University of Antwerp
CSB | Centre for Social Policy Herman Deleeck

Floore Bursens, Silvia De Poli, Sofia Maier, Gerlinde Verbist

Bridging Climate and Social Equity: Progressive Carbon Tax Simulations for Belgium

Working Paper
No. 25/03
March 2025

University of Antwerp

University of Antwerp
Herman Deleeck Centre for Social Policy
https://www.uantwerpen.be/en/research-groups/csb

Bridging Climate and Social Equity: Progressive Carbon Tax Simulations for Belgium

Floore Bursens[1], **Silvia De Poli**[2], **Sofia Maier**[3], **Gerlinde Verbist**[1*]

[1] Centre for Social Policy (University of Antwerp)

[2] Universidad Complutense de Madrid

[3] Joint Research Centre

Working Paper No. 25/03

March 2025

Abstract

This paper explores the distributive impact of a hypothetical carbon tax on households' transport and energy consumption in Belgium. It focuses on the welfare effects across population groups and along the income distribution, as well as on the expected budgetary and environmental effects, accounting for consumer responses under a partial equilibrium microsimulation framework. Given the well-known regressive features of consumption taxes in general, and of energy- or carbon-related taxes in particular, this study evaluates various methods for making the carbon tax more progressive and assesses how these methods affect the overall distributional outcomes. We assess both the expected results as well as the feasibility of each of the tax design scenarios, considering the effect on household income and its distribution vis-a-vis the expected reduction in greenhouse gas emissions.

Keywords: Carbon tax, Belgium, Green EUROMOD, regressivity, just transition, price elasticity

Acknowledgments: The authors are greathful to all those who contribute to the development, update and dissemination of the EUROMOD model. Special thanks go to Salvador Barrios and David Klenert for their feedback on the original draft. The authors are also particularly grateful to their JRC colleagues who have worked in the HBS-SILC matching and in the development of Green EUROMOD, especially Antonio F. Amores, Ilda Dreoni and Hannes Serruys. Any errors in this work remain the sole responsibility of the authors.

*Corresponding author: Gerlinde Verbist (gerlinde.verbist@uantwerpen.be)

Executive Summary

The paper examines the impact of a hypothetical progressive carbon tax on household energy and transport consumption in Belgium, focusing on its distributional, budgetary, and environmental effects.

The study uses Green EUROMOD, the EU tax-benefit microsimulation model extended with carbon footprints (based on matched data from EU-SILC, EU-HBS and environmental intensities from EXIOBASE) to perform static simulations, while accounting for partial-equilibrium demand responses (own-price elasticities).

Carbon taxes tend to be regressive, disproportionately affecting lower-income households. The study evaluates various tax designs to offset this impact while maintaining effectiveness in reducing GHG emissions. Four tax designs are analysed, including a flat tax, tax allowances, product-specific rates (energy vs. transport), and progressive rate structures, to explore their impact on income distribution and emissions reductions.

A flat 80 EUR carbon tax would lead to a relative tax burden of 1.3% of household disposable income, on average. The simulated flat tax is regressive: the highest relative tax burden would be experienced by the lowest quintile (around 2% in the flat rate scenario), and a much lower tax burden faced by the top quintile (less than 1%).

Results suggest that a flat tax of 80 euro (€) would decrease energy-related GHG emissions by 2.5% and transport emissions by 5.1%. These are partial-equilibrium estimates based on own-price elasticities estimated by Temursho and Weitzel (2024).

While progressive tax structures reduce regressivity, they do not fully eliminate it. Taxing transport rather than energy leads to better equity outcomes, as transport expenditures tend to absorb larger income shares at the middle and top of the income distribution, with respect to energy expenditures. The study suggest that there is no inherent trade-off between environmental and redistributive objectives—taxing transport emissions more heavily reduces both inequality and GHG emissions more effectively than energy-focused taxation

The modelled tax would generate approximately €2.16 billion, with an average household tax burden of €446 per year. Revenue recycling through lump-sum transfers (€196 per inhabitant) could totally offset the regressivity of the tax and lead to inequality-decreasing effects. But the government would only need about half of these additional revenues to perfectly offset the increase in inequality and attain the same income concentration as in the baseline (measured by the Gini coefficient.)

Overall, our study shows that a well-designed carbon tax—particularly one that differentiates tax rates by product category—can enhance fairness without compromising GHG emission reductions. However, fully offsetting the tax's negative redistributive effects through progressive (and feasible) tax designs remains challenging. Therefore, compensatory cash transfers may still be necessary—at least as a complementary measure—to fully offset the adverse consequences for low- and middle-income households.

1 Introduction

In 2015, at the Paris Climate Conference, the governments present decided to limit the average temperature increase to less than 2°C, and to make additional efforts to limit it to 1.5°C (UNFCCC, 2015). To achieve this goal, the European Commission developed the European Green Deal. This committed European Union (EU) member states to reduce greenhouse gas (GHG) emissions by 55% from 1990 levels by 2030 and to become climate neutral by 2050 (UNFCCC, 2015). Climate neutral refers to an economy with net zero GHG emissions: a reduction of CO_2 emissions to near zero, combined with the absorption of the remaining emissions into the atmosphere (European Commission, s.d.-a). Under the Climate Law this became legally binding for EU member states. Economists agree that an important instrument to achieve emission reductions, also for households, is a carbon tax. Targeting households has the advantage that such a carbon tax does not generate competitiveness issues or carbon leakages as is the case when taxing production (Hepburn et al., 2020; Parry et al., 2022). Moreover, household emissions on housing energy and transport are also foreseen to be subject to carbon pricing in the expansion of the EU Emissions Trading Scheme (EU ETS) within the framework of the European Green Deal (European Commission, s.d.-a).

During the ecological transition and the pursuit of the objectives of the European Green Deal, it is important to consider three different dimensions: ecological effectiveness, economic efficiency, and social justice. To embrace a "just transition", policy measures must be both ecologically and economically efficient, but must also consider their redistributive effects (Boyce, 2018). The literature suggests that a carbon tax can be seen as an economically and ecologically efficient tool (Edenhofer, 2015; Stiglitz et al., 2017). Nevertheless, especially in high-income countries a carbon tax can be regressive and lead to negative redistributive effects (Boyce, 2018; Callan et al., 2009; Wier et al., 2005). This means that poorer households are hit relatively harder than richer households (Flues & Thomas, 2015). Countries that already implement a carbon tax often use a flat rate, which is a fixed tax per amount of CO_2 emissions. This kind of tax mainly creates regressivity since households from lower income groups pay proportionally more in carbon taxes than households from higher income groups (Poterba, 2017). Klenert and Mattauch (2016) and Klenert, Schwerhoff, et al. (2018), following the double dividend hypothesis (Bovenberg, 2002; Goulder, 1995), however, suggest that an environmental tax can lead to a 'double dividend of redistribution' if the environmental tax revenue is recycled through a lump-sum or a progressive income tax reform. It is important to study and disseminate results on the expected impact of climate policies across households, as this might enhance public support for such policies (Douenne & Fabre, 2022; Klenert, Mattauch, et al., 2018)

This paper explores the redistributive impact of a hypothetical carbon tax on households' transport and energy consumption in Belgium, thereby exploring to what extent the regressive features of a carbon tax can be countered by changing its design. We focus on Belgium, a relatively rich country with a high carbon footprint. Over the past decades carbon emissions have been decreasing in Belgium, though the pace of the reduction has slowed considerably since 2014 and extra efforts are needed to reach national emission targets. There has been debate and policy preparatory work about a carbon tax in Belgium -see e.g., Klimaat.be (2018a, 2023) and Klimaat.be (2018a)-, but until now it has not been implemented. This contrasts with 23 countries in Europe that already have a carbon tax on non-ETS sectors, ranging from 122.87 euros per tonne of CO_2 emissions in Switzerland to 0.09 euros per tonne in Poland; the average carbon tax rate across these 23 European countries was 49.23 euros as of April 2024 (Mengden, 2024). The paper focuses on the welfare effects across population groups and along the income distribution, as well as on the expected budgetary and environmental effects, accounting for consumer responses under a partial equilibrium microsimulation framework. It uses the recently developed `Green EUROMOD', an extended version of the EU tax benefit microsimulation model that includes household carbon footprints from

EXIOBASE's input-output tables. This study evaluates various methods for making the carbon tax more progressive and assesses how these methods affect the overall distributional outcomes. We assess both the expected results as well as the feasibility of each of the tax design scenarios, considering the effect on household income and its distribution vis-a-vis the expected reduction in GHG emissions.

In section 2 we discuss the rationale, objectives and characteristics of a carbon tax. We focus on the different options of making a carbon tax progressive by changing its design. After explaining data and methodology in Section 3, the empirical outcomes are presented (Section 4). The paper ends with a discussion and conclusion in Section 5.

2 Making Carbon Taxes Progressive

Why a carbon tax?

“Greenhouse gas emissions are externalities and represent the biggest market failure the world has seen” (Stern, 2008). A carbon tax is a Pigouvian tax which internalizes the externality (Metcalf & Weisbach, 2009). Taxing carbon increases the cost of fossil fuels, resulting in a decrease in both fossil fuel consumption and associated CO_2 emissions (Beiser-McGrath & Bernauer, 2019). It is an essential part of demand-side policies in climate-mitigation strategies, as it aims to reduce overall energy demand by encouraging energy conservation and saving on the consumption side (Yi, 2015). There is a consensus among economists that for the reduction of GHG emissions an efficiently designed system of carbon pricing should be preferred over non-market and regulatory instruments (Baranzini et al., 2017; Timilsina, 2022). It is the most cost-effective way to reduce GHG emissions (Stiglitz et al., 2017). In the short term, it encourages households, businesses, and governments in an efficient way to reduce their emissions. In the long run, it provides incentives for innovations to reduce the cost of reducing emissions (Boyce, 2018). On top of that, the cost to the government of such carbon pricing is fairly low, especially compared to other policies that aim to reduce GHG emissions (Baranzini et al., 2017). Carbon pricing can be done either in the form of an emission-trading system or of a carbon tax. For households, the carbon tax, which imposes a tax per unit CO_2 emissions, is the most relevant carbon pricing instrument. A carbon tax is a useful tool for climate policy as it can cover huge emissions at relatively low administrative costs (Zhang et al., 2016). On top of that, a carbon tax can promote improvement and innovation in technology, equipment and capital investment in countries where it is implemented (Eide et al., 2014).

The main objective: ecological effectiveness, reducing emissions

Many empirical studies show that a carbon tax can effectively reduce carbon emissions or at least moderate their growth (Andersson, 2019; Köppl & Schratzenstaller, 2023). On top of that, research shows that implementing a carbon tax improves environmental quality but also reduces the production and consumption of carbon-emitting goods. Some case studies have already been conducted in Sweden to investigate the ecological effectiveness of a carbon tax. Sweden is an interesting example since it has already imposed a carbon tax since 1991 (Johansson, 2000) and on top of that, this tax is of a high level. In 2024, the tax was €118.35 per tonne of CO_2 emissions (Mengden, 2024). However, some case studies present little evidence for ecological effectiveness (Lin & Li, 2011; Shmelev & Speck, 2018). In turn, other studies show that an emissions tax in the transportation and residential sectors does reduce emissions (Andersson, 2019; Runst & Thonipara, 2020; Thonipara et al., 2019). In European countries other than the Nordic countries, less research has been done for now on the ecological effectiveness of a carbon tax (Köppl & Schratzenstaller, 2023). Studies do show that carbon taxes in France, the United Kingdom and

Switzerland have caused reductions in CO_2 emissions (Dussaux, 2020; Hintermann & Zarkovic, 2020; Martin et al., 2014). Thus, there is mixed evidence on the ecological effectiveness of a carbon tax.

Efficiency considerations

While the main objective of a carbon tax is ecological effectiveness, i.e. reducing GHG emissions, it has economic efficiency and social inequality arguments matter. In general, the literature points towards the economic efficiency of this type of policy: it appears that at the macro-level the carbon tax reduces GHG emissions without negatively affecting economic growth, employment, and competitiveness (see for instance Andersen et al. (2007); Goulder (2000); Metcalf and Stock (2020)). This is why carbon pricing is considered a very useful policy tool, as “it can achieve a great deal at low cost and high efficiency” (Hepburn et al, 2020).

Equity considerations: regressivity

In terms of social inequality the literature shows that a carbon tax in general has a regressive effect, i.e. the relative tax burden increases with living standards, thus increasing inequality (see e.g. Callan et al. (2009); Fullerton et al. (2011); Marron and Toder (2014); Joumard et al. (2013); Fremstad and Paul (2019)). Boyce (2018) found that for the United States households in the highest ranks of the income distribution emit the most and thus pay more in absolute terms in carbon taxes than middle- and lower-income households. However, relative to their household income and expenditures, higher-income households pay less (Boyce, 2018). Also in Ireland, Callan et al. (2009) found that a carbon tax is regressive, though the extent of regressivity varies according to type of expenditure, being more pronounced for a tax on emissions for home heating than for motor fuel (Callan et al., 2009). Also for Denmark Wier et al. (2005) found that the carbon tax became smaller in relative terms as income increases. The main reason for this regressive pattern is that emission intensive goods like housing energy make up a large part of poor households’ expenditures.

Revenue recycling options for reversing the regressivity impact

A socially sensitive ‘recycling’ of carbon tax revenues is one way to address this problem of regressivity. Recycling means injecting carbon tax revenues back into society in some way. There are several options for this. Timilsina (2022) lists the ways of recycling most commonly proposed in the literature, such as a reduction in other taxes or a benefit to households. In addition, one can also use the funds to subsidise low-carbon or carbon-neutral technology, to reduce national debt or to support energy-intensive industries exposed to international competition. From the economic perspective of cost efficiency (i.e. their impact on GDP or welfare), Timilsina (2022) ranks revenue recycling schemes from a carbon tax based on the literature as follows. Recycling tax revenues to invest or to reduce capital taxes or corporate taxes are the best options based on efficiency, as they can generate economic gains (i.e. an increase in GDP or welfare); even if they generate economic losses, those losses would be the smallest compared to other revenue recycling schemes. Using carbon tax revenue to reduce labour taxes comes next, followed by a transfer to households as a lump-sum benefit. Using carbon tax revenue to reduce public debt, subsidise clean technologies or increase public spending are the most expensive options for recycling carbon tax revenue into the economy. From the equity perspective, however, the ranking turns out to be very different. A reduction of taxes on income from capital leads to a further increase in regressivity and income inequality. After all, income from capital is relatively more situated at the top of the income distribution and a reduction of such a tax on this income will favour higher incomes relatively more. So this scores poorly from the social inequality perspective. Revenue recycling by giving households a lump-sum benefit is then a clearly better instrument, as relatively low incomes will benefit more. Such a benefit is also known as a carbon dividend. For instance, with the ‘*Greenhouse Gas Pollution Pricing Act*’ of 2018, Canada introduced such a ‘*carbon fee and dividend*’ at the federal level, of which mainly higher-income earners are net contributors, while by far most households gain from the system. Several studies have investigated the distributive consequences of such revenue recycling schemes. Little attention has, however, been paid to designs within the carbon tax system to make it more progressive, which is the focus of this paper.

Making a carbon tax progressive

We investigate the different options of making a carbon tax progressive, by changing the basic building stones of the tax. These basic building blocks are (1) the tax base, (2) the tax rate, and (3) possible tax allowances, which all represent deviations from a traditional flat-rate carbon tax. A first option is to adjust the tax base, which most commonly is the amount of CO_2 a household emits. One might choose to apply differential rates here between goods depending on the intensity of use by lower versus higher income households (Maier et al., 2024). Emissions caused by food, energy, alcohol, and tobacco are rather equally distributed across income groups, while transport, clothing and footwear, communication, recreation and culture, restaurants and hotels are more concentrated at the top of the income distribution (Maier et al., 2024). To make the effects of a carbon tax less regressive, one might charge higher rates on consumption of the latter group. A second way is to give an exemption for up to a certain amount of CO_2 emissions, so-called “green allowances” (Maier et al., 2024). Research shows that poorer households emit less in terms of energy and transportation than richer households (Druce, 2017; Sager, 2019). Therefore, it could be useful to provide a carbon tax allowance based on CO_2 emissions. The motivation is twofold: make the system less regressive by reducing the tax burden on low-consumption households, while simultaneously sending a message about what constitutes sustainable behaviour (Maier et al., 2024). The final option to reduce the regressive effects of a carbon tax is to apply a progressive rate structure. Instead of using a flat rate where everyone pays the same rate per unit of CO_2 emissions, one can use a differentiated tax rate where the rate per tonne of emissions increases as the household's emissions rise. This can have a progressive effect because the average tax rate, or the amount of tax paid as a percentage of income, increases as income increases (Varela, 2016). These options differ not only in terms of design, but also in terms of practical feasibility, a topic on which we come back in the discussion.

3 Data and methodology

This research paper will use Green EUROMOD to devise and simulate different designs for a progressive carbon tax imposed on households in Belgium. Green EUROMOD expands the EU tax-benefit microsimulation model EUROMOD from the European Commission with data on household carbon footprints from consumption. As such, it allows for the simulation of green taxes considering the GHG emission content.

First, this section will describe the data used for this research (3.1). Next, it will explain how microsimulations are carried out within the framework of Green EUROMOD (3.2). Then, it introduces the different tax designs that are simulated (3.3) and how the redistributive effects and tax burden will be measured (3.4). Finally, it explains how the behavioural reactions are estimated (3.5).

3.1 Data

The data sources used in this research paper are the EU Statistics on Income and Living Conditions (EU-SILC), the Household Budget Survey (HBS) and EXIOBASE. Both household surveys, the EU-HBS and EU-SILC are from 2015. EU-SILC collects data on income, socio-demographic characteristics and living conditions of households. It is the official source of income poverty and inequality measurement at the EU level. Data on social exclusion and housing conditions are collected primarily at the household level, while information on employment, education, and health are taken from individuals as young as 16 years old. Income variables are also collected primarily from individuals (Eurostat, s.d.-a). This study uses the cross-sectional data.

HBS is conducted in all member states and are harmonized ex post by Eurostat (Eurostat, s.d.-c). They are national surveys that focus on household expenditure on goods and services. The main purpose is to calculate the weights for the consumer price index (Eurostat, s.d.-c). In addition, it is also an important working tool to analyze and describe the consumption habits of the population at the Belgian (and European) level (Statbel, s.d.).

EXIOBASE is a global "Multi-Regional Environmentally Extended Supply and Use Table and Input-Output Table." The Supply Table refers to the supply of both domestic and imported goods and services by product and type of supplier in base prices, while the Use Table shows the use of goods and services by product and type of use in purchase prices (Tukker et al., 2009). The input-output table refers to the fact that all the information from the entire economy of a country is placed in the model. The output then obtained from this is linked to emissions. In this way, one knows how many emissions each good causes within an economy. Multi-regional refers to the fact that countries and world regions are distinguished from each other. This contrasts with a single-region input-output model, which assumes that imported goods and services are produced using the same technology as domestic technology in the same sector. The advantage of using a single-region model is that analyses are more specific and detailed (Wiedmann, 2009). Multi-regional input-output tables contain data that describe the complex network of global economic relationships and their environmental consequences (Stadler et al., 2018).

These three data sources are linked to each other. First, data from HBS is linked to data from EU-SILC through imputation. This allows for research on direct taxes and cash benefits as well as indirect taxes (Amores et al., 2023). Then, data from EXIOBASE is also linked to this, providing a dataset that includes information on income, expenditure and emission coefficients (see below). This linkage was carried out by the Joint Research Centre (JRC) and is documented in a study that undertakes carbon tax simulations for all the EU 27 countries (Maier et al., 2024). The JRC is the internal scientific service of the European Commission. The JRC provides independent, science-based knowledge to support EU policies to have a positive impact on society (European Commission, s.d.-c).

3.2 Methodology: tax-benefit model Green EUROMOD

Microsimulation is a broad spectrum of modelling techniques that work at the level of individual units. It involves the application of various rules to simulate changes in behavior. The best-known application of the microsimulation method is to study effects of changes in tax and benefit policies on income distribution, but it is also a useful method to analyze existing income distribution and redistribution (Figari et al., 2015). EUROMOD allows researchers and policymakers to examine for instance the redistributive effects of changes in taxes and benefits. Data is coded in the same way for all EU member states, making it easy to compare countries and implement policy swaps. EUROMOD is a static microsimulation model. It considers only the first-order effects of a policy measure. Thus, behavioral changes are not taken into account (Sutherland & Figari, 2013). EUROMOD contains three central elements: the coded policy measures, the input microdata, and the software (European Commission, s.d.-d). EUROMOD's standard input data comes from EU-SILC (see section 3.1). In this research paper, we will work with Belgium's 2019 policy system.

This paper uses Green EUROMOD, which is the new environmental extension of the EU tax-benefit model EUROMOD. The Green EUROMOD model extends the input databases used for the simulation of consumption taxes in EUROMOD with information on GHG emissions associated with household consumption (European Commission, s.d.-b; Maier et al., 2024)

Green EUROMOD uses emission coefficients, also called GHG multipliers. These emission coefficients from EXIOBASE are imputed into HBS-SILC EUROMOD files through bridging matrices (Maier et al., 2024). The emission coefficients consist of direct and indirect GHG emissions. Direct emissions are generated by the burning of fossil fuels by households, e.g. caused by car use and heating (energy and transport). Indirect emissions are emissions integrated in the production and trade of goods (Lévay et al., 2021). The emission coefficient or multiplier (m_p) is then the number of tonnes of CO$_2$ equivalent GHG emissions ($tC02e$) per euro spent on good p.

$$m_p = m_{p,direct} + m_{p,indirect} \qquad [1]$$

Using this emission coefficient, the household carbon footprint (HCF_h) can be calculated as in equation [2]. This carbon footprint is the sum of the product of the emission coefficient of all consumption categories or products p, and the income shares going to those products p, ys_p (from HBS) and disposable income (Y_h^{disp}), which comes from EU-SILC and EUROMOD.

$$HCF_h = \sum_{p=1}^{P} m_p \, ys_{ph} \, Y_h^{disp} \qquad [2]$$

In the case of Belgium, there are 193 consumption categories considered in the estimation of carbon footprints (i.e., P=193). The most recent year for which the bridge between EXIOBASE and EUROMOD has been done is 2019, while the most recent EUROMOD file with imputed expenditures from HBS refers to expenditures from 2015. Therefore, we use EUROMOD model to uprate market incomes from HBS 2015 to 2019 and then apply the tax-benefit rules of that year to obtain incomes after direct taxes, social insurance contributions, and considering cash benefits.

3.3 Simulated carbon tax designs

Though a carbon tax has been the topic of debate in Belgium it has until now not been implemented. In preparatory policy work the Federal Climate Change Department presents three possible price trajectories, along with impacts on the buildings and transportation sectors (Klimaat.be, 2018b), which serves as an interesting starting point for our hypothetical household carbon tax scenarios. The Climate Change Department suggested the following prices: 40, 70 or 100 euros per tonne of CO2 for 2030 (Klimaat.be, 2018a). A carbon price of 70 euros per tonne could generate 2.6 billion euros annually in Belgium by 2030. The report therefore also indicates what could be done with the revenue generated to reduce the potentially negative impacts and thus enhance acceptability. In general, part of the revenue could be used to reduce labor costs or the cost of electricity. Another part of the revenue could be used to compensate the most vulnerable, since a carbon tax in the building sector could be regressive. Finally, the report indicates that revenues from the transportation sector could be redistributed through measures that encourage active forms of transportation, public transport and electric travel. In 2023, the Climate Change Department published the report 'The landscape of carbon and energy pricing and taxation in Belgium', which was produced in collaboration with the FOD Finance (Klimaat.be, 2023). The report suggests that carbon and energy tax reforms will be necessary in the coming years to enable the transition to a climate-neutral economy (Klimaat.be, 2023). A recent study for Belgium shows that carbon emissions would reduce significantly when carbon pricing is introduced in the transport and building sector in Belgium (Heyndrickx et al., 2022).

In this paper we simulate a carbon tax on two types of goods, notably housing energy and transport fuels, which account for 33% of total CO_2e GHG emissions. These include mainly vehicles fuel and heating. These two categories are also the ones that will be liable to the ETS2 system envisaged by the EU Green Deal as of 2027. We exclude electricity from the tax base, as a major part of the green transition includes an electrification of the economy, and hence incentives for green electricity are part of this strategy (for a similar approach for Sweden, see Ricardo Energy and Environment (2018)). We consider both direct and indirect emissions in the tax base; although in both cases direct emissions are the bulk (about 59 and 80% for transport and energy, respectively).

Even though Belgium currently does not have a carbon tax on household emissions, this does not mean that consumption, and more specifically energy and transport fuels, are not taxed.[1] However, these taxes are not related to the carbon content of the products and we leave them in place for the alternative tax designs that we simulate.

Table 1: Overview of the different simulated scenarios of tax designs (TD)

Scenario		Tax rate in euro (2019 values)	Threshold in tonne CO_2e
TD1	**Flat tax rate** per tonne of CO_2e GHG emissions on transport fuel and energy consumption	80	n/a
TD2	Flat rate with **tax allowance** calculated at p25 of yearly GHG emissions in each category	103.58	p25 (E: 0.45; T: 0.24)
TD3	Different tax rates according to **product category**		
TD3_b	Higher rate for **transport** fuel emissions	E: 51; T: 120	n/a
TD3_t	**Only transport** fuel emissions	E: 0; T: 191	n/a
TD3_e	**Only energy** emissions	E: 137; T: 0	n/a
TD4	Progressive rate structure on yearly GHG emissions, with three rates and two thresholds (p25 and p75)	0; 80; 150	p25 (E: 5; T:0.24) p75: (E: 1.9; T:1.4)

Notes: E= Energy; T=Transport fuel; p25 and P75 are percentiles 25th and 75th, respectively.

Table 1 summarizes the various designs of carbon taxes that will be simulated. We start with a flat rate scenario of 80 euros per tonne of CO_2 emissions[2] (TD1) which will also serve as reference scenario for the

---

[1] In Belgium there are different types of taxes on energy and fuel. For taxes on energy, four types can be distinguished. First, there is a 6% VAT on energy. Second, there is the energy tax, which is an indirect tax, levied on the consumption of electricity. Third, there is also a federal contribution to finance certain public service obligations and to finance the costs incurred by the control and regulation of the electricity market. Finally, there is also a regional energy tax, introduced by regional governments (Commissie voor de Regulering van de Elektriciteit en het Gas, s.d.). For fuel, we distinguish between gasoline, diesel and liquid petroleum. In 2023, the VAT rate on gasoline and diesel was 17%. Excise tax rates were 32%, resp. 22% on gasoline resp. diesel. On liquid petroleum gas, there is only a 17% VAT rate (FOD Volksgezondheid en Veligheid van de Voedselketen en Leefmilieu, 2023).

[2] Our tax covers all GHG emissions, but we refer to tonnes of (equivalent) CO2 emissions. To do so we merge all GHG -i.e., Carbon dioxide (CO2), Methane (CH4), Nitrous oxide (N2O), Hydrofluorocarbons (HFCs),

other alternative designs. The other tax designs are set up in such a way that they are budgetary neutral as compared to TD1; scenario TD1 generates 2.16 billion euro in revenue. This is about 10% of the revenues generated by VAT.

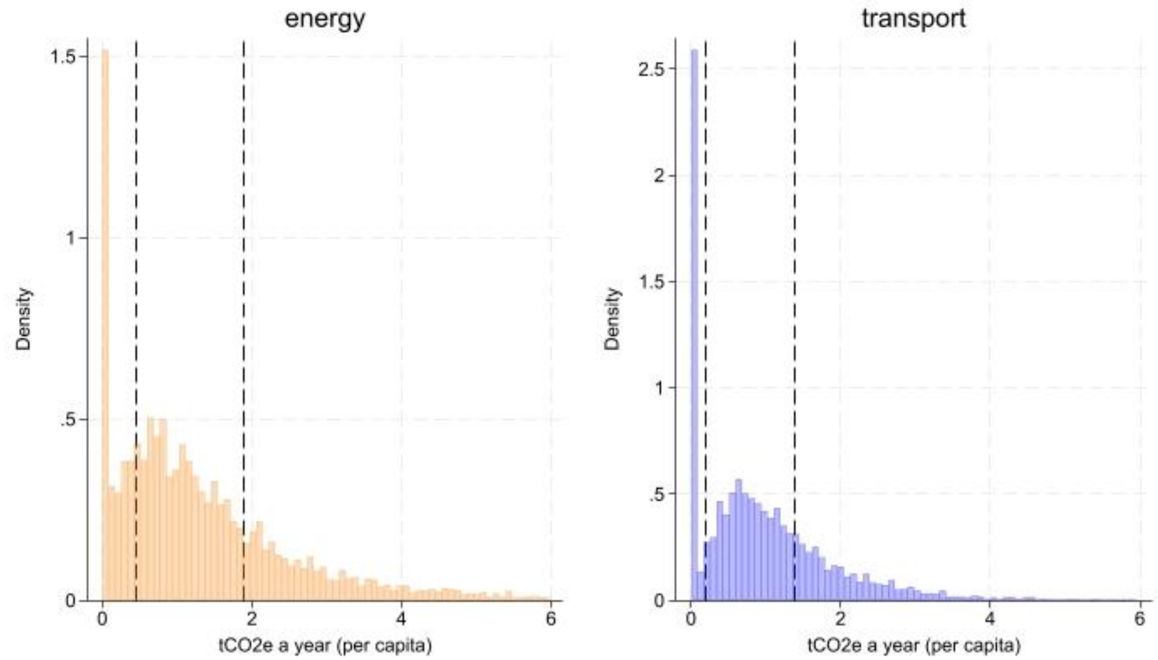
In scenario TD2 we introduce an allowance, which means that emissions under a certain threshold per year remain untaxed. The allowance takes into account household size and is calculated separately for energy and transport. The threshold is set at percentile 25 (p25) of emissions for each category (see Figure 1); emissions above the threshold are taxed at a flat rate of 103.58 euro, which is determined in such as to achieve budget neutrality.

In scenario TD3 we apply different tax rates according to product category, thereby presenting three variations of the scenario. Scenarios TD3_t and TD3_e can be considered as hypothetical extreme scenarios where we either collect all the budget through a tax on transport fuel (rate of 191 euro), resp. on energy; these scenarios are included mainly for illustrative purposes. Scenario TD3_b is in between with a higher rate for transport. The motivation for this differentiation relates to the fact that energy-related emissions are more concentrated among low-income households than transport-related emissions. We chose to tax emissions from transport at 120 euros per tonne of CO_2, a rate that is about 50% higher than the baseline but still meaningful on policy grounds, as it is not that far from actual carbon tax rates in some high-income countries. The rate for energy (51 euros, see Table 1) is endogenously estimated to ensure budget neutrality with respect to TD1.

Finally in scenario TD4 we apply a progressive rate structure on emissions with three rates that increase with total yearly GHG emissions. This rate structure takes into account the household size and is again calculated separately for energy and transport. Households emitting less than percentile 25 are taxed at 0 euro per tonne CO_2 emissions. Households emitting between percentile 25 and percentile 75 (p75) are taxed at 80 euros per tonne. Green EUROMOD is used to determine the tax rate for households emitting more than p75, ensuring again budget equivalency.

Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6), Nitrogen trifluoride (NF3)- weighting them by their Global Warming Potential (GWP100) as from the IPCC.

Figure 1. Histograms of per capita GHG emissions (tCO2e) from transport and energy



Notes: vertical dashed lines indicate the percentiles 25 and 75 of each consumption distribution. Data from Green EUROMOD (expenditure from HBS 2015 uprated with EUROMOD to 2019 under constant income shares assumption). Energy excludes electricity. Transport considers only vehicle fuels. About 15% and 25% of the population have zero expenditures on these two items.

3.4 Welfare effects

To measure the welfare effect of the simulated tax reforms, this study uses the concept of compensating variation. The loss in welfare after a shock in prices generated by the introduction of the tax is measured as the additional income that a household would need to keep the consumption basket of the baseline under the new prices (Feindt et al., 2021; Linden et al., 2024)). This is what is called equivalent income, following King (1983).

Incomes are pooled at the household level, are net of direct taxes and social insurance contributions and include cash benefits. This is what we call “disposable income”, i.e., incomes to spend or save. The OECD equivalence scale is used to compare the incomes of households of different size and composition (Eurostat, s.d.-b). The so-called ``modified-OECD equivalence scale" assigns a value of 1 to the first member of the household, 0.5 to each subsequent adult (>14 years) and 0.3 to each child (<14 years) (OECD, s.d.).

The tax burden is an important indicator to assess the redistributive effects of the tax, and it is calculated, in a standard way, as taxes paid as a share of a household's equivalent disposable income in the baseline (Amores et al., 2023).

To measure the redistributive effect of the simulated carbon taxes, the Gini coefficient of equivalised income before the tax will be compared to the Gini coefficient of income after the tax (an income calculated under compensating variation, as explained above). This is also known as the Reynolds-Smolensky index (Reynolds & Smolensky, 1977). The Gini coefficient compares the cumulative proportions of the population with the cumulative proportions of the income they have. The value of the Gini coefficient is between zero and one. Zero represents perfect equality, one represents perfect inequality. If the value for the Reynolds-Smolensky index is positive, it means that the distribution of income after the tax is less concentrated than the distribution before the tax (Reynolds & Smolensky, 1977). This happens when the tax is progressive. Progressivity in relative terms can be calculated using the Kakwani index (Kakwani, 1977). This compares the share in total sum of taxes with the share in income before taxes (Gini coefficient before taxes). A positive value for the index means that the tax is progressive (Kakwani, 1977). Following Kakwani's decomposition of the RS indicator, the more progressive (or regressive) the tax, and the larger the tax burden, the stronger the redistributive effect of the tax will be (see, e.g., (Verbist & Figari, 2014).

The distributional consequences of a carbon tax across households can also be measured across non-income dimensions. This paper examines the effects of each carbon tax design on the horizontal distribution, considering the following different household and individual characteristics: household size, number of rooms, household types by composition, region (urban, middle or rural area), and energy poverty. For each of these variables, the tax burden will be shown for each carbon tax design in relative and absolute terms.

3.5 Behavioural effects

The ultimate goal of taxing carbon is to reduce the consumption of carbon-intense goods and services, by internalizing in the price at least part of the adverse environmental effects of this consumption. In the context of this study, to have realistic outcomes, it is important to take into account behavioral responses of households (Douenne, 2018). When households reduce consumption in response to the change in prices after the introduction of a tax, the tax burden, regressivity and the amount of revenues for the government change (West & Williams, 2017). In addition, there will also be an effect on GHG emissions. This paper will also examine the changes in prices and in GHG emissions from the simulated implementation of a carbon tax on energy and transport fuel consumption.

Household consumption expenditures ($X_j,$ for household "j") is the sum of the product of baseline consumed quantities (q_{jk}) of each consumption category k of the consumption basket (with K total elements) and consumer prices (p_k). In what follows, "b" stands for baseline (or before-tax), "a" for after-tax. Therefore, household consumption before the tax is calculated as follows:

$$X_{jb} = \sum_{k=1}^{K} q_{kjb}\, p_{kb} \qquad [3]$$

Households surveyed in the HBS report consumption expenditures in monetary terms, and not in quantities. Departing from these reported expenditures, and combining it with own-price elasticities from the literature, this study provides estimates of the after-tax expenditures and household tax liabilities, as well as on the change in government revenues and GHG emissions from the tax and consumption responses. To simplify the following expressions, it is assumed that there is only one consumption item in the basket. As such, before and after-tax expenditures at the household level are defined as follows:

$$X_{jb} = q_{jb}p_b \qquad [4]$$

$$X_{ja} = q_{ja}p_a \qquad [5]$$

Ceteris paribus, the overnight or static carbon tax liabilities at the household level ($\boldsymbol{CT_j^*}$)[3] are calculated as the product between household's total GHG emissions in the baseline (i.e., household carbon footprints: $HCF_{jb} = \overline{m}X_{jb}$, expressed in tCO_2e, for a given constant multiplier $\overline{m}$) and the simulated carbon tax rate ($\boldsymbol{\tau}$), defined in EUR per tCO_2e (see equation 6).

$$CT_j^* = \tau\, HCF_{jb} = \tau\overline{m}X_{jb} \qquad [6]$$

This tax amount (in EUR) is what households would need to pay to keep consuming the same basket of goods (i.e., inelastic demand). With this, it is possible to estimate the after-tax expenditures under the assumption of constant quantities ($\boldsymbol{X_{ja}^*}$) as follows:

$$X_{ja}^* = X_{jb} + CT_j^* = X_{jb} + \tau\overline{m}X_{jb} = X_{jb}(1 + \tau\overline{m}) \qquad [7]$$

At the same time, after-tax expenditures under constant quantities can be expressed, similarly to equation 2, like in equation 6 (by substituting q_{ja} by q_{jb}, and p_a by p_a^*)

$$X_{ja}^* = q_{jb}p_a^* \qquad [8]$$

For a given tax rate (τ) and multiplier ($\overline{m}$), and for a perfectly elastic supply –i.e. no change in producer prices–[4] the expected percentage change in consumer prices (Δp) can be obtained from the change in expenditures:

$$\frac{X_{ja}^*}{X_{jb}} = \frac{p_a^*}{p_b} = \Delta p + 1 \qquad [9]$$

The percentage change in consumed quantities ($\Delta\boldsymbol{q}$) is estimated from the price-elasticity ($\boldsymbol{\varepsilon_p}$)[5] and the estimated price change:

$$\varepsilon_p = \frac{\Delta q}{\Delta p} \rightarrow \Delta q = \varepsilon_p \Delta p \qquad [10]$$

Then, if we apply this elasticity to all households equally,[6] the after-tax expenditures (equation 11) and carbon tax liabilities (equation 10) at the household level can be estimated as follows:

$$X_{ja} = \mathrm{X_{jb}}\Delta q = \mathrm{X_{jb}}\varepsilon_p \Delta p \qquad [11]$$

$$CT_j = \tau m X_{ja} \qquad [12]$$

Government revenues (GR^*) under constant quantities and considering the response in demand (GR) are calculated as follows:

---

[3] "*" is used to refer to the overnight/static results (i.e., constant quantities).

[4] If supply would be positive-sloped, the final increase in the consumer price would be smaller than the one that is estimated under constant quantities. This elastic-supply assumption is very convenient to estimate the expected change in prices from expenditures. It is not a hard assumption in this case, as the supply of energy is quite elastic

[5] We use an elasticity estimated by previous literature, in particular, those published by Temursho and Weitzel for the EU countries, based on HBS (2024)

[6] This is a simplification assumption, as elasticities may vary across households, e.g. by income levels.

$$GR^* = \sum_{j=1}^{N} CT_j{}^* \qquad GR = \sum_{j=1}^{N} CT_j$$

Therefore, if the own price elasticity is negative, then the estimated tax burden and government revenues are smaller with behavioural effects than in the static scenario (where demand is assumed to be inelastic):

$$if\ \varepsilon_p < 0\ \rightarrow CT_j < CT_J{}^*\ \rightarrow\ GR < GR^*$$

Finally, the change in GHG emissions is equal to the change in expenditures, for a given multiplier.

$$\Delta GHG_j = \frac{mX_{ja}}{mX_{jb}} - 1 = \Delta X_j$$

Since in our framework we are considering two items (energy and transport), which have different price-elasticities, all these steps are estimated separately for each category. We use the price elasticities (-0.109 for energy, -0.328 for transport) reported by Temursho and Weitzel (2024), which are also based on EU-HBS.

4 Results: welfare effects

We now present the estimated welfare and redistributive effects of the simulated carbon taxes. As mentioned before, the 80-euro carbon tax on energy and transport would generate a budget of 2.16 billion euros. This corresponds to an average tax per household per year of 446.5 euros. We now take a closer look at the different welfare effects of our carbon tax scenarios. We first look at their redistributive effect and progressivity (sub-section 4.1), and the tax burden overall and per quintile. Next, we assess horizontal welfare effects with a breakdown of the tax burden by different socio-economic characteristics (sub-section 4.2). Finally, we show the refined estimates of the budgetary effects and the potential impact of the simulated taxes on GHG emissions, under a partial equilibrium framework, by accounting for the own-price elasticity of energy and transport, thus providing proxy for the environmental effectiveness of the tax.

4.1 The impact on incomes: redistributive effect and progressivity

This section presents and discusses the redistributive effect and progressivity for each design. To assess these social inequality effects, taxes and incomes are equivalized considering the household size and composition (for more information on the methodological approach to the welfare assessment and estimation of redistributive effects see section 3). Table 2 presents the impact on inequality for each scenario, by showing the Reynolds-Smolensky index for the redistributive effect and the Kakwani index for the progressivity or regressivity of the carbon tax.

In each scenario inequality increases due to the carbon tax. In the baseline, the flat rate carbon tax increases the Gini coefficient by 0.0015 points. Inequality increases the most in the extreme scenario of full taxation on energy (TD3_e, with a redistributive effect of -0.0020) and the least when only transport is taxed (TD3_t, with a redistributive effect of -0.0008). As compared to the baseline, the other three scenarios (tax-free allowance, progressive rate structure, different rates for energy and transport) have a somewhat smaller negative impact on inequality, and differences among them are minor. The negative Kakwani index (reflecting the regressivity of the tax) is in line with these outcomes, with scenario TD3_e having the largest absolute value of the Kakwani and scenario TD3_t the smallest. This is consistent with previous findings in the literature: the burden of the carbon tax (as an income share) decreases as income increases (Boyce, 2018; Wier et al., 2005). This is driven by the decreasing income shares of expenditure in both categories along the income distribution (see Figure A1.0 in Appendix).

Table 2: Summary table of inequality (Gini), redistributive effect (RE), and progressivity (Kakwani) across scenarios

	Gini baseline	Gini after tax	RE	Kakwani index
TD1: flat tax	0.2221	0.2236	-0.0015	-0.1212
TD2: tax allowance	0.2221	0.2234	-0.0013	-0.1038
TD3_b: tax rates by product (both)	0.2221	0.2234	-0.0012	-0.1004
TD3_t: tax rates by product (only transport)	0.2221	0.2230	-0.0008	-0.0639
TD3_e: tax rates by product (only energy)	0.2221	0.2241	-0.0020	-0.1637
TD4: progressive rate structure	0.2221	0.2234	-0.0012	-0.0989

Notes: simulations based on SILC and EU-HBS for 2015, with EUROMOD policy system and EXIOBASE data from 2019.

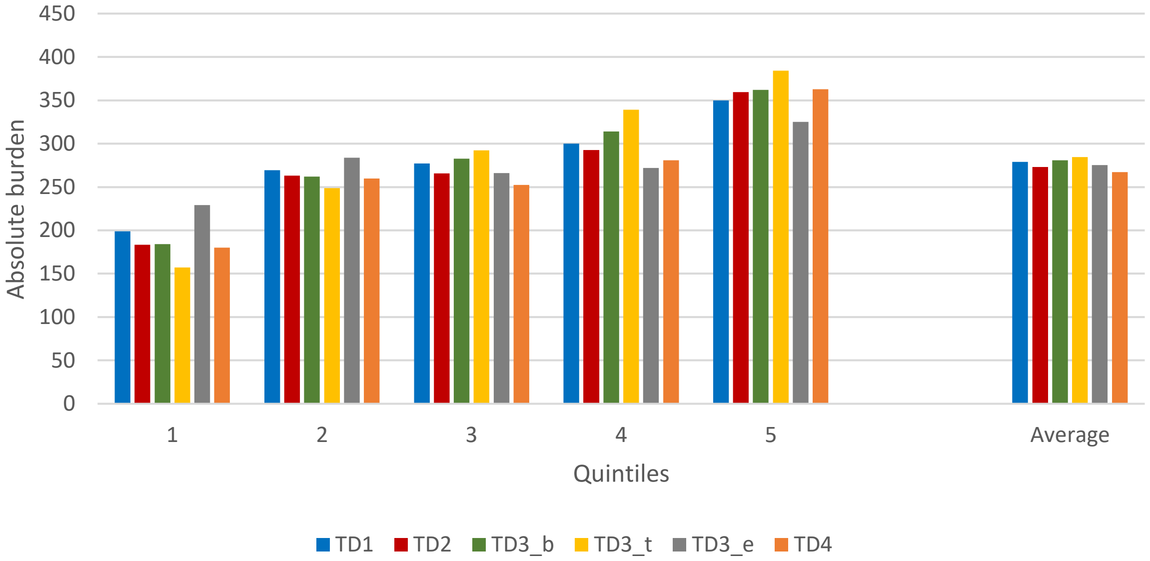
Interestingly, the cushioning effect of the alternative tax (more progressive) designs is limited when we look at the difference in the redistributive effect with the Gini coefficient. Even in the most progressive tax design (TD3_t), the increase in Gini is not even halved (still about 53% that that of the flat-tax in TD1).

The distribution of the absolute and relative tax burden over quintiles is shown in Figure 2. The relative tax burden is calculated as the ratio of the carbon tax over disposable household income before the carbon tax. While in absolute terms, low-income households pay less taxes than higher incomes, they face a higher burden on their income.

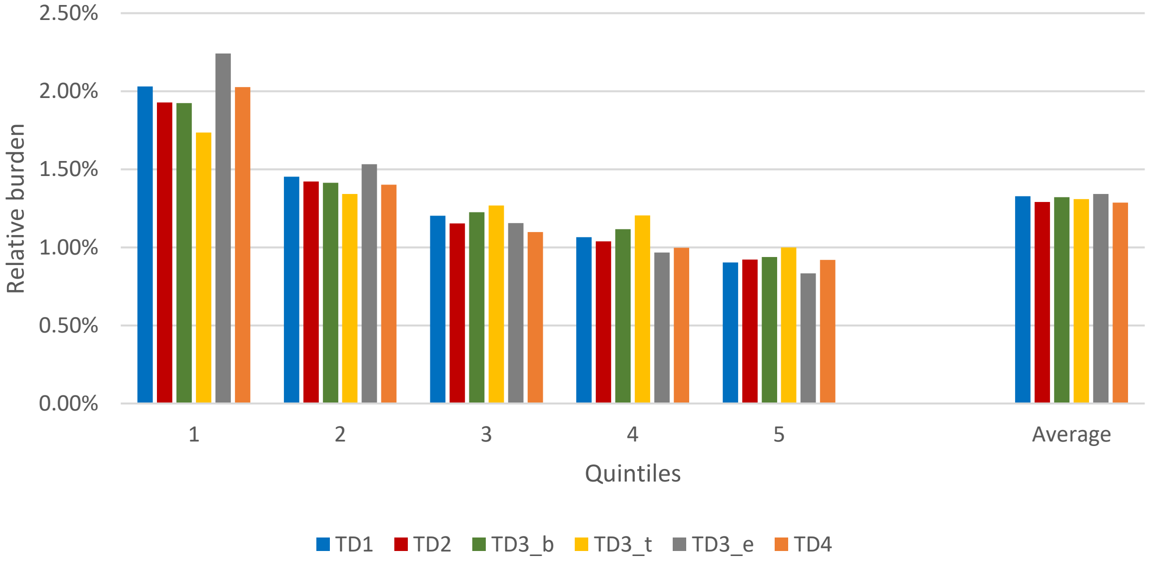
On average, households pay 1.3% of their disposable income on the carbon tax. Figure 2 clearly shows the regressive pattern, with the highest relative tax burden experienced by the lowest quintile (around 2% in the flat rate scenario TD1), and a much lower tax burden faced by the top quintile (less than 1% in TD1). In all scenarios (even in TD3_t, which is the least regressive) the tax weighs more heavily on lower income households. This is especially true in scenario TD3_e (all carbon tax on energy; the most regressive tax design) we observe the highest tax burden for the lowest quintile.

Figure 2: Tax burden by income quintile absolute (panel a) and relative (panel b)

Panel (a): Absolute tax burden in euro



Panel (b): Relative tax burden, as a % of disposable income



Notes: simulations based on SILC and EU-HBS for 2015, with EUROMOD policy system and EXIOBASE data from 2019.

4.2 Horizontal distribution: tax burden across socio-economic groups

The tax burden is heterogenous in terms of income and also across other socio-economic variables. We discuss here the welfare effects by household size and composition, characteristics of the house (size and location) as well as whether the household faces energy poverty or not. The figures with the absolute and relative tax burden according to these characteristics can be found in Annex 1. We briefly discuss here the main patterns.

In terms of household size, our results confirm findings from previous studies -e.g. Callan et al. (2009)- that a carbon tax weighs more heavily on smaller households, both in absolute and relative terms. This is the case for the baseline scenario (TD1, flat carbon tax), where the relative burden for a single household is around 1.7%, whereas it is around 1% for a four person household. But also for all other scenarios we find this pattern. This pattern is even stronger for scenarios TD2 (Allowance) and especially TD4 (the progressive rate structure), where singles now face a tax burden of more than 2% and households with 4 or more members pay less than 1%. Interestingly, the difference across scenarios is largest for single person households, indicating how the lack of economies of scale for this household type leads to higher tax burdens when progressivity is organized through either a tax-free allowance (TD2) or a progressive rate structure (TD4). For larger households the difference in tax burden across scenarios is far more limited, regardless of whether the additional persons in the household are children or adults (see Figure A.1.2 in Annex on household types).

In terms of characteristics of the house we look at both size (number of rooms) and location. The relative tax burden in the baseline (TD1) decreases with number of rooms, which correlates with the number of persons in the household, highlighting again the impact of economies of scale. These economies of scale also explain that the highest relative tax burden is found for houses with 3 or less rooms in scenario TD3_e, which puts the entire tax burden on energy only. In terms of location,[7] the relative tax burden is rather similar across scenarios and households in urban, rural or intermediate areas.

Finally, we also isolate the tax burden for households that are energy poor, using the so-called `2M indicator". According to this measure, households are considered energy poor when the proportion of their income spent on energy is more than twice the national median (see Thema and Vondung (2020) for its definition and Maier and Dreoni (2024) for a cross-country comparison of this indicator and others available at the EU level). On average their tax burden in all simulated scenarios is much higher than for households that are not energy poor. Energy poor households face a much higher tax burden, when energy would be the sole tax base (scenario TD3_e), but also in the case of designs which aim to achieve progressivity through an allowance (TD2) or a progressive rate structure (TD4). This outcome is clearly linked to the distribution of energy expenditures (and related carbon content) and the definition of the energy poverty indicator. If only transport emissions would be taxed (TD3_t), then the tax burden on energy poor households is considerably lower.[8]

---

[7] The data allow to distinguish location according to degree of urbanisation and distinguish the following three categories: rural, middle, and urban on the basis of the proportion of the population living in rural grid cells. Rural regions are those where more than 50% of the population lives in rural grid cells, middle regions where 20% to 50% of the population lives in rural grid cells, and urban regions where less than 20% of the population lives in rural grid cells.

[8] Energy poverty indicators based on expenditures usually cover only residential energy and exclude fuels or transport-related expenditures. If we would redefine energy poverty considering both type of expenses (i.e., by classifying as energy poor those individuals living in households with income shares of total expenses in energy and transport that are above twice the median), comparative results across scenarios would change (e.g., the tax burden of the energy poor in TD3_t would be even higher) but we would still identify stronger welfare effects among the energy poor.

4.3 Effect on consumption and GHG emissions

By incorporating price-elasticities to account for the potential reaction of consumption demand after the introduction of the carbon tax, this section re-estimates the tax burden and government revenues for each tax design, as well as the expected impact on GHG emissions. The methodological steps and assumptions involved have been introduced in section 3.5.

Overall, assuming full pass through of the tax to consumer prices (e.g., under perfectly elastic supply, see Section 3.5 for more details), the simulated carbon taxes would result in an increase in consumer prices of about 19% (see Table 3). Yet, there are clear differences across products. For instance, while energy prices would rise by approximately 22%, transport prices would experience a smaller increase of around 16%. This pattern holds across all scenarios except for Scenario 3 (i.e., product-specific rates), where the price increase varies depending on the design.

We then use the own-price elasticity estimated by Temursho and Weitzel (2024) to estimate the expected reduction in expenditures, and as such, in GHG emissions.[9] Results suggest that a flat tax of 80 euro would decrease energy-related GHG emissions by 2.5% and transport emissions by 5.1%. More progressive designs, such as tax allowances or rates by thresholds, yield similar outcomes. On the other hand, applying different tax rates by products (scenario TD3_b) would be the most effective scenario in reducing GHG emissions (1.6% and 7.6%, respectively, for energy and transport). The higher effectiveness from taxing transport consumption reflects its greater price elasticity and the higher tax rates applied under this design.

Table 3 presents also the results for the two extreme scenarios, where only transport (TD3_t) or energy (TD3_e) are taxed. These scenarios provide insights into the relative contributions of each sector to emissions reductions and the price impacts within the same budget constraints. Taxing only transport (TD3_t) would achieve the largest overall reduction in emissions (about 5.1%). However, it would result in a sharp price increase for transport of approximately 37%, raising concerns about its acceptability and hence feasibility (see further in the Discussion Section). On the other hand, taxing only energy (TD3_e) would translate in a similar increase in prices, but with a lower effectiveness on total emissions. These single-product scenarios illustrate the range of possible emission reductions achievable by focusing taxation on specific sectors, even if with significant trade-offs in terms of feasibility and equity.

Table 3: Change in prices, GHG emissions (CO_2e) and budget, across scenarios

	$(p_b + CT^*) / p_b$			% change in CO2e emissions			Budget
Scenarios	Energy	Transport	Total	Energy	Transport	Total	(million euros)
TD1	22.7	15.5	19.0	-2.51	-5.09	-3.59	2,080
TD2	21.8	16.4	19.0	-2.44	-5.37	-3.66	2,055
TD3_b	14.5	23.3	19.0	-1.61	-7.63	-4.13	2,041
TD3_t	0.0	37.2	19.0	0.00	-12.19	-5.09	1,894
TD3_e	38.9	0	19.0	-4.31	0.00	-2.51	2,065
TD4	22.2	16.0	19.0	-2.50	-5.25	-3.65	2,027

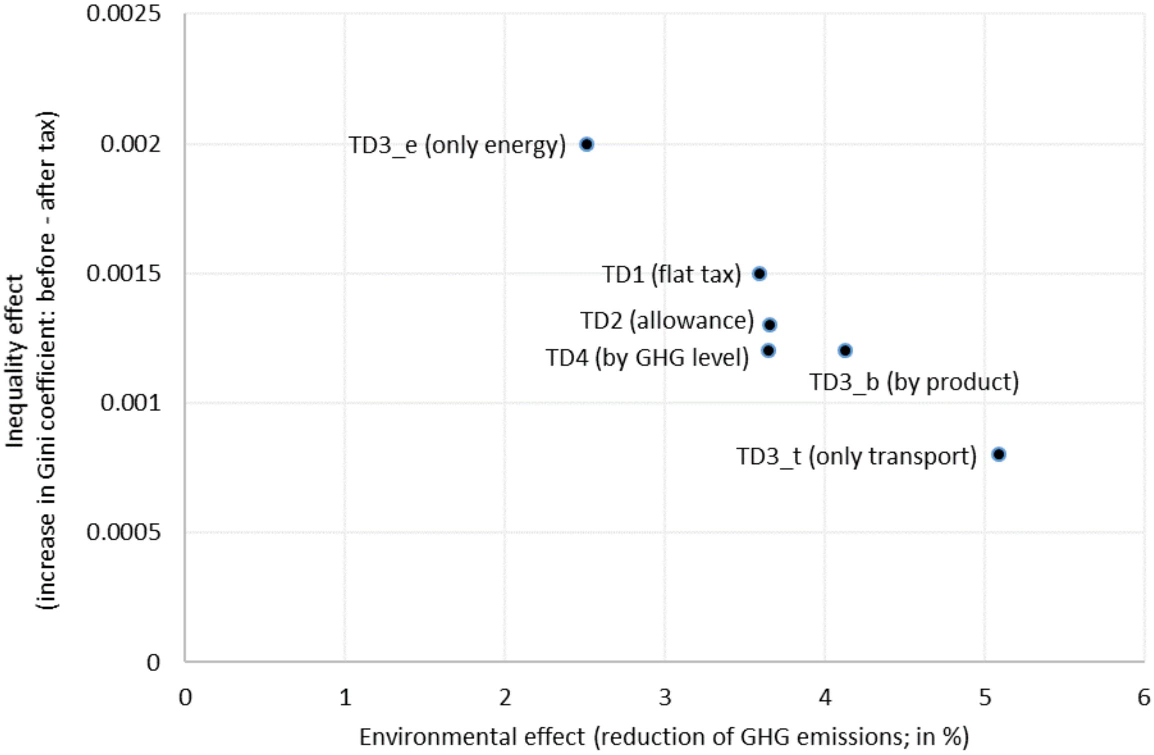
Notes: main results from the simulation of the four carbon tax designs accounting for the reduction in consumer demand, considering own-price elasticities. Budget in million euros of 2019 (yearly).

---

[9] We also discuss the implications of different elasticities across the distribution (income deciles) on the redistributive effect of the simulated tax scenarios (results are not substantially different from the main results presented in 4.1 - see Annex 2.1)

In the last column, we present the government revenues for each tax design, considering the behavioural reactions (changes in consumption demand). In the flat tax scenario, government revenues would be 2,080 million euros (about 3.6% less than in the static analysis, following the same piece of reduction of the GHG emissions, which is the tax base). As expected, more progressive designs result in larger GHG reductions and smaller government revenues, as households tend to cut emissions that are subject to higher tax rates. Moreover, those tax designs that feature a higher rate on transport achieve more progressive outcomes, stronger GHG reductions (and lower government revenues) than the rest because of the higher own-price elasticities of transport consumption.

Figure 3: Environmental and redistributive effects: is there a trade-off?



Notes: simulations based on SILC and EU-HBS for 2015, with EUROMOD policy system and EXIOBASE data from 2019.

Figure 3 shows that, at least between the tax designs we have simulated here, there is not a trade-off between distributional and environmental outcomes. In fact, taxing only transport (TD3_t) would yield the best distributional and environmental outcomes (i.e., the smallest increase in inequality – as it can be appreciated in the vertical axis – and the largest decrease in GHG emissions – as it can be appreciated in the horizontal axis). At the other extreme, taxing only energy (TD3_e) achieves the worst results in these two dimensions. These are even worse than in the flat tax scenario (TD1).

These extreme opposite results in terms of redistributive results from TD3_e and TD3_t are explained by the homogeneous income shares of expenditures on energy across the income distribution, in contrast with the increasing shares of transport expenditures. Similarly, the extreme results in terms of their environmental impact are explained by the difference in their own-price elasticities: after the tax, the simulated decrease in transport consumption is much larger than in energy consumption.

In between, there are TD3_b (tax rates by product), TD2 (tax allowances) and TD4 (rates by threshold) lead to very similar distributional outcomes, but TD3_b leads to the best environmental effects.

5 Discussion and conclusion

As discussed in Section 2, one of the major social issues of a carbon tax is its regressive character: the tax burden is relatively higher for low incomes as compared to high incomes. In this paper we have investigated in a systematic empirical way to what extent this regressivity can be countered by a different design of the carbon tax itself. We have developed several hypothetical scenarios that deviate from a flat rate carbon tax to illustrate the impact on social inequality on the one hand and on carbon emissions on the other. The calculated alternative designs simulate variations with respect to the two basic building blocks of a carbon tax, notable the tax base and the tax rate. For the tax rate we developed two alternative scenarios, one that provides for each household a base exemption on emissions and one that that applies a progressive rate structure on total emission of the household. For the tax base we have calculated three options that differentiate between different product categories: we used two extreme scenarios that put the entire tax burden either on transport fuel or on energy, and one intermediate scenario that provides a lower rate on energy, as this category is in relative terms the most important one for lower income groups.

Our results show that it is very difficult to offset the regressivity by changing the design of the carbon tax. There is a reduction in regressivity when one applies an exemption or a progressive rate structure, but the impact is relatively small, and the tax still increases inequality. Regressivity can be more reduced when changing the tax base and differentiate according to product category (thereby targeting the product that is more present higher up the income ladder with a higher rate), but also in these scenarios the tax remains regressive and increases inequality. More refined differentiation by focusing taxes on luxury goods (such as flights, private jets, luxury cars), as is analysed by Oswald et al. (2023), is probably progressive (due to the distribution of these goods) and may provide a much fairer distribution of the tax burden.

Interestingly, our results also show that the least regressive scenarios are also those that reduce emissions the most. This is to a large extent due to the fact that income elasticities of transport fuel emissions are markedly higher than the ones of energy emissions: when transport fuel emissions are taxed more heavily the behavioural response in terms of emission reduction will be largest.

Several papers have demonstrated that the regressive character of the carbon tax can be countered by recycling the corresponding revenue and that the most pro-poor way to do this is through a so-called carbon dividend. All the tax design scenarios we have simulated lead to an increase in government revenues that so far have not been used in the simulations to compensate households. If these revenues were recycled and transferred back to households, the overall regressivity of the tax is more easily cushioned. We have performed an additional simulation with a lump sum transfer (see Annex 2 for results) illustrating that the double dividend of the carbon tax (i.e. generating both beneficial effects in terms of environmental and distributional outcomes) can be achieved. If the overall budget is divided among the population in the shape of a lump sum cash transfer, this would be about 196 EUR. With it, inequality would not increase but reduce (with about 0.0012 Gini points). We also estimated that about half (100 EUR) of the transfer would be needed to completely offset the increase in inequality after the flat tax, keeping inequality unchanged with respect to the baseline (in Annex 2 we show the distribution of the change in household disposable income by quintile of a carbon tax with a carbon dividend as compensatory measure). Hence, our results show that the way the tax revenue is recycled is crucial for the inequality impact of a carbon tax, and that a carbon dividend may be an instrument to be considered for this purpose.

When policy makers consider a carbon tax, it is also important to take account of the perspectives of (1) practical feasibility and (2) public acceptability. We stress that the scenarios we have simulated are hypothetical in order to illustrate the potential distributive effects. From a practical point of view there are, however, several obstacles to implement these scenarios. A major problem is that in order to make an alternative tax design work, one needs information on total emissions per year and household. This would require accurate tracking by the state of household consumption information, as well as of the carbon content of this consumption. This might be difficult and costly, an argument that is also put forward against a progressive consumption tax. The combination of a carbon tax and a cash transfer may encounter additional practical barriers, as it entails the involvement of different policy domains, notably the tax system and the transfer domain. Moreover, providing a cash transfer may lead to changes in consumption patterns or rebound effects, which together with potential strategic household behaviour may limit the carbon tax ecological effectiveness.

Also, it is important to clarify the implications of the policy (Saelim, 2019) and to take account of public acceptability issues (see Bergquist et al. (2022) and Maestre-Andrés et al. (2019)). . A clear illustration of this is the Yellow Vests movement in 2018 in France. Our most ecologically effective and least regressive hypothetical scenario entails to put the full tax burden on emissions from transport fuels only. The proposed carbon tax in France, however, illustrates that this may not be seen as a fair tax if it is expected to disproportionately affect lower- and middle-income households, particularly those in rural areas who rely heavily on cars for transportation and do not have alternative means because of lack of public provisions nearby. Douenne and Fabre (2022) stress the importance of the households' perception of a carbon tax (and dividend) for the acceptability of such a policy.

In sum, our analysis leads us to the conclusion that the regressivity of a carbon tax on household consumption of energy and transport fuel can be at least partially countered with more progressive designs, but that other or complementary measures, such as cash transfers from revenue recycling, may be needed if the goal is to fully offset the inequality increasing effects of the carbon tax.

References

Amores, A. F., Maier, S., & Ricci, M. (2023). Taxing household energy consumption in the EU: The tax burden and its redistributive effect. *Energy Policy*, *182*, 113721. https://doi.org/https://doi.org/10.1016/j.enpol.2023.113721

Andersen, M. S., Barker, T., Christie, E., Ekins, P., Gerald, J., Jilkova, J., Junankar, S., Landesmann, M., Pollitt, H., & Salmons, R. (2007). Competitiveness Effects of Environmental Tax Reforms (COMETR). Final report to the European Commission. *National Environmental Research Institute, University of Aarhus*.

Andersson, J. J. (2019). Carbon taxes and CO2 emissions: Sweden as a case study. *American Economic Journal: Economic Policy*, *11*(4), 1-30.

Baranzini, A., Van den Bergh, J. C., Carattini, S., Howarth, R. B., Padilla, E., & Roca, J. (2017). Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(4), e462. https://doi.org/https://doi.org/10.1002/wcc.462

Beiser-McGrath, L. F., & Bernauer, T. (2019). Could revenue recycling make effective carbon taxation politically feasible? *Science advances*, *5*(9), eaax3323. https://doi.org/https://doi.org/10.1126/sciadv.aax3323

Bergquist, M., Nilsson, A., Harring, N., & Jagers, S. C. (2022). Meta-analyses of fifteen determinants of public opinion about climate change taxes and laws. *Nature Climate Change*, *12*(3), 235-240. https://doi.org/https://doi.org/10.1038/s41558-022-01297-6

Bovenberg, A. L. (2002). Green tax reforms and the double dividend: an updated reader's guide. In *Environmental Policy Making in Economies with Prior Tax Distortions* (pp. 73-96). Edward Elgar Publishing. https://doi.org/https://doi.org/10.4337/9781035304639.00010

Boyce, J. K. (2018). Carbon Pricing: Effectiveness and Equity. *Ecological Economics*, *150*, 52-61. https://doi.org/https://doi.org/10.1016/j.ecolecon.2018.03.030

Callan, T., Lyons, S., Scott, S., Tol, R. S., & Verde, S. (2009). The distributional implications of a carbon tax in Ireland. *Energy Policy*, *37*(2), 407-412. https://doi.org/https://doi.org/10.1016/j.enpol.2008.08.034

Commissie voor de Regulering van de Elektriciteit en het Gas. (s.d.). *Hie is de energieprijs opgebouwd?* https://www.creg.be/nl/consumenten/prijzen-en-tarieven/hoe-de-energieprijs-opgebouwd

Douenne, T. (2018). *The vertical and horizontal distributive effects of energy taxes*.

Douenne, T., & Fabre, A. (2022). Yellow vests, pessimistic beliefs, and carbon tax aversion. *American Economic Journal: Economic Policy*, *14*(1), 81-110. https://doi.org/10.1257/pol.20200092

Druce, V. (2017). *Rich US households produce more CO2 each year from driving than the entire carbon footprint of poor households over 8 months*. The London School of Economics and Political Science https://www.lse.ac.uk/granthaminstitute/news/a-rich-american-household-typically-produces-more-carbon-dioxide-emissions-each-year-from-driving-than-the-entire-carbon-footprint-of-a-poor-household-over-8-months/

Dussaux, D. (2020). The joint effects of energy prices and carbon taxes on environmental and economic performance: Evidence from the French manufacturing sector. https://doi.org/https://doi.org/10.1787/b84b1b7d-en

Edenhofer, O. (2015). *Climate change 2014: mitigation of climate change* (Vol. 3). Cambridge University Press.

Eide, J., de Sisternes, F. J., Herzog, H. J., & Webster, M. D. (2014). CO2 emission standards and investment in carbon capture. *Energy Economics*, *45*, 53-65. https://doi.org/https://doi.org/10.1016/j.eneco.2014.06.005

European Commission. (s.d.-a). *Europese Klimaatwet* https://climate.ec.europa.eu/eu-action/european-climate-law_nl

European Commission. (s.d.-b). Green EUROMOD. https://joint-research-centre.ec.europa.eu/scientific-activities-z/fiscal-policy-analysis-0/taxation-and-social-policy-households/taxation-consumption-including-green-taxation/green-euromod_en

European Commission. (s.d.-c). *Joint Research Centre*. https://commission.europa.eu/about-european-commission/departments-and-executive-agencies/joint-research-centre_en

European Commission. (s.d.-d). What is EUROMOD? https://euromod-web.jrc.ec.europa.eu/overview/what-is-euromod

Eurostat. (s.d.-a). *EU statistics on income and living conditions*. https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions

Eurostat. (s.d.-b). *Glossary: Equivalised disposable income*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Equivalised_disposable_income#:~:text=The%20equivalised%20disposable%20income%20is,according%20to%20their%20age%2C%20using

Eurostat. (s.d.-c). *Household budget Survey* https://ec.europa.eu/eurostat/web/microdata/household-budget-survey

Feindt, S., Kornek, U., Labeaga, J. M., Sterner, T., & Ward, H. (2021). Understanding regressivity: Challenges and opportunities of European carbon pricing. *Energy Economics*, *103*, 105550. https://doi.org/https://doi.org/10.1016/j.eneco.2021.105550

Figari, F., Paulus, A., & Sutherland, H. (2015). Chapter 24 - Microsimulation and Policy Analysis. In A. B. Atkinson & F. Bourguignon (Eds.), *Handbook of Income Distribution* (Vol. 2, pp. 2141-2221). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-444-59429-7.00025-X

Flues, F., & Thomas, A. (2015). The distributional effects of energy taxes. https://doi.org/doi:https://doi.org/10.1787/5js1qwkqqrbv-en

FOD Volksgezondheid en Veligheid van de Voedselketen en Leefmilieu. (2023). *The landscape of carbon and energy pricing and taxation in Belgium*. Retrieved from https://climat.be/doc/landscape-carbon-energy-pricing-taxation.pdf

Fremstad, A., & Paul, M. (2019). The Impact of a Carbon Tax on Inequality. *Ecological Economics*, *163*, 88-97. https://doi.org/https://doi.org/10.1016/j.ecolecon.2019.04.016

Fullerton, D., Heutel, G., & Metcalf, G. E. (2011). *Does the indexing of government transfers make carbon pricing progressive?*

Goulder, L. H. (1995). Environmental taxation and the double dividend: a reader's guide. *International tax and public finance*, *2*, 157-183. https://doi.org/https://doi.org/10.1007/BF00877495

Goulder, L. H. (2000). Economic impacts of environmental policies. *NBER Reporter Online*(Spring 2000), 5-10.

Hepburn, C., Stern, N., & Stiglitz, J. E. (2020). “Carbon pricing” special issue in the European economic review. *European Economic Review*, *127*, 103440. https://doi.org/https://doi.org/10.1016/j.euroecorev.2020.103440

Heyndrickx, C., Bachus, K., De Bevere, A., Grandjean, G., Schepers, W., Van der Loo, S., Vanpée, R., Vanrykel, F., & Van Zeebroeck, B. (2022). Proposal for a green tax reform. *Proposal for a green tax reform*.

Hintermann, B., & Zarkovic, M. (2020). Carbon Pricing in Switzerland: A Fusion of Taxes, Command-and-Control, and Permit Markets. *ifo DICE Report*, *18*(01), 35-41.

Johansson, B. (2000). The carbon tax in Sweden. *Innovation and the Environment*, *85*, 85-148.

Joumard, I., Pisu, M., & Bloch, D. (2013). Tackling income inequality: The role of taxes and transfers. *OECD Journal: Economic Studies*, *2012*(1), 37-70.

Kakwani, N. C. (1977). Measurement of Tax Progressivity: An International Comparison. *The Economic Journal*, *87*(345), 71-80. https://doi.org/10.2307/2231833

King, M. A. (1983). Welfare analysis of tax reforms using household data. *Journal of Public Economics*, *21*(2), 183-214. https://doi.org/https://doi.org/10.1016/0047-2727(83)90049-X

Klenert, D., & Mattauch, L. (2016). How to make a carbon tax reform progressive: The role of subsistence consumption. *Economics Letters*, *138*, 100-103. https://doi.org/https://doi.org/10.1016/j.econlet.2015.11.019

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., & Stern, N. (2018). Making carbon pricing work for citizens. *Nature Climate Change*, *8*(8), 669-677. https://doi.org/https://doi.org/10.1038/s41558-018-0201-2

Klenert, D., Schwerhoff, G., Edenhofer, O., & Mattauch, L. (2018). Environmental taxation, inequality and Engel's law: The double dividend of redistribution. *Environmental and Resource Economics*, *71*(3), 605-624. https://doi.org/https://doi.org/10.1007/s10640-016-0070-y

Klimaat.be. (2018a). *Belangrijkste resultaten*. https://klimaat.be/2050-nl/koolstoftarifering/belangrijkste-resultaten

Klimaat.be. (2018b). *Het nationaal debat over koolstoftarifering*. https://klimaat.be/klimaatbeleid/belgisch/nationaal/koolstoftarifering

Klimaat.be. (2023). Nieuw federaal rapport legt de nood aan hervormingen in de koolstof- en energiebelastingen bloot. https://klimaat.be/news/2023/koolstof-en-energiebelastingen

Köppl, A., & Schratzenstaller, M. (2023). Carbon taxation: A review of the empirical literature. *Journal of Economic Surveys*, *37*(4), 1353-1388. https://doi.org/https://doi.org/10.1111/joes.12531

Lévay, P. Z., Vanhille, J., Goedemé, T., & Verbist, G. (2021). The association between the carbon footprint and the socio-economic characteristics of Belgian households. *Ecological Economics*, *186*, 107065. https://doi.org/https://doi.org/10.1016/j.ecolecon.2021.107065

Lin, B., & Li, X. (2011). The effect of carbon tax on per capita CO2 emissions. *Energy Policy*, *39*(9), 5137-5146. https://doi.org/https://doi.org/10.1016/j.enpol.2011.05.050

Linden, J., O'Donoghue, C., & Sologon, D. M. (2024). The many faces of carbon tax regressivity—Why carbon taxes are not always regressive for the same reason. *Energy Policy*, *192*, 114210. https://doi.org/https://doi.org/10.1016/j.enpol.2024.114210

Maestre-Andrés, S., Drews, S., & Van den Bergh, J. (2019). Perceived fairness and public acceptability of carbon pricing: a review of the literature. *Climate policy*, *19*(9), 1186-1204. https://doi.org/https://doi.org/10.1080/14693062.2019.1639490

Maier, S., De Poli, S., & Amores, A. F. (2024). *Carbon taxes on consumption: distributional implications for a just transition in the EU*. JRC Working Papers on Taxation and Structural Reforms No 9/2024

Maier, S., & Dreoni, I. (2024). Who is "Energy Poor" in the EU? JRC Working Papers on Taxation and Structural Reforms-No 5/2024

Marron, D. B., & Toder, E. J. (2014). Tax policy issues in designing a carbon tax. *American Economic Review*, *104*(5), 563-568. https://doi.org/10.1257/aer.104.5.563

Martin, R., De Preux, L. B., & Wagner, U. J. (2014). The impact of a carbon tax on manufacturing: Evidence from microdata. *Journal of Public Economics*, *117*, 1-14. https://doi.org/https://doi.org/10.1016/j.jpubeco.2014.04.016

Mengden, A. (2024). *Carbon Taxes in Europe*. https://taxfoundation.org/data/all/eu/carbon-taxes-europe-2024/

Metcalf, G. E., & Stock, J. H. (2020). Measuring the macroeconomic impact of carbon taxes. *AEA Papers and Proceedings*, *110*, 101-106. https://doi.org/10.1257/pandp.20201081

Metcalf, G. E., & Weisbach, D. (2009). The design of a carbon tax. *Harv. Envtl. L. Rev.*, *33*, 499.

OECD. (s.d.). *What are equivalece scales?* https://www.oecd.org/els/soc/OECD-Note-EquivalenceScales.pdf

Oswald, Y., Millward-Hopkins, J., Steinberger, J. K., Owen, A., & Ivanova, D. (2023). Luxury-focused carbon taxation improves fairness of climate policy. *One Earth*, *6*(7), 884-898. https://doi.org/10.1016/j.oneear.2023.05.027

Parry, I., Black, S., & Zhunussova, K. (2022). *Carbon taxes or emissions trading systems?: instrument choice and design*. International Monetary Fund Washington, DC, USA.

Poterba, J. M. (2017). Is the gasoline tax regressive? In *Distributional Effects of Environmental and Energy Policy* (pp. 31-50). Routledge.

Reynolds, M., & Smolensky, E. (1977). Post-Fisc Distributions of Income in 1950, 1961, and 1970. *Public Finance Quarterly*, *5*(4), 419-438. https://doi.org/10.1177/109114217700500402

Ricardo Energy and Environment. (2018). Sweden Energy and Carbon Tax Policy: Rethinking Decarbonisation Incentives – Policy Case Studies. https://esc-production-2021.s3.eu-west-2.amazonaws.com/2021/09/Sweden-Case-Study-FINAL.pdf

Runst, P., & Thonipara, A. (2020). Dosis facit effectum why the size of the carbon tax matters: Evidence from the Swedish residential sector. *Energy Economics*, *91*, 104898.

Saelim, S. (2019). Carbon tax incidence on household demand: Effects on welfare, income inequality and poverty incidence in Thailand. *Journal of Cleaner Production*, *234*, 521-533. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.06.218

Sager, L. (2019). Income inequality and carbon consumption: Evidence from Environmental Engel curves. *Energy Economics*, *84*, 104507. https://doi.org/https://doi.org/10.1016/j.eneco.2019.104507

Shmelev, S. E., & Speck, S. U. (2018). Green fiscal reform in Sweden: econometric assessment of the carbon and energy taxation scheme. *Renewable and Sustainable Energy Reviews*, *90*, 969-981. https://doi.org/https://doi.org/10.1016/j.rser.2018.03.032

Stadler, K., Wood, R., Bulavskaya, T., Södersten, C. J., Simas, M., Schmidt, S., Usubiaga, A., Acosta-Fernández, J., Kuenen, J., & Bruckner, M. (2018). EXIOBASE 3: Developing a time series of detailed environmentally extended multi-regional input-output tables. *Journal of Industrial Ecology*, *22*(3), 502-515. https://doi.org/https://doi.org/10.1111/jiec.12715

Statbel. (s.d.). *Huishoudbudgetonderzoek*. https://statbel.fgov.be/nl/enquete/huishoudbudgetonderzoek-hbs

Stern, N. (2008). The economics of climate change. *American Economic Review*, *98*(2), 1-37. https://doi.org/10.1257/aer.98.2.1

Stiglitz, J. E., Stern, N., Duan, M., Edenhofer, O., Giraud, G., Heal, G. M., La Rovere, E. L., Morris, A., Moyer, E., & Pangestu, M. (2017). Report of the high-level commission on carbon prices.

Sutherland, H., & Figari, F. (2013). EUROMOD: the European Union tax-benefit microsimulation model. *International journal of microsimulation*, *6*(1), 4-26.

Temursho, U., & Weitzel, M. (2024). Consumer demand in EU member states. *Publications Office of the European Union, Luxembourg* https://doi.org/10.2760/376288

Thema, J., & Vondung, F. (2020). EPOV indicator dashboard: Methodology guidebook. *Wuppertal Institut für Klima, Umwelt, Energie GmbH: Wuppertal, Germany*, 2021-2009.

Thonipara, A., Runst, P., Ochsner, C., & Bizer, K. (2019). Energy efficiency of residential buildings in the European Union–An exploratory analysis of cross-country consumption patterns. *Energy Policy*, *129*, 1156-1167. https://doi.org/https://doi.org/10.1016/j.enpol.2019.03.003

Timilsina, G. R. (2022). Carbon taxes. *Journal of Economic Literature*, *60*(4), 1456-1502. https://doi.org/10.1257/jel.20211560

Tukker, A., Poliakov, E., Heijungs, R., Hawkins, T., Neuwahl, F., Rueda-Cantuche, J. M., Giljum, S., Moll, S., Oosterhaven, J., & Bouwmeester, M. (2009). Towards a global multi-regional environmentally extended input–output database. *Ecological Economics*, *68*(7), 1928-1937. https://doi.org/https://doi.org/10.1016/j.ecolecon.2008.11.010

UNFCCC. (2015). Paris agreement. Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change (21 session, 2015: Paris).

Varela, P. (2016). What are progressive and regressive taxes. *Tax and Transfer Policy Institute*.

Verbist, G., & Figari, F. (2014). The redistributive effect and progressivity of taxes revisited: An international comparison across the European Union. *FinanzArchiv/Public Finance Analysis*, 405-429. http://www.jstor.org/stable/43297214

West, S. E., & Williams, R. C. (2017). Estimates from a consumer demand system: implications for the incidence of environmental taxes. In *Distributional Effects of Environmental and Energy Policy* (pp. 117-140). Routledge.

Wiedmann, T. (2009). A review of recent multi-region input–output models used for consumption-based emission and resource accounting. *Ecological Economics*, *69*(2), 211-222. https://doi.org/https://doi.org/10.1016/j.ecolecon.2009.08.026

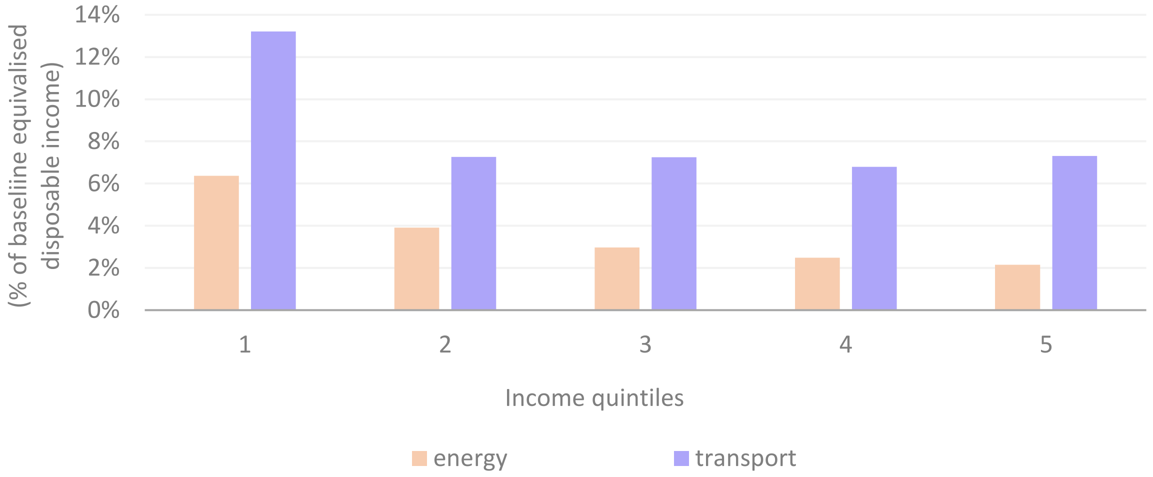
Wier, M., Birr-Pedersen, K., Jacobsen, H. K., & Klok, J. (2005). Are CO2 taxes regressive? Evidence from the Danish experience. *Ecological Economics*, *52*(2), 239-251. https://doi.org/https://doi.org/10.1016/j.ecolecon.2004.08.005

Yi, H. (2015). Clean-energy policies and electricity sector carbon emissions in the US states. *Utilities Policy*, *34*, 19-29. https://doi.org/https://doi.org/10.1016/j.jup.2015.04.001

Zhang, K., Wang, Q., Liang, Q.-M., & Chen, H. (2016). A bibliometric analysis of research on carbon tax from 1989 to 2014. *Renewable and Sustainable Energy Reviews*, *58*, 297-310. https://doi.org/https://doi.org/10.1016/j.rser.2015.12.089

Annex 1: Figures for distribution of tax burden according to socio-economic characteristics (horizontal distribution outcomes)

Figure A.1.0: Income shares of expenditures on transport and energy across income quintiles



Notes: transport fuels and residential energy (excluding electricity), based on HBS-SILC matched files from 2015, updated to 2019.

Figure A.1.1: Absolute (left) and relative (right) tax burden by household size

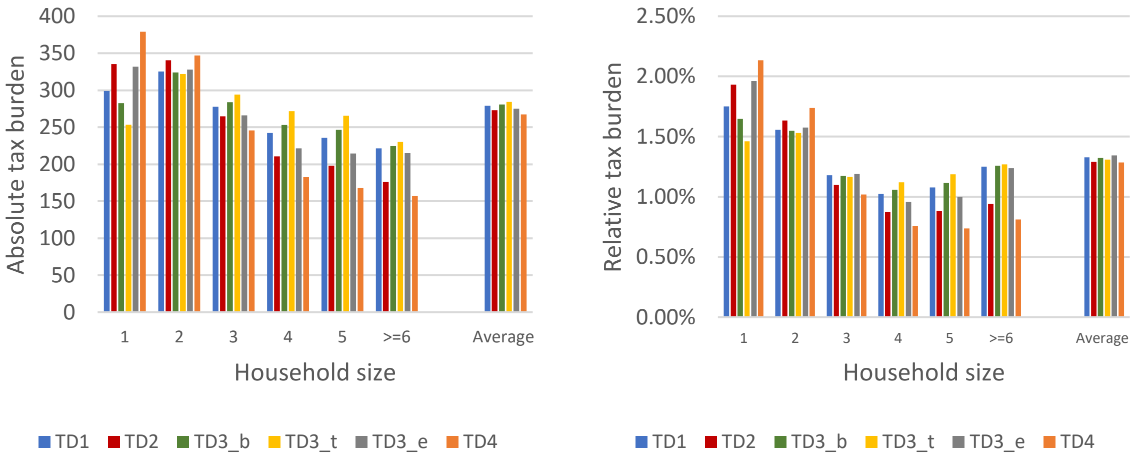


Figure A.1.2: Absolute (left) and relative (right) tax burden by household type

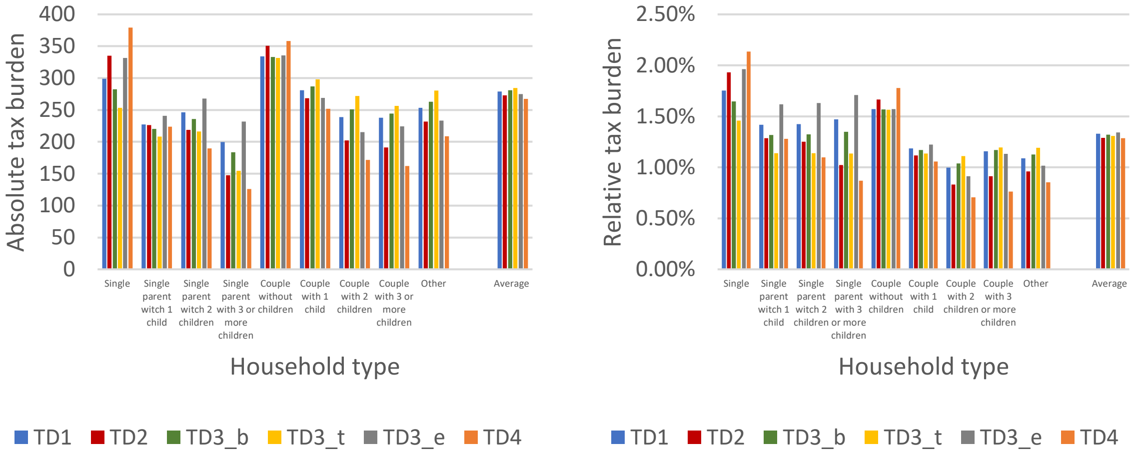


Figure A.1.3: Absolute (left) and relative (right) tax burden by number of rooms

Figure A.1.4: Absolute (left) and relative (right) tax burden by region

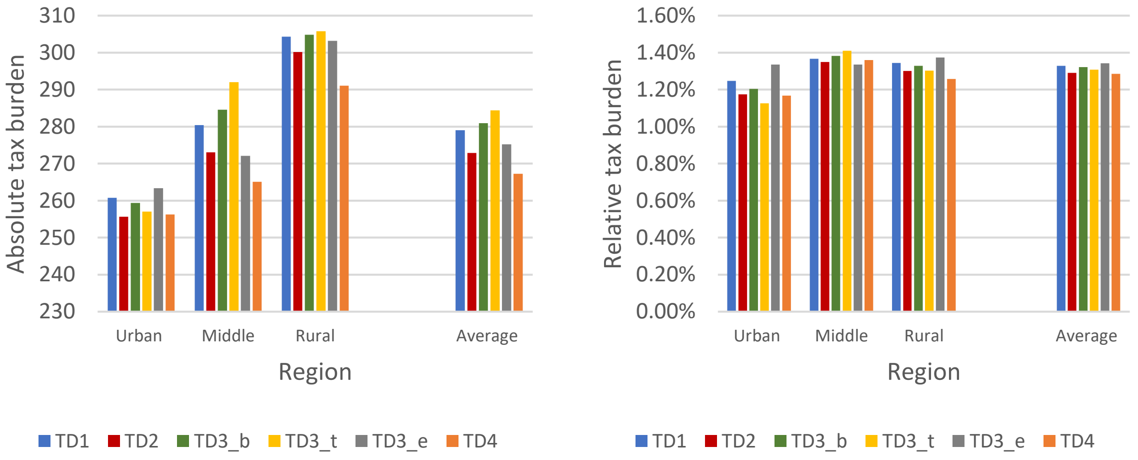


Figure A.1.5: Absolute (left) and relative (right) tax burden by energy poverty

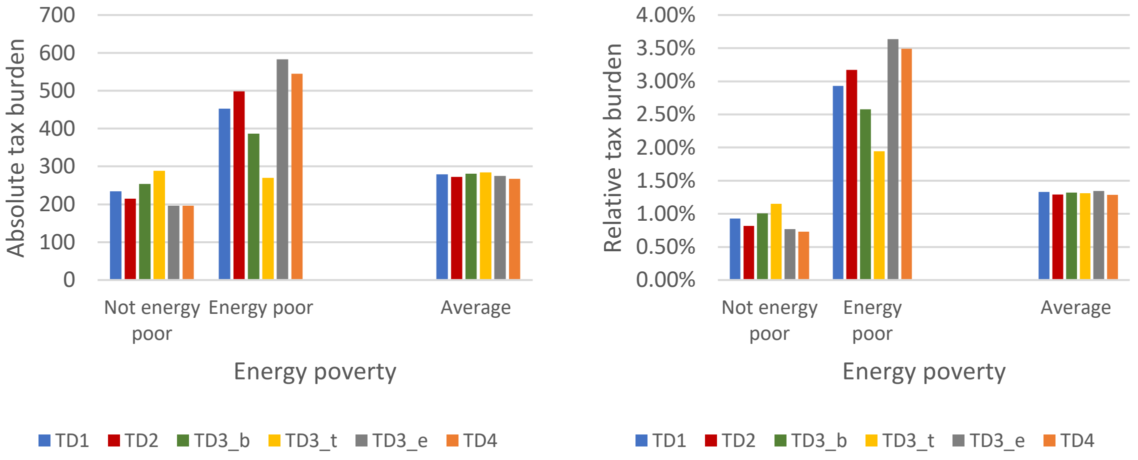
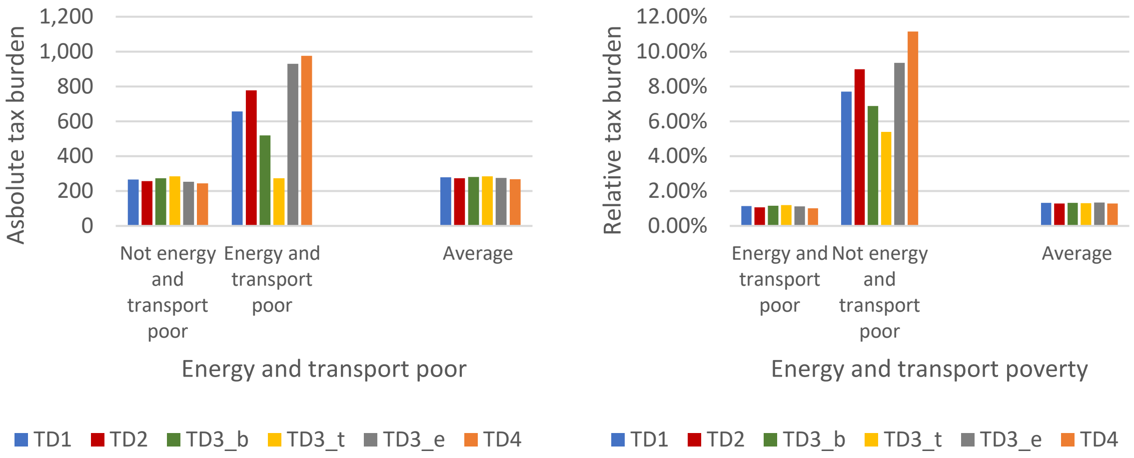


Figure A.1.6: Absolute (left) and relative (right) tax burden by energy and transport poverty



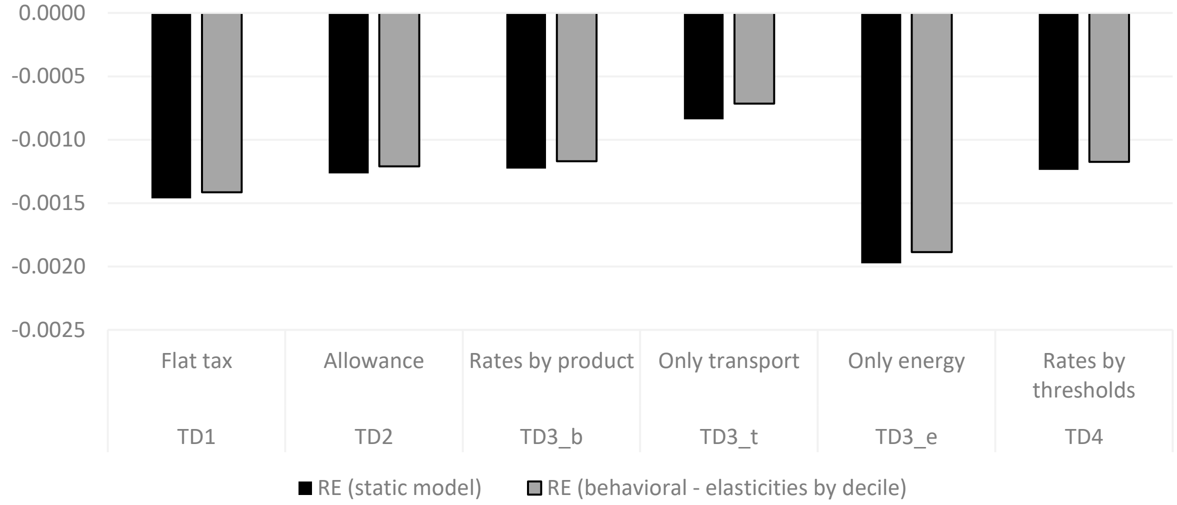
Notes: simulations based on SILC and EU-HBS for 2015, with EUROMOD policy system and EXIOBASE data from 2019.

Annex 2: Additional simulations

2.1. Redistributive effect, considering own-price elasticities by income decile

When behavioural responses (i.e., the decrease in consumption following the increase in consumer prices generated by the carbon tax, given the negative own-price elasticities) are accounted for, the overall tax burden is smaller than in the static simulated scenario. In our main results, we presented the change in budgetary effects and the simulated decrease in GHG of the simulation with behavioral responses, using only one own-price elasticity per product category, under a partial-equilibrium framework. We did not re-estimate distributional effects, as the response was not varying with incomes. However, if we would want to get closer to reality, these elasticities may actually differ between low-, middle- and high-income households, and this could influence the redistributive effects of the simulated tax. To evaluate this, we plug in our model the own-price elasticities of residential energy and transport fuels by (expenditure) deciles estimated by Temursho and Weitzel (2024). We then apply the same empirical framework explained in section 3.2 and re-estimate the tax-burden. As expected, the overall distributive effect is slightly smaller with respect to the static results, across all scenarios/tax designs (see the synthetic redistributive effects measured by the change in the Gini coefficient in Figure A.2.1). This is because the own-price elasticity tends to decrease with incomes, which leads to a stronger reduction in consumed quantities and, therefore, in the tax burden at the bottom, with respect to the simulated burden presented in the main results, where consumed quantities are assumed to remain unchanged.

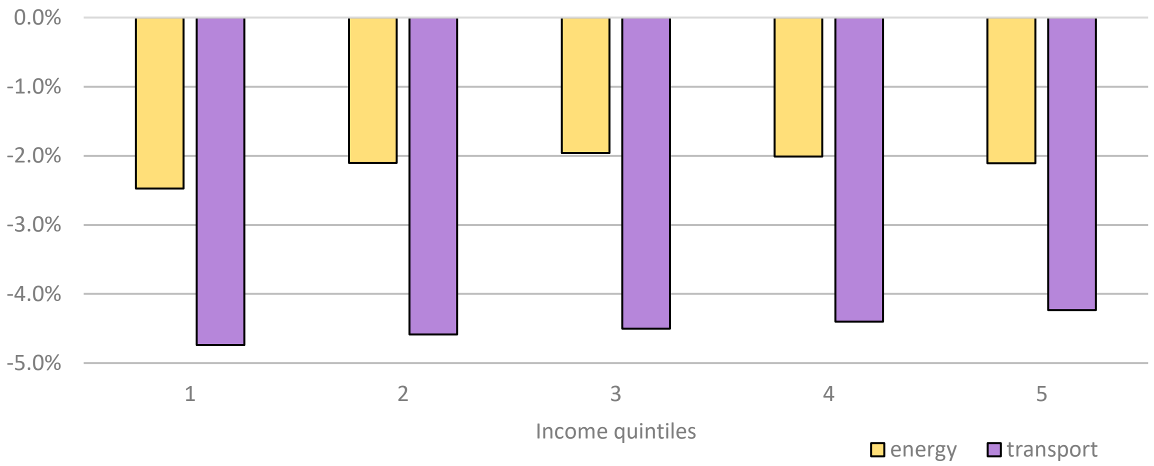
Figure A.2.1 Redistributive effect of the tax burden across scenarios (without and with behavioural responses)



Notes: Redistributive effect ("RE") of the simulated carbon taxes without and with elasticities by expenditure decile from Temursho and Weitzel (2024). Redistributive effect calculated with re-ranking (Gini of baseline equivalised disposable income – Gini of post-tax equivalised income)

There are at least four important observations to make here. One is that elasticities are not large and as such, the overall redistributive effect does not substantially change from the static analysis. Second, focusing only on the tax burden (which is the same than analysing only post-tax incomes) can hide the welfare effect driven by the actual reduction of consumed quantities. This is what happens with low-income households: they end up facing lower tax liabilities with respect to the static scenario, but this is not because they face lower effective tax rates but simply because they restrict more their consumption (see Figure A.2.2). The sum of both effects (change in tax liabilities and change in quantities) is what actually drives the overall welfare effect and corresponds to the compensating variation welfare approach that is typically used in the literature (and this is why these are the main redistributive results discussed in the paper). Third, these partial-equilibrium behavioural responses are not considering the potential effect on the consumption of complementary or substitute goods, as no cross-price elasticities are considered. Fourth, other more general equilibrium effect, including the effect on factor prices are not considered in this setting, and as such, results could be interpreted as short-term responses.

Figure A.2.2 Simulated change in quantities (under the new prices) by income quintile (Flat Tax scenario)



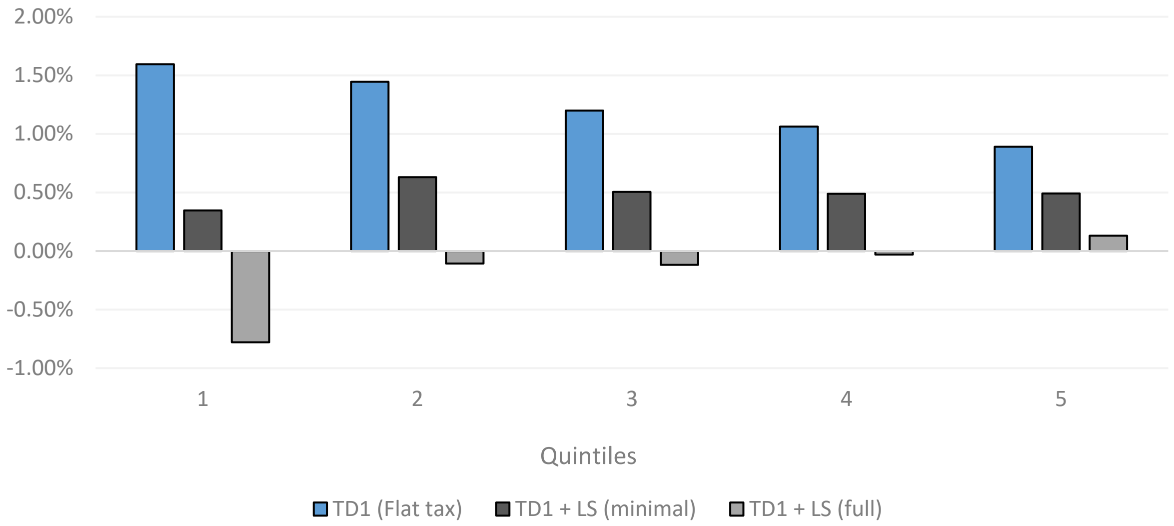
Notes: estimated change in consumed quantities (under the new prices - flat tax scenario TD1), with own-price elasticities by decile from Temursho and Weitzel (2024).

2.2. Simulating revenue recycling in the form of a lump-sum transfer

The inequality-increasing effects of the progressive tax designs simulated in section 4 are, in the most "progressive" design (the extreme case where only transport is taxed, and at high rates), 40% lower than the flat tax. All simulated tax designs lead to an increase in government revenues that have not been used in the simulations to compensate households. Dividing the overall budget among the population in the shape of a lump sum cash transfer would result in a transfer of about 196 EUR. This would lead to a reduction in inequality of about 0.0012 Gini points. About half (100 EUR) of such lump-sum transfer would be needed to completely offset the increase in inequality after the flat tax, keep inequality unchanged with respect to the baseline.

The relative change in incomes before and after the tax (tax burden) across income quintiles is plotted in Figure A.2.3 Here it is possible to appreciate that under the compensation with full budget (LS full) the bottom 80% of the population would end up with higher incomes than before, and only the fifth quintile would end up losing. On the contrary, in the scenario where the lump-sum transfer is the minimum that guarantees a null effect on the Gini coefficient, all quintiles end-up losing with respect to baseline, but those at the bottom would be the least affected (completely reverting the situation observed with the flat tax).

Figure A.2.3. Change in equivalised household disposable income, by quintiles



Notes: TD1: flat tax scenario, LS (minimal): lump sum transfer that keeps the Gini coefficient unchanged, LS (full): lump-sum transfer that uses the whole budget.