budgetary terms. We discuss further the implications and feasibility of this scenario and the possibility of further disaggregating tax differentiation by sub-products in the next section (5).

#### 4.2.4 An EU-level assessment of all carbon tax scenarios

We have seen that the expected distributional and budgetary effects of these simulated hypothetical tax reform scenarios vary widely across countries. Now we consider the results of these scenarios from an EU-level perspective with Figure 8, which shows the main distributional (in terms of Gini difference) and budgetary effects (aggregate EUR bn) for the 27 EU countries.

Figure 8: Redistributive and budgetary effect across scenarios: EU perspective




Notes: Simulated results based on Green EUROMOD. GHG footprints ($tCO_2e$) based on environmental extensions from EXIOBASE 2019, HBS 2015, EU-SILC 2015 and EUROMOD tax-benefit rules of 2019."pooled" refers to the EU-level results (where all inhabitants are pooled together as a single country adjusting their incomes are to account for differences in the cost of living by purchasing power standards (Eurostat's $prc_p pp_i nd$ variable, 2019).

The tax revenues of scenarios 1.1, 2.2 and 3.1 are equivalent by construction, they all lead to an EU-level budget gain of EUR 208 bn. In the middle, we have the flat carbon tax of EUR 80 with green allowances

(S2.1), with a reduced but still positive budgetary effect, of EUR 135 bn. On the other end of the spectrum, the flat tax with compensatory measures (S1.2 and S1.3) would result in no budgetary gains.

Contrarily, the distributional outcomes are the best in the revenue-neutral tax designs where the revenues from the flat carbon tax are recycled with cash transfers (S1.2 and S1.3). The strongest decrease on average and the largest dispersion is observed in 1.3, where the amount of the compensatory transfer is equal for all EU inhabitants (regardless of the increase in tax revenues at the country level).

For the tax designs with positive budgetary effects, we observe inequality-increasing effects in almost all EU countries. With the flat tax without compensations (S1.1), the Gini coefficient increases by 0.0073, on average, ranging from 0 to 0.02 across the 27 EU countries. The increase in inequality would be lower when green tax allowances are introduced (0.0019 under S2.1 and 0.0032 under S2.2). These are about 1/4 and 1/2 the increase in inequality simulated with the flat tax without compensation (S1.1), respectively. Under different tax rates by product (S3), the increase in inequality is somewhere in between: less than with the flat tax without compensation (S1.1) but more than with the green allowances (S2.1 and S2.2). On average, the Gini increases by 0.0051. Differently from the green allowances (S2), in this case, all countries experience an inequality-increasing effect in the range (0-0.016) as shown in Table B.7.

The cross-country simple EU average is very close to the median across all the revenue-collecting scenarios. However, the pooled average leads to systematically higher inequality-increasing effects in all scenarios. This is simply because the carbon tax is not only affecting more low-income households within countries but also more low-income countries within the EU (as it is fixed with an absolute value). Therefore, the distributional results from an EU compensation are worse, in line with what Feindt et al. (2021) reported for 23 EU countries.

Since low-income EU countries tend to have higher levels of income inequality (most of them are Central, Eastern or Southern European countries), designs including compensations (S1.2 and S1.3) would reduce the cross-country dispersion in inequality, whereas the flat tax without compensations (S1.1) increases divergence between countries. On the other hand, EU countries with lower per capita income levels tend to have also lower levels of emissions, especially at the bottom of the distribution (see Figure B.3). Therefore, the green allowance (S2.1 and S2.2) is more effective in mitigating the regressive effect of the flat tax in these countries. Consequently, the undesirable increase in inequality is greater in high-income countries than in low-income countries.

# 5 Discussion

In this section, we discuss the results from our analysis, considering: i) behavioural assumptions of our micro-simulations, ii) the use of disposable income for the distributional analysis, and iii) the feasibility of the scenarios from the point of view of the coexistence of other carbon pricing initiatives, its EU-wide nature and its practical implementation. Based on these limitations we also suggest some future roads for research.

First, our micro-simulations do not account for behavioral responses, meaning potential changes in consumption demand or general equilibrium effects from the simulated carbon taxes are not considered. Consequently, our results should be interpreted as "overnight" effects. Although this imposes some limitations, especially for mid- and long-term analyses, this strategy is commonly used to assess short-term welfare effects of changes in prices or taxes (see, e.g., Amores et al., 2023a, Vandyck et al., 2021, and Feindt et al., 2021). In fact, the literature has suggested that price elasticities of necessity goods (e.g., food and energy), which are among the most carbon-intensive, are not far from zero (Linden et al., 2024;

Labandeira et al., 2017). While beyond the scope of this paper, future research could benefit from applying price elasticities—or ideally, tax elasticities as suggested by Andersson, 2019, who finds that in Sweden, the elasticity of carbon tax is three times larger than the price elasticity—to re-estimate the distributional and budgetary effects. This approach would allow for partial equilibrium ex-ante estimates of potential GHG emissions reductions under various hypothetical carbon tax scenarios.

Since these price/tax elasticities are usually negative (in fact, the primary goal of environmental taxes is to actually reduce the consumption of highly-polluting goods and service) our overnight estimates of the budgetary and redistributive effects could be interpreted as upper bounds. However, it is important to note that self-reported consumption from HBS may underestimate actual consumption, which could partly offset this overestimation, at least in what concerns the budgetary effects.[25]

Moreover, another limitation from the static nature of our micro-simulations is that we do not account for rebound effects when comparing different policy designs. These effects impose an additional limitation to the implementation of compensatory cash transfers, even more, if targeted to low-income households. Some studies have, in fact, shown that environmental policies directed at changing consumer behaviour are most effective when targeted at high-income households, given the higher rebound effect of lower-income households (e.g., see Murray, 2013).

Second, we use equivalised household disposable income to estimate the average tax burden and assess the regressivity and distributional effects of the simulated fiscal reforms. When we mention an "inequality-decreasing effect", we are referring to a decrease in the concentration indicator (e.g., Gini coefficient) of post-tax equivalised disposable income. In this regard, we would like to stress that choosing disposable income rather than other measures (e.g., expenditures) makes an important difference when assessing the regressivity of the policy. As shown by Thomas (2022) for the analysis of consumption taxes, as well as by Feindt et al. (2021) for the simulation of an EU carbon tax, using expenditures (instead of incomes) to assess redistributive effects, make these taxes less regressive. This is simply because savings, which increase with incomes, are left apart (Maier and Ricci, 2024; Linden et al., 2024).

Third, we discuss the plausibility of our scenarios in the current policy context. It seems reasonable to start highlighting that our simulated consumption-based carbon taxes (footprint approach) come on top of some already existing carbon pricing initiatives (mostly based on the emitter approach), such as the EU ETS and some country-specific carbon taxes (see Table 1).

Therefore, the first question that arises here is to what extent an EU carbon tax on consumers may well complement these existing carbon pricing initiatives. There are, at least in theory, some good reasons for the implementation of consumption-based carbon taxes on top of other carbon pricing initiatives. These can, for example, overcome some limitations that are typically associated with the cap and trade systems, such as carbon leakages (i.e., shifting GHG emissions from local producers to production abroad, through imports) and the potential weak pass-through to prices.[26] Carbon leakages and competitiveness problems linked to it can be relieved by making carbon border adjustments (as the new CBAM will attempt to) and/or making households directly responsible for the GHG emissions related to their consumption. In

[25] If self-reported consumption is under-reported, we might underestimate both aggregate expenditures and total GHG emissions, leading to an underestimation of carbon tax liabilities. This under-reporting is common in certain consumption categories, such as alcohol and tobacco. However, some of the most carbon-intensive categories, like housing energy, are typically reported accurately because this consumption is invoiced monthly, making it easier for respondents to recall compared to categories with more sporadic consumption.

[26] Although the literature has actually suggested that pass-through of the cost of emissions is actually quite strong (see, e.g., Cludius et al., 2020, Fabra and Reguant, 2014).

this line, Böhringer et al. (2021) argue that adding a consumption tax on all use of goods that are covered by the free allowances of the ETS is optimal from both a regional and global welfare perspective, in line with previous studies (Böhringer et al., 2017; Holland, 2012; Eichner and Pethig, 2015).

In our study, the simulated carbon taxes come on top of the already existing carbon pricing initiatives embedded in our baseline prices. Note that the forthcoming ETS2 on households does not foresee free allowances, so there might be some overlapping. In any case, the tax designs assessed in this paper could be fine tuned to exclude products under ETS2 or any other product. In this sense, an interesting complement to our study would be to further refine the tax design scenarios to make them more compatible (complementary) to other carbon pricing initiatives by, for example, considering only those GHG emissions exempted from ETS and ETS2.

Another important consideration regarding the feasibility of our scenarios is that a flat carbon tax implemented at the EU level, without adjustments for differences in purchasing power or income, would, *ceteris paribus*, disproportionately affect low-income households within countries and even more so those in low-income countries. Such hypothetical tax could be accompanied by compensatory measures or adjustments based on each country's purchasing power. Note that energy products are among the most carbon-intensive, and while all countries face the same international energy prices, their purchasing power varies. This disparity leads to significant differences in the energy bill burden across countries, even at similar efficiency levels. Implementing a flat carbon tax across countries would further widen this gap. In this sense, we have shown that low-income households in low-income countries would be those benefiting the most from the EU-level revenue-neutral compensatory cash transfer (S1.3). And more in general, both compensatory measures (S1.2 and S1.3) would revert the inequality-increasing effect within countries.

Improving the distributional outcomes of the tax are fundamental to justify its just transition objectives, as using carbon taxation with the only purpose of raising funds suffer from little support (Valencia et al., 2023).[27] In this sense, a flat carbon tax with revenue-neutral compensatory cash transfers to households (S1.2 and S1.3) could be promising, as it is not revenue-increasing and leads to the best distributional outcomes. However, these have at least three important limitations: i) they depend on two different policies (the tax and the transfer), which could challenge their accountability and with it their public support, ii) they are difficult to implement (phase-out strategy, eligibility of beneficiaries, etc.), iii) they do not take into account changes in consumption patterns nor rebound effects, which together with potential strategic behaviours by households can limit their efficacy.[28]

As revenue-neutral compensatory measures are not very feasible in the current policy context, we may want to explore further the advantages and disadvantages of the other simulated scenarios, where we try to make the carbon tax more progressive (or less regressive) by design. The different carbon tax rates across aggregate consumption categories (scenario 3) are, in principle, also relatively easy to implement, as they mimic what consumption taxes do (e.g., by applying reduced VAT rates to first-necessity goods

[27] In their literature review covering 35 studies and 70 surveys suggests that greener spending has higher public support than raising taxes for the only purpose of raising public funds, while evidence is mixed on the support for cash transfers, with wide cross-country variation. Along this line, a recent study for Germany (Sommer et al., 2022) suggests that green spending also increases public support for carbon pricing, but for the case of cash transfers, untargeted measures are more preferred than targeted ones. An interesting discussion on targeted vs untargeted price-related measures as well as income support measure related to the recent hike in energy prices, including the case of Germany, can be found in Amores et al. (2023b) and Amores et al. (2023a).

[28] A way to deal with the latter, and encourage greener demand habits for the additional incomes received as compensation would be to restrict its use to the purchasing of greener products and/or to invest in greening the capital stock, such as in house insulation, etc.

or higher rates to health-detrimental consumption categories). However, we have shown that the gain in progressivity obtained from applying different carbon taxes to consumption categories (e.g., by taxing transport at a higher level than food or heating) is limited and involves the establishment of arbitrary thresholds.[29] In this sense, the carbon tax with green allowances (S2.1 and S2.2), where the first 2.2 $tCO_2e$ are tax exempted) seem more attractive. Overall, although these tax exemptions are not progressive enough to prevent an increase in inequality, they offset a large part of the negative redistributive consequences of the flat carbon tax.

The main drawback of these tax-exempted instruments is their challenging practical implementation, requiring $CO_2$ footprint labeling for all consumption items and a voucher system for households to purchase products accounting for their first 2.2 $tCO_2e$ without the carbon tax, similar to free allowances in the EU ETS. This system could be operationalized through a centralized process where the retailer registers purchases against consumers' ID, mimicking the VAT collection system across the supply value chain. However, beyond the technical challenge that could be solved with blockchain technology, this poses privacy concerns as the central system would track purchases and identify frequented retailers. An alternative based on an anonymous voucher also has disadvantages, as it might be prone to the loss of the vouchers or even a black market of free carbon allowances. Therefore, a technological solution that combines privacy with nontransferable allowances could be envisaged, at least theoretically. Finally, there could also be potential concerns related to cross-border fraud (in case of a flat tax adjusted by the purchasing power of countries to avoid distortions of the single market).

# 6 Concluding remarks

In this study, we assess the distributional consequences of various hypothetical carbon taxes on household consumption across the 27 EU countries. This is especially relevant in the current economic and political landscape in Europe, where fostering "greener" consumer habits and ensuring the public acceptability of such measures are crucial for a just transition.

To simulate these alternative carbon tax designs, we extend the EU tax-benefit micro-simulation model EUROMOD, with information on GHG emission intensities at a very detailed product level from an environmentally extended input-output model (EXIOBASE). With this "Green EUROMOD" extension, we estimate household-level carbon footprints, including emissions from both domestic production and imports, as well as trade and transport services. This is what allows us to simulate carbon taxes for the EU27 countries within a consistent and harmonized empirical framework, based on EU-SILC incomes. As such, our distributional analysis uses the same income concept as Eurostat for the EU-level official measurement of income poverty and inequality.

Our estimates suggest that per capita GHG emissions in the EU are still well above the "sustainable levels" of about 2/2.5 tons of $CO_2e$ a year) consistent with the international (Paris) agreements (see, e.g., Chancel et al., 2022; Gore, 2021; and Ivanova et al., 2016). These emissions vary widely across countries and income groups. Per capita GHG emissions of the lowest income quintiles of the 27 EU countries (bottom 20%) average slightly above 4 $tCO_2e$, while the richest quintile averages over 8 $tCO_2e$. In fact, only the poorest (in terms of incomes) 10% of all individuals in the EU (pooled together, regardless of

[29] The design with different tax rates across products (S3.1) could be enhanced through a better identification of the goods to tax at a lower or higher rate, depending on their share of emissions and the impact on inequality. This can be observed in figures B.6, B.8 and B.7, where we show (for the subcategories of food, transport and energy, for each country) how the impact of a EUR 80 flat tax on every single good would affect inequality and the related share of emissions.

their country of residence) have consumption patterns that are compatible with the 2/2.5-sustainable threshold.

The results from our microsimulations suggest that a flat carbon tax on household consumption (EUR 80 per $tCO_2e$) would be inequality-increasing in all 27 EU Member States, without exception. This negative redistributive effect comes from the regressivity of the tax when it is assessed against the distribution of household disposable incomes. This regressivity arises because lower-income households, which allocate a larger portion of their income to consumption rather than savings, bear a heavier tax burden. This aligns with the findings of Linden et al. (2024) and mirrors the regressive nature of consumption taxes relative to disposable income (Maier and Ricci, 2024; Decoster et al., 2010). The tax's regressivity is further exacerbated by differences in consumption patterns, with low-income households spending more (higher income shares) on GHG-intensive categories like food and residential energy.

The distributional effect largely varies across EU Member States. Countries that would experience the strongest inequality-increasing effects are mostly Central and Eastern European countries. This cross-country dispersion is primarily explained by the differences in the tax burden. While the simulated consumption-based carbon tax would represent almost 9% of disposable income in Hungary, Poland and Greece, it is only 2% in Sweden and France. Differences in the tax burden are mainly driven by the decreasing gradient of income shares of household consumption expenditures across countries' per capita income, the same that drives the regressivity within countries. Again here, there are differences in consumption profiles reinforcing this pattern: the expenditure shares of highly polluting goods (such as heating, food and transport) tend also to be larger in lower-income countries (and households).

This flat carbon tax of EUR 80 per $tCO_2e$ could generate up to EUR 208 billion annually for the EU, more than double the projected budget for the Social Climate Fund. Our results suggest that if these revenues were used to compensate households with a lump-sum cash transfer, the increase in inequality would be fully reverted. However, the practical and political feasibility of these cash transfers is somehow limited. This is why we explore ways of making the carbon tax less regressive and, with it, improving the distributional outcomes without relying on such compensatory measures. In this sense, we show that progressive tax structures, with tax allowances and (although to a lesser extent) differentiating tax rates across products (like VAT), perform relatively well in preventing large inequality-increasing effects and, at the same time, boosting government revenues. These are also quite attractive since they do not depend on a complementary policy (such as the cash transfer), which could make their implementation more challenging, and hamper their public acceptability. These results underscore the potential for carbon taxes to serve as effective tools for both environmental and fiscal policy, provided they are carefully designed to address equity concerns.

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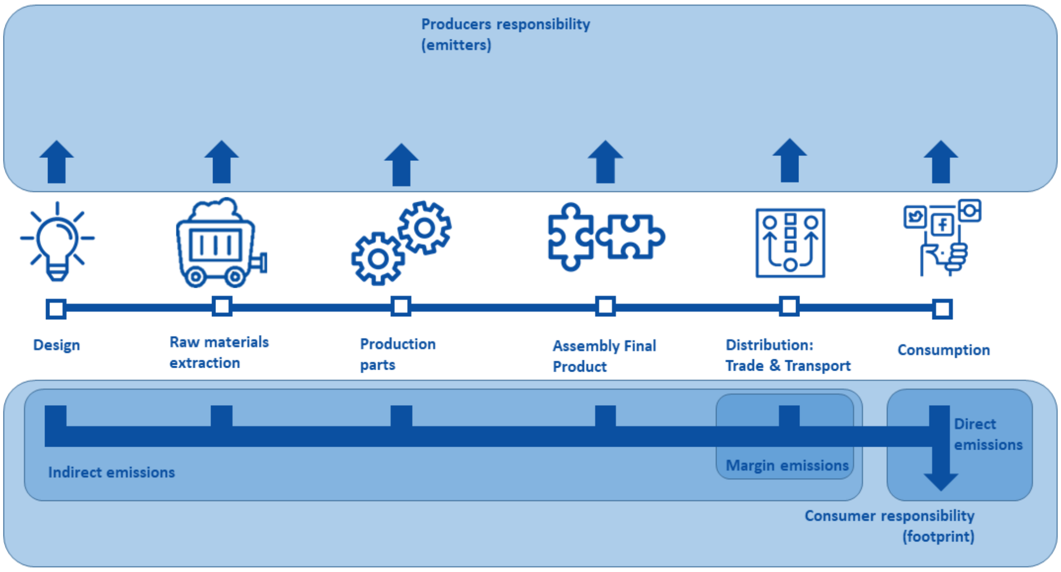
# A Appendix A: data and imputations

## A.1 Approaches on the implementation of the Polluter Pays Principle

Figure A.1: Producer Based Approach vs Consumer Based Approach




Source: Own elaboration.

## A.2 Imputation of HBS consumption expenditures into SILC

This subsection describes the imputation method used to impute households consumption expenditures reported in HBS to SILC's surveyed households. Since the households interviewed in these two surveys are not the same, merging information from one to another requires an imputation method.[30]

To identify similar households across surveys, we adopt the semi-parametric procedure developed by Akoğuz et al. (2020), which combines the estimation of Engel curves (see, for instance, Decoster et al., 2010) with matching techniques. Below we provide a brief step-by-step description of this procedure.

1. **Calculate the source income shares**: For each household $h$'s in the source dataset, $s$ (HBS), the expenditure on a good $i$, $e^s_{h_p}$, is converted into a share of disposable income, $y^s_h$:

$$w^s_{h_p} = \frac{e^s_{h_p}}{y^s_h}, \qquad p \in P \tag{9}$$

[30]In general, we use HBS 2015, with a few exceptions. One is Germany, because a consistent dataset was not available at the time of calculation. Another is Italy, where the process is further complicated due to the absence of net household income data in the HBS surveys. To address this, we first impute income data to HBS using a third survey, the 2010 Survey on Household Income and Wealth (SHIW), before merging HBS with SILC. Finally, another exception is Austria, which is based on proprietary national data from 2010. For more details, see Akoğuz et al. (2020).

These shares are calculated for the $P$ goods available in the HBS (around 200 for most countries).

2. **Aggregate the source income shares**: These income shares are aggregated under broader categories, indexed by $X = A, B, ....$ Thus, the income share of expenditure category X, $W^s_{h_X}$:

$$W^s_{h_X} \equiv \sum_{p \in P_X} w^s_{h_p} \tag{10}$$

3. **Regression analysis**: Source income shares $W^s_{h_X}$ are regressed against a set of covariates common to both the HBS (source, $s$) and SILC (recipient, $r$) datasets. This regression draws on the specification of Engel curves.[31]

   Since aggregated categories $X$ may still have zero expenditures, a two-step regression is performed:

   (a) **Probit model**: The probability of positive expenditure on category $X$ is modelled using a probit model:

   $$Pr\left(W^s_{h_X} > 0\right) = 1 - \phi\left(-\gamma^{'}_X x^s_h\right) = \phi\left(-\gamma^{'}_X x^s_h\right) \tag{11}$$

   where $\phi(\cdot)$ is the standard normal distribution function, $x^s_h$ denotes the vector of covariates for household $h$ in the source dataset $s$, and $\gamma^{'}_X$ contains parameters to be estimated.

   (b) **Regression model**: For households with positive expenditures, a continuous regression model is estimated:

   $$W^s_{h_X} = \beta^{'}_X X^s_h + \epsilon_{h_X}, \qquad W^s_{h_X} > 0 \tag{12}$$

4. **Fitted Values for income shares**: The estimated parameters $\widehat{\gamma}$ and $\widehat{\beta}$ are used to generate fitted values for the income shares of expenditures on the aggregated categories $X$for all households in both HBS and SILC:

$$W^d_{h_X} = \phi\left(-\widehat{\gamma}^{'}_X x^d_h\right) \widehat{\beta}^{'}_X X^d_h, \qquad d = s, r \tag{13}$$

   where $s$ and $r$ denote respectively HBS and SILC.

5. **Distance calculation**: Using the vectors of fitted shares, $\widehat{W}^d$, calculated in the previous step, the Mahalanobis distance between a household $h$ in HBS, and a household $g$ in SILC is defined as:

$$dist\,(h, g) = dist\left(W^r_g, W^s_h\right) = \sqrt{\left(\widehat{W}^r_g - \widehat{W}^s_h\right)^{'} \Sigma^{-1} \left(\widehat{W}^r_g - \widehat{W}^s_h\right)} \tag{14}$$

   where $\Sigma$ is the covariance matrix of the vectors $\widehat{W}^d$, using data from both datasets.

6. **Matching households**: The household $h$ in HBS that has the smallest distance to a household $g$ in the SILC is selected as the match.

7. **Detailed expenditures**: For each match paired $(h, g)$, the income shares of expenditures at the most detailed level of products $p \in P$ for the EU-SILC household $g$, are obtained from the corresponding values of the HBS household $h$:

$$w^r_{g_p} = w^s_{h_p} \tag{15}$$

[31]The covariates include a third-degree polynomial in the log of incomes and detailed household composition characteristics, such as number of household members by gender, labour market status, and age.

## A.3 Green EUROMOD: bridging EXIOBASE to HBS

The step-by-step methodology, coefficients and validation results are reported in Amores et al. (2024). Here we summarize the main steps and methodological choices.

EXIOBASE (v3.8 database) has environmental extensions listed individually in 1707 categories. Most uses of these extensions involve an aggregation of, e.g., different material quantities. Carbon footprints were calculated as the amount of the different GHG in kg$CO_2$-equivalents per yearusing the Global Warming Potential 100 (GWP100), which equivalences are $CO_2$: 1, $CH_4$: 28, $N_2O$: 265, $SF_6$: 23,500.

1. **Direct and indirect intensities**: In this step, we estimate direct and indirect intensities separately. The direct emissions are only relevant for burnable fuels in EXIOBASE. One point of confusion is the treatment of biomass, which is partly treated as an agricultural product in the EXIOBASE energy accounts. The combustion of biomass results in non-$CO_2$ air emissions (biomass is assumed carbon neutral in the $CO_2$ accounts in EXIOBASE). Household emissions are stored in a 3 dimensional matrix in EXIOBASE (extension $\times$ product $\times$ final demand category). These intensities refer to the GHG emissions or other environmental pressures per unit of consumption. Note, total expenditure is used, as these emissions occur on the domestic territory, but can result from the purchase of either domestically produced or imported fuels. For indirect emissions, GHG intensities (emissions per EUR) are obtained from an environmentally extended input-output model built over EXIOBASE at basic prices. All emission sources are allocated to different types of final demand. However, at the sector and transaction level, significant noise may occur in the data, as many small values are estimated with a very low level of accuracy but have an indiscernible impact on total results.

2. **GHG intensities into purchasers' prices**: They need to be transformed into purchasers' prices. To do so, we use the tables of trade and transport margins, and taxes less subsidies on products to relocate the trade and transport services and their associated emissions to the final products consumed by households.

3. **Bridge matrix**: We build bridging matrices to estimate the GHG intensities in COICOP from the EXIOBASE results. We follow a very similar methodology than Ivanova and Wood (2020) but at a much more product granularity (COICOP 5 digits).

   Bridge matrices are usually constructed to bridge between two common observations in two different classifications. For the purpose here, the "observation" is the expenditure of households. The expenditure of households is available in the EXIOBASE classification and is also available in the EUROMOD classification. Given the availability of expenditure in both classifications, bridge matrices can then be estimated in value terms that show the value of products in one classification in terms of the other classification at teh same time.

   While the mapping of EXIOBASE products to EUROMOD products could be done with a manual approximate mapping based on expert choice, the use of "bridge matrices" enhances the accuracy of the accounting as balances are kept: i) all emissions from the source data are transferred to the model provided that bridges converged to the aggregate data during balancing, ii) bridges are calibrated for every country and year aggregate data, what no expert could do manually, and iii) the correspondence between classifications is often such that many products of EXIOBASE products correspond to many products in EUROMOD, so it is not only a matter of aggregation in order to keep the balances mentioned above.

4. **Reconcile the bridge**: The procedure to reconcile the bridge to the EXIOBASE and EUROMOD data is based on the bi-proportional balancing technique RAS commonly used in the

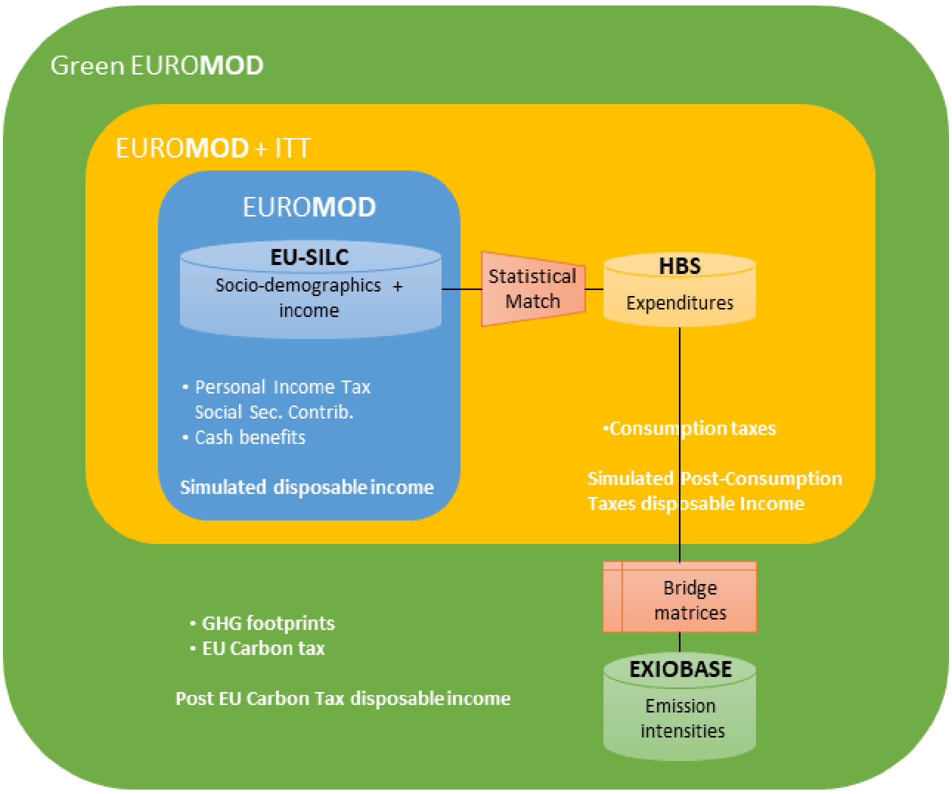
reconciliation of input-output data. RAS is an iterative (optimization) approach, based on entropy theory, where the initial estimate (prior based on statistical data from National Statistical Institutions and expert criteria) of a matrix is alternatively scaled to match the row totals (EXIOBASE) followed by the column totals (EUROMOD calibrated to National Accounts) trying to minimize the divergence from the prior until convergence to an small threshold.

Resulting from the noise in IO calculations, outlier removal is performed on the emission intensities. A number of tests were done on the data in relation to distributions, and the effect of using standard deviations and interquartile ranges. A standard procedure was implemented that a) removed most visual outlier data, b) removed values with low precision, c) did not significantly affect the overall quantification of total emissions but that could distort the results at product level-country.

The emission multipliers generally follow a log-normal distribution. Hence, prior to outlier removal, the multipliers were log-transformed, resulting in a roughly normally distributed dataset.

Figure A.2 shows the main building blocks of the so-called "Green EUROMOD" model, a recent extension developed to incorporate, on top of consumption taxes, household $CO_2$ footprints into the EU-wide tax-benefit microsimulation model EUROMOD.[32]

Figure A.2: Data, interaction of sources and imputations




Note: Green EUROMOD extension: imputation of GHG intensities on HBS-SILC matched files to obtain household carbon footprints associated with consumption expenditures.

[32]EUROMOD is a free and publicly available model and software (https://euromod-web.jrc.ec.europa.eu/download-euromod). Microdata is accessible under application to Eurostat. The Green EUROMOD extension will become public with Amores et al. (2024).

# B Appendix B: Additional results tables and figures

Table B.5: Endogenous carbon tax rates (scenarios 2.2 and 3.1)

| Country | Scenario 2.2<br>$CO_2$ tax over 2.2 tons | Scenario 3<br>$CO_2$ tax - highest rates |
|---|---|---|
| AT | 104 | 105 |
| BE | 112 | 122 |
| BG | 249 | 131 |
| CY | 129 | 108 |
| CZ | 113 | 197 |
| DE | 106 | 141 |
| DK | 115 | 103 |
| EE | 109 | 256 |
| EL | 120 | 168 |
| ES | 164 | 114 |
| FI | 113 | 110 |
| FR | 146 | 108 |
| HR | 232 | 133 |
| HU | 137 | 201 |
| IE | 105 | 123 |
| IT | 122 | 133 |
| LT | 161 | 132 |
| LU | 100 | 119 |
| LV | 123 | 107 |
| MT | 199 | 104 |
| NL | 110 | 112 |
| PL | 126 | 294 |
| PT | 166 | 133 |
| RO | 230 | 292 |
| SE | 155 | 100 |
| SI | 132 | 121 |
| SK | 225 | 130 |
| EU average | 145 | 144 |

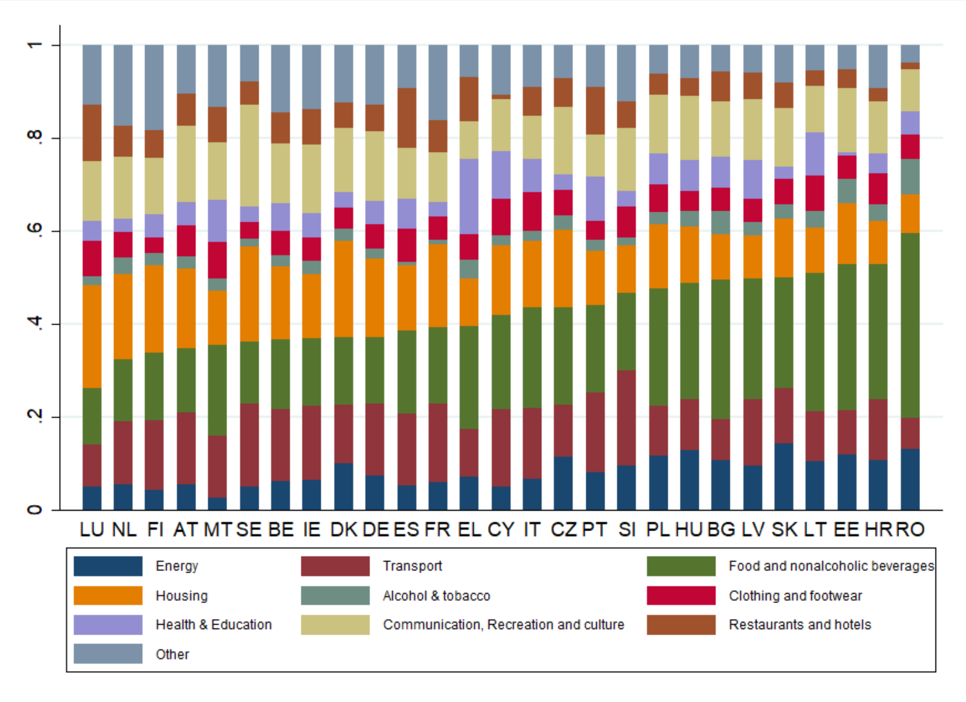
Table B.6: Average tax burden by income quintiles

| | Quintile 1 | | | | Quintile 5 | | | |
|---|---|---|---|---|---|---|---|---|
| Scenario | S1.1 Flat80 | S2.1 GA 2.2 | S2.2 GA 2.2-FB | S3.1 Prog40 | S1.1 Flat80 | S2.1 GA 2.2 | S2.2 GA 2.2-FB | S3.1 Prog40 |
| AT | 5.1 | 3.3 | 4.3 | 4.6 | 3.2 | 2.7 | 3.5 | 3.4 |
| BE | 4.4 | 2.4 | 3.4 | 4.0 | 3.0 | 2.3 | 3.3 | 3.1 |
| BG | 7.3 | 0.2 | 0.5 | 5.3 | 5.0 | 2.7 | 8.4 | 5.7 |
| CY | 5.0 | 1.8 | 3.0 | 4.8 | 3.0 | 2.3 | 3.7 | 3.1 |
| CZ | 11.9 | 7.4 | 10.5 | 9.9 | 5.4 | 4.1 | 5.8 | 6.3 |
| DE | 6.9 | 4.9 | 6.5 | 6.0 | 2.5 | 2.0 | 2.7 | 2.8 |
| DK | 3.7 | 2.3 | 3.3 | 3.8 | 2.1 | 1.6 | 2.3 | 2.1 |
| EE | 14.3 | 9.8 | 13.3 | 11.4 | 4.7 | 3.7 | 5.0 | 5.3 |
| EL | 18.9 | 11.0 | 16.5 | 17.2 | 6.0 | 4.5 | 6.8 | 6.8 |
| ES | 5.3 | 1.3 | 2.7 | 4.9 | 2.2 | 1.3 | 2.7 | 2.3 |
| FI | 4.0 | 2.3 | 3.3 | 3.8 | 2.6 | 2.0 | 2.9 | 2.7 |
| FR | 2.8 | 1.1 | 2.0 | 2.7 | 1.6 | 1.1 | 1.9 | 1.6 |
| HR | 7.9 | 1.1 | 3.2 | 7.0 | 4.2 | 2.2 | 6.3 | 4.5 |
| HU | 12.3 | 3.7 | 6.3 | 10.5 | 7.1 | 4.9 | 8.4 | 8.3 |
| IE | 7.8 | 5.4 | 7.1 | 7.1 | 3.0 | 2.5 | 3.2 | 3.3 |
| IT | 7.0 | 3.7 | 5.7 | 6.3 | 2.9 | 2.2 | 3.4 | 3.2 |
| LT | 9.8 | 3.4 | 6.7 | 8.8 | 3.4 | 2.0 | 4.0 | 3.7 |
| LU | 5.0 | 3.6 | 4.5 | 4.7 | 2.7 | 2.3 | 2.9 | 2.8 |
| LV | 6.8 | 2.0 | 3.1 | 5.6 | 5.1 | 4.1 | 6.3 | 5.4 |
| MT | 3.5 | 0.9 | 2.3 | 3.2 | 1.7 | 0.9 | 2.2 | 1.7 |
| NL | 5.5 | 3.6 | 4.9 | 5.2 | 2.6 | 2.0 | 2.7 | 2.7 |
| PL | 13.6 | 7.0 | 11.0 | 11.8 | 6.2 | 4.4 | 7.0 | 7.3 |
| PT | 9.0 | 3.6 | 7.5 | 7.8 | 2.9 | 1.8 | 3.8 | 3.2 |
| RO | 11.9 | 2.2 | 6.2 | 10.5 | 5.9 | 3.0 | 8.7 | 7.0 |
| SE | 2.8 | 1.3 | 2.6 | 2.8 | 1.4 | 0.8 | 1.6 | 1.4 |
| SI | 7.6 | 4.2 | 6.9 | 7.0 | 3.2 | 2.2 | 3.7 | 3.5 |
| SK | 6.7 | 1.5 | 4.3 | 5.8 | 3.5 | 1.6 | 4.5 | 3.9 |

Table B.7: Distributional effects of the simulated reforms: change in Gini coefficient and in the S8020 indicator across scenarios and countries

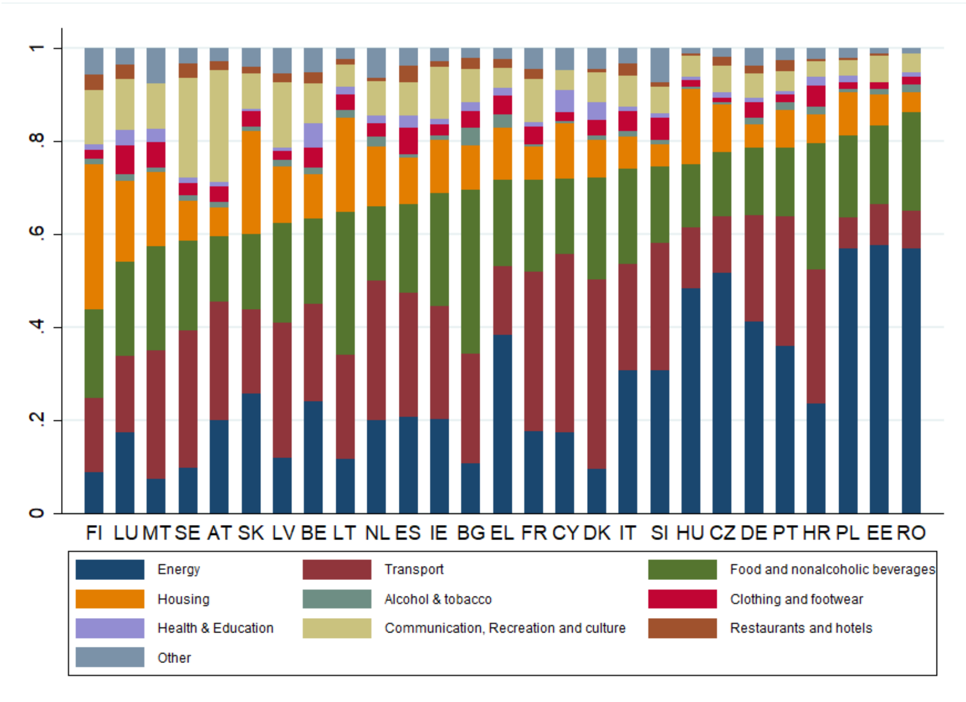
| Scenario | Change in Gini | | | | | | Change in S8020 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1.1 | S1.2 | S1.3 | S2.1 | S2.2 | S3.1 | S1.1 | S1.2 | S1.3 | S2.1 | S2.2 | S3.1 |
| | Flat80 | S1.1 + Cnt comp | S1.1 + EU comp | GA | GA - FB | Prog40 | Flat80 | S1.1 + Cnt comp | S1.1 + EU comp | GA | GA - FB | Prog40 |
| SE | 0.0022 | -0.0021 | -0.0039 | 0.0004 | 0.0010 | 0.0021 | 0.0535 | -0.0347 | -0.0710 | 0.0177 | 0.0347 | 0.0516 |
| FR | 0.0025 | -0.0033 | -0.0051 | 0.0002 | 0.0006 | 0.0023 | 0.0484 | -0.0781 | -0.1175 | 0.0009 | 0.0017 | 0.0430 |
| FI | 0.0029 | -0.0047 | -0.0032 | 0.0007 | 0.0010 | 0.0024 | 0.0492 | -0.0886 | -0.0622 | 0.0095 | 0.0136 | 0.0404 |
| DK | 0.0030 | -0.0029 | -0.0020 | 0.0012 | 0.0025 | 0.0029 | 0.0628 | -0.0596 | -0.0411 | 0.0262 | 0.0381 | 0.0627 |
| BE | 0.0031 | -0.0050 | -0.0034 | 0.0009 | 0.0014 | 0.0023 | 0.0449 | -0.1104 | -0.0806 | 0.0027 | 0.0038 | 0.0278 |
| MT | 0.0033 | -0.0030 | -0.0082 | 0.0001 | 0.0010 | 0.0028 | 0.0821 | -0.0809 | -0.2107 | 0.0015 | 0.0039 | 0.0677 |
| LV | 0.0034 | -0.0160 | -0.0162 | -0.0027 | -0.0038 | 0.0015 | 0.1220 | -0.7332 | -0.7398 | -0.1395 | -0.2162 | 0.0119 |
| AT | 0.0038 | -0.0063 | -0.0027 | 0.0014 | 0.0020 | 0.0028 | 0.0676 | -0.1206 | -0.0542 | 0.0225 | 0.0295 | 0.0443 |
| BG | 0.0044 | -0.0172 | -0.0420 | -0.0048 | -0.0142 | 0.0001 | 0.1810 | -0.8890 | -1.8524 | -0.1813 | -0.5674 | -0.0263 |
| CY | 0.0044 | -0.0082 | -0.0090 | -0.0003 | -0.0002 | 0.0038 | 0.0991 | -0.2266 | -0.2472 | -0.0214 | -0.0350 | 0.0851 |
| LU | 0.0044 | -0.0053 | -0.0010 | 0.0024 | 0.0031 | 0.0037 | 0.1035 | -0.1210 | -0.0227 | 0.0570 | 0.0718 | 0.0861 |
| ES | 0.0048 | -0.0058 | -0.0110 | 0.0002 | 0.0006 | 0.0040 | 0.2000 | -0.2911 | -0.5129 | 0.0016 | 0.0034 | 0.1640 |
| NL | 0.0053 | -0.0036 | -0.0015 | 0.0028 | 0.0041 | 0.0046 | 0.1130 | -0.0793 | -0.0346 | 0.0589 | 0.0825 | 0.0949 |
| SK | 0.0058 | -0.0050 | -0.0139 | -0.0002 | 0.0006 | 0.0037 | 0.1101 | -0.1023 | -0.2633 | -0.0020 | -0.0056 | 0.0672 |
| HR | 0.0061 | -0.0094 | -0.0240 | -0.0018 | -0.0038 | 0.0046 | 0.1934 | -0.3084 | -0.7220 | -0.0529 | -0.1569 | 0.1327 |
| IT | 0.0063 | -0.0063 | -0.0059 | 0.0021 | 0.0035 | 0.0048 | 0.2089 | -0.1904 | -0.1777 | 0.0753 | 0.1174 | 0.1556 |
| SI | 0.0071 | -0.0041 | -0.0051 | 0.0027 | 0.0049 | 0.0059 | 0.1827 | -0.0822 | -0.1030 | 0.0791 | 0.1340 | 0.1457 |
| DE | 0.0073 | -0.0035 | -0.0001 | 0.0046 | 0.0063 | 0.0055 | 0.2106 | -0.0919 | -0.0001 | 0.1326 | 0.1793 | 0.1517 |
| PT | 0.0088 | -0.0055 | -0.0119 | 0.0017 | 0.0041 | 0.0068 | 0.3634 | -0.1682 | -0.3825 | 0.1008 | 0.2180 | 0.2744 |
| IE | 0.0093 | -0.0042 | 0.0004 | 0.0061 | 0.0083 | 0.0077 | 0.2244 | -0.1344 | -0.0179 | 0.1365 | 0.1820 | 0.1785 |
| RO | 0.0099 | -0.0173 | -0.0487 | -0.0018 | 0.0026 | 0.0044 | 0.4651 | -0.8888 | -2.0198 | -0.0605 | -0.1814 | 0.2652 |
| HU | 0.0104 | -0.0182 | -0.0232 | -0.0004 | 0.0004 | 0.0045 | 0.2959 | -0.6641 | -0.8054 | -0.0628 | -0.1108 | 0.1187 |
| LT | 0.0116 | -0.0068 | -0.0140 | 0.0027 | 0.0062 | 0.0096 | 0.4124 | -0.2792 | -0.5213 | 0.0806 | 0.1677 | 0.3187 |
| CZ | 0.0132 | -0.0072 | -0.0036 | 0.0071 | 0.0108 | 0.0078 | 0.2710 | -0.1783 | -0.1040 | 0.1334 | 0.1955 | 0.1504 |
| EE | 0.0164 | -0.0063 | -0.0004 | 0.0101 | 0.0142 | 0.0121 | 0.6061 | -0.1971 | -0.0046 | 0.3652 | 0.5168 | 0.3664 |
| PL | 0.0164 | -0.0102 | -0.0118 | 0.0067 | 0.0132 | 0.0093 | 0.3806 | -0.3280 | -0.3646 | 0.1205 | 0.1992 | 0.2298 |
| EL | 0.0201 | -0.0099 | -0.0074 | 0.0097 | 0.0157 | 0.0162 | 0.8297 | -0.3466 | -0.2646 | 0.3821 | 0.6094 | 0.6629 |
| Min | 0.0022 | -0.0182 | -0.0487 | -0.0048 | -0.0142 | 0.0001 | 0.0449 | -0.8890 | -2.0198 | -0.1813 | -0.5674 | -0.0263 |
| Average | 0.0073 | -0.0073 | -0.0103 | 0.0019 | 0.0032 | 0.0051 | 0.2215 | -0.2546 | -0.3629 | 0.0476 | 0.0566 | 0.1471 |
| Median | 0.0058 | -0.0058 | -0.0059 | 0.0012 | 0.0025 | 0.0044 | 0.1827 | -0.1682 | -0.1777 | 0.0225 | 0.0347 | 0.1187 |
| Max | 0.0201 | -0.0021 | 0.0004 | 0.0101 | 0.0157 | 0.0162 | 0.8297 | -0.0347 | -0.0001 | 0.3821 | 0.6094 | 0.6629 |

Figure B.1: Share expenditures by type of good and country



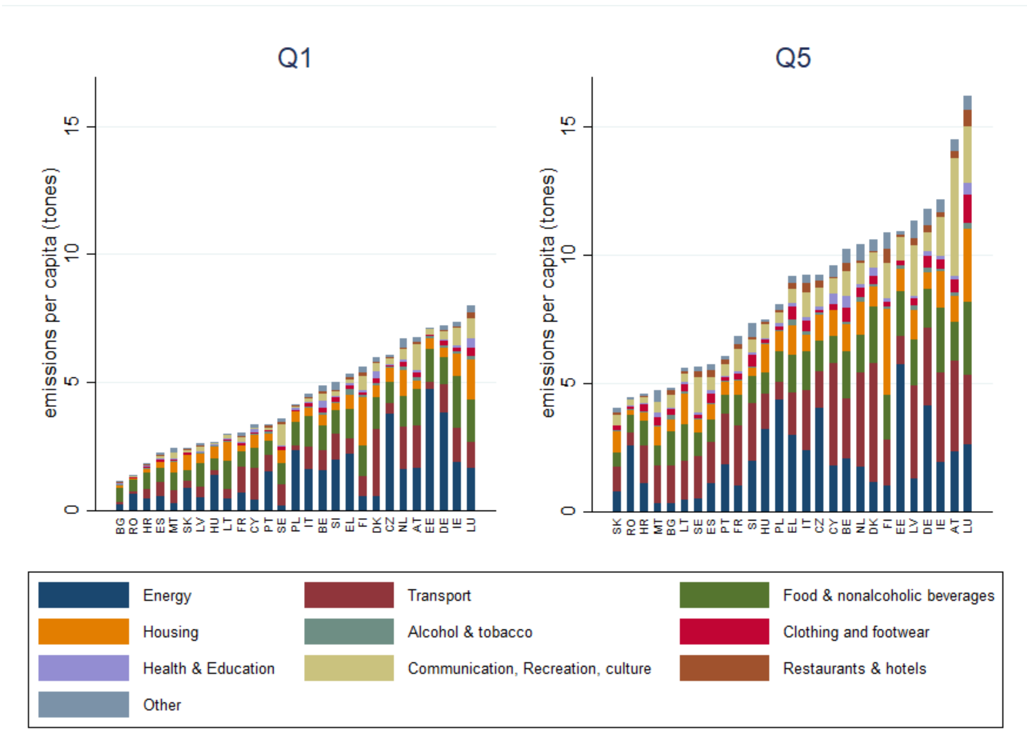

Source: EU-SILC 2015 matched with HBS 2015

Figure B.2: Share of GHG emissions by type of good and country




Source: EU-SILC 2015 matched with HBS 2015 and EXIOBASE 2019

Figure B.3: Per capita GHG emissions by type of good and countries in the first and fifth quintiles.




Source: EU-SILC 2015 matched with HBS 2015 and EXIOBASE 2019

Figure B.4: Distributional effect: change in S8020 ratio

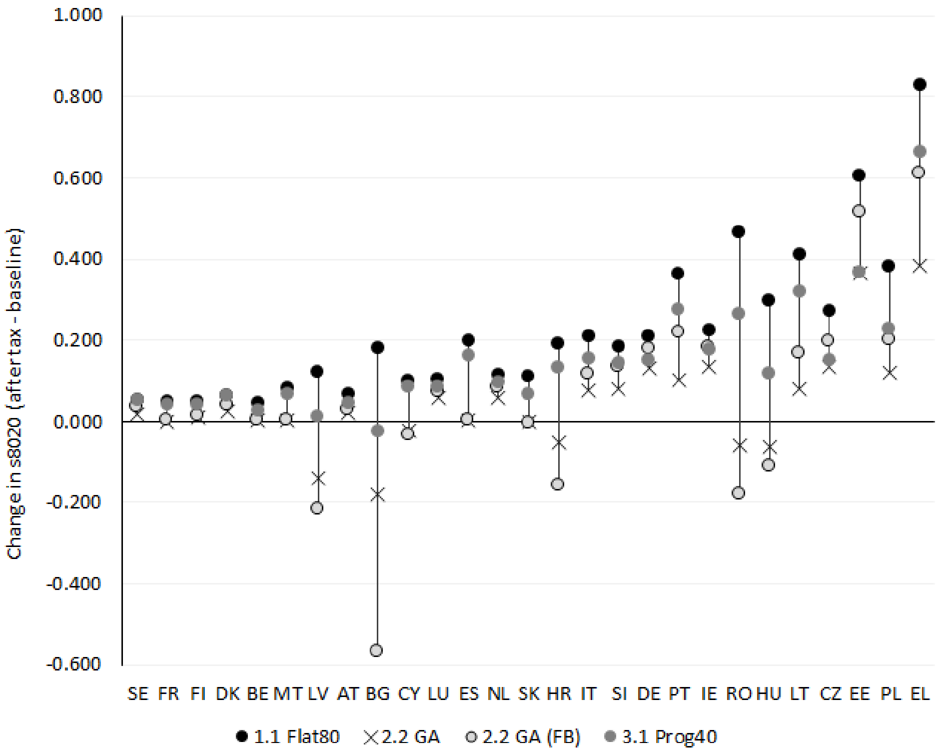



Figure B.5: Carbon tax (S1.1) vs consumption taxes: average tax rate and redistributive effect

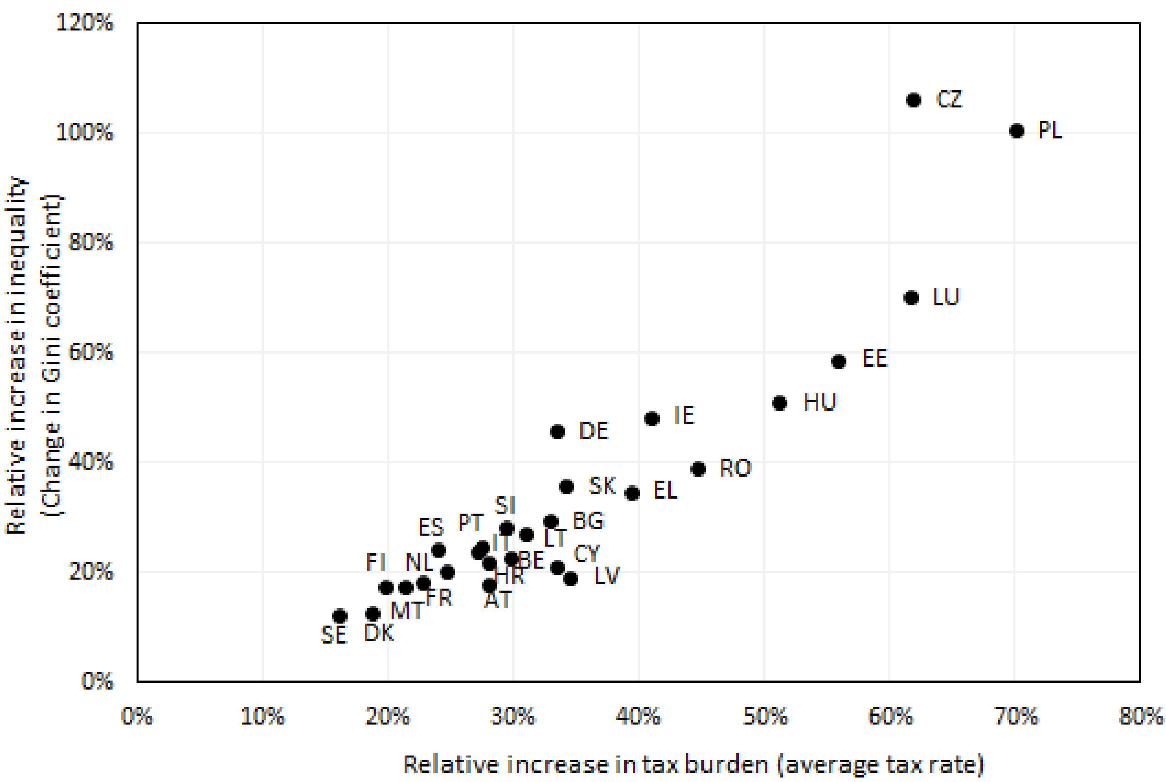


Figure B.6: Share of GHG emissions taxed and impact on Gini coefficient: decomposition Food

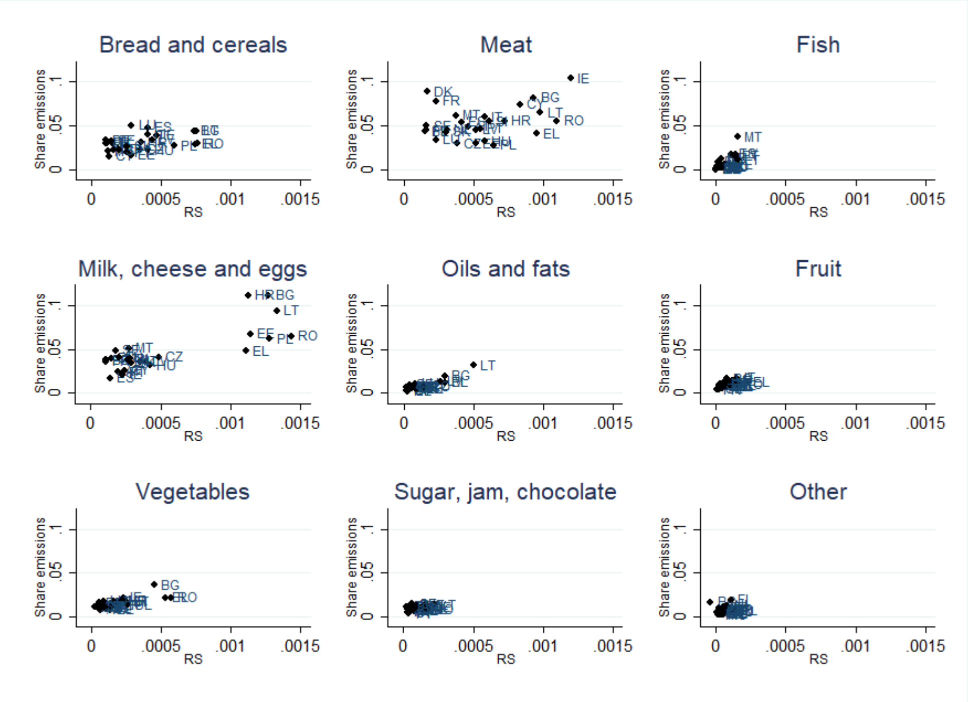



Figure B.7: Share of GHG emissions taxed and impact on Gini coefficient: decomposition Energy

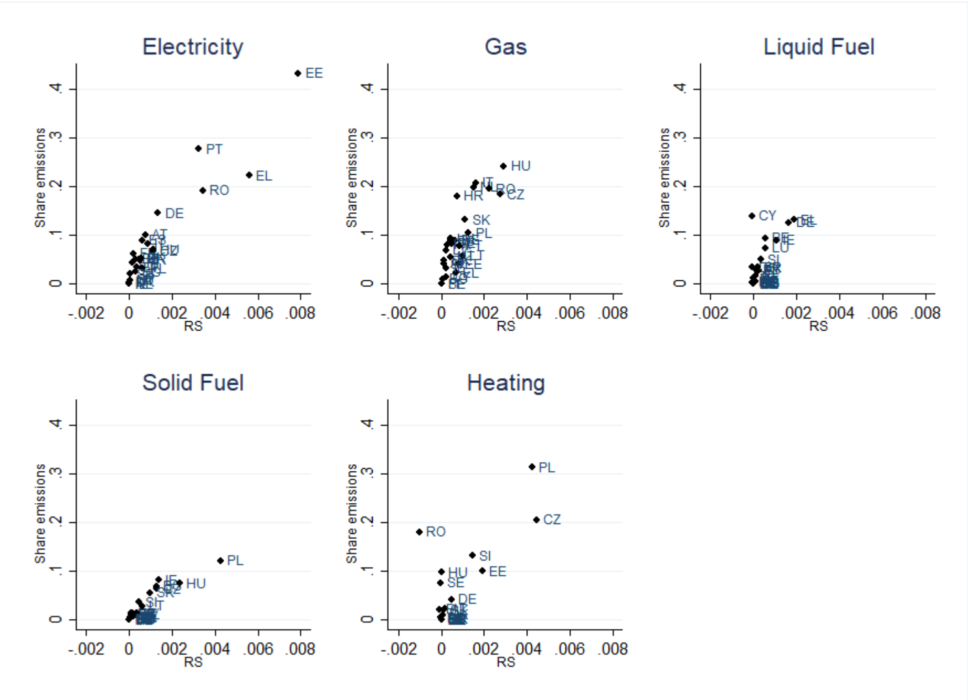
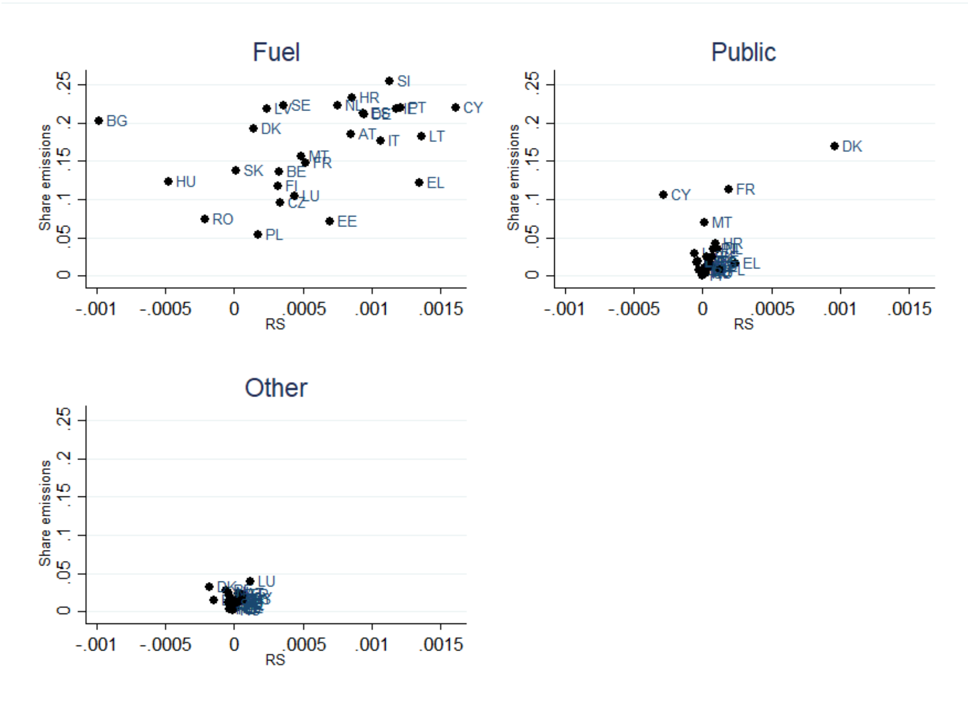


Figure B.8: Share of GHG emissions taxed and impact on Gini coefficient: decomposition Transport



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