

Beyond income deciles: understanding the variation in welfare losses caused by EU ETS2 among Belgian households

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[20223677]

Master's thesis

Master Social-Economic Sciences

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Abstract

This study examines how the costs and benefits of EU ETS2 will be distributed across Belgian households. It provides a comprehensive assessment of both vertical and horizontal distributional effects. Moving beyond conventional analyses that focus solely on income deciles, the study investigates how welfare effects vary across demographic and socio-economic household characteristics, as well as by differences in household expenditure. The analysis is based on an integrated household-level dataset containing information on income, expenditure, and associated emissions. EU ETS2 is modelled as a €45/tCO₂ carbon tax under seven policy scenarios reflecting alternative uses of Social Climate Fund (SCF) resources. Using both bivariate and multivariate techniques, the study demonstrates that low-income households, households living in Wallonia, single-person households and households relying on solid or liquid fuels for residential heating experience the largest welfare losses from EU ETS2. However, distributional outcomes vary substantially across policy scenarios, highlighting the extent to which they are shaped by policy design choices. By connecting these findings to principles of distributive justice, this study formulates three policy recommendations. First, SCF resources should be targeted towards narrowly defined vulnerable groups to mitigate regressive outcomes. Second, to address disproportionate horizontal burdens, particular attention should be given to households living in Wallonia, single-person households, and households relying on solid or liquid fuels for residential heating. Third, the level of targeted support should increase in response to rising EU ETS2 allowance prices.

Keywords: EU ETS2, revenue recycling, distributional effects, microsimulation, distributive justice

Deze studie onderzoekt hoe de kosten en baten van EU ETS2 verdeeld zullen worden over Belgische huishoudens. Ze biedt een omvattende analyse van zowel verticale als horizontale verdelingseffecten. In tegenstelling tot conventionele analyses die zich uitsluitend richten op inkomensdecilen, onderzoekt deze studie hoe welvaartseffecten variëren naargelang demografische en sociaaleconomische huishoudkenmerken, en verschillen in uitgavenpatronen. De analyse is gebaseerd op een geïntegreerde dataset op huishoudniveau met informatie over inkomen, uitgaven en bijbehorende emissies. EU ETS2 wordt gemodelleerd als een CO₂-belasting van €45/tCO₂ onder zeven beleidsscenario's die alternatieve aanwendungen van de middelen uit het Sociaal Klimaatfonds (SKF) weerspiegelen. Met behulp van zowel bivariate als multivariate methoden toont de studie aan dat huishoudens met een laag inkomen, huishoudens in Wallonië, alleenstaanden en huishoudens die afhankelijk zijn van vaste of vloeibare brandstoffen voor woningverwarming de grootste EU ETS2 welvaartsverliezen ervaren. De verdelingseffecten verschillen echter aanzienlijk tussen de beleidsscenario's, wat benadrukt hoezeer ze worden bepaald door beleidskeuzes. Door deze bevindingen te koppelen aan principes van distributieve rechtvaardigheid formuleert deze studie drie beleidsaanbevelingen. Ten eerste zouden middelen uit het SKF gericht moeten worden naar nauw afgebakende kwetsbare groepen om regressieve uitkomsten te beperken. Ten tweede verdient de situatie van huishoudens in Wallonië, alleenstaande huishoudens en huishoudens die afhankelijk zijn van vaste of vloeibare brandstoffen voor woningverwarming bijzondere aandacht, om een disproportionele horizontale verdeling te vermijden. Ten derde moet de gerichte ondersteuning toenemen bij stijgende EU ETS2- emissierechtenprijzen.

Trefwoorden: EU ETS2, herverdeling van inkomsten, verdelingseffecten, microsimulatie, distributieve rechtvaardigheid

Table of contents

1	Introduction.....	4
2	Conceptual and theoretical framework	5
2.1	Distributive justice and climate change	5
2.2	Drivers of vulnerability to welfare losses caused by climate policies	7
2.2.1	Vertical analysis	7
2.2.2	Horizontal analysis.....	9
3	The policy instruments	14
3.1	EU ETS2	14
3.2	The Social Climate Fund	15
4	Data and methodology	17
4.1	Data.....	17
4.2	Empirical strategy	18
4.3	Policy scenarios.....	20
4.3.1	EU ETS2 allowance price	20
4.3.2	Revenue recycling scenarios.....	20
5	Results	22
5.1	Bivariate analysis	23
5.1.1	Vertical analysis	23
5.1.2	Horizontal analysis.....	26
5.2	Multivariate analysis	32
5.3	Sensitivity analysis	35
6	Discussion and policy recommendations	36
7	Conclusion	40
8	Scientific integrity.....	41
9	Bibliography.....	43
10	Appendix	50

List of tables and figures

List of tables

Table 1: Emission coefficients (tCO ₂ per € of expenditure)	18
Table 2: Overview of policy scenarios.....	21
Table 3: Overview of budgetary effects.....	23
Table 4: Inequality before and after EU ETS2 (€45/tCO ₂).....	25
Table 5: Most affected household type per scenario	31
Table 6: OLS regression results of relative EU ETS2 (€45/tCO ₂) welfare effects by household characteristics	32
Table 7: Inequality before and after EU ETS2 (€85/tCO ₂).....	51
Table 8: OLS regression results of relative EU ETS2 (€85/tCO ₂) welfare effects by household characteristics	53

List of figures

Figure 1: Distribution of EU ETS2 (€45/tCO ₂) welfare losses across income deciles	24
Figure 2: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by age of the reference person.....	27
Figure 3: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by region	27
Figure 4: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by degree of urbanisation.....	28
Figure 5: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by household composition	28
Figure 6: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by employment status	29
Figure 7: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by educational attainment	30
Figure 8: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by housing tenure	30
Figure 9: Distribution of EU ETS2 (€45/tCO ₂) welfare losses by fuel type for heating	31
Figure 10: Distribution of EU ETS2 (€85/tCO ₂) welfare losses across income deciles	50
Figure 11: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by age of the reference person	51
Figure 12: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by region	51
Figure 13: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by degree of urbanisation.....	52
Figure 14: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by household composition	52
Figure 15: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by employment status	52
Figure 16: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by educational attainment	53
Figure 17: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by housing tenure	53
Figure 18: Distribution of EU ETS2 (€85/tCO ₂) welfare losses by fuel type for heating	53

1 Introduction

Following the landmark Paris climate agreement of 2015, the European Union (EU) launched the European Green Deal (EGD) in 2019. The European Climate Law, adopted two years later, has made the EGD's goal of climate neutrality by 2050 legally binding for all EU member states. It has also written into law the intermediate target of reducing net greenhouse gas (GHG) emissions by at least 55% by 2030, as compared to 1990 levels (European Union, 2021). To achieve this intermediate target, the EU has adopted the Fit for 55 policy package which revised earlier climate policies and introduced new ones. A crucial part of the Fit for 55 package is its reform of the EU Emissions Trading System 1 (EU ETS1), the EU's main tool for reducing GHG emissions. EU ETS1 is a cap-and-trade system, creating a market for emission allowances, while simultaneously ensuring that emissions decrease in line with the EU's targets. With the Fit for 55 reform, the emission reduction goals of EU ETS1 have been ambitiously increased from -43% to -62% as compared to 2005, when the program was launched. Additionally, the policy package has introduced a separate new ETS for buildings, road transport and other (small industry) sectors not yet covered by EU ETS1. The new system, EU ETS2, will become fully operational in 2028 (European Council, 2025).

Carbon pricing mechanisms such as EU ETS2 are widely regarded as a key component of the policy mix required to achieve ambitious emission reduction targets. Environmental economists generally agree that, when compared to other climate policies, such mechanisms are among the most cost-effective ways to reduce emissions (Baranzini et al., 2017). Rooted in Pigouvian theory, carbon pricing seeks to internalise the external costs of emissions by incorporating them into market prices. This creates incentives for polluters to reduce emissions whenever the marginal cost of abatement is lower than the carbon price. In theory, this leads to cost-effective decarbonisation, as emissions reductions are undertaken where they are cheapest to achieve (Haywood & Jakob, 2023). If, ideally, the carbon price equals the marginal external cost of emissions, pollution occurs only when its economic benefits exceed its cost. Alternative policies, such as government subsidies or production standards, do not guarantee such economic efficiency (Gugler et al., 2021).

However, carbon pricing mechanisms have also attracted substantial criticism. Although their effectiveness is generally accepted, authors have emphasised the importance of complementary policy instruments. Some advocate for such measures out of concern for economic competitiveness (e.g. Rey & Madiès, 2021), while others stress equity and public acceptability concerns (e.g. Eisl & Nguyen, 2025; Markkanen & Anger-Kraavi, 2019). The latter arise from the fact that carbon pricing mechanisms may disproportionately burden vulnerable households. For example, as lower-income households, on average, spend a larger share of their budget on energy-intensive necessity goods than higher-income households, increasing the price of GHG emissions can cause them to lose a larger share of their purchasing power (Feindt et al., 2021). As EU ETS2 will extend the EU's carbon market to fuel combustion from road transport and buildings, sectors inherently intertwined with households' activities, concerns about such regressive effects have grown. Indeed, ex ante policy analyses have demonstrated that the welfare effects of EU ETS2 can vary substantially across income deciles (e.g. Adiyia, 2025; Costa & Dobbelaere, 2025).

This study will build on the existing impact analyses of EU ETS2 but will take a more comprehensive approach. While most studies have focused on the *vertical* distributional impacts of EU ETS2, i.e., on how its welfare effects differ across the income deciles, this study additionally takes into account the *horizontal* distributional impacts. That is to say, it aims to understand what factors, beyond one's place on the income distribution, drive the vulnerability to be negatively affected by EU ETS2. As income deciles are heterogeneous, the extent of welfare losses can vary considerably even among households within the same income category. These within-decile differences are precisely what this research seeks to explain. It will do so for the Belgian context, trying to gain a more nuanced understanding of the vulnerability of Belgian households to welfare losses caused by EU ETS2. Therefore, the central research question is: *"What factors explain the variation in welfare losses caused by EU ETS2 among Belgian households?"*

To answer this research question, this study simulates seven scenarios, each under an EU ETS2 allowance price of €45/tCO₂, to estimate the welfare effects of various policy options. Given the considerable uncertainty associated with the price of EU ETS2 allowances, the study conducts a sensitivity analysis under a price of €85/tCO₂. Subsequently, both bivariate and multivariate techniques are used to explain the absolute and relative welfare burdens caused by EU ETS2. A range of demographic and socio-economic household characteristics, as well as differences in expenditure are used to explain the variation in these welfare burdens. To do this, the study relies on an integrated dataset combining information on household income, expenditure, and associated emissions. The dataset is constructed from three primary sources: the 2022 EU Statistics on Income and Living Conditions (EU-SILC), the 2015 Household Budget Survey (HBS), and emissions coefficients from the 2014 PEACH2AIR database.

An evidence-based answer to the central research question is crucial to ensure the effectiveness of the Social Climate Fund (SCF). The primary goal of the SCF is to address and alleviate the social and economic impacts of EU ETS2. One of the ways in which it will do so, is by compensating households that are negatively affected by the introduction of EU ETS2 (European Commission, 2023). It goes without saying that in order to do so, such households need to be identified. If the identification process of vulnerable households occurs in a narrow or insufficient way (e.g. by only looking at a household's income), SCF resources might not reach the households that need them most. This research can thus provide valuable insights to, for example, the Belgian federal and regional governments on how to target and allocate SCF resources effectively.

While previous studies have examined the vertical and horizontal distributional effects of other climate policies, a comprehensive distributional analysis of EU ETS2 has remained largely absent. Costa and Dobbelaere (2025) and Trinomics B.V. (2025) come closest to such an assessment. Although this study will be similar, especially in methodological approach, it provides some insightful extensions. First and foremost, both studies do not consider any revenue recycling scenarios, therefore ignoring the effect of the Social Climate Fund on the distribution of costs and benefits. Secondly, neither study connects its findings to principles of distributive justice, therefore failing to offer guidance to policymakers on how to balance efficiency and equity considerations. This study aims to overcome these limitations to provide a more complete and policy-relevant analysis of EU ETS2.

The thesis is structured as follows. Section 2 outlines the theoretical concepts that will return throughout the study, providing an overview of the existing literature on distributive justice and the factors which drive vulnerability to negative impacts of climate change policies. Section 3 provides a technical explanation of EU ETS2 and the SCF, the policy instruments under examination. The empirical analysis follows in the subsequent sections: Section 4 explains the applied methodology, Section 5 presents the results, and Sections 6 and 7 discuss the policy implications and main conclusions, respectively.

2 Conceptual and theoretical framework

2.1 Distributive justice and climate change

Climate justice is an aspect taken into consideration in the design of almost all EU's climate policies. Policies which claim to strive for decarbonisation, will also stress the importance of a "fair" or "just" transition. While a lot of importance is attached to the concept on paper, it is unclear what climate justice means in practice. A single encompassing definition of climate justice does not exist in academia, nor in policymaking. This is understandable: because both climate change and climate justice are such complex issues, there are many ethical considerations to be made about how to approach them.

Attempting to capture this complexity, most authors define climate justice as a multi-dimensional concept. The two dimensions first outlined by Paavola & Adger (2002) recur in almost every discussion on climate justice: the distributive dimension and the procedural dimension. *Distributive justice* relates to how the costs and benefits

of climate change and climate change policies are distributed across groups of people and time, while *procedural justice* refers to how, and by whom, climate policy decisions are made (Paavola & Adger, 2002). Authors have expanded upon this framework by adding other dimensions. Schlosberg (2003) adds *recognitional justice*, referring to the importance of acknowledging group identity and respecting divergent climate change experiences coming from cultural, ethnic, racial and gender differences. In their three-dimensional framework, McCauley and Heffron (2018) advocate to add *restorative justice*, requiring the repair or rectification of climate change damages suffered by individuals, communities and countries. Yet even then the list may not be complete: Cañizares et al. (2024) define as many as six dimensions, adding *retributive justice*, *justice in system outcomes* and *intergenerational justice* to the mix. All of this points to the complexity and multi-dimensional nature of climate justice.

This study zooms in on the distributive dimension. It examines how the costs and benefits of EU ETS2 are distributed across different groups, and subsequently, whether this distribution can be considered fair. A crucial question that follows is: what constitutes a fair distribution? Davidson (2021) explores how fairness principles from moral philosophy can be applied to the distribution of climate change costs. He demonstrates how different philosophical traditions come to different conclusions as to what can be regarded as a “fair” distribution. For example, while right-libertarians might demand that all countries and individuals take up an equal burden in reducing emissions, utilitarians would argue in favour of a progressive distribution of costs based on the principle of diminishing marginal utility.

Davidson (2021) further notes that, in practice, the most important ethical framework guiding the distribution of climate mitigation and adaptation burdens is the *Common But Differentiated Responsibilities and Respective Capabilities* (CBDR-RC) principle outlined in the United Nations Framework Convention on Climate Change (UNFCCC). The principle mandates greater responsibility from developed countries given their larger contribution to historical GHG emissions and their greater financial capacity to pay for mitigation and adaptation efforts. More precisely, Article 3 of the UNFCCC (1992) states that “*The Parties should protect the climate system [...], on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities.*”

The CBDR-RC principle closely aligns with the responsibility and capability approach to distributive justice proposed by Büchs and Mattioli (2024). Responsibility refers to an actor’s or entity’s contribution to climate change, commonly measured through GHG emissions, while capability captures the capacity to mitigate or adapt to a changing climate. From this perspective, climate policies are distributionally unjust if those who have contributed the least to climate change (responsibility) or possess the least capacity to adjust to it (capability) bear the greatest burdens. Distributional outcomes therefore always have to be weighed against these two factors.

When applied at the household level, the responsibility and capability approach has clear implications for the vertical distribution of costs and benefits: higher-income households should bear larger burdens, as they are both responsible for a disproportionate share of GHG emissions (Lévay et al., 2021) and possess greater financial capacity to mitigate and adapt to climate-related costs. However, its implications for the horizontal distribution are less straightforward. While it is possible to identify, within income deciles, which household characteristics are associated with higher GHG emissions (as demonstrated by Lévay et al. (2021)), it is considerably more difficult to assess a household’s capability to mitigate or adapt to climate change on the basis of characteristics other than income.

This can lead to potentially ambiguous implications for distributive justice. For example, the responsibility component could justify imposing a greater burden on rural households if they have higher emissions, whereas the capability component may instead allocate a greater burden to urban households, given their potentially greater access to low-carbon alternatives and adaptation opportunities. Despite the growing literature on climate justice, limited attention has been given to what the concept of distributive justice implies for the distribution of climate-related costs and benefits within income groups. Whenever the responsibility and

capability components lead to conflicting implications, a defensible middle ground may be to strive for horizontal neutrality, i.e., a distribution of costs and benefits which does not disproportionately burden any one household type relative to another. This preserves equal treatment of households with similar economic means, an equality principle commonly adopted in the distributional analysis literature (Paavola & Adger, 2006; Saraswat & Kumar, 2016; Sommer et al., 2022).

Up until now, the discussion of a fair distribution of costs and benefits was made in normative terms. However, there is a clear instrumental reason for why attention should be given to fairly distributing the costs and benefits of climate policies: it enhances their effectiveness. No case better illustrates this than the yellow vest movement, which protested against the decision of the first Macron government to increase a carbon tax in 2018. The movement included many rural and poor French who felt that their disadvantaged position would become even more threatened due to the tax's effect on fuel prices. They argued that the policy was unfair because it would burden them most, while hardly affecting the wealthy urban population. After months of social unrest, the increase in the carbon tax was suspended (de Vries et al., 2024). The yellow vests are just one example; a literature review on the factors that shape public support for climate policies identifies perceived policy fairness as one of the crucial determinants (Dreus & Van den Bergh, 2016). This finding is important, given that ambitious climate policies depend on strong public support (Schaffer, 2024). This implies that concern for distributive justice is crucial because it is part of a larger chain of events: the perception of a fair distribution of costs and benefits shapes public support, which in turn determines the level of ambition of climate policies.

2.2 Drivers of vulnerability to welfare losses caused by climate policies

As the previous section demonstrated, there are both normative and instrumental reasons to care about distributive justice. However, in many cases the burdens of climate policies are unequally distributed, hitting more vulnerable groups the hardest. While such impacts are clearly at odds with the justice principles discussed above, they are often a natural consequence of the way in which policies are designed. This section provides an overview of the factors that make certain household types vulnerable to welfare losses arising from climate policies.

2.2.1 Vertical analysis

Most research focuses on the vertical dimension of distributive justice: it looks at how costs and benefits of climate policies are shared across income groups (e.g. Adiyia, 2025; Fragkos et al., 2021; Kerkhof et al., 2008; Zachmann et al., 2022). The recurring finding is that higher income groups lose more due to climate policies in absolute terms, but that this is hardly ever the case in relative terms. For example, Adiyia (2025) estimates that, after the introduction of EU ETS2, heating costs increase by €154 (0.8% of household budget) for the lowest expenditure decile, and by €325 (0.3% of household budget) for the highest expenditure decile in Belgium. Trinomics B.V. (2025), who provide an elaborate impact analysis in preparation of Belgium's Social Climate Plan, demonstrate a similar dynamic: households in the lowest expenditure decile face an additional expenditure of €207 (1.0%), while households in the highest expenditure decile face an additional expenditure of €368 (0.4%).

Such regressive outcomes are commonly the result of consumption taxes which cover necessity goods. The income-elasticity of demand for necessity goods is low, which means that their consumption does not rise proportionally to income. In other words, the proportion of income spent on necessity goods decreases across the income deciles. Any increase in the price of necessity goods therefore has the largest relative impact on poorer households (Blasco et al., 2023). This explains the effects documented by, for example, Adiyia (2025): as home energy consumption is relatively evenly distributed across income groups, it takes up a much larger income share of poorer households than it does of richer households. A carbon tax or ETS which increases the price of heating will thus lead to much larger welfare losses for poor households than for rich households. This dynamic explains why carbon pricing mechanisms tend to have regressive outcomes. A meta-analysis by Ohlendorf et al.

(2021) covering 53 empirical studies on the distributional outcomes of carbon pricing demonstrates that regressive impacts are established in approximately two-thirds of cases.

Many other types of climate policies can have similar effects. Zachmann et al. (2022) provide an extensive overview of the vertical distributional effects of climate policies. Climate subsidies for low-carbon technologies (e.g. rooftop solar panels) can be regressive because low-income households are less likely to invest in clean technology when there are high upfront costs, and thus less likely to receive the subsidy. A similar dynamic causes vehicle standards to be regressive: as it is more difficult for low-income households to switch to modern, less fuel-intensive vehicles, they will bear a disproportionate burden from low-emission zones or emission standards. Labour market policies which favour low-carbon sectors, depending on their design, can also be regressive. Regressivity might arise because low-income households are more likely to be employed in carbon-intensive industries (e.g. coal mining). However, evidence for this effect is mixed, as low-income sectors can also benefit from the energy transition. For example, increased renovation rates required to make buildings more energy-efficient can increase the demand for manual workers (Zachmann et al., 2022).

This final example demonstrates that climate policies by no means have to be regressive. There are many ways in which they can be made distributionally neutral, or even progressive. Even carbon taxes, which have been repeatedly shown to hit low-income groups the hardest, can be made progressive given careful policy design. The first way to do so is by levying the carbon tax on income-elastic carbon-intensive consumption. The idea is simple: a carbon tax on goods that are disproportionately consumed by higher income groups will yield significant environmental benefits while reducing inequality. A carbon tax on air transport offers a perfect illustration. Ivanova and Wood (2020) demonstrate that, within the EU, emissions from air travel are highly concentrated among higher-income households. With an expenditure elasticity of 1.5, air travel is the most elastic consumption category included in their analysis: as total expenditure doubles, expenditure on air travel increases by 150%. Similarly, Büchs and Mattioli (2024), who simulate four types of carbon flight taxes in the United Kingdom, find that flight emissions are distributed very unequally across the income distribution. Households in the highest income decile generate 7.5 times more flight emissions than those in the lowest decile. As a result, all four carbon flight tax designs examined by the authors produce progressive distributional outcomes.

Revenue recycling is the second way to make carbon taxes progressive. Even when a carbon tax is levied on goods which take up a disproportionate share of the expenditure of low-income households, progressive outcomes can be achieved by redistributing the revenues raised from the tax back to taxpayers. A distinction has to be made between revenue-raising carbon taxes, in which a portion of the revenues contributes to the government budget, and revenue-neutral carbon taxes (also known as an environmental tax reform), where all revenues are returned to taxpayers (Mintz-Woo, 2024). Revenues can be returned to taxpayers through, broadly speaking, three recycling mechanisms. First, revenues can be directly transferred to households as a lump-sum payment, which can be targeted or universal. While a universal transfer recycles the revenues as an equal per capita payment, a targeted transfer restricts beneficiaries to specific population groups. Second, the revenues can be used to cut distortionary taxes (e.g. on labour or capital) which can yield a “double dividend” by reducing emissions while increasing productivity. Third, the funds may be allocated to households indirectly through investments in green technologies or in sectors with high economic multipliers. The first two options are most commonly discussed in the literature (Timilsina, 2022). Note that, while the discussion is now focused on a carbon tax, the same is true for revenues arising from the auctioning of emission permits in an ETS.

Klenert et al. (2018) provide an overview of the performance of these various recycling mechanisms in terms of efficiency, equity and public acceptability. From an efficiency perspective, recycling revenues through a capital or corporate tax cut is preferable, especially in the long run, given the highly distortionary nature of these taxes. Labour tax reductions are more efficient than targeted or universal transfers, but less efficient than capital or corporate tax reductions. As highlighted by Timilsina (2022), the appeal of reducing distortionary taxes lies in preventing, or at least partly offsetting, the so-called “tax interaction effect”. This occurs when carbon pricing amplifies the distortionary effects of taxes already in place. For example, when a carbon tax raises energy prices, real wages are reduced, which in turn discourages labour supply and amplifies the inefficiencies associated with

income taxation. In such cases, the anticipated “double dividend” may be reversed, and the carbon tax may even result in net welfare losses (Ekins & Barker, 2001).

The ranking of recycling mechanisms is exactly the opposite from an equity perspective: income inequality is reduced the most by targeted transfers, followed by uniform transfers, labour tax reductions and capital or corporate tax reductions. With regards to public acceptability, Klenert et al. (2018) find that transfers-based mechanisms are more popular than tax cuts. Bachus et al. (2019), who explore public acceptability with greater depth, find that earmarking, i.e. using the revenues for measures that benefit the environment, most strongly increases public support. The authors similarly observe a trade-off between acceptability and efficiency: the measures that are most economically efficient receive the lowest levels of public support. Given these various trade-offs, the most ideal recycling mechanism is likely to depend on the policy goal. When distributional concerns are given priority, targeted transfers outperform other mechanisms. When efficiency concerns are greatest, corporate tax cuts are most suitable. If the primary aim is to increase public support, earmarking the revenues is preferable.

According to Klenert et al. (2018), uniform lump-sum recycling is most favourable in more general circumstances. The authors advance two main arguments. First, lump-sum payments can be made in salient ways, thereby increasing public support. Second, even when distributed as an equal per capita transfer, such payments generate progressivity given that the same transfer has a larger proportional impact on the incomes of poorer households. Mintz-Woo (2024) reaches a similar conclusion, stressing that lump-sum transfers are both politically appealing and morally justifiable from a distributive justice point of view. However, the author adopts a relatively narrow conception of distributive justice: he claims that uniform transfers are morally justifiable because they offset the regressivity caused by the tax. Yet, by solely focusing on the vertical income dimension, this claim misses the inequalities that are hidden within the income deciles. Sommer et al. (2022) justify an equal per capita transfer from the perspective of atmospheric property rights. If these rights are universal, i.e. held by all individuals collectively, then the revenue generated from their auctioning should be distributed universally as well.

While revenue-recycling can achieve distributional outcomes which favour low-income groups on average, it is crucial to be aware that some low-income households can nonetheless lose out significantly due to a carbon tax. As demonstrated by Goedemé (2022), averages obscure underlying dynamics: just because a policy favours (or at least does not further harm) lower-income groups, does not mean that everyone within those groups is equally protected. That is why horizontal distributional analysis should complement the vertical analysis to ensure that revenue recycling reaches those who need it most.

2.2.2 Horizontal analysis

As was made clear above, to fully assess the societal distribution of costs and benefits caused by climate policies, it does not suffice to only look at the vertical, i.e. income, dimension. This is because income groups are heterogeneous: they contain a large variety of households. As a consequence, costs and benefits can be distributed very unequally, even among households belonging to the same income decile. In fact, Cronin et al. (2019), in their simulation of a carbon tax with revenue recycling in the United States, find that variation along the horizontal dimension exceeds variation along the vertical one.

That is why the horizontal analysis, which aims to understand how costs and benefits are distributed within income groups, is a crucial complement to the vertical one. However, few studies have applied such a comprehensive approach to EU ETS2. The literature that covers horizontal distributional effects of climate policies will be discussed here. The discussion is structured around three main drivers of horizontal heterogeneity: demographic characteristics, socio-economic factors, and differences in household expenditure. Each of the factors discussed below will return in the empirical analysis and be used to explain the variation in welfare losses caused by EU ETS2.

2.2.2.1 Within-decile demographic differences

The demographic factors that are included in this research are age, residence location and household composition. These factors have been included in earlier studies of climate policies and seem highly relevant in explaining horizontal differences in vulnerability to welfare losses.

The first factor, age, has been shown to be correlated with both GHG emissions and vulnerability to be disproportionately burdened by climate policies. Controlling for a range of socio-economic characteristics, Lévy et al. (2021) find a significant non-linear effect of age of the reference person on emissions among Belgian households. This supports the common finding that age and GHG emissions follow an inverted U-shaped relationship: GHG emissions tend to rise with age up to a certain point and then decline (Büchs & Schnepf, 2013; Lim et al., 2020; Zagheni, 2011). Lévy et al. (2021) further specify that the age-gradient of emissions is stronger in some consumption categories (e.g. private transport), and much weaker in others (e.g. goods). These results imply that the inverted U-shaped emission pattern is likely the outcome of changing lifestyles with age. For example, a household with a middle-aged reference person might conduct a lot of family travel, which might be less common among younger or older households.

Studies that examine how the costs and benefits of climate policies are distributed across age groups often conclude that older households are disproportionately burdened by climate policies as compared to younger households. Douenne (2020), studying the vertical and horizontal distributive effects of French energy taxes, finds a non-linear pattern: the effect of the policy (after revenue recycling) is positive and increasing with age, up to some point, after which it becomes negative. Similarly, Heyndrickx et al. (2022), who simulate a hypothetical €20/tCO₂ carbon tax with equal lump-sum recycling, find that while the policy package has positive effects for households whose reference person is between 18 and 65 years old, it has negative effects for households whose reference person is over 65. Such households appear to be particularly vulnerable to increases in the price of heating fuels.

Despite the fact that older households, on average, have lower emissions as compared to middle-aged households, both empirical studies demonstrate their increased vulnerability. Such a distribution does not adhere to the responsibility and capability approach to redistributive justice introduced in Section 2.1. More specifically, it conflicts with the responsibility component, as the most burdened age group is not the group with most emissions. Furthermore, when considering the capability component, old age may, if anything, reduce a household's capacity to mitigate or adapt to climate change due to structural constraints associated with ageing. For example, since older people are more likely to spend time at home, they have greater energy needs and are less flexible to lower energy consumption in response to rising prices (Büchs & Schnepf, 2013). However, when assessing capability, it is important to acknowledge the interaction between age and income. While old age may add an additional layer of vulnerability for low-income households, its relevance is likely reduced for high-income households with greater financial capacity to absorb additional costs. Nonetheless, energy taxes such as the one examined by Douenne (2020), which disproportionately burden older households even after controlling for income, appear difficult to reconcile with principles of distributive justice.

Residence location, and more specifically the level of urbanisation, have also been included in multiple distributive analyses of climate policies. The literature generally demonstrates that, holding other factors constant, households in rural areas have higher emissions than those in urban areas. A first explanation for this finding is a high dependency on private transport: rural households commonly have longer commuting distances, and because public transport is limited, they more commonly make use of cars (Haywood & Jakob, 2023). A second explanation relates to residential energy demand. Rural dwellings are more likely to be older, larger and detached, characteristics commonly associated with lower energy performance. In the Belgian context, Reusens et al. (2022), for instance, show that among dwellings sold in 2021, houses in relatively more rural Wallonia were, on average, 24 years older than those sold in predominantly urban Flanders and were 3 p.p. more likely to be detached. This could help explain why Lévy et al. (2021) find that, when controlling for other characteristics,

Walloon households emit about 8% more on average than Flemish households. They confirm that this difference is mainly driven by higher emissions from domestic energy use and transport of Walloon households.

Consistent with these findings, policy analyses generally conclude that rural households experience larger welfare losses from carbon taxation than urban households. Such a distribution is empirically documented in several countries including Belgium (Bursens et al., 2025), Denmark (Wier et al., 2005), and the United Kingdom (Feng et al., 2010). Similarly, Trinomics B.V. (2025) identifies rural and Walloon households as particularly vulnerable to the introduction of EU ETS2. Their analysis shows that households in sparsely populated areas are expected to face an expenditure increase of 1.1%, compared to only 0.5% for households in densely populated areas. This disparity is driven primarily by increased expenditure on heating oil and coal in the rural areas. In regional terms, while a Walloon household is expected to see its costs rise by 0.9%, the increase is more limited for Flemish and Brussels households, at 0.5% and 0.4%, respectively.

Based on the results above, the implications for distributive justice may appear straightforward: as rural households emit more than urban households on average, it may seem justifiable that they carry a larger burden of climate policies. However, as highlighted in Section 2.1, responsibility for climate change, reflected through GHG emissions, is only part of the picture. Capability, i.e. the capacity to mitigate or adapt to climate change, is equally important when assessing the fairness of a distribution of costs and benefits. Higher carbon footprints among rural households may partly reflect emissions that are difficult to avoid. Limited access to public transportation, for example, illustrates that rural households sometimes lack the opportunity to reduce their emissions. Given the conflicting implications of the responsibility and capability components, the most just distribution may ultimately be one that does not disproportionately burden rural households relative to urban ones, or vice versa.

Note that such “hard-to-abate” emissions may be especially acute for low-income households, who do not have the means to invest in making their homes or vehicles more energy efficient. This suggests that, within the horizontal analysis, it may be required to reconsider the vertical dimension: a carbon tax that disproportionately affects higher-income rural households may be justifiable, while one which disproportionately affects lower-income rural households is not.

Household composition seems to be a third relevant factor. Household size, the number of children, and the age of children, all seem to play a role in determining the vulnerability of households to be disproportionately burdened by climate policies. Larger households tend to emit more than smaller households, but emissions do not increase proportionally with additional members. For Belgian households, total emissions increase by only 20 percent for the first additional adult, and 10 percent for the first additional child (Lévay et al., 2021). The economies of scale enjoyed by larger households have also been demonstrated by Ivanova and Büchs (2020): within the EU, a one-member household has a per capita carbon footprint that is about twice as large as that of a five- or more person household. The authors note that, as a consequence, the rising trend of single households might put upward pressure on emissions. However, household economies of scale vary considerably across consumption domains. While they are strong in housing-related categories, such as electricity expenditure or rent, they are much weaker or absent in areas such as food or transportation expenditure.

Cui and Wu (2025) examine expected EU ETS2 burdens across various household types. They find that single-person, single-parent and childless households are more strongly affected than couples with children. They demonstrate that these disparities can be mitigated by recycling carbon revenues equally to each household or, to a lesser extent, by subsidising housing fuels. Using the carbon revenues to subsidise transport fuels is ineffective in this case, because smaller households are characterised by a disproportionate expenditure on housing energy, but not by a disproportionate expenditure on transport. More broadly, it is important to note that subsidising energy prices for social purposes is never an adequate strategy, as it weakens incentives to transition away from fossil fuels (Bachus & Dunne, 2024).

In line with Cui and Wu (2025), Trinomics B.V. (2025) demonstrates that, among all household types considered, single-person households are expected to experience the largest increase in energy poverty after the introduction of EU ETS2. Other studies similarly highlight the vulnerability of smaller households to being disproportionately impacted by the introduction of a carbon tax (e.g. Bursens et al., 2025; Douenne, 2020; Wier et al., 2005).

2.2.2.2 Within-decile socio-economic differences

Demographic characteristics explain only part of the within-decile variation in vulnerability to the negative impacts of climate policies. Based on the available literature, socio-economic factors, such as employment status, educational attainment and housing tenure status, can similarly be expected to explain some of the horizontal disparities caused by climate policies.

Although the educational attainment and employment status of the household reference person are inevitably intertwined with household income, they seem to have a direct effect on emissions, and subsequently on the vulnerability to the negative impacts of carbon taxes. Lévy et al. (2021) demonstrate that emissions tend to rise with educational attainment, even after controlling for income. This effect is driven mostly by an increase in emissions related to “services” (e.g. leisure activities or health services) when comparing low-educated individuals with high-educated individuals. This may reveal different preferences across educational levels, which can translate into less or more emission-intensive consumption. It may also be driven by differences in access to wealth, an economic resource not included in their analysis.

With respect to employment status, Lévy et al. (2021) find that households whose reference person is unemployed have a significantly lower carbon footprint than households whose reference person is employed. They find no significant differences when comparing households whose reference person is employed with those whose reference person is a student, a homemaker, incapacitated, or retired. Based on these results, the greatest responsibility for climate change appears to lie with the group of highly educated, employed individuals, while lower-educated and unemployed individuals have contributed less. One could assume that the majority of highly educated and employed individuals have a relatively greater capacity to mitigate or adapt to climate change, so that the responsibility and capability approach justifies a carbon tax which allocates a higher burden to this group.

In the literature, results on how educational and employment groups are affected by climate policies are relatively scarce. Heyndrickx et al. (2022), who simulate a €20/tCO₂ carbon tax with equal lump-sum recycling, find that, all else constant, households with an employed reference person gain more from the policy as compared to households with a self-employed, unemployed, or retired reference person. Interestingly, without controlling for additional factors, the pattern is reversed: on average, households with an unemployed reference person benefit from the reform, while households with a working reference person do not. Only after including variables such as car ownership and housing size does the model demonstrate that employment reduces, rather than increases, vulnerability to welfare losses following the introduction of a carbon tax.

Due to the close correlation between income and education, carbon taxes can be expected to have the largest relative impact on households whose reference person has a low level of education. However, as discussed extensively in the vertical analysis, the extent to which this effect occurs depends crucially on the applied recycling mechanism. Vandyck and Van Regemorter (2014) demonstrate that households with a highly educated reference person benefit more when revenues are recycled through a reduction in taxes on labour income than when revenues are transferred through an increase in welfare payments. The reverse is true for households with a low-educated reference person.

Finally, the tenure status of a household, whether the household is a tenant or owner, could also contribute to the extent households are negatively affected by climate policies. The literature that studies housing tenure status alongside climate policies frequently mentions the *split incentives problem*. The problem most commonly

occurs when tenants pay the monthly energy bill while landlords are in charge of making energy-efficient investments. In such a setting, game theory suggests a structural underinvestment in energy-efficient technologies (Gillingham et al., 2012). The idea is simple: while tenants enjoy the benefits of such investments in the form of a reduced energy bill, landlords have to incur the costs. Landlords have the incentive to supply cheap appliances (e.g. refrigerators) regardless of how energy efficient they are and opt for energy sources with the lowest upfront costs (e.g. the heating oil boiler which was already in place) (Bird & Hernández, 2012). As a consequence, tenants might end up in a situation in which they make use of energy-inefficient appliances which run on highly polluting energy sources. Such a situation would make them structurally vulnerable to strong welfare losses after the introduction of a carbon tax (Melvin, 2018). Additionally, the split incentives problem would make the tax ineffective: while it increases the energy bills for tenants, it does not incentivise landlords to make energy-efficient investments, as there is still no personal benefit for them in doing so.

The split incentives problem would suggest that tenants (involuntarily) have inefficiently high carbon footprints. Yet, the analysis of Lévy et al. (2021) demonstrates that, among Belgian households, tenants have a considerably smaller carbon footprint than owners. This does not mean that no inefficiency arises due to the split incentives problem: tenants may want to reduce emissions even more. One explanation for these results could be that the effects of the split incentives problem are offset by another mechanism, for example, tenants having smaller dwellings than owners. However, as Lévy et al. (2021) control for the number of rooms in the house, as a proxy for its size, their results appear to show limited effects of the split incentives problem. Similarly, Heyndrickx et al. (2022) find no significant difference between owners and renters in terms of welfare losses caused by a carbon tax.

2.2.2.3 Within-decile expenditure differences

While the discussion has mainly focused on household characteristics, it is important to also shed light on household consumption patterns. Similar households may differ considerably in their level of energy consumption. Differences may arise because some rely on fossil fuels for their heating or transportation, while others do not; some use their car intensively, others opt for public transportation; some live in large houses, others in small flats (Heyndrickx et al., 2022). Although these consumption choices may be correlated with socio-demographic characteristics, household expenditure seems to be a crucial determinant of vulnerability to welfare losses, even after controlling for factors such as income or education.

Of all expenditure differences, the most important one might be the difference in fuel type used for residential heating. The most recent figures indicate that Belgian households primarily rely on natural gas (64.2%) or heating oil (21.2%). The use of environmentally friendly alternatives, such as heat pumps, although increasing, remains limited (FOD Economie, 2025; 2022 figures). These figures are concerning, as research has consistently demonstrated that the introduction of a carbon tax hits households that rely on natural gas or heating oil the hardest, relative to households that do not (Berry, 2019; Douenne, 2020; Heyndrickx et al., 2022). In their analysis, Heyndrickx et al. (2022) demonstrate that the heating method is, by a considerable margin, the most important determinant of household vulnerability to the negative impacts of a carbon tax. They find that a €20/tCO₂ tax with equal lump-sum recycling results in an additional loss of €6.67 per month for households heating with natural gas and €16.57 for households relying on heating oil, both compared to households that heat with electricity. This highlights that welfare losses can vary substantially even among households relying on fossil fuels.

In a preliminary analysis of EU ETS2's impact on heating expenses among Belgian households (without revenue recycling), Costa and Dobbelaere (2025) find that, when controlling for demographic and socio-economic household characteristics, households that use heating oil are 34 percentage points more likely to see a large increase in expenses as compared to households that rely on natural gas. As the emission factor of heating oil, i.e. the amount of CO₂ released per unit of energy produced, is only slightly higher than that of natural gas (77.4 tCO₂/TJ versus 74.1 tCO₂/TJ (VEKA, 2026)), these substantial differences in vulnerability cannot be explained by carbon intensity alone. Rather, they likely reflect differences in housing characteristics associated with each

heating method, such as building age or energy performance. This suggests that the observed vulnerability is not driven directly by the type of heating fuel, but by correlated factors which are not included in the analysis.

Protecting vulnerable households that rely on fossil fuels for residential heating, while simultaneously reducing emissions, is not an easy task. Environmentally friendly heating systems, such as heat pumps, need to become the most economically attractive option, while households' overall purchasing power should be protected. The attractiveness of heat pumps depends on the ratio between electricity and natural gas prices. Wouter (2025) demonstrates that, in Belgium, heat pumps are often the cheapest alternative when the electricity-to-gas price ratio is 2.2 or lower. By increasing the price of fossil fuels, carbon pricing mechanisms reduce this ratio and thereby improve the relative competitiveness of heat pumps. However, such mechanisms should be implemented jointly with revenue recycling to protect households from welfare losses associated with higher heating costs during the transition. Without the combined implementation of these measures, there is a substantial risk of lock-in effects, whereby households are unable to afford investments in less carbon-intensive heating systems (Vanhille et al., 2019). In such cases, carbon pricing leads to welfare losses without resulting in the intended behavioural response.

This section has demonstrated the many ways in which climate policies can negatively affect the welfare of households. Vulnerability to disproportionate welfare losses arising from such policies runs through society, in all possible directions. Identifying which households suffer the greatest burdens from climate policies is a necessary first step in assessing whether such policies can be considered distributionally just. Before turning to that assessment, the following section provides a detailed overview of the two central policy instruments examined in this study: EU ETS2 and the Social Climate Fund.

3 The policy instruments

3.1 EU ETS2

Before moving to the empirical analysis, it is crucial to understand what EU ETS2 is and how it will work. The system was introduced as part of the EU's Fit for 55 package in 2021. EU ETS2 is a new emissions trading system (ETS) designed to run in parallel with EU ETS1, which has covered electricity generation and energy-intensive industry since 2005. EU ETS2 extends carbon pricing to CO₂ emissions from fuel combustion in buildings, road transport, and small industry, sectors not yet covered by EU ETS1. Although climate policies already exist for these sectors, overall progress in decarbonisation has been insufficient (European Commission, 2023). For example, while emissions from EU ETS1 sectors were halved between 2005 and 2023, emissions from road transport declined by only 4.4% over the same period (European Environment Agency, 2025). EU ETS2 is considered a crucial instrument for achieving further emission reductions.

EU ETS2 will be fully operational from 2028 onwards. It was first planned to enter into force in 2027 but was postponed by one year in the 2025 amendment of the European Climate Law. Its main target is to reduce CO₂ emissions from the EU ETS2 sectors by 42% by 2030 (as compared to 2005) to ensure sufficient progress to the overall EU goal of climate neutrality by 2050. Similar to the existing ETS, EU ETS2 will operate based on a "cap-and-trade" mechanism. Total emissions are limited by an annually decreasing cap, which is expressed in emission allowances. One allowance gives the right to emit one tonne of CO₂ (European Commission, 2023). Initially, the EU-wide cap for 2027 was set at 1,036,288,784 allowances (corresponding to 1,036 MtCO₂), based on the average emissions from EU ETS2 sectors from 2016 to 2018. It is currently unclear how EU ETS2's postponement affects the number of allowances that will be available in 2028, when the system is set to start (Vella et al., 2026). Progress towards EU ETS2's emission target is ensured by annually decreasing the number of issued allowances. More specifically, the number of allowances will decrease yearly through a linear reduction factor of 5.10%, to be increased to 5.38% in later years, in accordance with Article 30c(1) of the new ETS Directive 2023/959.

In contrast to EU ETS1, which allocates a considerable amount of free emission allowances, all allowances under the new system will have to be purchased in auction, on the so-called primary market. After having purchased the allowances, the covered entities can freely trade them on the secondary market. This creates market incentives for reducing emissions: entities which have surplus emission allowances can sell these to entities which lack allowances to cover their emissions. As a result, it becomes profitable to decrease one's emissions, and more expensive to continue to emit at high levels. As in EU ETS1, the borrowing of emission allowances is prohibited, but entities are allowed to bank, i.e. save, emission allowances for future use. This feature increases the flexibility of entities in designing their long-term compliance strategies (Vella et al., 2026).

To avoid placing any administrative burden on end consumers, compliance obligations under EU ETS2 will fall upstream on fuel suppliers. This means that fossil fuels retailers, selling for example gasoline, diesel or heating oil, will need to monitor and report the emissions released by the combustion of the fuels they place on the market, as well as surrender the corresponding emission allowances. While these fossil fuel retailers are formally the ones paying for emission allowances, most, if not all, of the costs are expected to be passed through to end consumers through increased fuel prices (Haywood & Jakob, 2023).

By increasing the price of fossil fuels, the system aims to incentivise consumers and households to move away from carbon-intensive economic activity by opting for low-carbon alternatives. However, to prevent carbon prices from rising to undesirably high levels in the initial years of the system, several price stability mechanisms will be put into place (Günther et al., 2024). First, the initial auction volume in 2028 will be increased by 30% to provide sufficient market liquidity, a practice known as “frontloading”. This implies that emission allowances from later years are auctioned earlier, improving liquidity now at the cost of more stringent reduction requirements later.

Second, just as its sibling system, EU ETS2 will come with its own Market Stability Reserve (MSR2). The MSR2 is a reserve containing 600 million EU ETS2 emission allowances which serves to mitigate insufficient or excessive supply of allowances on the market (European Commission, 2023). Specifically, if the total number of allowances in circulation (TNAC) falls below 210 million, 100 million additional allowances are released. Conversely, if the TNAC exceeds 440 million, 100 million allowances are deducted and placed into the reserve (Article 1a (5-6) of Directive 2023/959).

Finally, the MSR2 can also be used to react directly to an increase in the price of emission allowances. In the first three years after the system is introduced, a price level above €45/tCO₂ (for at least two consecutive months) triggers the release of 20 million additional allowances, for a maximum of two times per year (Article 30h (2) of Directive 2023/959). Similarly, if the average price for three months rises to two (respectively three) times the average price of the previous six months, 50 (respectively 150) million additional allowances will be released (Article 30h (1-2) of Directive 2023/959).

In response to increasing political pressure, the European Commission appears determined to limit price increases during the early phases of EU ETS2: it has proposed to amend the MSR2 to strengthen the “soft” price cap it provides. Specifically, the proposed amendment would increase the number of allowances released when the price exceeds €45/tCO₂, allowing up to 80 million additional allowances to be released annually. In addition, the Commission aims to respond more quickly to reductions in the TNAC by raising the threshold for releasing extra allowances from 210 million to 260 million allowances (European Commission, 2025a).

3.2 The Social Climate Fund

EU ETS2 will not be introduced on its own, but is part of the Fit for 55 policy package. A second crucial element of that package is the Social Climate Fund (SCF). Its main purpose is to address and alleviate the social and economic impacts of EU ETS2. As explained in the previous section, these impacts can be large, and risk being distributed unevenly. That is why the SCF, in addition to providing resources for investments that reduce

emissions in the EU ETS2 sectors, offers temporary direct income support for vulnerable households (Sabato et al., 2023).

As set out in Regulation 2023/955, the SCF will become operational one year prior to the implementation of EU ETS2. During this initial phase, it will be financed through revenues generated from the auctioning of allowances under EU ETS1. From 2028 onwards, once EU ETS2 is fully operational, the SCF will be funded by revenues from the auctioning of EU ETS2 allowances, up to a total amount of €65 billion. Additionally, member states are required to top-up their SCF funding with 25% by using national resources to co-finance the measures which they intend to implement. The total amount of the SCF, made available up until 2032, therefore adds up to €86.7 billion (Sabato et al., 2023). To ensure a fair distribution across the member states, these funds are distributed by making use of an allocation formula, which considers total population, gross national income, household carbon emissions, the population at risk of poverty living in rural areas, and the percentage of households at risk of poverty with arrears on utility bills. Based on this formula, Poland (17.6%), France (11.2%) and Italy (10.8%) will receive the largest share of funding. Belgium will receive 2.55% of the total climate fund, or €1.656 billion in absolute numbers (Jüngling et al., 2025).

Taking into account Belgium's own contribution of 25%, the total budget available for measures included in the national Social Climate Plan adds up to €2.208 billion. Within Belgium, 13.13% (€217 million) will be allocated to the federal government, while the Flemish and Walloon region receive 43.42% (€952 million) and 32.95% (€728 million) respectively. The remaining 10.50% (€232 million) is allocated to the Brussels-Capital region (Klimaat.be, 2025). These funds are to be spent in the 2027-2032 period. Importantly, as both the total size and the distribution of the SCF are determined ex ante, the available resources are not directly linked to the revenues generated by EU ETS2. In other words, while higher emission allowance prices increase auction revenues, this does not translate into a larger SCF. For example, if the average allowance price in auction reaches €60/tCO₂ by 2032, total revenues would exceed €250 billion, while the SCF would remain fixed at €65 billion (Eisl & Nguyen, 2025). This approach has been criticised by experts, as a higher EU ETS2 allowance price increases the impact on (vulnerable) households, without a corresponding increase in support. By making the SCF proportional to the collected revenues, it could better respond to rising needs as a result of increasing prices (Hengalová, 2024).

In order to receive access to the SCF, each member state must draft their own Social Climate Plan (SCP). After having consulted local and regional authorities, economic and social partners and civil society, member states are required to submit a spending proposal to the European Commission, clearly outlining how the obtained funding will be used up until 2032. The funds can be used for a large range of measures and investments, leaving member states with considerable discretion in how to use them. However, Article 8 of Regulation 2023/955 limits the resources that can be used for direct income support at 37.5% of the nationally obtained funds. Member states can freely determine through which mechanisms to provide this direct income support (e.g. direct payments, tax reductions, increased benefits, etc.). They can also decide which population groups are eligible for support, allowing them to target support and address disproportionate burdens as they see fit. The deadline for submission of the national SCPs was set on the 30th of June 2025. Not a single member state succeeded in meeting this deadline. At the time of writing, 11 months after the deadline, just eight member states (Croatia, Greece, Latvia, Lithuania, Malta, the Netherlands, Slovenia and Sweden) have submitted plans, of which only Sweden's had been adopted.

The fact that so many member states have failed to meet the deadline demonstrates that it is difficult to reach agreements on which groups should receive most support. Policymakers are faced with many things to take into consideration: efficiency, equity and political feasibility. Jüngling et al. (2025) emphasise the central role of Social Climate Plans in securing public support for the Fit for 55 policy package, including EU ETS2. As noted earlier, perceived fairness is a key driver of public acceptance of climate policies. Consequently, significant pressure rests on the Social Climate Fund (and on member states' Social Climate Plans) to deliver distributionally just outcomes. To contribute to this, the rest of this study will investigate the vertical and horizontal distributional outcomes of EU ETS2, taking into account alternative uses of the SCF resources.

4 Data and methodology

4.1 Data

Three data sources are combined for this study. Information on income, socio-demographic characteristics and living conditions is obtained from the EU Statistics on Income and Living Conditions (EU-SILC) from 2022. Information on household expenditure, which is not available in EU-SILC, was obtained from the 2015 Household Budget Survey (HBS). Although both datasets are collected and harmonised across all EU member states, this study is restricted to Belgian households. The data from the HBS has been linked to the data from EU-SILC through imputation by the Joint Research Centre (JRC) of the European Commission (Amores et al., 2023; Bursens et al., 2025). Next, the combined HBS-SILC dataset is processed through EUROMOD, the EU's tax-benefit microsimulation model, applying the Belgian tax-benefit system. This step yields simulated values for disposable income, social insurance contributions, and social benefits received.

While the resulting dataset would suffice for analysing the distributional effects of most taxes, studying the effects of an ETS additionally requires information on household-level emissions. This study relies on the emission coefficients from the PEACH2AIR database, which contains detailed information on emissions released per euro of expenditure. Such "GHG multipliers" differ by consumption category to reflect differences in emission intensities (Bursens et al., 2025). The PEACH2AIR database was constructed in 2018 and refers to the year 2014. Its emission coefficients are derived from two underlying sources: the Belgian national emission inventory and COPERT, a European road transport emission inventory model (Frère et al., 2018; Lévy et al., 2021). Incorporating this information into the HBS-SILC dataset results in an integrated dataset containing information on income, expenditure, and associated emissions at the household level (Bursens et al., 2025).

To illustrate the integration of these data sources, consider the computation of EU ETS2's impact on household expenditure for natural gas. First, household disposable income (derived from EUROMOD, based on EU-SILC) is combined with expenditure shares for natural gas (obtained from HBS) to estimate total spending on natural gas. This expenditure is then multiplied by the corresponding CO₂-coefficient from the PEACH2AIR database, yielding the associated CO₂ emissions. Multiplying these emissions by a predetermined carbon price (see Section 4.3.1) gives the impact of EU ETS2.

More formally, as presented by Maier et al. (2024), we can define Z_{ip} , the annual expenditure (in euros) spent by household i on consumption category p , as:

$$Z_{ip} = w_{ip} \cdot Y_i^d \quad (1)$$

where w_{ip} denotes the expenditure share of household i on consumption category p and Y_i^d represents household disposable income.

Total CO₂ emissions associated with this expenditure are then calculated as:

$$CO_2(Z_{ip}) = Z_{ip} \cdot m_p \quad (2)$$

where m_p is the CO₂ emission coefficient of consumption category p .

Substituting (1) into (2) demonstrates the contribution of each data source:

$$CO_2(Z_{ip}) = \underbrace{w_{ip}}_{\text{HBS}} \cdot \underbrace{Y_i^d}_{\text{EU-SILC}} \cdot \underbrace{m_p}_{\text{PEACH2AIR}}$$

$CO_2(Z_{ip})$ serves as the tax base for estimating the impact of EU ETS2. In other words, the EU ETS2 burden is computed by multiplying $CO_2(Z_{ip})$ with a chosen carbon price.

4.2 Empirical strategy

The main objective of this study is to assess how the costs and benefits of EU ETS2 will be distributed across the Belgian population. This section outlines how EU ETS2 is modelled, and subsequently, how its welfare effects are captured.

EU ETS2 is modelled as a carbon tax. While there are fundamental differences between an emissions trading system and a carbon tax, the literature provides justification for this approach. Goulder and Schein (2013), in a comprehensive review comparing both policy instruments, conclude that they tend to result in similar economic and distributional outcomes, as well as comparable emission reductions, provided that emission allowances are auctioned rather than freely allocated. Therefore, for the purpose of the simulation, modelling EU ETS2 as a carbon tax is a suitable simplification.

The carbon tax is levied on the CO_2 emissions released from household expenditure on residential heating and fuels for road transport. Specifically, emissions from five categories of the Classification of Individual Consumption According to Purpose (COICOP) are taken into account. Four categories relate to housing: expenditure on natural gas, liquefied hydrocarbons (e.g. butane and propane), liquid fuels (e.g. heating oil) and solid fuels (e.g. coal). One category relates to private transport: expenditure on fuels and lubricants. Emissions from these categories are multiplied by a predetermined carbon price (see Section 4.3.1) to compute the EU ETS2 burden at the household level.

The PEACH2AIR database provides CO_2 emission coefficients for each of the five consumption categories considered. When coefficients are available at a more disaggregated level, this study uses the average coefficient of the corresponding COICOP subcategories. For the final category, fuels and lubricants for private transport, a weighted average is constructed using market shares as weights, based on information provided by FOD Economie (2026). Table 1 reports the resulting emission coefficients, expressed as tonnes of CO_2 released per euro of expenditure.

Table 1
Emission coefficients (tCO₂ per € of expenditure)

COICOP code	Category p	Coefficient m_p
04521	Natural gas	0.0027850
04522	Liquefied hydrocarbons	0.0014940
04531	Liquid fuels	0.0036985
04541	Solid fuels	0.0072930
07221	Fuels and lubricants	0.0017200

Source: Based on tables 2 (p16) and 3 (p18) from Frère et al. (2018).

The welfare effects of EU ETS2 are measured using a compensating variation approach. That is, the welfare loss is defined as the additional household income required to maintain initial consumption levels following the introduction of EU ETS2 (Bursens et al., 2025; Maier et al., 2024). This implies that the expenditure shares for each consumption category remain constant before and after the policy is introduced. As a result, the analysis captures only the immediate, “overnight”, welfare effects, and does not account for potential behavioural responses.

The absolute welfare burden for household i is calculated by multiplying CO_2 emissions from ETS2-covered consumption categories by the carbon price:

$$AbsBurden_i = \sum_{p \in P^{ETS2}} CO_2(Z_{ip}) \cdot \tau$$

where $P^{ETS2} = \{04521, 04522, 04531, 04541, 07221\}$ denotes the set of EU ETS2-covered COICOP categories and τ represents the carbon price (€/tCO₂).

The relative burden is obtained by dividing the absolute burden by household disposable income:

$$RelBurden_i = \frac{\sum_{p \in P^{ETS2}} CO_2(Z_{ip}) \cdot \tau}{Y_i^d}$$

Put differently, the absolute welfare effect is obtained by multiplying the “EU ETS2 carbon footprint”, i.e. the sum of CO₂ emissions resulting from expenditure on the relevant COICOP categories, by the EU ETS2 carbon price (see Section 4.3.1). This absolute burden is divided by total household disposable income to compute the relative burden. Household disposable income is defined as total annual income, pooled at the household level, after the deduction of direct taxes and social security contributions, and the addition of cash transfers and benefits (Bursens et al., 2025).

It is important to note that to compute the relative welfare effect, disposable income is top- and bottom-coded to limit the influence of extreme values. Without this adjustment, the relative burdens are heavily affected by outliers, as dividing by negative, very small, or very large incomes distorts the results. Outliers are identified using the Luxembourg Income Studies (LIS) top- and bottom-coding procedure, which is based on the interquartile range (IQR) of the logarithm of household disposable income. More specifically, household disposable incomes falling three times the IQR below the 25th percentile are bottom-coded while incomes falling three times the IQR above the 75th percentile are top-coded (Neugschwender, 2020). In practice, this results in 31 households with negative or very low household disposable incomes being assigned the lower-bound value of €1,351.78 and 5 households with exceptionally high household disposable incomes being assigned the upper-bound value of €1,060,707.70.

The absolute and relative income burdens are analysed using a broad range of household characteristics. These characteristics, introduced in Section 2.2, capture both vertical and horizontal dimensions of vulnerability to welfare losses caused by climate policies. The only vertical driver of vulnerability included in the analysis is household disposable income, equivalised using the modified OECD equivalence scale to make incomes comparable across households of different sizes and compositions. More precisely, household disposable income is adjusted by assigning a weight of 1 to the first adult, 0.5 to each additional adult (aged over 14), and 0.3 to each child (aged under 14), and then scaling income accordingly (OECD, 2013). Horizontal drivers included in the analysis encompass demographic characteristics, socio-economic characteristics and differences in expenditure.

In Section 5, these characteristics are used both individually and jointly to explain the variation in welfare losses caused by EU ETS2. First, a bivariate analysis assesses the distribution of income losses across each characteristic separately. Second, a linear regression model is employed to evaluate their joint explanatory power, with the relative welfare effect as dependent variable. For each scenario, the model is specified as:

$$RelBurden_i = \alpha + \beta_1 \ln(inc_i) + \beta_2 Fuel_i + \delta v_i + \gamma z_i + u_i$$

where $RelBurden_i$ denotes the relative EU ETS2 welfare loss of household i , inc_i is yearly household disposable equivalised income and $Fuel_i$ captures the main fuel type used by the household for residential heating. The vector v_i captures demographic characteristics (age, location, and household composition) and vector z_i includes socio-economic characteristics (employment status, years of education, and tenure status). The parameters $\alpha, \beta_1, \beta_2, \delta, \gamma$ are the coefficients to be estimated. All analyses are performed using Stata version 19.5 SE.

For variables defined at the individual rather than household level, the value of the reference person is used. The reference person is defined as the household member with the highest disposable income. In the case of a tie, the oldest individual is selected.

4.3 Policy scenarios

4.3.1 EU ETS2 allowance price

There is substantial uncertainty regarding the future price levels of EU ETS2 emission allowances. Such uncertainty is inherent to emissions trading systems, which fix the quantity of emissions while allowing prices to adjust accordingly. This is the crucial difference with a carbon tax, which fixes the price per tonne of emissions and relies on this price signal to achieve emission reductions. Günther et al. (2024) illustrate the considerable price uncertainty by modelling long-term EU ETS2 allowance price trajectories under different policy scenarios, estimating a range from €71/tCO₂ under strong and effective energy policies to €261/tCO₂ under weak policy conditions by 2030. While these estimates demonstrate the crucial role of policymakers, they are of limited relevance for this study, as only short-term effects are accounted for.

Given this focus on short-term, “overnight” impacts, this study adopts a baseline allowance price of €45/tCO₂. As discussed in Section 3.1, this corresponds to the price threshold that triggers the release of 20 million additional allowances from the MSR2, thereby functioning as a “soft” price cap in the initial years of the system. The proposed amendment of the MSR2 demonstrates the considerable political pressure to keep price levels as low as possible in the first years, increasing the plausibility of a €45/tCO₂ price scenario. This price level has been adopted in the scientific literature (e.g. Haywood & Jakob, 2023), and in assessments produced by the European Commission (2025b) itself.

However, to account for the considerable price uncertainty, a higher price level of €85/tCO₂ is adopted as sensitivity analysis. This price level corresponds to the short-term upper bound price expectation put forward by the European Commission (2025a) in its proposed MSR2 amendment. It is furthermore sufficiently different from the baseline scenario, enabling a meaningful comparison. While the sensitivity analysis is discussed in less detail, all results related to €85/tCO₂ carbon price can be found in the appendix. Most price assumptions in the existing literature fall within the €45–€85/tCO₂ range applied in this study (e.g. Adiyia, 2025; Cui & Wu, 2025; Haywood & Jakob, 2023; Jüngling et al. 2025; Trinomics B.V., 2025).

The analysis assumes that the EU ETS2 carbon price is fully passed through to final consumers, an assumption which is commonly applied in environmental microsimulation models (Linden et al., 2026). Although evidence on the pass-through rates of carbon taxes is limited, the literature provides empirical indication that a full pass-through rate is justified. For example, Fabra and Reguant (2014) show that, in the Spanish wholesale electricity market, EU ETS1 allowance prices are almost fully passed through to consumers via higher electricity prices. In the context of EU ETS2, recent simulation studies similarly adopt a full pass-through assumption (e.g. Adiyia, 2025; Costa & Dobbelaere, 2025; Haywood & Jakob, 2023; Trinomics B.V., 2025).

4.3.2 Revenue recycling scenarios

As discussed earlier, this study also accounts for the role of the Social Climate Fund (SCF) by considering several revenue recycling scenarios. More precisely, six recycling mechanisms are considered, in addition to a baseline scenario without revenue recycling which captures the direct distributional impact of EU ETS2. Given the study’s focus on the welfare of households, all scenarios are specified to have a direct effect on household disposable income. Consequently, no scenario includes earmarking of funds for investments that primarily benefit the environment, as their welfare effects are difficult to capture using the available income and expenditure data.

In each recycling scenario, the full Belgian allocation from the SCF is assumed to be redistributed to households, despite the formal cap of 37.5% on direct income support. This simplifying assumption avoids overestimating the burden of EU ETS2: excluding the remaining 62.5% of funds would neglect the indirect welfare gains associated with structural investments. For example, subsidies for home energy-efficiency improvements or reductions in public transport fares can lower household energy and transport expenditure, thereby reducing vulnerability to EU ETS2, without being classified as direct income support. As these indirect benefits cannot be modelled with the available data, incorporating the full SCF allocation results in a more balanced approximation than excluding them altogether.

A second simplifying assumption concerns the regional allocation of the Belgian SCF. The analysis does not account for the fact that most of the funds are managed at the regional level and abstracts from the distribution of competences between the federal and regional governments. While this is a limitation to take into account when interpreting the results, it significantly enhances the feasibility of the modelling exercise. A final assumption is that the Belgian SCF allocation (€2.208 billion) is distributed evenly over the 2027-2032 period, resulting in an annual budget of €368 million. As Belgium's Social Climate Plan has not yet been submitted at the time of writing, more precise information on the temporal allocation is not yet available.

Each recycling scenario will be analysed under a price level of €45/tCO₂ and €85/tCO₂, resulting in a total of 14 scenarios considered as part of this study. More detailed accounts of each scenario are provided below Table 2, which gives an overview of all recycling scenarios.

Table 2
Overview of policy scenarios

Name	Description	Central price scenario	Sensitivity analysis
S1 Baseline	No recycling	€45/tCO ₂	€85/tCO ₂
S2 Universal transfer	A one-time payment of €72 to all Belgian households	€45/tCO ₂	€85/tCO ₂
S3 Poverty-targeted transfer	A one-time payment of €672 to all Belgian households below the at-risk-of-poverty threshold	€45/tCO ₂	€85/tCO ₂
S4 Energy poverty transfer	A one-time payment of €314 to all Belgian households in 2M-energy poverty	€45/tCO ₂	€85/tCO ₂
S5 Social housing transfer	A one-time payment of €827 to all Belgian households residing in social housing	€45/tCO ₂	€85/tCO ₂
S6 Labour tax reduction	A 1.16% reduction in social insurance contributions	€45/tCO ₂	€85/tCO ₂
S7 Electricity excise duty reduction	A full removal of electricity excises, supplemented by a €42 payment to all Belgian households	€45/tCO ₂	€85/tCO ₂

In S1, the baseline scenario, no revenue recycling occurs. This provides an estimate of the direct distributional impact of EU ETS2 and highlights which societal groups are most affected in the absence of compensatory measures. As such, this first scenario is a replication of earlier impact assessments by Costa and Dobbelaere (2025), and Trinomics B.V. (2025). In S2, the universal transfer scenario, the entire annual budget is distributed equally among all Belgian households, regardless of their size or income. Based on the weighted sample data, Belgium is estimated to have 5,126,285 households, resulting in an annual lump-sum transfer of approximately €72 per household.

Three recycling scenarios will target the available €368 million to specific vulnerable groups. Note that, in all three scenarios, the identification of vulnerable households occurs *before* the implementation of EU ETS2, i.e. based on the original dataset. S3, the poverty-targeted transfer scenario, restricts payments to households below the at-risk-of-poverty (AROP) threshold, defined as 60% of the national median equivalised disposable income.

The AROP threshold is widely used within the EU as an income-based indicator of vulnerability. In total, 547,911 Belgian households (10.69%) fall below this threshold, implying a transfer of approximately €672 per household.

S4, the energy poverty transfer scenario, targets households experiencing energy poverty. Given that EU ETS2 is expected to increase energy prices, this group warrants particular attention. Moreover, targeting energy-poor households allows the analysis to move beyond purely income-based eligibility criteria, which is in line with the study's focus on multiple dimensions of vulnerability. Following the recommendation of Maier and Dreoni (2026), who provide an overview of different definitions of energy poverty, this study identifies energy-poor households using the 2M indicator. A household is classified as 2M-energy-poor when its share of income spent on residential energy exceeds twice the national median. As noted by Maier and Dreoni (2026), this indicator is particularly well-suited for microsimulation, as it depends directly on both income and expenditure. To operationalise the indicator, energy expenditure is restricted to COICOP category 045 (housing energy), which includes expenditure on electricity, natural gas, liquefied hydrocarbons, liquid fuels, solid fuels, and other heating sources (e.g. district heating and hot water). Based on this definition, 1,171,530 Belgian households (22.85%) are classified as 2M-energy-poor, resulting in a transfer of approximately €314 per household.

S5, the social housing transfer scenario, constitutes the final targeted transfer scenario. In this case, all 444,883 households (8.68%) residing in social housing receive a transfer of approximately €827. While such a transfer is unlikely to occur in practice, it can be interpreted as an approximation of allocating the full SCF budget to investments in social housing, which would lower housing-related expenditures for these households. Investments in social housing are widely regarded as a key example of eco-social policy, as they can simultaneously reduce residential emissions and advance social policy goals (Mandelli, 2022). A lump-sum transfer to these households serves as a proxy for such investments. Note that, to operationalise this scenario, the study relies on the housing tenure variable provided by EU-SILC. All households classified under "tenants, rent at reduced price" are assumed to reside in social housing. This is a simplification, as the category may also include other forms of reduced-rent arrangements. However, these are assumed to represent only a very small share of observations. Accordingly, throughout the remainder of the analysis, "households residing in social housing" refers to all households in the reduced-rent category.

In the final two scenarios, revenues are recycled through tax reductions rather than lump-sum transfers. In S6, the labour tax reduction scenario, social insurance contributions for employees and self-employed individuals are reduced. Total contributions amount to €31.85 billion, implying that the available €368 million allows for a proportional reduction of 1.16%. In S7, the electricity excise duty reduction scenario, the excise rate for electricity is reduced. EUROMOD provides estimates for the total excises paid by each household based on household expenditure on electricity. The sum of simulated electricity excises amounts to €153.9 million, meaning that the available €368 million is more than sufficient to fully offset these taxes. This scenario therefore eliminates electricity excises entirely and redistributes the remaining funds through an additional lump-sum transfer of approximately €42 per household. This is in line with the energy tax shift recently announced by the Belgian federal government, which lowers excise duties on electricity while increasing those on natural gas.

5 Results

This section presents the main results of the simulation and is divided into two parts. The bivariate analysis, which describes the relative and absolute income burdens across different population groups, is presented in Section 5.1. Its structure mirrors that of Section 2.2, distinguishing between a vertical and a horizontal analysis, the latter covering demographic, socio-economic and expenditure-related differences. While bivariate results provide insights into average effects across groups, they do not allow the identification of direct effects of household characteristics on incurred welfare losses. Therefore, all explanatory variables are subsequently included together in an econometric model. By controlling for multiple household characteristics simultaneously, the effect of each characteristic can be isolated. The results of this multivariate analysis are presented in Section 5.2.

However, before being able to assess the welfare effects of EU ETS2, it is important to first consider the policy's budgetary implications. Table 3 provides an overview of how much revenues are raised per year by EU ETS2, and subsequently, how much, if any, are returned to the population.

Table 3

Annual EU ETS2 budgetary effects

	S1 (€45/tCO ₂)	S2-S7 (€45/tCO ₂)	S1 (€85/tCO ₂)	S2-S7 (€85/tCO ₂)
EU ETS2 revenues (€)	1.225 billion	1.225 billion	2.314 billion	2.314 billion
Amount recycled (€)	0	368 million	0	368 million
Share recycled (%)	0	30.04	0	15.90
Net budgetary effect (€)	1.225 billion	875 million	2.314 billion	1.946 billion

Note: Own calculations, based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Estimates are weighted using household weights.

None of the analysed scenarios are budget-neutral: total revenues generated through EU ETS2 exceed the amounts recycled to households through the Social Climate Fund (SCF). While Belgium's annualised SCF allocation amounts to approximately €368 million, total EU ETS2 revenues, calculated as the weighted sum of household-level EU ETS2 payments, amount to €1.225 billion annually under an allowance price of €45/tCO₂. The surplus €875 million is returned to the Belgian government, although a small portion may also be used to finance SCF allocations of other member states (Jüngling et al., 2025). When the allowance price increases to €85/tCO₂, total EU ETS2 revenues rise substantially to €2.314 billion per year, while the SCF allocation remains unchanged. As a result, the share of revenues recycled back to Belgian households declines to only 15.90%.

These budgetary effects have two important implications for the interpretation of the empirical results that follow. First, EU ETS2, as modelled in this study, necessarily results in a negative average net welfare effect. This directly follows from the fact that the revenues collected from Belgian households exceed the amounts redistributed through the SCF. It is important to note that while the revenues that are not directly returned to households "disappear" in the analysis, they remain within the government budget and may therefore generate additional welfare gains. Such effects are not captured within the scope of this study. Second, the net budgetary effect of Scenario 1 differs fundamentally from that of Scenarios 2 to 7. Because no revenue recycling occurs in the baseline scenario, it necessarily produces a larger average welfare loss. As a result, the welfare losses in Scenario 1 should not be directly compared to the welfare losses in later recycling scenarios.

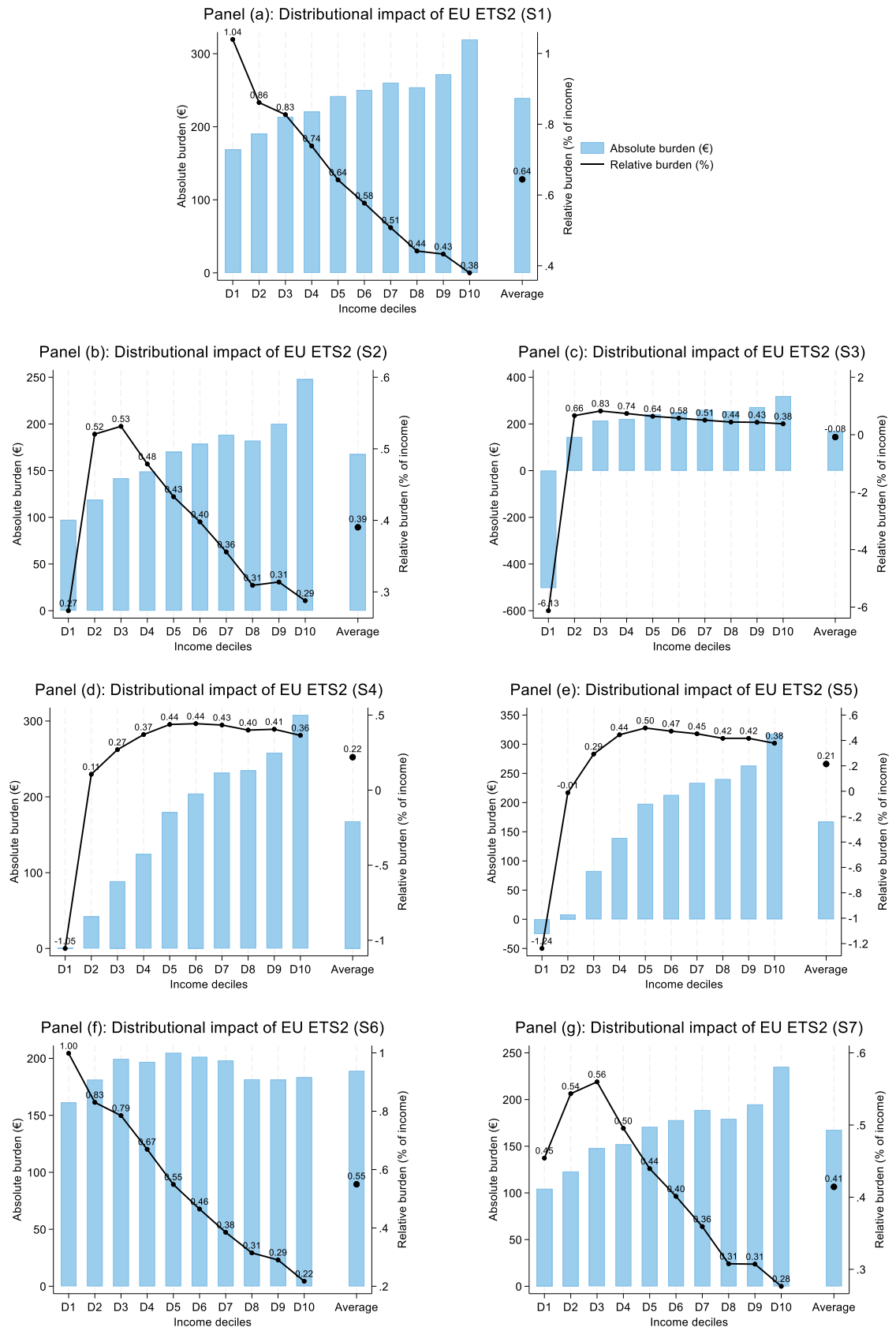
5.1 Bivariate analysis

5.1.1 Vertical analysis

Panels (a) to (g) of Figure 1 illustrate the distribution of EU ETS2 burdens (and benefits) across income deciles for each scenario, assuming an allowance price of €45/tCO₂. When examining the figure as a whole, a clear distinction emerges between the targeted transfer scenarios (S3, S4 and S5) and untargeted ones (S2, S6 and S7). A key difference relates to the welfare effects experienced by the bottom income decile. This income group experiences welfare gains when transfers are targeted, but loses substantially, especially in relative terms, when revenue recycling is untargeted. Accordingly, targeted transfers generate progressive outcomes, with relative burdens increasing along the income distribution, whereas untargeted schemes fail to do so.

Figure 1

Distribution of EU ETS2 (€45/tCO₂) welfare losses across income deciles



Note: Own calculations, based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

To formally examine the effects of EU ETS2 on income inequality, this study relies on the Reynolds-Smolensky (RS) index, defined as the difference between the Gini coefficient of equivalised disposable household income before and after the introduction of a tax. The Gini coefficient captures inequality by comparing the cumulative share of income with the cumulative share of the population, ranging from zero (perfect equality) to one (perfect inequality). Note that to calculate the Gini-coefficient, in accordance with the recommendations of Neugschwender (2020) and to reduce the influence of outliers in equivalised disposable household income (i.e. negative, extremely low, or extremely high incomes), equivalised disposable household income is top-bottom coded following the LIS procedure, as presented in Section 4.2.

A positive (negative) RS index implies that income inequality has decreased (increased) following the introduction of a tax (Bursens et al., 2025). The progressive and regressive patterns observed graphically are confirmed by Table 4: inequality increases in S1, S2, S6, and S7, and decreases in S3, S4, and S5. A more detailed discussion of the distributional effects of each scenario is provided below Table 4.

Table 4

Inequality before and after EU ETS2 (€45/tCO₂)

	Gini before EU ETS2	Gini after EU ETS2	Reynolds-Smolensky index
S1	0.21677	0.21767	-0.00090
S2	0.21677	0.21713	-0.00036
S3	0.21677	0.21516	0.00161
S4	0.21677	0.21643	0.00034
S5	0.21677	0.21608	0.00069
S6	0.21677	0.21788	-0.00111
S7	0.21677	0.21727	-0.00050

Note: Own calculations, based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights. Equivalised disposable household income is top-bottom coded following the LIS procedure.

S1 provides an estimate of the direct welfare effects of EU ETS2 in the absence of revenue recycling. Under this scenario, households experience an average welfare loss of €239 in absolute figures, or 0.64% relative to income. Consistent with the literature, higher income deciles lose more in absolute terms, while lower income deciles are more heavily affected in relative terms. More specifically, households in the first income decile are expected to incur an absolute welfare loss of €169, while households in the tenth decile lose, on average, €319. However, when expressed relative to income, the pattern is reversed: welfare losses are highest for the first decile at 1.04% and steadily decline to 0.38% for the tenth decile. As a result, inequality increases, with the Gini coefficient rising from 0.21677 to 0.21767 (RS = -0.00090). The magnitude of these results closely aligns with earlier impact analyses by Adiyia (2025) and Costa and Dobbelaere (2025).

In S2, where a uniform transfer of €72 is distributed to all households, absolute burdens are reduced, but the overall pattern remains similar. The average absolute welfare loss drops to €167, the average relative loss to 0.39%. Households in the first decile experience a welfare loss of €97 on average, compared to €247 in the tenth decile. The relative welfare effect is low for the bottom income decile, rises sharply for the second and third deciles, and decreases afterwards. The particularly low relative burden observed in the bottom decile is largely driven by households with very low incomes that face limited EU ETS2 costs but still receive the €72 transfer. For instance, for households with incomes at the lower-bound value of €1,352, the transfer corresponds to an income gain of 5.3%. Such cases heavily suppress the average relative income burden in this group. As the same transfer represents a larger share of income for lower-income households, differences in relative burdens are less pronounced than in S1. As a result, inequality increases, but to a lesser extent than in S1, with an RS index of -0.00036.

In the targeted transfer scenarios S3, S4, and S5, the recycling mechanisms achieve progressive outcomes. When the SCF revenues are transferred to households at risk of poverty (S3), the relative and absolute burdens are, on average, negative for households in the first decile, who gain €502 (or 6.13%) after the policy is introduced.

However, benefits are heavily concentrated at the bottom of the distribution: the average loss in the second decile (€144; 0.66%) is only slightly lower than in S1, and higher deciles are unaffected by the recycling. Inequality decreases in S3, with an RS index of 0.00161. The strong welfare gains among the bottom income decile also affect the aggregate results: although the average welfare loss is €168 in absolute terms, it equals -0.08% (indicating a slight welfare gain) in relative terms.

When revenues are allocated to 2M-energy-poor households (S4), they benefit the lower deciles more evenly. On average, Belgian households experience a welfare loss of €168 in absolute terms and 0.22% in relative terms. The welfare burden increases across the income distribution, ranging from €1 (-1.05%) in the first decile to €308 (0.36%) in the tenth decile. The relative burden peaks at 0.44% in the sixth decile. Inequality is reduced, though less strongly than in S3 (RS = 0.00034). When revenues are targeted to households residing in social housing (S5), the outcomes fall in between those of S3 and S4. The welfare loss is reversed for the bottom income decile, who experience an income gain, and is reduced heavily for the second decile, who lose €8 on average. The welfare losses for upper deciles resemble those in S1, when no revenue recycling occurred. The relative burden peaks at 0.50% in the fifth decile. Inequality declines moderately (RS = 0.00069), with a redistributive effect stronger than in S4 but weaker than in S3.

Finally, untargeted recycling scenarios S6 and S7 remain regressive. This is especially so when the SCF revenues are used to decrease social insurance contributions (S6). In this case, the average welfare loss amounts to €189 in absolute terms and 0.55% in relative terms, both of which are substantially higher than in the preceding scenarios. The absolute welfare burden is distributed evenly across the income deciles, implying a highly skewed distribution of the relative burden. The gap between the welfare burden of the top and bottom decile is larger than in any other scenario: while households in the bottom decile lose on average 1.00%, households in the top decile are expected to lose 0.22%. The RS index is equal to -0.00111, implying that inequality increased even more than it did in S1, when no recycling occurred. Note, however, that according to the double dividend hypothesis, this scenario achieves gains in economic productivity, which are not captured as part of the simulation.

In S7, where the SCF budget is used to remove electricity excises and provide a €42 uniform transfer to all households, the outcome remains regressive, although less pronounced than in the absence of revenue recycling. On average, Belgian households experience a welfare loss of €167 in absolute terms and 0.41% in relative terms. Households in the bottom decile are expected to lose €104 (0.45%), compared to €235 (0.28%) for households in the top decile. Inequality increases (RS = -0.00050), but less so than when no recycling occurs, or when revenues are used to decrease social insurance contributions.

The discussion above again highlights that the scenarios considered are not budget-neutral: average welfare losses are positive, even after revenue recycling is introduced. This follows from the fact that only a fraction of the revenues (30.04%) is redistributed to households. In a fully budget-neutral setting, where all revenues are returned to the population, the average net welfare effect would be zero by construction, implying that net winners could exactly compensate net losers. In contrast, the simulations show a persistent aggregate welfare loss (€239 in S1 and approximately €167 in most recycling scenarios), indicating that a substantial share of revenues is not returned to the population. It is important to emphasise that these unreturned revenues remain within the public budget and may therefore generate future welfare gains. However, such effects lie outside the scope of this analysis and are therefore not accounted for in the welfare calculations.

5.1.2 Horizontal analysis

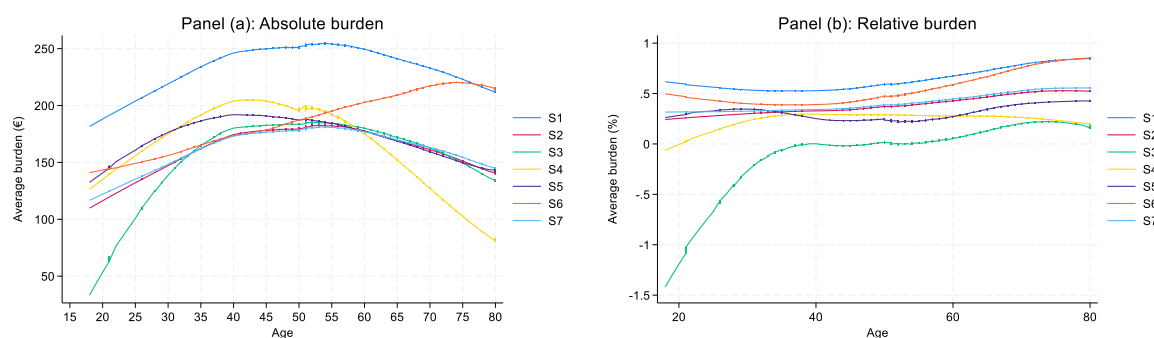
While a clear income-gradient emerges when examining the distribution of welfare losses across the income deciles, it remains important to look at other dimensions of vulnerability. Even if a certain policy achieves progressive outcomes on average, some population groups may suffer disproportionate welfare losses. To illustrate this: while the average EU ETS2 impact without recycling is equal to €169 (1.04%) in the lowest decile, within this group, 10% loses more than €358 (2.03%). To better understand what drives these vulnerabilities, the analysis must move beyond income groups.

5.1.2.1 Welfare losses across demographic groups

In this section, welfare losses are compared across three household demographic characteristics: age, residence location, and household composition. Figure 2 visualises how the absolute and relative welfare effects differ according to the age of the reference person.

Figure 2

Distribution of EU ETS2 (€45/tCO₂) welfare losses by age of the reference person



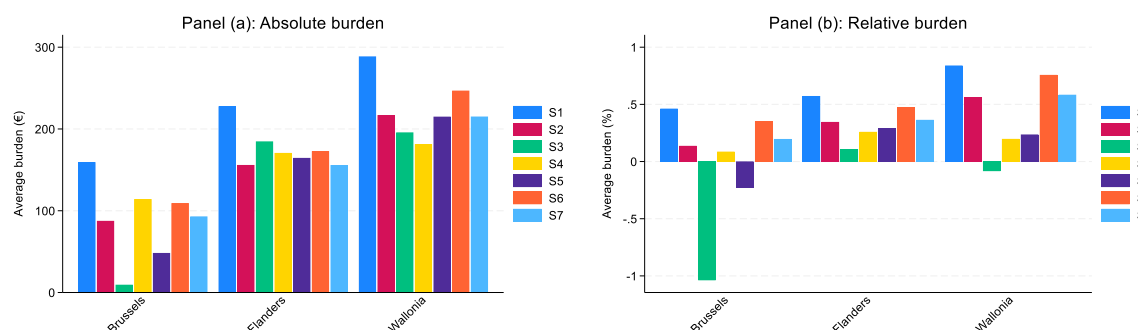
Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

While there appears to be a relationship between the age of the reference person and the experienced welfare losses, its role differs across the different recycling scenarios. In absolute terms and in the absence of revenue recycling (S1), an inverted U-shaped relationship emerges: the welfare loss peaks at age 54 and decreases afterwards. This falls in line with the results of Lévy et al. (2021), who demonstrated a similar non-linear relationship between age and GHG emissions. In relative terms, however, this pattern largely disappears, suggesting that households with a middle-aged reference person have higher incomes. Younger households benefit most when transfers are directed towards households at risk of poverty (S3), while older households gain more under transfers targeted at 2M-energy-poor households (S4). By contrast, tax reduction scenarios (S6 and S7) affect households more evenly across the age distribution, simply shifting the baseline distribution slightly downwards. However, note that older households benefit considerably less from the reduction in social insurance contributions (S6).

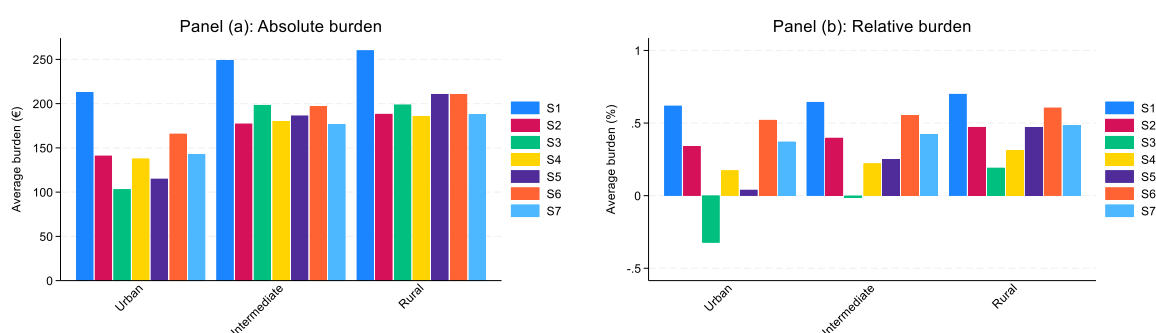
Figure 3 visualises the distributional impact of EU ETS2 across the Belgian regions. Figure 4, relatedly, presents the welfare losses by degree of urbanisation.

Figure 3

Distribution of EU ETS2 (€45/tCO₂) welfare losses by region



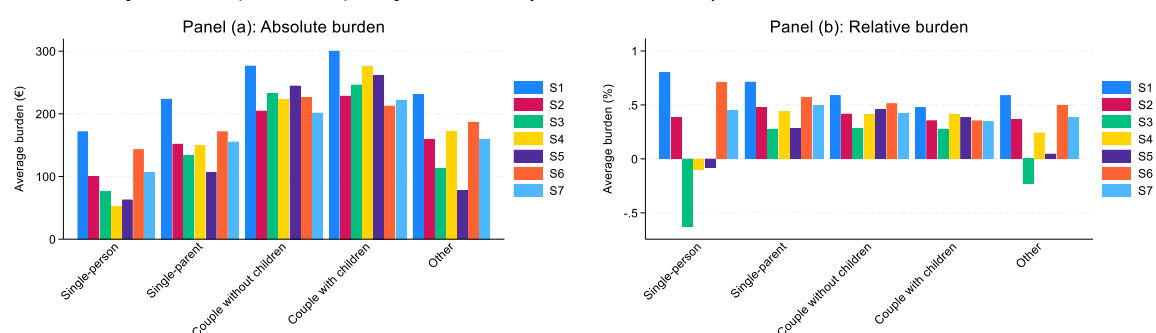
Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

Figure 4*Distribution of EU ETS2 (€45/tCO₂) welfare losses by degree of urbanisation*

Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

Figures 3 and 4 demonstrate that heterogeneity in welfare losses is clearly also driven by residence location. Households in Wallonia consistently experience greater welfare losses, in absolute terms, than those living in Flanders and Brussels. In the absence of revenue recycling (S1), households in Wallonia incur an average loss of €289, compared to €227 in Flanders and €159 in Brussels. In relative terms, the picture is similar in the baseline scenario, but changes once revenue recycling is introduced. In the three targeted transfer scenarios, Flanders emerges as the most impacted region, while Brussels and Wallonia benefit more strongly from revenue recycling. Regional disparities are smallest in S4, where transfers are targeted at 2M-energy-poor households, with welfare burdens ranging from €114 (0.09%) in Brussels to €181 (0.20%) in Wallonia. The distribution across urbanisation levels offers some insight into the regional disparities: the vulnerability of predominantly rural Wallonia as compared to (sub-)urban Flanders and Brussels falls in line with the broader vulnerability of rural households, which experience greater welfare losses than intermediate and urban households in all seven scenarios considered.

The final demographic characteristic considered as part of the analysis is household composition. Figure 5 shows how welfare effects are distributed across different household types. Five categories are distinguished: single-person households (one adult), single-parent households (one adult with at least one child), couples (two adults), couples with children (two adults with at least one child), and a residual “other” category. Children are defined as individuals younger than 18 years.

Figure 5*Distribution of EU ETS2 (€45/tCO₂) welfare losses by household composition*

Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

The absolute welfare burden is largest for couples with children in all but one scenario. They lose, on average, €312 in the absence of revenue recycling. Note, however, that these burdens are not equivalised. This implies that the burden is not adjusted for household size. Doing so would strongly alter the picture: after applying the

modified OECD scale, single-person households are the most affected category (€170; equivalised) while couples with children are least affected (€133; equivalised).

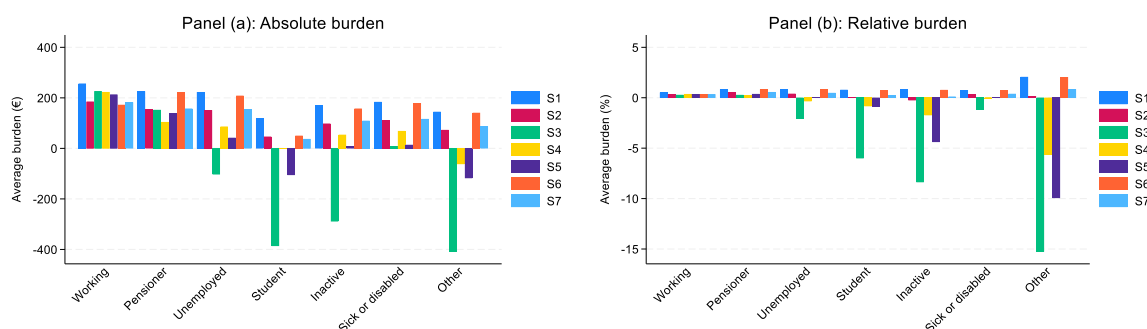
A similar shift occurs when expressing the welfare burden relative to income. The relative welfare burden is largest for single-person households (0.80%) and smallest for couples with children (0.48%) in the baseline scenario. However, the vulnerability of single-person households is substantially mitigated under the targeted transfer scenarios. In particular, they benefit most strongly when transfers are directed toward households at risk of poverty (S3), though their relative welfare burden is also reduced under the other targeted recycling schemes.

5.1.2.2 Welfare losses across socio-economic groups

This section examines the distribution of EU ETS2 welfare effects across employment status, educational attainment, and housing tenure. Beginning with employment status, Figure 6 illustrates how average welfare losses differ according to the employment status of the household reference person.

Figure 6

Distribution of EU ETS2 (€45/tCO₂) welfare losses by employment status



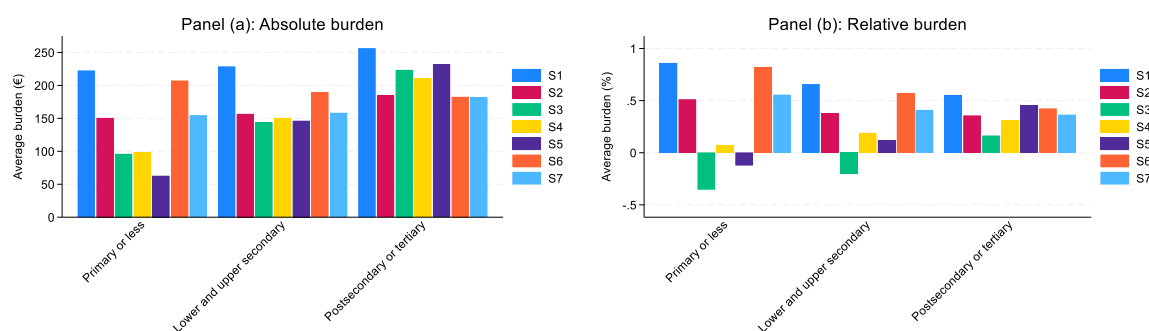
Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

Welfare losses vary across employment status, although the extent of this variation differs across scenarios. When no recycling occurs, households with a working reference person are impacted most in absolute numbers (€256), while households in the “other” category are most affected in relative terms (2.06%). The residual “other” category causes some distortion in the analysis. Only 29 households fall into this category, with a relatively low mean disposable income of €20,250. Therefore, in some transfer scenarios, they appear to gain very strongly. While the average relative burdens in this group visually suppress the variation between the other groups, differences do occur.

Households with a working reference person are commonly the most affected group in absolute terms, but tend to be less affected in relative terms. In the baseline scenario, they are expected to lose 0.50%, compared to 0.83% for pensioner households, 0.84% for unemployed households, 0.78% for student households, 0.80% for inactive households, 0.73% for sick or disabled households, and 2.06% for households in the residual category. This distribution shifts substantially once revenue recycling is introduced. The transfer to households at risk of poverty (S3) particularly benefits households whose reference person is a student, inactive, unemployed, or in the residual category. The transfer to households residing in social housing (S5) similarly benefits student and inactive households and fully offsets EU ETS2-induced welfare losses for unemployed and sick or disabled households. By contrast, the labour tax reduction scenario (S6) primarily benefits households with a working reference person.

Figure 7

Distribution of EU ETS2 (€45/tCO₂) welfare losses by educational attainment



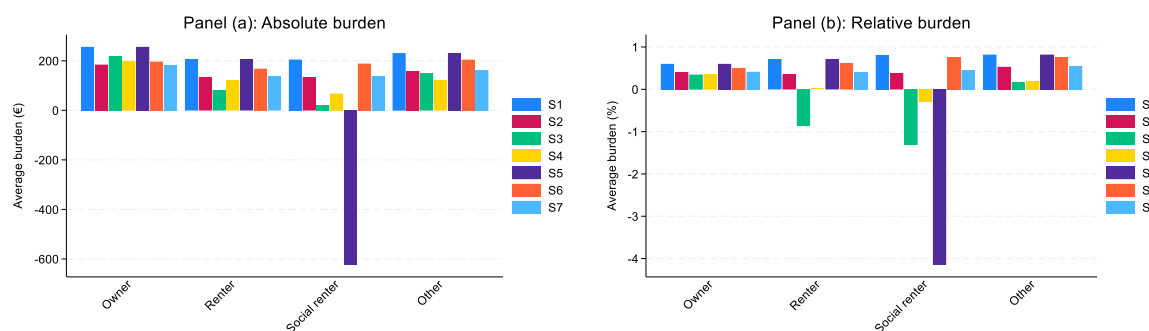
Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

Figure 7 presents the distribution of EU ETS2 by educational attainment of the reference person. It is similar to that across income groups: in the baseline scenario a “regressive” pattern emerges in relative terms. Households with a low-educated reference person lose 0.86% of disposable income, compared to 0.66% for those with secondary education and 0.55% for those with postsecondary education. This pattern is reversed in the targeted transfer scenarios, where higher-educated households bear larger relative burdens, but remains when revenues are distributed uniformly or used for tax reductions. The absolute burden increases with educational attainment in all scenarios except when revenues are used to decrease social insurance contributions.

The final socio-economic characteristic considered is housing tenure. Figure 8 presents welfare effects across four categories: homeowners (with or without a mortgage), private renters, social renters, and a residual “other” category.

Figure 8

Distribution of EU ETS2 (€45/tCO₂) welfare losses by housing tenure



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

In the baseline scenario, absolute welfare losses range between €204 and €255, indicating limited variation across tenure types. A similar pattern is observed in relative terms, although owners face slightly lower burdens as compared to other groups. Revenue recycling causes some variation across housing tenure groups, but effects remain moderate. Households in social housing benefit most strongly from targeted transfers, especially, and unsurprisingly, when all revenues are targeted to them (S5).

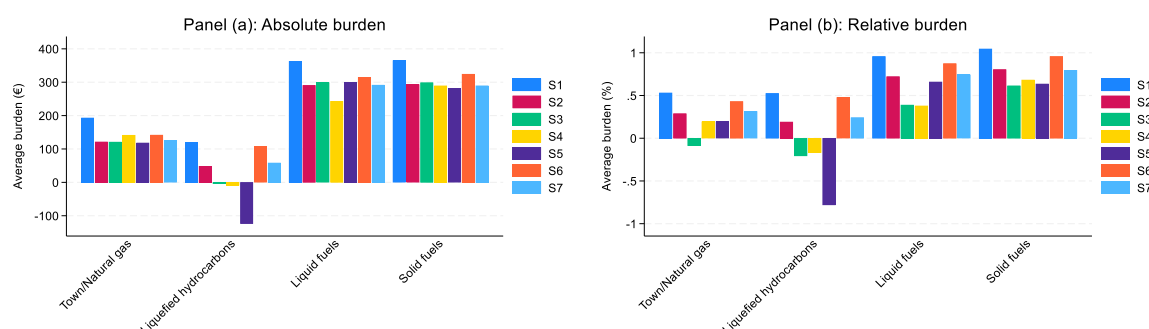
5.1.2.3 Welfare losses by fuel type

The final part of the bivariate analysis considers the EU ETS2 welfare losses by main fuel type used for residential heating. Four categories are considered: town/natural gas, liquefied hydrocarbons (e.g. butane or propane), liquid fuels (e.g. heating oil), and solid fuels (e.g. coal or firewood). A household is assigned a main fuel type if

expenditure on that source is larger than spending on any other heating source. Based on this definition, the majority of households rely on either natural gas (54.18%) or liquid fuels (39.51%). The distribution of welfare losses by fuel type is presented in Figure 9. Across all seven scenarios, households that mainly rely on either liquid or solid fuels are expected to incur greater welfare losses, in absolute and relative terms, than households relying on natural gas or liquefied hydrocarbons.

Figure 9

Distribution of EU ETS2 (€45/tCO₂) welfare losses by fuel type for heating



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

To conclude the bivariate analysis, Table 5 summarises the main results by identifying, for each scenario, the household type that is most affected in relative terms.

Table 5

Most affected household type per scenario

	Income decile	Age	Region	Household composition	Employment status	Educational attainment	Tenure status	Fuel type
S1	D1	80	Wallonia	Single-person	Other	Primary or less	Other	Solid fuels
S2	D3	80	Wallonia	Single-parent	Pensioner	Primary or less	Other	Solid fuels
S3	D3	74	Flanders	Couple without children	Working	Postsecondary or tertiary	Owner	Solid fuels
S4	D6	38	Flanders	Single-parent	Working	Postsecondary or tertiary	Owner	Solid fuels
S5	D5	80	Flanders	Couple without children	Pensioner	Postsecondary or tertiary	Other	Liquid fuels
S6	D1	80	Wallonia	Single-person	Other	Primary or less	Social renter	Solid fuels
S7	D3	80	Wallonia	Single-parent	Other	Primary or less	Other	Solid fuels

Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €45/tCO₂. Estimates are weighted using household weights.

Table 5 demonstrates the importance of policy design. The characteristics of the most affected household vary substantially across scenarios, indicating that distributional outcomes are sensitive to the chosen revenue recycling mechanism. This implies that policymakers can, to a certain extent, influence which types of households are most affected. The relative welfare effect is most responsive to the applied revenue recycling mechanism when considering income deciles, residence location, household composition and educational attainment. For income, the most affected group shifts away from the bottom deciles in S4 and S5, reflecting their progressive

effects. Household composition alternates between single-persons, single-parents, and couples without children, implying that household type and size interact with policy design. Educational attainment and residence location also vary considerably, with lower-educated and Walloon households burdened most in untargeted recycling scenarios, while higher-educated and Flemish households emerge as most affected in the targeted transfer scenarios. By contrast, categories such as age and fuel type show limited variation across scenarios.

A further recurring feature is the prominence of the “other” category for variables such as employment status or tenure status. While this could suggest a particular vulnerability of residual groups, it is important to note that these categories often contain relatively few observations. As such, their average outcomes are more sensitive to outliers and should therefore be interpreted with caution.

5.2 Multivariate analysis

This section presents the result of the Ordinary Least Squares (OLS) regressions which explain the variation in EU ETS2 welfare losses in relative terms (i.e. as a percentage of income). The explanatory variables include household income, main heating fuel type, and a set of demographic and socio-economic characteristics. Table 6 reports the estimated coefficients and their significance levels. Seven models are estimated, each corresponding to a different revenue recycling scenario and assuming an EU ETS2 allowance price of €45/tCO₂. The discussion of the results is structured around the seven scenarios, examining the effects of each household characteristics under the various recycling mechanisms.

Table 6

OLS regression results of relative EU ETS2 (€45/tCO₂) welfare effects by household characteristics

Variables	S1	S2	S3	S4	S5	S6	S7
Log income	-5.021*	5.893*	116.347***	39.008***	3.931	-4.985*	1.850
Square of log income	-0.224	-0.296*	-5.586***	-1.880***	-0.207	-0.220	-0.102
Age of reference person	0.000	-0.003	-0.002	0.006	-0.005	-0.003	0.001
Square of age	0.000	0.000	0.000	-0.000	0.000	0.000	0.000
Residence location (ref.: Flanders)							
Brussels	-0.159***	-0.104**	-0.301*	0.238**	-0.178*	-0.164***	-0.113***
Wallonia	0.112***	0.134***	0.284***	0.106*	0.128***	0.116***	0.114***
Household composition (ref: Single)							
Single parent	-0.144**	-0.013	0.886**	0.509***	0.128	-0.134**	-0.024
Couple without children	-0.137***	-0.012	-0.096	0.267***	0.049	-0.095***	-0.039
Couple with children	-0.211***	-0.034	0.175	0.313***	0.013	-0.154***	-0.072**
Other	-0.183***	-0.032	0.196	0.334***	0.151	-0.144***	-0.063*
Employment status of reference person (ref: Working)							
Pensioner	0.016	0.025	0.426***	0.059	0.029	0.149**	0.025
Unemployed	-0.032	0.022	0.203	0.088	0.078	0.068	0.005
Student	-0.226	-0.188	-0.859	0.704	-0.257	-0.135	-0.150
Inactive	0.077	0.061	-0.753	0.368	-0.632	0.022	0.031
Sick or disabled	-0.069	-0.044	0.403*	0.015	0.067	0.068	-0.053
Other	1.694	1.846	2.575	1.995*	1.837	1.810	1.773

Table 6 (continued)

Variables	S1	S2	S3	S4	S5	S6	S7
Education of reference person (ref.: Primary or less)							
Lower and upper secondary	-0.046	-0.067	-0.315**	-0.092	-0.059	-0.048	-0.058*
Postsecondary and tertiary	0.002	-0.027	-0.454***	-0.098	-0.023	-0.014	-0.023
Residence tenure (ref.: Owner)							
Renter	0.008	0.017	0.118	0.028	0.139	0.011	0.015
Social renter	0.024	0.072	0.451***	0.022	-3.668***	0.043	0.047
Other	0.078	0.106	0.403*	0.084	0.154*	0.085	0.081
Main fuel type: residential heating (ref.: Town/Natural gas)							
Liquefied hydrocarbons	-0.283***	-0.267***	-0.153	-0.205	-0.409***	-0.283***	-0.256***
Liquid fuels	0.369***	0.368***	0.342***	0.154***	0.346***	0.370***	0.369***
Solid fuels	0.408***	0.422***	0.586***	0.484***	0.369***	0.403***	0.392***
Intercept	28.473*	-29.137	605.018***	202.162***	-18.034	28.328*	-8.092
Observations	5,344	5,344	5,344	5,344	5,344	5,344	5,344
R ²	0.328	0.209	0.680	0.449	0.491	0.373	0.221

Note: For all categorical variables, the reference category is indicated between brackets. Robust standard errors. Estimates are weighted using household weights. Assumes an EU ETS2 allowance price of €45/tCO₂.

Source: own calculations, based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014).

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In S1, when no revenue recycling occurs, four household characteristics have a statistically significant effect on the expected relative welfare loss. First, the linear term of the logarithm of income is negative and significant, implying that the relative welfare burden decreases as income rises. The quadratic term for log income is insignificant, indicating that the effect of income is linear in the baseline scenario. This finding is consistent with the strong regressivity observed in panel (a) of Figure 1. As discussed in Section 4.2, income refers to household disposable equivalised income.

Second, residence location appears to be a crucial driver of incurred welfare losses: holding other factors constant, a household in Brussels is expected to lose 0.159 p.p. less than a household in Flanders, while a household in Wallonia is expected to lose 0.112 p.p. more. Third, household composition seems to play an important role. All household types included in the analysis are expected to lose significantly less than single-person households. Finally, main fuel type for residential heating is a strong determinant of experienced welfare losses. Compared to households relying primarily on natural gas, households using liquefied hydrocarbons are expected to lose a smaller share of their income following the introduction of EU ETS2. By contrast, households primarily dependent on liquid fuels (e.g. heating oil) or solid fuels (e.g. firewood) are expected to incur significantly larger losses.

Age (and its square), educational attainment and employment status of the reference person, as well as housing tenure status, are insignificant, implying that they do not directly determine the EU ETS2 relative welfare burden of households. This demonstrates the importance of assessing the explanatory power of household characteristics jointly: while a clear gradient emerged in the bivariate analysis by, for example, educational attainment, its explanatory power disappears when controlling for other factors. This implies that variation observed in the bivariate analysis is driven by related household characteristics.

The analysis for S2, in which the SCF was distributed as a €72 transfer per household, is largely analogous. The variables that were insignificant in the baseline scenario remain insignificant. However, the relation between income and the relative welfare burden is no longer linear. A positive linear term and negative quadratic term, both significant, imply that the relationship is concave: the welfare burden increases with income (i.e. progressivity), up to a point, after which it decreases with income (i.e. regressivity). The turning point occurs at the relatively low annual income of €21,224. Only 32% of households have an income below this level, implying that that regressivity remains for the largest part of the income distribution. Progressivity at the bottom of the income distribution can be explained by the fact that the €72 transfer has a large relative effect for very low incomes. These results fall in line with the bivariate analysis (see Figure 1, panel (b)), which demonstrated increasing welfare burdens up to decile three, and decreasing welfare burdens afterwards. Finally, note that the variation in welfare losses across household compositions has disappeared, with all household types incurring similar losses as single-person households. Variation across regions and by main fuel type remain significant, in line with the baseline scenario.

Greater shifts occur in S3, when the SCF is distributed as a €672 transfer to households at risk of poverty. Both the linear and quadratic income terms remain significant, but the turning point shifts upwards. Welfare burdens are expected to increase with income up to an income €33,330, after which they decrease. 73% of households fall below this income level, implying that the relative welfare burden increases with income for the majority of the income distribution. This explains why inequality, as measured by the Gini index, decreased in scenario 3. Household composition effects also shift, with single-parent households emerging as the most heavily affected category. For the first time, several socio-economic characteristics are significant. Households with a pensioner or sick or disabled reference person are expected to incur significantly greater welfare burdens than households with a working reference person. Additionally, welfare burdens are expected to decrease with educational attainment: households with middle- or high-educated reference persons lose significantly less than households with a low-educated reference person. Finally, households living in social housing are expected to lose significantly more than households that own their dwelling. In line with the baseline scenario, age of the reference person is insignificant, while region of residence and main fuel type remain highly significant.

In S4, where the SCF budget is used to transfer €314 to 2M-energy-poor households, an important shift occurs in the distribution across household compositions. While single-person households were among the most affected in the previous scenarios, they are now the least affected category. This implies that they benefit much more from the energy-poverty targeted transfer than other household types. Additionally, an interesting regional shift occurs: Flanders is now expected to be impacted least, while households in Wallonia and Brussels are expected to lose out significantly more. As in the previous two scenarios, the relationship between income and relative welfare burden is concave. The relative income burden is expected to be maximised at an income of €31,965, slightly below the turning point of S3. All other characteristics take on the same sign and significance as in the baseline scenario.

In S5, when €827 is distributed to households living in social housing, the coefficients on income become insignificant. This implies that, once taking into account all other characteristics, the model no longer predicts the relative welfare burden to change with income. Most coefficients resemble those in the baseline scenario, both in magnitude and significance. The key exception is housing tenure: social renters experience substantially lower welfare losses (by 3.67 p.p.) than homeowners, directly reflecting the design of the transfer. Another noticeable difference with the effects observed in the baseline is that there is no longer any variation in welfare losses across household composition: all household types lose a similar share of their income after the policy is introduced.

In S6, in which all SCF resources are used to decrease social insurance contributions by 1.16%, regressivity returns: the effect of household income is negative and linear. Single-person households are once again the most affected household type, while couples with children are impacted the least after the policy is introduced. Households whose reference person is a pensioner experience significantly greater welfare losses than households whose reference person is working. The effects of other household characteristics remain broadly consistent with the baseline scenario.

Few variables are statistically significant in S7, when the SCF budget is used to fully remove electricity excises and allocate a €42 per capita payment. Regional differences and differences by fuel type remain important drivers, but household income and other household characteristics are largely insignificant.

Overall, four characteristics emerge as robust determinants of relative welfare losses across the scenarios. First, household income: the (squared) logarithm of household income is significant in five out of seven scenarios. In S1 and S6, the linear term is negative and the quadratic term insignificant, implying that the relative burden linearly decreases as income increases. This corresponds to the strongly regressive outcomes observed in Figure 1. In S2, S3 and S4, both terms are significant, implying an inverted U-shaped relationship: while the relative burden first increases with income, it decreases once a turning point is reached. Note that this turning point is much higher in S3 and S4, implying that progressivity is achieved for a greater part of the income distribution. Second, residence location: in all but one scenario, households in Brussels face lower relative burdens than those in Flanders, while Walloon households face higher burdens. Interestingly, households in Brussels become the most impacted category in S4, when the transfer is targeted to households in energy poverty. Third, household composition: single-person households appear to be systematically more vulnerable, although targeted transfers can substantially mitigate this effect. Fourth, fuel type: households relying on liquid or solid fuels consistently incur greater welfare losses, and none of the recycling mechanisms alleviate this burden.

5.3 Sensitivity analysis

As discussed earlier, there is considerable uncertainty regarding the future price of EU ETS2 allowances. To address this, a sensitivity analysis is conducted using a higher carbon price of €85/tCO₂. This corresponds to the upper-bound short-term price estimate provided by the European Commission (2025a) and differs substantially from the central scenario of €45/tCO₂. Despite the higher carbon price, the revenue recycling scenarios are kept unchanged. This reflects the true functioning of the SCF, as the amount of funds is fixed ex ante and does not adjust to higher carbon prices. This section briefly summarises the main findings. Detailed tables and figures are reported in the appendix.

Overall, increasing the carbon price to €85/tCO₂ does not fundamentally alter the distributional patterns of EU ETS2, but it does increase the magnitude of its welfare effects. The bivariate vertical analysis (see Figure 10) confirms the previously established pattern: absolute welfare losses increase across the income distribution, while relative welfare losses decline with income. As before, this pattern can only be (partly) reversed under targeted revenue recycling. However, the magnitude of the welfare burdens almost doubles at the higher carbon price. In the absence of revenue recycling, Belgian households experience an average welfare loss of €452, or 1.22% when expressed relative to household income. Once the SCF is taken into account, the average absolute welfare loss drops to approximately €380 in most scenarios, with varying relative welfare losses.

In contrast to the central price scenario, inequality increases in almost all cases. Targeted transfers in S4 and S5, which previously reduced inequality, are no longer sufficient to offset the regressive impact of the higher carbon price. Inequality decreases only when transfers are targeted to households at risk of poverty. The effects on inequality are summarised in Table 7.

The results of the bivariate horizontal analysis (see Figure 11 to 18) are similar to those of the €45/tCO₂ scenario. While welfare losses have increased, both in absolute and relative terms, the higher carbon price does not seem to have deepened horizontal disparities. The same household types appear to be most vulnerable: lower-educated households, single-person and single-parent households, households living in Wallonia, and those relying on solid or liquid fuels. Differences by age, employment status, and housing tenure remain relatively limited, although they vary depending on the recycling mechanism.

The results of the multivariate analysis (see Table 8) do not change fundamentally. There are two notable differences. First, while the sign and significance of the logarithm of income and its square are as before, their magnitude has changed. When the effect of income is negative and linear (S1 and S6), the coefficient has become

much larger in absolute value. This implies that the relative burden declines more steeply with income, suggesting strong regressivity. When the effect of income is concave (S3 and S4), the turning point has shifted downwards. This implies that regressivity occurs for a greater part of the income distribution than before. Second, regional differences between Brussels and Flanders are no longer statistically significant in S3 and S4. This implies that targeting households at risk of poverty or experiencing energy poverty can eliminate disparities between these regions, although households in Wallonia continue to face significantly greater welfare losses.

Finally, although the analysis demonstrates substantially greater welfare losses under higher EU ETS2 prices, it is important to note that the budgetary implications of the €85/tCO₂ scenario differ from those of the central price scenario. As demonstrated in Table 3, EU ETS2 revenues amount to €2.314 billion, implying that only a small fraction (15.90%) is returned to the population through the SCF. While the surplus revenues are not taken into account in this study, it is important to acknowledge that they remain part of the government budget and may therefore generate additional welfare gains.

6 Discussion and policy recommendations

The empirical analysis has demonstrated the persistently regressive nature of EU ETS2. Without revenue recycling, EU ETS2 disproportionately affects lower-income households. Even when revenue recycling is introduced, the Social Climate Fund (SCF) only mitigates regressivity when support is targeted at specific vulnerable groups. If such targeting does not occur, i.e. when the funds are used to benefit the entire population, inequality is expected to increase. Although household income emerges as a crucial determinant of vulnerability to welfare losses caused by EU ETS2, other household characteristics also play an important role. As a result, substantial variation in welfare losses is expected even among households belonging to the same income group. This horizontal variation appears to be driven mainly by household composition, residence location, and main fuel type used for residential heating. This section seeks to explain these results by connecting them to the previous literature. Subsequently, it formulates several policy recommendations, drawing on the main concepts provided by the literature on distributive justice. Finally, it addresses the main limitations of the study.

There is a relatively straightforward explanation for why EU ETS2, just as most consumption taxes that cover necessity goods, is regressive. The main reason is that the income-elasticity of energy demand is low: expenditure on energy, and thus on the fossil fuels used to generate that energy, does not rise proportionally to income. As a result, the expenditure share devoted to fossil fuels decreases across the income deciles. This makes lower-income households more vulnerable to welfare losses arising from higher fossil fuel prices or carbon pricing (Maier et al., 2024). This pattern is structural and helps explain why the regressivity of carbon pricing is so extensively documented in the academic literature (e.g. Adiyia, 2025; Bursens et al., 2025; Costa & Dobbelaere, 2025; Douenne, 2020; Kerkhof et al., 2008). The present empirical analysis confirms that the regressive effects of EU ETS2 persist across most policy scenarios. Regressivity is only reversed when revenues are redistributed through targeted transfers. More specifically, inequality decreases when EU ETS2 is implemented jointly with transfers directed at households at risk of poverty, households experiencing energy poverty, or households residing in social housing. All three measures benefit the bottom income deciles most, offering strong relief for the welfare burden caused by EU ETS2.

Besides income, household residence location is an important determinant of EU ETS2 welfare losses. Households living in Brussels are consistently less affected than those in Flanders, while households in Wallonia experience larger welfare losses. The literature offers two potential explanations for this regional distribution. First, regional differences in the dependence on private road transport likely play a role (Ivanova & Wood, 2020; Haywood & Jakob, 2023). The data indicate that expenditure on fuels and lubricants for private transport is systematically higher in Wallonia and lower in Brussels compared to Flanders. More specifically, mean (median) expenditure is €148 (€140) higher in Wallonia, while it is €294 (€300) lower in Brussels. These differences are significant and provide a plausible (partial) explanation for the observed regional variation in EU ETS2 welfare effects. A second explanation relates to regional differences in residential energy expenditure. Reusens et al. (2022) show that dwellings in Wallonia are, on average, older and more often detached than those in Flanders

and Brussels. This may explain the observed differences in annual expenditure on residential heating: mean (median) expenditure is €260 (€245) higher in Wallonia, and €365 (€410) lower in Brussels, both compared to Flanders. These differences in energy consumption contribute to the persistent regional variation in welfare losses observed in this and earlier studies (e.g. Bursens et al., 2025 and Trinomics B.V., 2025).

A second demographic characteristic which drives vulnerability to EU ETS2 welfare losses is household composition. Cui and Wu (2025) were the first to analyse the system's welfare effects by family type, finding that single-person households, single-parent households, and couples without children are significantly more vulnerable than couples with children. This study partly confirms these findings, while highlighting the particularly pronounced vulnerability of single-person households. This vulnerability is likely driven by the absence of economies of scale in energy consumption. As demonstrated by Lévy et al. (2021), household emissions do not rise proportionally with additional household members: they increase by only 20% with the first additional adult, and by 10% with the first additional child. Consequently, larger households tend to have lower emissions per capita, while often being able to rely on multiple income sources. Together, these factors reduce their relative EU ETS2 welfare burden compared to smaller households. Similar conclusions have been reached by Trinomics B.V. (2025) and Bursens et al. (2025). However, it is important to note that, despite their disadvantage, single-person households do not have to be the most affected group. In fact, they become the least affected household type when revenues are recycled through transfers targeted at households experiencing energy poverty. Thus, recycling mechanisms that offer relief to high energy needs, through targeted transfers or other compensatory measures, can substantially mitigate the vulnerability of smaller households.

Finally, the main fuel type used for residential heating appears to be a crucial determinant of welfare losses caused by EU ETS2. Households primarily relying on liquefied hydrocarbons (e.g. butane or propane) for residential heating are consistently less affected than households using natural gas, while those dependent on liquid and solid fuels experience significantly larger losses. Notably, fuel type is the only household characteristic that is statistically significant across all seven policy scenarios. This finding is in line with previous studies that have identified fuel type as a key determinant of vulnerability to carbon pricing (Costa & Dobbelaere, 2025; Heyndrickx et al., 2022). Given the high emission intensity of solid fuels (see Table 1), the high burden associated with their use is expected. Based on how the simulation occurred, households heavily reliant on solid fuels are by construction more vulnerable to welfare losses. However, the same explanation does not fully apply for liquid fuels, which have a much lower emission coefficient. This suggests that other factors are at play: unobserved housing characteristics, such as energy performance, may for example contribute to the observed differences.

Several important policy implications arise from these results. First, to counter regressivity, the Social Climate Fund should be targeted to specific vulnerable groups. Given the nature of household energy consumption, regressivity will persist unless financial support is directed towards narrowly defined vulnerable groups. This study has demonstrated three ways to achieve progressive, i.e. inequality-decreasing, outcomes: by targeting transfers to households at risk of poverty, to households experiencing energy poverty, or to households residing in social housing. Among these options, transfers targeted at households at risk of poverty achieve the strongest reduction in inequality ($RS = 0.00161$), although the other two mechanisms distribute benefits more evenly across the lower income deciles.

Addressing the regressive outcomes of EU ETS2 is essential for aligning the policy with principles of distributive justice. The responsibility and capability approach introduced in Section 2.1 posits that distributional outcomes are unjust when those who have contributed least to climate change and possess the lowest capacity to adapt nonetheless bear the greatest welfare burden (Büchs and Mattioli, 2024). Applied to the vertical distribution, this implies that higher-income households should bear a larger share of the burden, as they are (1) responsible for a disproportionate share of GHG emissions (Lévy et al., 2021) and (2) have greater financial capacity to mitigate and adapt to climate-related costs, whereas lower-income households commonly do not.

Second, to address disproportionate horizontal burdens, particular attention should be given to single-person households, households living in Wallonia, and households relying on solid or liquid fuels for residential heating.

Single-person households can be protected by restricting transfers to households experiencing energy poverty. However, other measures aimed at alleviating energy costs can contribute as well, as it is the increased per capita energy expenditure of single-person households that makes them particularly vulnerable.

Unequal burdens by region or fuel type appear more difficult to counter. That is, none of the recycling scenarios considered in this study succeed in doing so. As established earlier, regional disparities seem to be the outcome of differing energy needs. Addressing these inequalities may require structural investments rather than direct income support. These could include, for example, investments in public transportation infrastructure or subsidies for home energy-efficiency improvements. In addition, greater protection for households in Wallonia could be achieved by reassessing the regional allocation of SCF resources. Currently, the Walloon government is set to receive 32.95% of the total budget. However, the results suggest that this allocation may be insufficient relative to incurred losses. As noted in Section 4.3.2, this study abstracts from the regional allocation by pooling the SCF budget at the federal level. However, when revenues are redistributed as an equal per-household transfer (S2), Walloon households receive approximately 31.70% of the total budget, just slightly below their formal allocation. Despite this, households in Wallonia are still expected to incur a 0.134 p.p. higher relative welfare loss than households in Flanders.

Offsetting the disproportionate burdens associated with the use of solid and liquid fuels is not feasible nor desirable. As such fuels are carbon-intensive energy sources, reducing their use is a central objective of EU ETS2. The system is designed to generate appropriate price signals that encourage households to shift away from these fuels toward cleaner alternatives. However, resources should be made available to facilitate this transition. Without sufficient financial support, households may be unable to switch to cleaner alternatives, leading to lock-in effects, whereby reliance on carbon-intensive fuels persists despite increasing costs (Vanhille et al., 2019). In such cases, the intended behavioural response does not occur, and already vulnerable households face disproportionately large welfare losses.

While the responsibility and capability approach applies very well to the vertical distribution, it has much less straightforward implications for the horizontal analysis. It is possible to determine which household types are most responsible by examining GHG emissions (as was done by Lévy et al. (2021)), but it is much more difficult to adequately assess the capability of households to mitigate or adapt to climate change based on household characteristics besides income. As discussed, small and rural households, for example, have structural disadvantages which make it much more difficult for them to reduce emissions. EU ETS2, just as any carbon tax, is an instrument which very well captures the responsibility component but is not adept at taking into account capability. To address this, policymakers should explicitly consider horizontal disparities, as EU ETS2 systematically disadvantages specific household types in the absence of compensatory measures.

Finally, the level of targeted support should increase in response to rising EU ETS2 allowance prices. A key limitation of the SCF, highlighted by both academics and policymakers, is that its budget is fixed ex ante and can therefore not adjust to fluctuations in the carbon price (Hengalová, 2024). In practice, higher allowance prices have two simultaneous effects: (1) they increase fossil fuel prices, thereby raising household welfare burdens, and (2) they generate additional auction revenues. To avoid increasing the welfare burden, both components should be connected so that higher revenues translate into additional support. The sensitivity analysis illustrates the importance of such flexibility. Under higher allowance prices, absolute welfare losses can exceed €600 per household and relative burdens may rise above 2%. Under these conditions, the current SCF budget appears insufficient to provide adequate compensation.

There are two ways to ensure that additional revenues are translated into additional support. A first option is to directly link the size of the SCF to revenues generated through the auctioning of EU ETS2 emission allowances. Although this would reduce the predictability that comes from fixing the budget ex ante, it would substantially increase the responsiveness of the fund to rising needs. Furthermore, a direct link between EU ETS2 revenues and the size of the SCF increases the transparency of the system. A second option, which may be more likely given the current legislative framework, is to redistribute additional allowance revenues to member states, conditional on their use for targeted household support. Current legislation requires member states to spend

additional allowance revenues on “climate action”. However, this concept is loosely defined, which increases the risk of ineffective and non-transparent revenue use (Jüngling et al., 2025).

Taking these policy implications into account is crucial to ensure public support. EU ETS2 has become, even prior to its implementation, a controversial instrument, with calls across the EU for its further postponement or abandonment. If the system disproportionately burdens any group, whether along the vertical or horizontal axis, it risks being perceived as fundamentally unfair. Perceived fairness, however, shapes public support for climate policies, which in turn determines both their political feasibility and long-term effectiveness (Dreus & Van den Bergh, 2016; Schaffer, 2024).

However, several limitations should be considered when interpreting the results of this study and the policy implications derived from them. A first set of limitations are inherent to microsimulation studies. Trying to ex ante estimate the distribution of costs and benefits of any policy is a difficult task, one which forces the researcher to make assumptions and predictions about future events. That is no different for this study.

Crucial assumptions are made related to the implementation of the SCF. First, the fund is assumed to be fully used for direct income support, despite the formal cap of 37.5%. In practice, the remaining 62.5% has to be spent on structural investments, therefore benefitting the population only indirectly. To prevent overestimating the welfare burden of EU ETS2, this study opts to include the full SCF envelope in each recycling scenario, as it is impossible to adequately model the (indirect) welfare effects of structural investments given the available data. Future research can attempt to include the welfare effects of earmarking the SCF, thereby respecting the formal cap and better reflecting its true functioning. A second simplification concerns the abstraction from the regional allocation and distribution of competences. Despite the fact that most of the SCF will be managed at the regional level, and thus most policy will have to be designed and implemented by the regional governments, this study pools the full budget at the federal level. Relatedly, it is important to acknowledge that the policy scenarios included in this study do not align perfectly with true policy options. For example, while it is theoretically interesting to examine the effects of a reduction in social insurance contributions, this is not a policy measure which can be implemented given the current regional distribution of competences.

Beyond assumptions related to the implementation of the SCF, the study is subject to several methodological limitations. First, it does not take into account behavioural adjustments to EU ETS2 price signals. As such, it only estimates the direct “overnight” welfare effects under different policy scenarios. Köppl and Schratzenstaller (2023) argue that this static approach may overstate regressive impacts, since households facing the largest welfare losses in the short run are those most likely to adjust their behaviour in the long run. However, note that the opposite may also be true: behavioural responses can reinforce unequal distributions, as households with greater capability can adapt more easily (e.g. by driving less or installing a heat pump), while more constrained households may have limited capacity to adjust and therefore continue to bear higher welfare losses.

Second, EU ETS2 is modelled as a carbon tax based on the CO₂ emissions resulting from expenditure on fossil fuels used for residential heating and private road transport. While detailed expenditure data are available for residential heating, only a single aggregated category for private road transport (i.e. expenditure on fuels and lubricants) could be taken into account. This limits the precision of the simulation, as more precise emission coefficients (e.g. for diesel, gasoline or LPG) had to be aggregated into one figure. Future studies providing a more detailed account of expenditure on fossil fuels for private transport are required, as currently, no study on Belgian households has been able to incorporate this information.

A further limitation relates to the data used as part of this study. The household budget survey of 2015 is used to obtain the household expenditure shares on the relevant product categories. However, expenditure patterns have likely changed over the past decade. The consumption of fossil fuels for residential heating and private transport may have declined, which could lead to an overestimation of the welfare effects of EU ETS2. Nonetheless, the 2015 HBS is likely more representative than the most recent HBS wave from 2020, as it better reflects a pre-pandemic and pre-energy crisis year (Trinomics B.V., 2025). Once the 2025 HBS wave is available, it is important that future research replicates existing EU ETS2 impact assessments in order to test their validity.

In addition, the study relies on the 2022 wave of the EU-SILC, a year still influenced by both the pandemic and the energy crisis. These events may have negatively affected household incomes, thereby influencing expenditure on fossil fuels and potentially affecting the estimated welfare impacts.

A final limitation of this study is theoretical, rather than practical. Because the analysis focuses on the socio-economic effects of EU ETS2, it necessarily provides only a partial assessment of the policy. More specifically, it does not account for the environmental benefits that the system will bring. The most comprehensive analysis would compare the distributional consequences of EU ETS2 not only to the status quo, but to the (future) distributional consequences in the *absence* of EU ETS2. This nuance is essential in the context of climate change, as the literature suggests that climate change impacts are themselves distributed unequally. For example, empirical evidence indicates that low-income households will suffer greater climate change-related damages than high-income ones (e.g. Bangalore et al., 2016; Carleton et al., 2022; Chancel et al., 2023). This implies that the distributional consequences of inaction may ultimately be more unequal and unjust than the distributional effects of climate policies, even when such policies impose disproportionate burdens on certain groups. In this sense, climate policy can also be understood as fundamentally contributing to distributive justice by reducing the unequal impacts of climate change.

Several important directions for future research follow from these limitations. First, the empirical findings should be validated under alternative assumptions to ensure their robustness. This includes examining how distributional outcomes vary under different EU ETS2 allowance prices, when incorporating behavioural responses, or under alternative specifications regarding the size and functioning of the SCF. In addition, once the Belgian Social Climate Plan is finalised, future research should assess the distributional effects of the actual policy measures it contains, rather than working with hypothetical scenarios. Second, it is important to repeat the distributional analysis with more recent and/or more precise data on household income and expenditure. Third, as the estimates of the distribution of EU ETS2 costs and benefits become more robust, future research should aim to more explicitly link these outcomes to normative frameworks of climate justice. This requires operationalising the concept of distributive justice in a way that is consistent with the theoretical literature, so that it can be given a more central place in the empirical analysis. Finally, future research must shed more light on the environmental benefits of EU ETS2, to provide a more balanced assessment of the policy.

7 Conclusion

This study aimed to provide a comprehensive understanding of the factors that explain the variation in welfare losses caused by EU ETS2 among Belgian households. To do so, it empirically examined how the costs and benefits associated with EU ETS2 and the Social Climate Fund (SCF) vary across population groups under different policy scenarios. The study examined both the vertical distribution of welfare effects (i.e. *across* income deciles) and the horizontal distribution (i.e. *within* income deciles). By relying on an integrated dataset combining information on household income, expenditure, and associated emissions, the study modelled EU ETS2 as a carbon tax of €45/tCO₂. In doing so, it provided an answer to the question: “*What factors explain the variation in welfare losses caused by EU ETS2 among Belgian households?*” While many household characteristics appear to be related to EU ETS2 welfare losses, this study identifies four key determinants: household equivalised disposable income, household composition, residence location and main fuel type used for residential heating.

Like most carbon pricing mechanisms, EU ETS2 is inherently regressive. While the absolute welfare burden increases across the income deciles, the relative burden (expressed as a share of income) decreases with income. As a result, income inequality, as measured by the Gini coefficient, is expected to increase following the introduction of EU ETS2. Such regressivity is only countered when SCF resources are targeted towards narrowly defined vulnerable groups. This study demonstrates that inequality decreases if EU ETS2 is implemented jointly with transfers directed at households at risk of poverty, households experiencing energy poverty or households residing in social housing. By contrast, when revenues are recycled through untargeted measures which benefit the population as a whole, regressive outcomes persist. Regressivity intensifies as the allowance price increases, as demonstrated by the €85/tCO₂ sensitivity analysis.

The main drivers of horizontal variation in EU ETS2 welfare losses are household composition, region of residence, and the main fuel type used for residential heating. These household characteristics help explain why variation in welfare losses may occur even among households with similar incomes. More specifically, single-person households, households living in Wallonia, and households relying primarily on liquid or solid fuels for residential heating are expected to be most strongly affected. Importantly, however, these distributional patterns are not fixed. For example, substantial relief for single-person households can be achieved by targeting support towards households experiencing energy poverty. It is more difficult to mitigate regional disparities through direct income support, suggesting that structural investments, such as expanding public transportation infrastructure or improving the energy performance of the housing stock may be necessary. Similarly, none of the considered recycling mechanisms eliminate the disproportionate burden on households dependent on solid or liquid fuels. However, directly compensating these households is not desirable, as EU ETS2 is intended to offer incentives to transition away from these carbon-intensive energy sources. Nonetheless, resources should be made available to support this transition so as to avoid lock-in effects which lead to increasing welfare losses without the desired behavioural response.

Other characteristics, such as the age, employment status, and educational attainment of the reference person, as well as housing tenure status, appear to be less important in explaining welfare losses caused by EU ETS2 once other factors are controlled for. Although some variation across these characteristics emerged in specific policy scenarios, the effects were inconsistent. Note, however, that clear gradients did appear when these characteristics were examined in isolation in the bivariate analysis. The existence of such apparent bivariate relationships highlights the importance of the multivariate approach: the true drivers of vulnerability can only be identified when household characteristics are analysed jointly rather than separately.

This study contributes to the existing literature in two main ways. First and foremost, it is the first study to explicitly examine the role of the SCF in shaping the distributional outcomes of EU ETS2 among Belgian households. While earlier distributional analyses for Belgian households exist (e.g. Costa & Dobbelaere, 2025; Trinomics B.V., 2025), none incorporate the welfare effects of the SCF, and therefore provide only a partial picture of the policy's distributional consequences. By contrast, this study evaluates distributional outcomes under six revenue recycling scenarios, explicitly taking into account the redistributive effects of the SCF. Second, the study is the first to connect the distributional effects of EU ETS2 to principles of distributive justice, thereby offering policymakers more comprehensive guidance on incorporating equity considerations into policy design.

By examining the distributional outcomes of EU ETS2 under various policy scenarios, this study highlights the crucial role of policy design. While EU ETS2 is inherently regressive and disproportionately affects certain household types, its distributional outcomes are not set in stone. Policymakers therefore have the responsibility to ensure that SCF resources are effectively targeted towards the households who need them most. Failing to do so may result in distributional outcomes in which already vulnerable households bear a disproportionate share of the burden. Such outcomes risk undermining perceived fairness and, consequently, public support for the policy.

8 Scientific integrity

Although limited, two Artificial Intelligence (AI) tools have been used throughout the research process. All use has followed the guidelines of the Faculty of Social Sciences of the University of Antwerp.

First, Elicit, an AI “research assistant”, was used to find relevant sources whenever information through conventional database searches (e.g. via Google Scholar) proved insufficient. Its use has led to the inclusion of Gillingham et al. (2012), Gugler et al. (2021), Lim et al. (2020) and Zagheni (2011). Each of these papers was thoroughly reviewed to assess their scientific quality and relevance.

Second, ChatGPT was used to improve the Stata code for Figures 1-18. I therefore cannot take full credit for their design. Additionally, I relied on the model to help rewrite sentences for clarity. At no point has the content of this study been AI-generated: all content is the product of my own writing and reflects the information I have gathered from the sources included in the bibliography. The use of AI tools was deliberately kept limited, with the aim of maximising the educational value of this learning process while minimising energy and water use.

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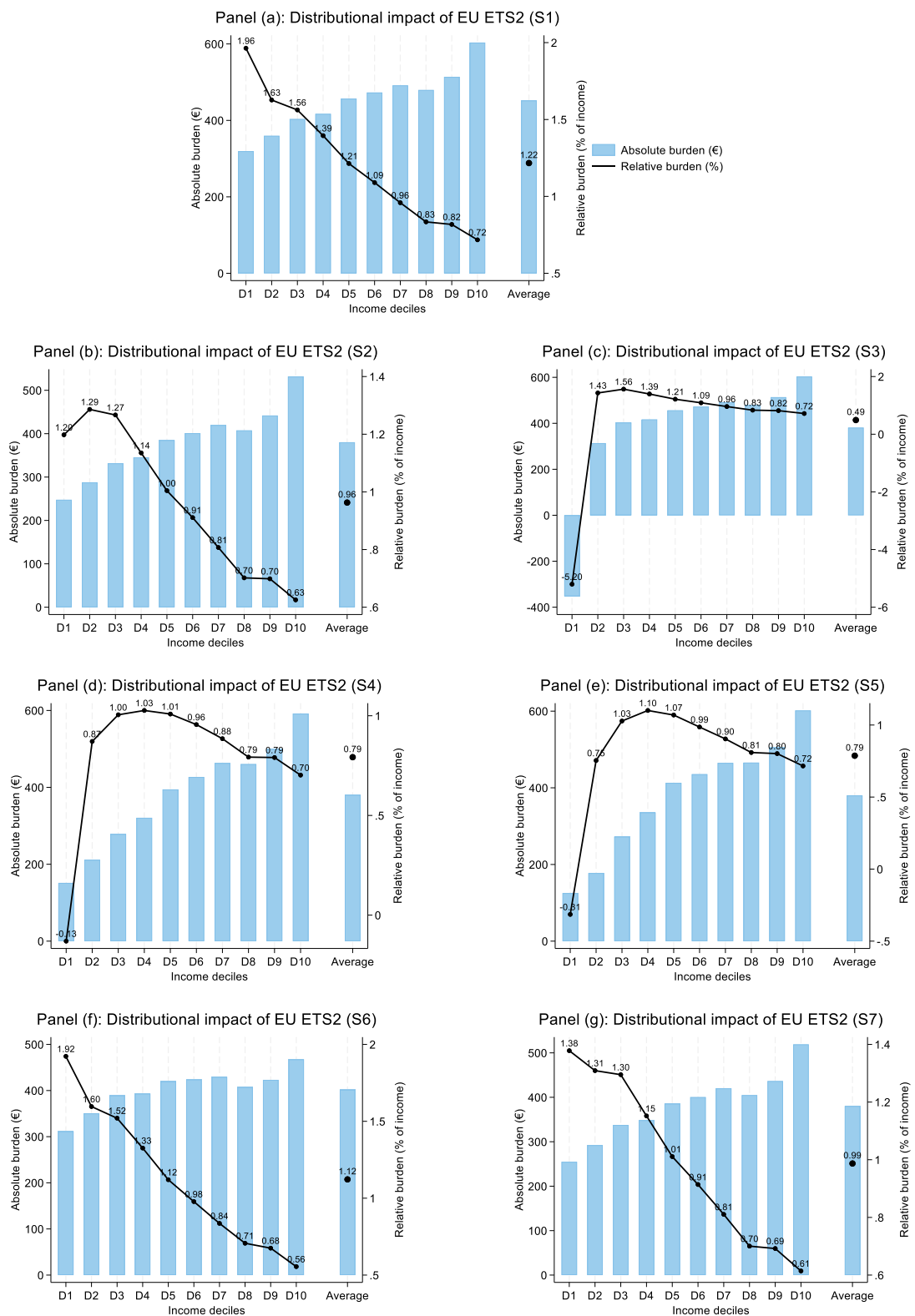
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10 Appendix

Figure 10

Distribution of EU ETS2 (€85/tCO₂) welfare losses across income deciles

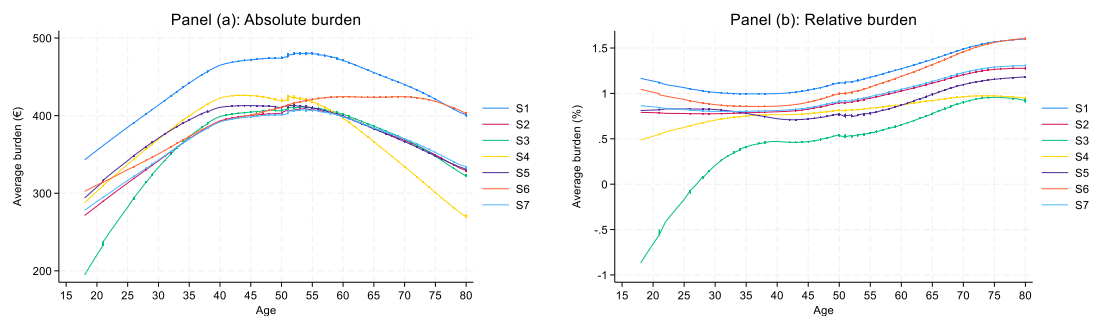


Note: Own calculations, based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

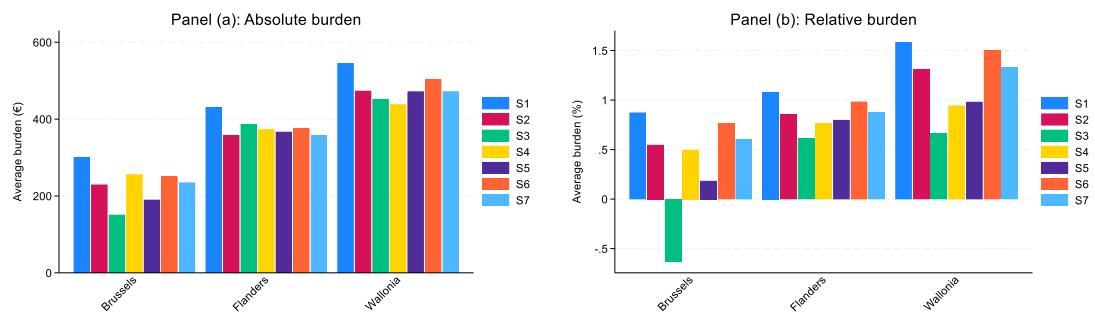
Table 7*Inequality before and after EU ETS2 (€85/tCO₂)*

	Gini before EU ETS2	Gini after EU ETS2	Reynolds-Smolensky index
S1	0.21677	0.21897	-0.00220
S2	0.21677	0.21842	-0.00165
S3	0.21677	0.21644	0.00033
S4	0.21677	0.2177	-0.00093
S5	0.21677	0.21736	-0.00059
S6	0.21677	0.21918	-0.00241
S7	0.21677	0.21857	-0.00180

Note: Own calculations, based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 11*Distribution of EU ETS2 (€85/tCO₂) welfare losses by age of the reference person*

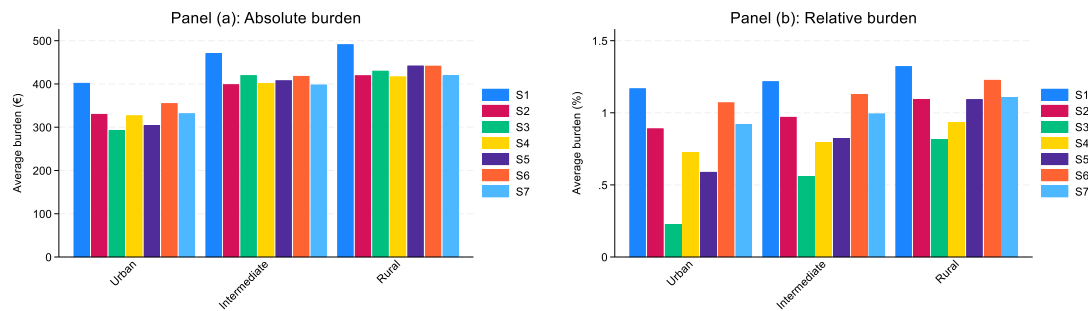
Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 12*Distribution of EU ETS2 (€85/tCO₂) welfare losses by region*

Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 13

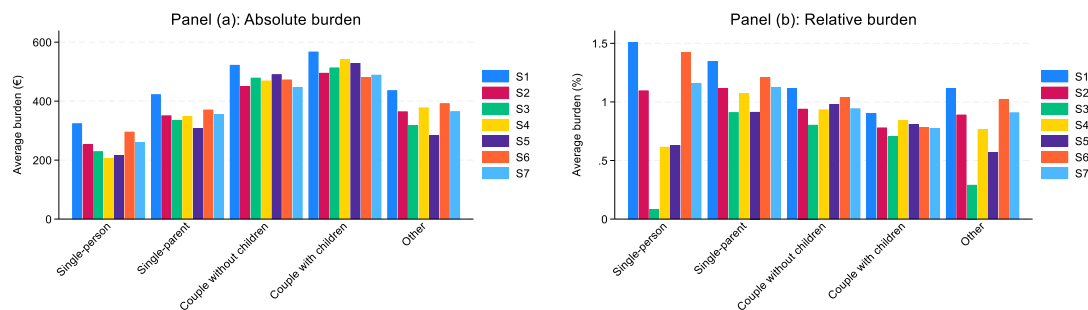
Distribution of EU ETS2 (€85/tCO₂) welfare losses by degree of urbanisation



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 14

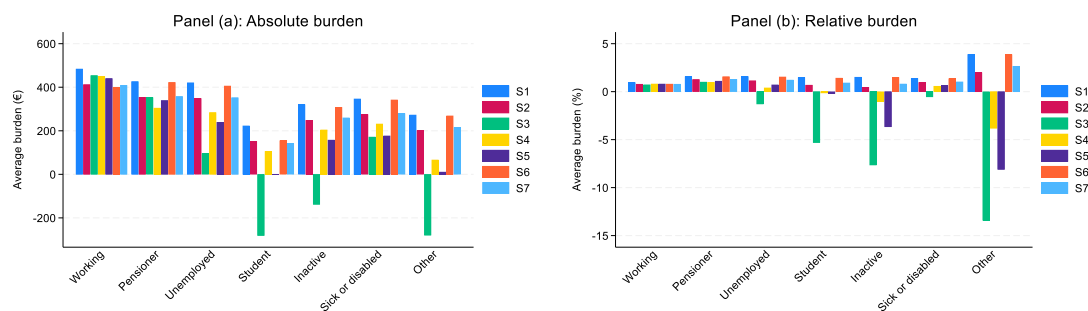
Distribution of EU ETS2 (€85/tCO₂) welfare losses by household composition



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 15

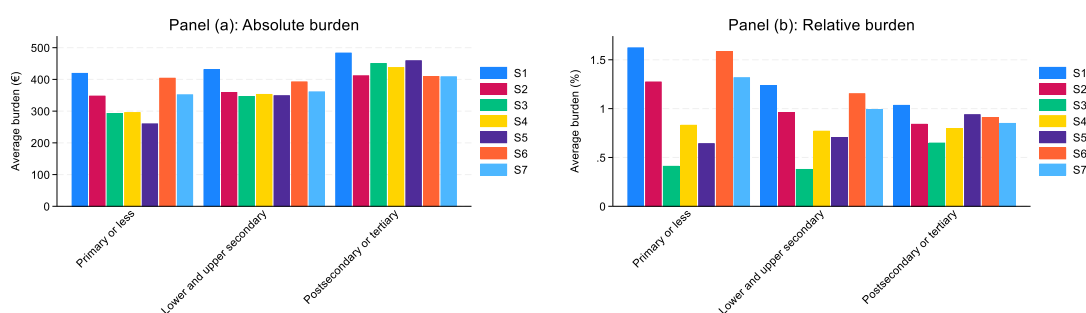
Distribution of EU ETS2 (€85/tCO₂) welfare losses by employment status



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 16

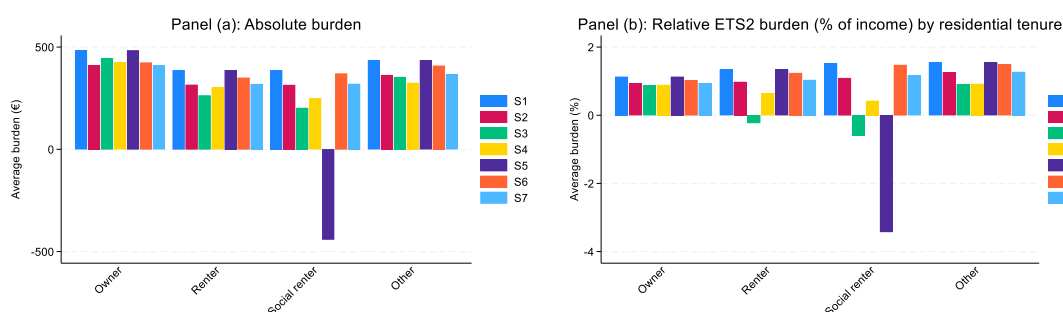
Distribution of EU ETS2 (€85/tCO₂) welfare losses by educational attainment



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 17

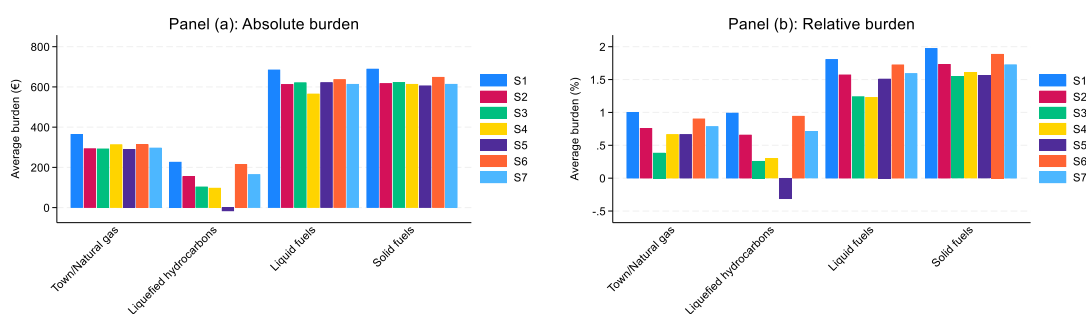
Distribution of EU ETS2 (€85/tCO₂) welfare losses by housing tenure



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Figure 18

Distribution of EU ETS2 (€85/tCO₂) welfare losses by fuel type for heating



Note: Own calculations based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). Assumes an EU ETS2 allowance price of €85/tCO₂. Estimates are weighted using household weights.

Table 8

OLS regression results of relative EU ETS2 (€85/tCO₂) welfare effects by household characteristics

Variables	S1	S2	S3	S4	S5	S6	S7
Log income	-9.484*	1.430	111.884***	34.554***	-0.533	-9.448*	-2.612
Square of log income	0.422	-0.097	-5.387***	-1.681***	-0.008	0.419	0.097
Age of reference person	0.001	-0.003	-0.002	0.006	-0.005	-0.002	0.002
Square of age	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 8 (continued)

Variables	S1	S2	S3	S4	S5	S6	S7
Residence location (ref.: Flanders)							
Brussels	-0.300***	-0.245**	0.159	0.096	-0.320**	-0.305***	-0.255***
Wallonia	0.211***	0.233***	0.383***	0.205***	0.228***	0.215***	0.214***
Household composition (ref: Single)							
Single parent	-0.272**	-0.115	0.757***	0.380***	-0.000	-0.262 **	-0.153
Couple without children	-0.260***	-0.134**	-0.218**	0.144***	-0.0731	-0.217***	-0.162***
Couple with children	-0.399***	-0.221***	-0.013	0.125*	-0.174**	-0.342***	-0.260***
Other	-0.344***	-0.194***	0.033	0.172**	-0.011	-0.306***	-0.225***
Employment status of reference person (ref: Working)							
Pensioner	0.030	0.039	0.440***	0.073	0.0428	0.163*	0.0390
Unemployed	-0.060	-0.007	0.175	0.059	0.049	0.040	-0.024
Student	-0.427	-0.389	-1.060	0.503	-0.458	-0.336	-0.351
Inactive	0.146	-0.007	0.684	0.299	-0.700	-0.046	-0.037
Sick or disabled	-0.130	-0.105	0.341	-0.046	0.006	0.006	-0.114
Other	3.200	3.352	4.081*	3.501	3.343	3.316	3.279
Education of reference person (ref.: Primary or less)							
Lower and upper secondary	-0.087	-0.108	-0.356**	-0.133	-0.010	-0.089	-0.099
Postsecondary and tertiary	0.004	-0.025	-0.452***	-0.096	-0.021	-0.012	-0.021
Residence tenure (ref.: Owner)							
Renter	0.015	0.024	0.125	0.035	0.146	0.018	0.022
Social renter	0.046	0.093	0.473***	0.044	-3.646***	0.064	0.069
Other	0.148	0.176	0.473*	0.153	0.223	0.155	0.151
Main fuel type: residential heating (ref.: Town/Natural gas)							
Liquefied hydrocarbons	-0.534***	-0.518***	-0.404*	-0.456***	-0.660***	-0.535***	-0.508***
Liquid fuels	0.697***	0.696***	0.670***	0.482***	0.673***	0.698***	0.697***
Solid fuels	0.771***	0.784***	0.949***	0.847***	0.734***	0.766***	0.755***
Intercept	53.781*	-3.828	579.018***	176.853***	7.273	53.637*	17.216
Observations	5,344	5,344	5,344	5,344	5,344	5,344	5,344
R ²	0.328	0.238	0.610	0.296	0.398	0.351	0.262

Note: For all categorical variables, the reference category is indicated between brackets. Robust standard errors. Estimates are weighted using household weights. Assumes an EU ETS2 allowance price of €85/tCO₂.

Source: own calculations, based on EU-SILC (2022), HBS (2015) and PEACH2AIR (2014). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$