The Horizontal Distributional Impacts of Carbon Pricing and Revenue Recycling Policies. A Microsimulation Study for Belgium.

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Abstract: We assess ex ante the distributional impacts of carbon pricing on heating and transport fuels on Belgian households through microsimulation modelling. Our analysis reveals significant variations in carbon payments among households with similar incomes, with heating system types emerging as a crucial determinant. The groups experiencing higher carbon burden include individuals aged 65 and above, singles, and households using heating oil. Redistributing the revenue equally per household, rather than per capita, per adult or per consumption unit, proves more effective in protecting the most affected households. Targeting transfers toward poorer households and customizing them based on heating system types not only offers enhanced protection for vulnerable households but also helps mitigate horizontal distributive impacts.

1. Introduction

The European Union is committed to reducing its greenhouse gas emissions by 55% by 2030 compared to 1990 levels and to achieving carbon neutrality by 2050. As part of the measures aimed at accomplishing these goals, the EU will introduce a new emissions trading scheme for the road transport and building sectors (ETS 2). Fuel suppliers in these sectors will be required to acquire emission permits for the release of CO_2 into the atmosphere through the combustion of the fuels they sell. Consequently, the prices of these fuels will rise to compensate for the added expense of procuring emission permits.

Policies that lead to an increase in fuel prices are often met with resistance. For instance, the surge in fuel prices caused by a carbon tax was a primary driver behind the Yellow Vests movement in France. Environmental policies in democratic countries tend to be shaped by public opinions (Anderson *et al.* (2017) Schaffer *et al.* (2022)). Lack of public support for a carbon pricing is the primary reason why it is not yet implemented in some countries, remains at very low levels, or is no longer increasing in others (Parry (2015), Ohlendorf *et al.* (2021)). Unlike other public policies aimed at reducing CO_2 emissions such as norms and standards or subsidies, carbon pricing generates fiscal revenues. There have been numerous calls to redistribute the carbon payments to households to enhance the political acceptability of the reform. For instance, the Economists' Statement on Carbon Dividend claims that "[t]o maximize the fairness and political viability of a rising carbon tax, all the revenue should be returned directly to U.S. citizens through equal lump-sum rebates. The majority of American families, including the most vulnerable, will benefit financially by receiving more in "carbon

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dividends" than they pay in increased energy prices." [1].

Aware of the need to support households in their energy transition, the European Union has planned the following measures: (i) capping the price at which a ton of carbon is traded on the ETS 2 market at €$45/tCO_2$ in the initial years of the scheme and (ii) allocating a portion of the revenue from the sale of emission rights to feed the Social Climate Fund, which aims to offer financial support to households.

In this paper, we conduct simulations to assess the potential impact of implementing a price of 45€/tCO_2 on heating and transport fuel consumption among Belgian households. Our analysis identifies the characteristics of the households that would be most impacted by this reform, and explores various options for recycling the resulting revenue to compensate them. These analyses are performed thanks to a microsimulation model running on microdata from the Househould Budget Survey.

We've uncovered several results in Belgium that echo findings already established in the literature of other developed countries. We observe that consumption of heating fuel remains relatively stable across income deciles, while consumption of transport fuels shows only a slight increasing pattern (see *e.g.* Flues & Thomas (2015) for 21 OECD countries). Consequently, our findings indicate that carbon pricing is regressive, as lower-income households tend to allocate a larger proportion of their income to energy taxes (see also *e.g.* Callan *et al.* (2009) for Ireland, Douenne (2020) for France, Grainger & Kolstad (2010) or Mathur & Morris (2014) for the US). However, when redistributing the carbon payments equally to households, we observe that the reform becomes progressive. This is due to higher-income households, on average, spending more on fuel (see also *e.g.* Douenne (2020), Fremstad & Paul (2019), or WilliamsIII *et al.* (2014)). More precisely, a carbon dividend policy results in an average gain for individuals in the first four income deciles and a loss for those in the remaining deciles. Overall, a majority of individuals benefit, with a higher proportion of winners among lower-income households. Energy poverty is also reduced.

Despite the consensus in the literature about the progressivity of a carbon dividend, surveys indicate that it is not very popular. In the study of Douenne & Fabre (2022) in France, 70% of the respondents oppose a carbon tax of €$50/tCO_2$ if the revenue were to be redistributed equally to each adult, whereas only 10% of them expressed explicit support for it. In their international survey, Dechezleprêtre *et al.* (2022) find that 37% of respondents in the 12 developed countries they cover were not in favour of a carbon dividend. Among the main factors influencing policy support of carbon dividends, there is the public perception of the policy's effectiveness in reducing CO_2 emissions, of its impact on lower-income households, and of its effect on respondents' purchasing power (Dechezleprêtre *et al.* (2022), Bergquist *et al.* (2022), Dabla-Norris *et al.* (2023)). The perceptions of respondents may however not be accurate. For example, only 14% of respondents believe they would benefit from the reform in Douenne & Fabre (2022), despite simulations suggesting that 70% of them should, and a majority of respondents incorrectly perceive the reform as regressive. Dechezleprêtre *et al.* (2022) demonstrate that respondents who receive information about the distributive effect of a carbon dividend tend to be more in favor of the policy compared to those who do not receive

1 The Economists' Statement on Carbon Dividend was published in the Wall Street Journal on January 17 2019 and signed by more than 3.000 US economists among which 28 Nobel Laureates.

such information. However, Douenne & Fabre (2022) show that distrust in political institutions and in the experts reduces the impact of information transmission on beliefs.

The lack of support for a carbon dividend, as evidenced in surveys, isn't solely due to misperception and distrust. According to Olson (1965), the implementation of political reforms becomes more challenging when the benefits are spread across the population, while the costs are concentrated, a characteristic akin to a carbon dividend policy. This argument is consistent with the loss aversion theory (Kahneman & Tversky (1979)), according to which losses are given more weights than gains. Even if ex ante simulations indicate that a majority of voters would gain with a carbon dividend, political acceptability is also tied to its impact on the most vulnerable and the most affected households.

We therefore pay a particular attention to the most impacted individuals, both among the entire population and among subgroups based on income and other socio-demographic characteristics. We find that the more vulnerable households are singles (see also Berry (2019)), those living in rural areas (see also Berry (2019)), aged at least 65 (see also Tian *et al.* (2023)) and using heating oil. These households were already at a higher risk of energy poverty before the reform. Furthermore, we identify the type of heating system as the most influential characteristic affecting carbon payments. Notably, households heating with oil face carbon payments more than twice as high as those heating with gas, a pattern observed across the entire income distribution.

We note considerable disparities in carbon payments among households sharing similar income levels, indicating that carbon pricing generates not only vertical but also horizontal distributive impacts (also observed in Cronin *et al.* (2019), Pizer & Sexton (2019) and Douenne (2020)). Therefore, despite the progressivity of a carbon dividend, we find that individuals experiencing a loss of more than 1% of their income are predominantly situated in the lowest income deciles (as also discussed in Rausch *et al.* (2011)). A carbon dividend may be perceived as unfair due to this concentration. We then compare alternative recycling scenarios. Among the equal redistribution schemes, the per capita redistribution rule, prevalent in Switzerland and extensively studied in the literature, results in a higher number of highly impacted individuals compared to the per household or per consumption unit redistribution rules. The per capita transfer tends to be overly favorable to households composed of two adults with children at the expense of singles without children, while the former having slightly higher fuel expenses but considerably higher incomes. Surprisingly, we have not found any paper comparing these alternatives in the literature. Furthermore, we find that proposing a more generous transfer to households utilizing oil heating systems notably reduces the variance of the impact and the number of highly affected individuals. This observation is consistent across the entire population and within subgroups where the proportion of heavily impacted individuals is notable, such as low-income individuals, the elderly, singles, and rural households. Previous studies suggested that horizontal distributive could not be easily alleviated due to substantial heterogeneity among households with similar income levels (Pizer & Sexton (2019) and Douenne (2020)). To our knowledge, this is the first paper showing that these horizontal distributive impacts can be significantly reduced by an appropriate use of the carbon payments.

In the remainder of this paper, we first present our data, methodology, and the reform simulated in section 2. Section 3 is devoted to the distributive impact of carbon pricing,

Fuel	Price increase, VAT inc.	Relative price increase, 2018
Gasoline	0.13 €/litre	+8.7 %
Diesel	0.14 €/litre	+9.5 %
Heating Oil	0.14 €/litre	+20.2 %
Natural Gas	9.5 €/MWh	+15.6 %

Table 1: Transport and heating fuels price increase

and Section 4 delves into alternative revenue recycling strategies. Finally, Section 5 concludes.

2. Methodology

2.1. *Data*

We use the Household Budget Survey (HBS) conducted in 2018 for which more than 6,000 households representative of the Belgian population accurately reported their expenditures over a 15-day period [2]. We multiplied these expenditures by two to obtain monthly values. The data include expenditures and quantities for transport fuels (gasoline and diesel), and only expenditures for heating fuels (natural gas and heating oil). Therefore, we used the average prices of heating fuel in 2018 and divided the total expenditure by this price to estimate the quantities of fuels consumed [3]. The dataset also incorporates socio-demographic characteristics of the households, including the income, age and employment status of each member; family composition; region; the type of housing occupied (house/apartment and owner/renter); and durable goods (cars, appliances).

2.2. *The reform*

We consider the introduction of a uniform carbon price of €45 per ton of CO_2 on heating (natural gas and heating oil) and transport fuels (diesel and gasoline), which is the highest price of emission permits during the first years of the extended EU-ETS to the transport and building sectors. We assume that the emission permits are subject to a VAT of 21%, and that the full carbon price on fuel purchased by households is passed on to consumers [4]. The price increase for the different fuels once carbon is priced is presented in Table 1. In relative terms, transport fuels are less impacted by the carbon price than heating fuels because their consumption is currently subject to much higher taxation.

2 HBS data are collected every two years in Belgium. We did not employ the 2020 data due to biases resulting from the COVID-19 crisis. The 2022 data are not available at the time of writing.

3 The price of heating oil in 2018 is available from StatBel (2022), while the prices of natural gas (social and standard rates) are accessible through the Belgian Regulation Agency on Electricity and Gas (CREG 2019) and `https://www.creg.be/fr/consommateur/tarifs-et-prix/tarif-social`). We used the social rate to compute the quantities consumed by social rate beneficiaries and the average standard rate to calculate the consumption of the remaining households.

4 Andersson (2019) provides empirical evidence supporting this assumption.

2.3. *Assumptions*

We assume that fuel consumption remains unchanged. In his meta-analysis, Labandeira *et al.* (2017) found low price elasticities in the short run, ranging from -0.017 to -0.293 for the energy sources studied here. Given that we assume no changes in consumption, we also overlook the environmental benefits associated with reduced fossil energy consumption [5].

Another limitation of our analysis is that we only consider the direct impact of the reform. However, firms' production costs are also affected by the studied reform, which could be reflected in the prices they charge and in the type of activities they engage in, which in turn modifies the factor prices. Indirect effects are typically significant when a global carbon tax is implemented, but in this case, the scope is limited to transport and heating. Although we do not address this issue, we have assumed that only the carbon payments associated with consumers' fuel consumption are redistributed to households. Carbon payments supported by firms may allow for the funding of compensatory measures for firms, potentially lowering the pressure on goods and factor prices [6].

3. Carbon pricing

In this section, we examine the impact of a carbon price of €45 per ton of CO_2 on household expenditures when the carbon payments are not redistributed. We analyze how the carbon payment evolves across the income distribution, study the factors influencing the carbon payment, and assess the reform's effects on specific households.

3.1. *Vertical and horizontal distributive impact*

Figure 1 presents, (a) the carbon payments per consumption unit (hereafter CU) and (b) the carbon burden for households grouped into equivalent income deciles [7]. For each income decile, a box indicates the range of the central 50% of the data, thus extending from the first to the third quartiles; a central line indicates the median value. Lines extend from each box up to the 10^{th} and 90^{th} percentiles, and the point indicates the mean value. Figure 1.a indicates that, on average, households incur a monthly carbon payment of €12.3 per consumption unit, with a slightly lower amount in lower-income deciles and a slightly higher amount in higher-income deciles. Figure 1.b, confirms that carbon pricing is regressive, which is consistent with findings in the literature. Lower-income households bear a relatively higher carbon burden compared to their higher-income counterparts, going from 1.14% of the individuals' income in the

5 Reaños & Lynch (2023) show that the carbon burden decreases considerably when accounting for these environmental benefits.

6 The literature on the distributive impact of global carbon pricing typically distinguishes between use-side effects (consumption) and source-side effects (sources of income) through CGE modeling. This body of research generally indicates that source-side effects tend to be progressive, thereby offsetting the regressivity associated with consumption patterns. See for example Rausch *et al.* (2011)

7 The carbon burden of a household is calculated by dividing their carbon payment by their income. Equivalent income is obtained by adding the incomes of all members of a household and dividing this total household income by the number of CU taken from the modified OECD equivalence scale, which is defined by 1 + (number of adults - 1) x 0.5 + number of children x 0.3. Each decile represents 10% of the population.

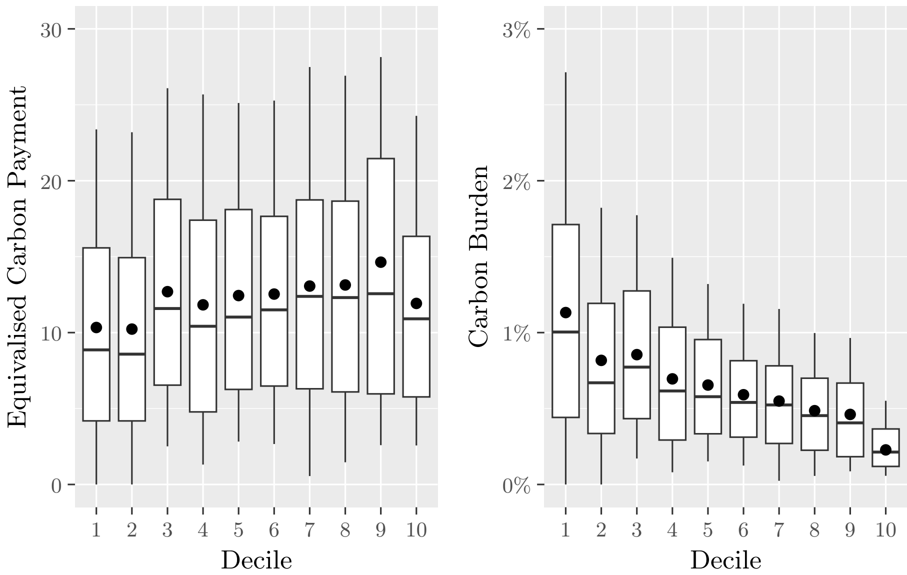

Figure 1: Carbon payment (a) and Carbon burden (b)

first decile to 0.23% in the tenth decile [8]. We also observe that there is considerable heterogeneity in carbon payment among households with similar equivalent incomes, which is more pronounced in lower deciles when we look at the carbon burden. We see for example in Figure 1.b that the carbon burden is greater than 2.7% for 10% of the individuals in the first decile, while it is greater than only 0.5% for 10% of the individuals in the tenth decile. These variations can be attributed to differences in factors such as car owneship, the type of cars, car usage, housing characteristics (*e.g.*, surface area, type of heating system and insulation), *etc.*

In Figure 2, we decompose the impact by sector, presenting the results (a) for transport and (b) for heating. On average, the carbon payment per consumption unit attributed to transportation amounts to €5.4 while it is equal to €6.9 for heating expenses. Notably, the average and median carbon payment associated with heating fuel exhibits relative stability across income deciles. The same holds for the other moments of the distribution. In contrast, the carbon payment for transportation exhibits an increasing trend as income levels rise [9]. We observe that the carbon payments for the most

8 There are two approaches to constructing deciles, either based on equivalent incomes or based on equivalent total expenditures. As in many other studies, we find that carbon pricing exhibits greater regressivity when deciles are based on income. We do not show this result for the sake of conciseness.

9 It is noteworthy that the carbon payment for transport fuel is zero for over 25% of individuals in each decile (50% if we look at the first two deciles). This can be attributed to the survey methodology, where individuals report their expenditure over a two-week period. Some individuals may use their cars without purchasing fuel during the surveyed period, while others may buy more fuel than they used. For individuals who heavily use their cars, the difference between actual fuel consumption and fuel expenditure is relatively small. Since our focus is primarily on individuals significantly affected by the reform, we find it acceptable that our results

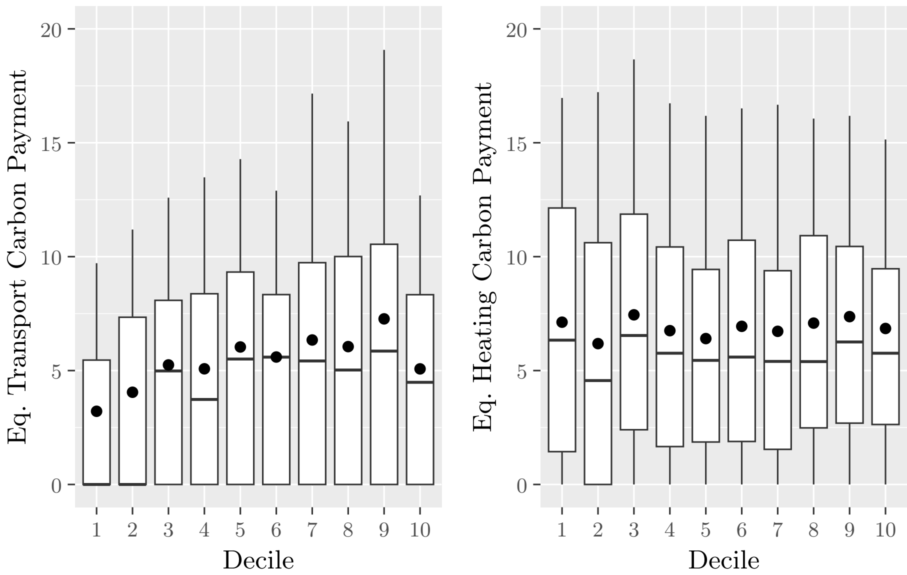

Figure 2: Monthly carbon payment for transport (a) and heating fuel (b)

affected individuals in the lowest income deciles are considerably lower for transport fuel compared to heating fuel. In contrast, the carbon payments for heating and transport are, on average, relatively similar among households in the highest income deciles.

We further decompose the carbon payment for heating by type of heating system in Figure 3. Our findings indicate that average carbon payment per consumption unit for heating remains relatively constant across income deciles for households with the same heating system. However, substantial variations are evident between households using different heating systems. On average, monthly carbon payments for heating amount to approximately €14 per consumption unit in each income decile for households heating with oil and about €6.5 for those with natural gas heating systems. The discrepancy in carbon payments between heating oil and natural gas can be attributed to several factors. Firstly, the carbon intensity of heating oil (0.26 kg of CO_2 per kWh) is higher than that of natural gas (0.2 kg of CO_2 per kWh). Additional insights related to the relationship between heating system type and housing characteristics are provided in Table 2. We observe that the proportion of households using heating oil is, on average, higher in buildings constructed before 1981 (they are assumed to be less well insulated). Furthermore, oil heating systems are only half as likely to be labeled as energy-efficient compared to gas systems. Additionally, heating oil systems are more commonly found in houses than in apartments. Lastly, oil heating systems are more prevalent in detached houses, which are more susceptible to energy loss compared to semi-detached or terraced houses.

may not be very precise for individuals with minimal impact. Moreover, these inconsistencies in expenditure reporting cancel out as soon as we look at a sufficient-enough aggregated level.

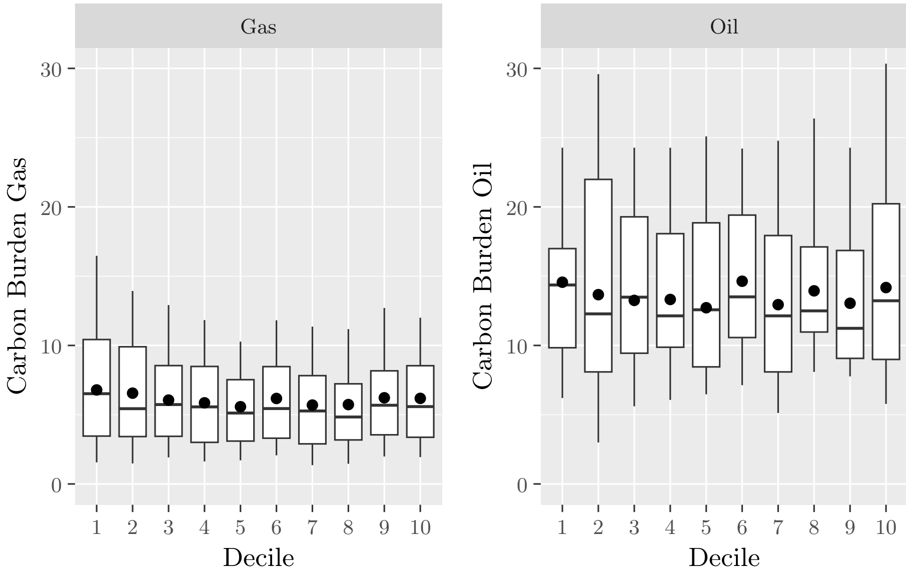

Figure 3: Monthly carbon payment for gas (a) and oil (b)

Heating	Before 1981	High Efficiency	House	Detached House	Semi Detached House	Terraced House
Oil	76.6 %	41.8 %	90 %	52.5 %	23.6 %	13.8 %
Gas	67.9 %	79.2 %	73.6 %	27.4 %	22.2 %	24 %

Table 2: Comparison of Housing based on Heating System

3.2. *Main determinants*

We conducted an econometric analysis using Ordinary Least Squares (OLS) regression to identify the main determinants of the monetary impact of carbon pricing. The dependent variable is the carbon payment per consumption unit. Our primary independent variables include Income, Region, Consumption Units in model 1, supplemented by the Type of Heating System in model 2 and the Number of Vehicules in model 3. Models 4 and 5 incorporate a set of housing and socio-demographic characteristics as control variables.

We lack access to some variables that might influence the monetary effect of the reform, such as dwelling characteristics (e.g., size, insulation) and commuting distances, among others. Additionally, various unobservable factors, like environmental concerns, play a substantial role. Nonetheless, our chosen variables collectively explain a significant portion of the variation in effects (with an R-squared value of 0.41). Furthermore, the variance inflation factor (VIF) is less than 2 for each explanatory variable except for Income, indicating that multicollinearity is not a significant issue in our estimation.

Several variables in our analysis are categorical. To establish the reference household, we selected the categories resulting in the lowest carbon payment. As a result, the coefficients of other variables are interpreted relative to this reference household, which is why they are positive for all categorical variables in model 5.

The results are presented in Figure 4. Compared to households heating with electricity, we find that the monthly carbon payment per consumption unit is on average €7 higher for those heating with gas, and €17 higher for those using heating fuel. The type of heating system has the most significant impact on the carbon payment, as evidenced by the R-squared value increasing from 0.1 to 0.36 between models 1 and 2. This effect remains robust when control variables are introduced. The number of cars and the type of housing also play a role. A household with one car, on average, experiences an increase of nearly €5 per month compared to a similar household without a car. Owning at least two cars results in an additional €7 per month. Residing in a house, as opposed to a flat, leads to a monthly increase of about €3 in carbon payment. Interestingly, households benefiting from social discounts for energy prices experience a €3.8 increase in carbon payment. This suggests that households benefiting from price reductions tend to consume more energy compared to otherwise similar households.

3.3. *Impact on categories of individuals*

We analyze the impact of the reform on specific groups of individuals. The results are summarized in Table 3. Our energy poverty definition, based on the "Fondation Roi Baudouin", identifies households within the first five deciles as energy poor if they spend over twice the median between energy bill and equivalent disposable income (after deducting housing expenses).

At the population level, our findings reveal that the carbon price increases the energy poverty rate by 3.3 percentage points, reaching 20%, and implies a carbon price burden higher than 1.46% for 10% of individuals.

We observe that the carbon price has a more significant effect on certain groups. In most cases, we also notice a more pronounced impact among groups that already experience higher energy poverty rates, thus exacerbating energy poverty among vulnerable groups. This is particularly evident for individuals in households with heads aged over 65, those using oil heating, and singles. Compared to others, these individuals face higher carbon prices per consumption unit and bear a heavier carbon burden both on average and among the most impacted individuals. For example, the energy poverty rate for singles increases to 41%, the monthly carbon price is €13.99 per consumption unit, representing 0.78% of their income, and 10% of them suffer a loss of more than 2% of income. Conversely, Brussels residents, those using heating systems other than oil or gas, and couples experience relatively lower adverse effects.

	(1)	(2)	(3)	(4)	(5)
(Intercept)	18.00 ***	10.71 ***	8.89 ***	11.41 ***	7.42 ***
	(0.44)	(0.44)	(0.48)	(0.75)	(1.00)
Income_1000	0.67 ***	0.47 ***	0.10	0.34 ***	0.15 *
	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)
Income_1000_sq	-0.01 ***	-0.01 ***	-0.00	-0.00 **	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Region Brussels	-2.32 ***	-2.02 ***	-0.27	-0.18	0.98 **
	(0.45)	(0.39)	(0.39)	(0.43)	(0.43)
Region Wallonia	5.76 ***	2.98 ***	2.81 ***	2.72 ***	2.54 ***
	(0.31)	(0.27)	(0.27)	(0.27)	(0.27)
Consumption Units	-5.04 ***	-5.19 ***	-6.08 ***	-5.92 ***	-6.59 ***
	(0.33)	(0.28)	(0.28)	(0.28)	(0.29)
Heating Oil		18.03 ***	17.43 ***	16.81 ***	16.54 ***
		(0.37)	(0.36)	(0.38)	(0.38)
Heating Gas		7.35 ***	7.21 ***	6.81 ***	6.71 ***
		(0.32)	(0.31)	(0.33)	(0.32)
High_Efficiency		1.19 ***	0.91 ***	0.64 **	0.70 ***
		(0.26)	(0.25)	(0.27)	(0.27)
Nbr.Cars 2 or more			7.13 ***		6.69 ***
			(0.43)		(0.45)
Nbr.Cars 1			4.89 ***		4.63 ***
			(0.32)		(0.33)
Two_Wheels			0.06		0.02
			(0.32)		(0.32)
Building Year				-0.11 **	-0.24 ***
				(0.05)	(0.05)
House				3.64 ***	2.68 ***
				(0.33)	(0.33)
Fossil_Boiler				1.06 ***	1.05 ***
				(0.34)	(0.33)
Fossil_Oven				0.03	-0.20
				(0.49)	(0.48)
Fossil_Cooker				-0.42	-0.45 *
				(0.26)	(0.26)
Renter				-0.95 ***	-0.92 ***
				(0.29)	(0.30)
Days Away				-0.01	-0.01
				(0.01)	(0.01)
Age_ref					0.03 ***
					(0.01)
Worker					0.56 ***
					(0.15)
Social Discount					3.76 ***
					(0.44)
N	6134	6134	6134	6020	6000
R2	0.10	0.36	0.39	0.38	0.41

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Figure 4: The determinants of the carbon burden

Characteristic	**CP (/CU)**	**CP Burden**	**Energy Poverty**	**Variation**	**CP Burden P90**
Total	12.30	0.53 %	20 %	+ 3.3 p.p.	1.46 %
Age < 65	11.84	0.49 %	15.3 %	+ 2.8 p.p.	1.33 %
Age >= 65	15.58	0.84 %	43.5 %	+ 5.9 p.p.	2 %
Brussels	8.53	0.38 %	15.5 %	+ 2.4 p.p.	1.07 %
Rest of Belgium	12.75	0.54 %	20.5 %	+ 3.4 p.p.	1.5 %
Other heating	5.18	0.24 %	14.1 %	+ 1.3 p.p.	0.76 %
Gas	10.92	0.45 %	17.5 %	+ 3 p.p.	1.23 %
Oil	20.44	0.91 %	30.1 %	+ 5.5 p.p.	2.15 %
House	13.21	0.54 %	19.1 %	+ 3.2 p.p.	1.48 %
Flat	8.51	0.44 %	22.8 %	+ 3.5 p.p.	1.33 %
Couples	12.02	0.5 %	13.8 %	+ 3.2 p.p.	1.27 %
Singles	13.99	0.78 %	41 %	+ 3.5 p.p.	2 %
Two or more cars	13.70	0.49 %	6.5 %	+ 1.8 p.p.	1.22 %
One car	12.22	0.59 %	25.1 %	+ 4.2 p.p.	1.63 %
No car	7.3	0.44 %	36.2 %	+ 3.5 p.p.	1.5 %

Table 3: Impact by socio-demographic characteristics

4. Budget neutral reforms

In this section, we make the assumption that the carbon payments collected from households are redistributed among them [10]. We analyze equal redistribution schemes in Section 4.1, and targeted redistribution schemes in Section 4.2. We use the term "net carbon burden" to denote the difference between the carbon payment and the received transfer, relative to income.

4.1. *Equal redistribution*

In our reference scenario, carbon revenues are redistributed equally among all households. We find that the reform becomes progressive in that case. As illustrated in Figure 5, the average net carbon burden is negative for the individuals in the four first income deciles, while it is positive and tends to increase in higher income deciles. Moreover, the majority of individuals encounter a net gain in the lower half of the income distribution, given that the median net carbon burden is negative in the first five income deciles. Conversely, the proportion of winners is smaller than 50% in higher income deciles. However, it is noteworthy that individuals with the highest carbon burden are

10 Other options are possible. Revenues can be used to reduce the carbon burden, which may have economic stimulus benefits. They can be directed towards financing green infrastructure investments, an option often favored by the public, or used to reduce public deficits. In this study, we focus on comparing the effectiveness of various types of transfers to households in protecting the households most affected by a carbon price.

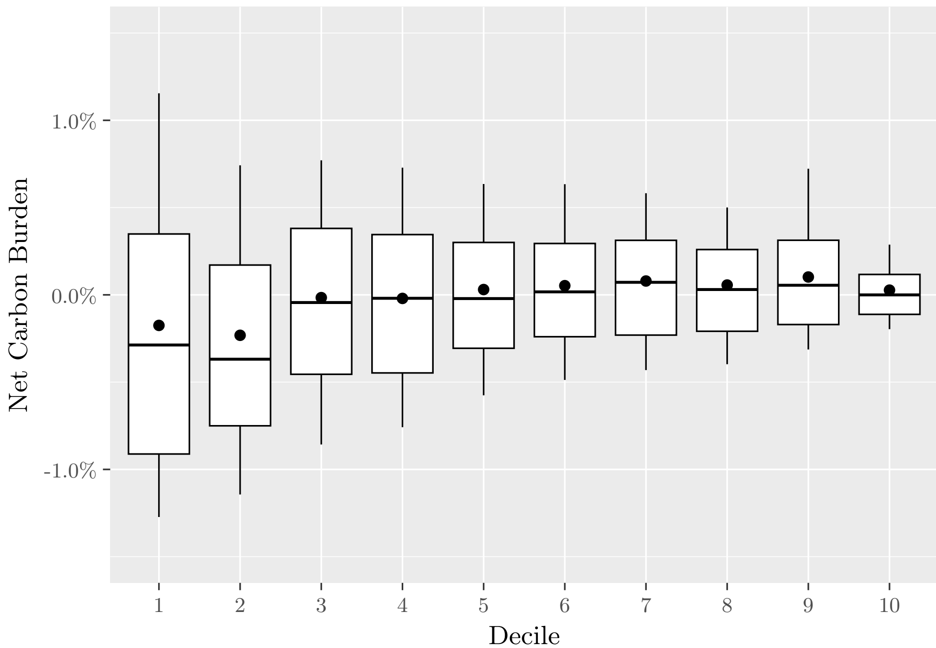

Figure 5: Net carbon burden for carbon dividend with redistribution per household

primarily concentrated in the first income deciles. For instance, the net carbon burden at the 90$^{\text{th}}$ percentile is 1.2% in the first income decile, compared to 0.67% for the entire population [11] We suspect that this finding is a factor explaining the lack of support for carbon dividend policies.

There are four primary variations of carbon dividend proposals with equal transfers discussed in the literature or implemented in some countries. In addition to the equal per household redistribution rule, we also encounter the equal per capita, per adult, or per consumption unit redistribution rules [12]. In our reference scenario, each household receives a monthly payment of €20.4. For the three other designs, transfers are as follows: €9.1 per person; €11.9 per adult and €13.3 per consumption unit.

In Table 4, we note that the net carbon burden for individuals aged 65 and older and for singles becomes negative, indicating that these individuals, on average, experience

11 This conclusion remains consistent regardless of the chosen indicator. For instance, we observe that the net carbon burden exceeds 1% for over 10% of individuals in the first income decile and over 5% for individuals in the second and third income deciles, compared to 4.5% at the population level. See Appendix 6.1 for a discussion of the robustness of this result to the choice of indicator.

12 Many academic studies focus on redistribution per household (see *e.g.*, Berry (2019)), or per individual (*e.g.*, Rausch *et al.* (2011), Cronin *et al.* (2019) or Budolfson *et al.* (2021)). In Switzerland, carbon tax revenue allocated to the population is distributed on a per-person basis, through an equal reduction in health insurance for all residents. The option of redistributing per adult is particularly relevant if the redistribution is carried out through reductions in income taxes, as is the case in British Columbia. The reference scenario of Douenne (2020) involves redistribution proportional to the number of consumption units, which is also examined in Berry (2019)

	Household	**Capita**	**Adult**	**CU**
Net carbon burden				
65+	-0.05%	0.26%	0.05%	0.12%
Oil	0.49%	0.4%	0.43%	0.43%
Singles	-0.26%	0.2%	0.24%	0.06%
Net carbon burden P90	0.67 %	0.68 %	0.68 %	0.62 %
65+	0.9 %	1.21 %	1.02 %	1.06 %
Oil	1.18 %	1.3 %	1.21 %	1.25 %
Singles	0.72 %	1.28 %	1.16 %	1.03 %
Net carbon burden > 1%	4.46 %	5.88 %	5.05 %	4.72 %
65+	8.6 %	13.7 %	10.4 %	10.6 %
Oil	13.5 %	15.6 %	15 %	14.2 %
Singles	6.2 %	15.4 %	13.1 %	10.3 %

Table 4: Equal redistribution schemes

a gain when redistribution is carried out at the household level. In contrast, the net carbon burden remains positive in the other scenarios. However, households heating with oil still experience a positive and high net carbon burden in all four scenarios. When focusing on the most impacted individuals in the entire population, we observe that the net carbon burden at the 90^{th} percentile is quite similar across the four policies. Still, the share of individuals with a net carbon burden higher than 1% is smaller when carbon payments are redistributed equally among households [13]. Moreover, in the three identified vulnerable groups, the net carbon burden at the 90^{th} percentile and the proportion of individuals with a net carbon burden higher than 1% are consistently smaller in the reference scenario.

These findings suggest that redistributing per household is the most effective strategy for protecting the most impacted individuals and vulnerable groups. Table 5 shows that that, on average, the carbon payment for heating fuel only slightly increases with household size, whereas income and the carbon payment for transport fuel exhibit substantial increases with household size. On average, having more than one adult in the household doubles the household's income, and the presence of children is associated with an average income that is 50% higher. As a result, policies that are more generous towards larger households tend to provide greater compensation to households facing only slightly higher carbon payments while having considerably higher incomes. In contrast, the policy scenario that does not account for household size tends to be more generous towards smaller households that concentrate a larger share of fragile households.

Furthermore, Table 8 indicates that the standard deviation of the net carbon burden

13 We show in Appendix 6.2 that the difference between the scenarios is even more pronounced when we compute the share of households that are highly impacted rather than the share of individuals.

	CP Heating	CP Transport	Income
>1 Adults, child	12.6 €	12.5 €	5684.2 €
>1 Adults, no child	13.9 €	9.6 €	3990.9 €
One Adult, child	11 €	6.9 €	2838.5 €
One Adult, no child	10.8 €	5.4 €	1827.8 €

Table 5: Household size, carbon payment and income

decile	Household	Capita	Adult	CU
1	11.9	13.9	12.4	12.1
2	8.6	9.3	8.4	8.4
3	6.8	7.5	6.9	6.7
4	6.0	6.5	6.2	5.9
5	5.2	5.7	5.4	5.2
6	4.5	5.0	4.8	4.6
7	4.3	4.7	4.4	4.3
8	3.8	4.3	4.0	3.9
9	3.7	3.9	3.8	3.7
10	2.1	2.4	2.2	2.2
Total	6.4	7.1	6.5	6.4

Table 6: Standard Deviation of Tax Burden for Different Carbon Dividend Schemes

within each income decile is lower in scenarios where the transfer is equal for each household or proportional to the number of consumption units. This suggests that these policy choices result in lower horizontal distributive effects by providing greater compensation to those who would otherwise face a higher net carbon burden.

In conclusion, redistributing carbon payments equally among households proves to be the most effective approach in providing protection for households, among the scenarios considering differentiated support based on household composition.

4.2. *Targeted redistribution schemes*

In this section, we explore four scenarios where half of the revenue is evenly distributed among all households, with each household receiving €10 from this portion, while the other half is allocated to compensate specific households. In the "Heating" scenario, households using oil or gas heating systems receive a premium. Compared to the others, oil-heated households receive an additional transfer of €20 per month, while gas-heated households receive an additional €10 per month. In the "Household 50" scenario, households in the first five deciles receive a monthly transfer of €30. The "Heating 50" scenario provides a transfer of €48.4 to households in the first five income deciles that heat with oil, and €29.2 to those heating with gas. Lastly, the "Social Rate 50" scenario reduces the unit price of heating fuels by 32.6% for households in the first five deciles. These reductions complement the existing social discounts on gas and electricity, along with the heating cheques currently in effect in Belgium, and are maintained in all our policy simulations [14].

Table 7 presents our results. We observe that each targeted policy analyzed provides better protection for households than our reference scenario. The carbon burden at the 90^{th} percentile and the proportion of individuals with a carbon burden higher than 1% are smaller for both the entire population and among fragile groups when the redistribution is targeted. Similarly, the average carbon burden of households heating with oil is high in the reference scenario but is significantly reduced in the others. The targeted scenarios allocate more funds to households that are, on average, more adversely affected (those heating with oil) and/or to those with fewer resources, thus reducing the net carbon burden for vulnerable groups.

The "Heating 50" scenario is more effective in reducing the proportion of highly impacted individuals than the "Household 50" scenario. Customizing the transfer based on heating type for low-income households allows for more precise targeting of the most affected households among the poorest. There are few individuals for which the net carbon burden is higher than one percent when targeting is based on heating and income. However, less support is then provided to the households in the last 5 deciles heating with oil, resulting in a higher net carbon burden at the 90^{th} percentile in the population.

Not surprisingly, we find that the most efficient approach to decrease the net carbon burden is by lowering the fuel price through a social rate, as it benefits relatively more intensive fuel consumers. However, this policy contradicts the concept of a carbon price by exempting a portion of the population from it. Interestingly, our results show that the capacity to reduce the net carbon burden in the population and in the fragile groups is comparable when a higher transfer is provided to poor households heating with fuel or when a social rate is implemented.

Reducing the cost of energy consumption or providing more generous transfers for heating systems with higher CO2 emissions might discourage investments in energy-efficient infrastructure. This could reduce the environmental effectiveness of the policy and potentially lead to higher long-term energy costs, especially in light of the expected trajectory of increasing carbon prices. However, it should be noted that these household support measures are generally not designed to be permanent. For example, the Social Climate Fund is expected to be operational between 2026 and 2032. Hence, households are encouraged to invest during this transitional phase to reduce their future energy consumption, as household support programs will be gradually phased out. In addition,

14 Certain households enjoy a preferential rate for their heating fuel consumption. Households living in social housing or receiving financial assistance from the "Centre Public d'Action Sociale" (CPAS - Social Welfare Center), the "Direction Générale des Personnes Handicapées" (DGPH - Directorate General for Persons with Disabilities) or the National Pensions Office are eligible for a social rate on their gas and electricity bills. Beneficiaries of the social rate paid an average of €33 per MWH for gas in 2018, a significant reduction from the standard rate of €60 per MWH. Additionally, households eligible for "increased intervention", a status granted to households with a total gross income in 2018 below €1592 plus €294 per dependent person, could receive a refund of €0.14 per liter of heating oil purchased in 2018 if they applied for it through CPAS.

	Household	Heating	House-hold 50	Heating 50	Social Rate 50
Net carbon burden					
65+	-0.05%	-0.08%	-0.38%	-0.43%	-0.4%
Oil	0.49%	0.2%	0.36%	-0.04%	0.08%
Singles	-0.26%	-0.22%	-0.64%	-0.57%	-0.45%
Net carbon burden P90	0.67 %	0.54 %	0.65 %	0.61 %	0.59%
65+	0.9 %	0.6 %	0.78 %	0.67 %	0.6%
Oil	1.18 %	0.88 %	1.08 %	0.93 %	0.88%
Singles	0.72 %	0.54 %	0.64 %	0.55 %	0.53 %
Net carbon burden > 1%	4.46 %	3.32 %	3.64 %	2.94 %	2.67 %
65+	8.6 %	5.3 %	5.6 %	4 %	3.7 %
Oil	13.5 %	8 %	12 %	8.5 %	7.5 %
Singles	6.2 %	4.3 %	4.7 %	3.5 %	3.5 %

Table 7: Targeted redistribution schemes

it is possible to mitigate these unintended disincentive effects. For example, support could be delivered in the form of energy vouchers, enabling homeowners to enhance the energy efficiency of their residences, rather than through cash transfers or lower energy prices.

Table 8 presents the standard deviations of the net carbon burden in each income decile and in the entire population. When comparing the results between the "Household" scenario and the "Heating" scenario, or between the "Household 50" scenario and "Heating 50," we observe that a transfer differentiated by heating system leads to a less sparse distribution of net carbon burden both within income deciles and in the entire population. Conversely, allocating more funds to lower-income households is linked to a higher dispersion of the carbon burden at the population level. This is because the net carbon burden of low-income households is already, on average, negative in the reference scenario. This leads to a more negative average carbon burden in lower deciles and a more positive average carbon burden in higher deciles, thereby increasing the dispersion at the population level.

Customizing the transfer based on heating type allows for more precise targeting of the most affected households, as heating type is the primary factor influencing the reform's monetary impact.

decile	**Household**	**Heating**	**Household 50**	**Heating 50**	**Social Rate 50**
1	11.9	10.1	13.1	11.1	8.3
2	8.6	7.3	9.3	8.4	6.4
3	6.8	5.7	7.3	6.8	5.4
4	6.0	5.0	6.5	5.6	4.7
5	5.2	4.4	5.5	4.9	4.2
6	4.5	3.8	4.4	4.4	4.4
7	4.3	3.7	4.2	4.2	4.2
8	3.8	3.3	3.8	3.8	3.8
9	3.7	3.2	3.7	3.7	3.7
10	2.1	1.8	2.1	2.1	2.1
Total	6.4	5.4	8.1	7.4	6.4

Table 8: Standard Deviation of Net Carbon Burden for Different Carbon Dividend Schemes

5. Conclusion

In this paper, we have conducted ex ante microsimulations to assess the distributional effects of implementing a carbon price of €45/tCO_2 on heating and transport fuel consumption of Belgian households. Our analysis confirms a few results that have been replicated in other developed countries since the beginning of the 90's. Notably, carbon pricing is regressive, disproportionately affecting lower-income households who allocate a larger share of their income to energy expenses. However, it can be made progressive by recycling the revenue back to households, given that wealthier households tend to spend more on fuel. More recently, a few studies have shown that there are significant disparities in carbon payments among households with similar income levels, revealing that horizontal distributional impacts are in fact stronger than vertical ones.

We show that the type of heating system emerges as the most influential factor of the carbon burden, with households using heating oil facing considerably higher carbon payments. This places lower-income households relying on oil in a particularly vulnerable position. Individuals aged at least 65, singles, and households using heating oil are particularly vulnerable as they face on average higher carbon burdens and a larger share of these individuals are highly impacted. Our research indicates that redistributing the revenue equally per household proves to be a more effective approach to reduce the carbon burden both at the population level and among the more fragile groups, compared to other redistribution schemes based on household composition. We have also explored targeted recycling schemes by customizing transfers based on heating system types and by increasing transfers to poorer households. We find that these alternatives are more effective in providing support to the most impacted households compared to equal redistribution schemes, and that horizontal distributive impacts can be tempered when oil-heated households get a higher transfer (possibly in the form of subsidies for switching to cleaner heating systems such as heat pumps).

These findings enhance our understanding of the distributional impacts of carbon

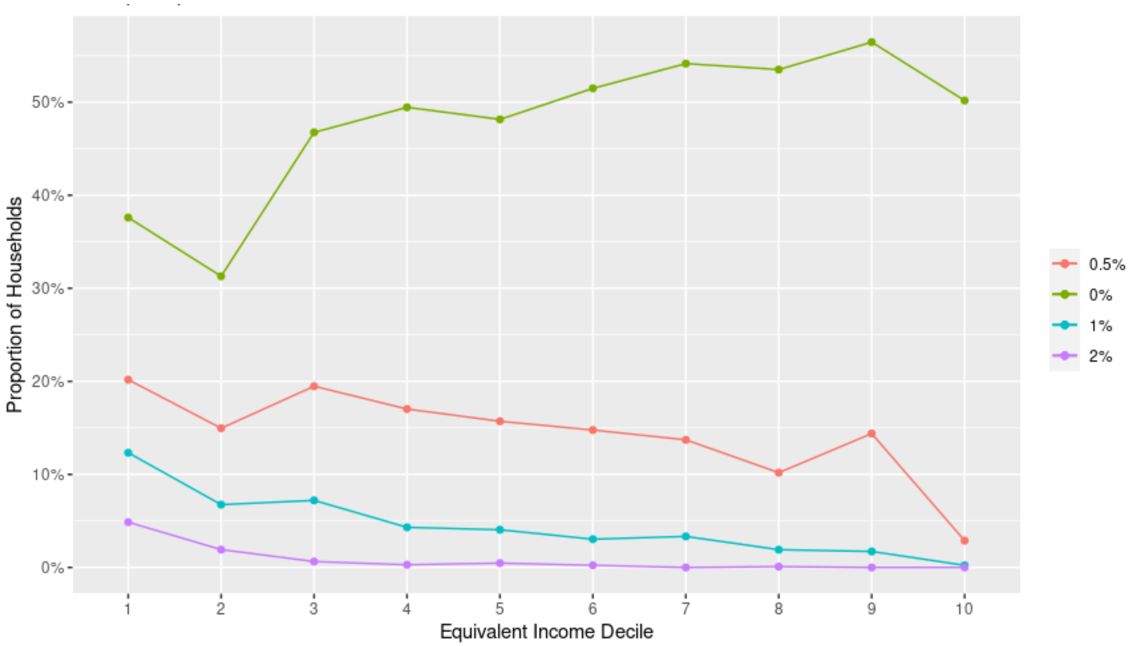

Figure 6: Proportion of Losers

pricing policies. To ensure a fair and socially acceptable reform, it is crucial to support households and address disparities. By implementing these strategies, policymakers can advance both social equity and environmental sustainability, thus promoting public acceptance and facilitating the transition to a low-carbon future.

6. Appendix

6.1. *Different threshold values of net burden*

In Figure 6, we depict the percentage of individuals residing in households that encounter a net burden across various threshold values, ranging from 0% to 2%. It is evident that the proportion of individuals with a positive net burden is lower among the first income deciles and tends to rise with income. Conversely, the percentage of individuals with a net burden surpassing a specific threshold is higher among lower-income households when the threshold is positive.

6.2. *Individuals versus households*

It is possible to measure our indicators at either the household or individual level. In the main text, we have chosen to measure them at the individual level. In Table 9, we compare the proportion of individuals and households experiencing with a net burden of at least 1%. We observe that the figures are higher when considering households rather than individuals. This is because single-person households are proportionally more affected, and their weight is relatively higher when households are used as the unit of measurement instead of individuals. In qualitative terms, our results remain consistent regardless of the choice of the unit of measurement, but the distinctions between scenarios become more pronounced when considering the number of households.

	Household	**Capita**	**Adult**	**CU**
Net burden >1% (Individuals)	4.5 %	5.9 %	5.1 %	4.7 %
Net burden >1% (Households)	5.5 %	10 %	7.8 %	7.3 %

Table 9: Net burden >1%. Individual versus household counts

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