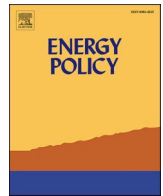




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# Carbon pricing and household burdens in newly affluent countries - An application to Lithuania

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## ABSTRACT

This paper assesses household burdens from a carbon tax with revenue recycling and compares them to price changes during the recent cost-of-living crisis. The illustration focuses on Lithuania, an OECD country that attained high-income status a decade ago, and that recently enacted a €60/ton CO<sub>2</sub> carbon tax despite a challenging policy context, with high poverty rates and major concerns about the affordability of energy and other necessities. Although households spend large shares of their budget on energy, the average impact of the carbon tax on their overall cost of living is comparatively modest. At around 3 % on average, it is substantially smaller than the impact of inflation between 2021 and 2024 (35.8 %). Results confirm that direct burdens from higher fuel prices fall disproportionately on lower-income households. But indirect effects of carbon pricing, from higher prices of goods other than fuel, are sizeable and broadly “flat” across the income distribution, which dampens regressivity. We simulate seven different options for compensating households by recycling carbon-tax revenues back to them through transfers or by lowering other taxes. When carefully designed, revenue recycling allows considerable scope for cushioning burdens, and for addressing concerns about disproportionate costs for some groups of households and voters.

## 1. Introduction

As part of strategies to tackle the causes of climate change, different forms of carbon pricing, such as carbon taxes, cap-and-trade systems and phase-outs of fossil-fuel subsidies, have been introduced or proposed to shift the marginal private cost of carbon towards its marginal social cost. These measures incentivise a reduction in emissions and the substitution of cleaner for dirtier fuels and technologies. They are recommended for their environmental effectiveness, because they are administratively simple and economically efficient, without being technologically prescriptive, and because they do not weigh on government budgets but, instead, create revenue (Pigou, 1920; Nordhaus, 1991; High-Level Commission on Carbon Prices, 2017; Pearson and Smith, 1991).

Across countries, including in the high-income OECD area, current carbon prices are well below levels that are considered in line with

national and international commitments, notably the targets affirmed in the Paris Agreement (OECD, 2022c,d). Numerous governments are therefore considering reforms to introduce or increase them. A particular challenge for carbon-pricing initiatives is their distributional impact, however. Mitigation policies are needed to prevent catastrophic impacts of climate change, and the associated costs for societies. In the short term, there can nevertheless be notable trade-offs between the intended incentives from higher carbon prices, and unintended distributional effects (Baranzini et al., 2000; Baumol and Oates, 1988). The pattern of these distributional effects, in turn, is a key driver of public and political support for fighting climate change (Büchs et al., 2011; Tatham and Peters, 2022). Understanding the size and incidence of household burdens from climate-change mitigation, even if temporary, is important for social welfare reasons (Baumol and Oates, 1988; Budolfson et al., 2021). It is also a key input into designing mitigation

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measures that governments can afford and voters are likely to support (Beiser-McGrath and Bernauer, 2019).

Carbon pricing tends to be less regressive at lower GDP levels because significant shares of the population cannot afford to fully satisfy their energy needs. Nonetheless, with binding spending constraints among the poor and other disadvantaged groups, even small price increases can create significant welfare losses. The relationship between national income and emissions, and consequently carbon-price burdens, is well documented (Dorband et al., 2019; Dasgupta et al., 2002), but non-linear and dependent on climate and other contextual factors (Ivanova et al., 2017). As countries transition to higher income levels, poorer and middle-class households tend to spend growing shares of their budgets on energy, e.g., as they rely more on motorized vehicles and transition away from traditional biomass for heating. During that transition, lower-income households can therefore be especially exposed to energy price shocks. They are typically also ill-equipped to draw on savings, invest in energy-saving technology, or reduce other expenditures, and may therefore need to cut back on essentials (OECD, 2022d; Sologon et al., 2025). Distributional impacts can be felt more strongly in countries with a high incidence of low household income or poverty, and where energy is a necessity due to climate conditions.

This paper studies the impact of a carbon charge recently adopted in Lithuania. Like other EU and OECD countries, Lithuania faces considerable need and pressures to reduce emissions (OECD, 2021b). Lithuania is a high-income country, but with national income lower than in comparator countries. It joined the OECD in 2018 and, despite high growth rates, GDP remains below EU and OECD averages. Poverty rates are among the highest in Europe<sup>1</sup> and households spend large parts of their budgets on energy. The affordability of necessities and associated equity concerns therefore feature prominently in national debates of price-based climate-change mitigation measures. The recent cost-of-living crisis has further heightened attention to household burdens from high or rising prices, and to energy prices in particular.

Regressive effects of carbon pricing, or a concentration of losses among specific groups, may therefore call for accompanying measures to compensate losers, while maintaining the fundamental price signals from carbon pricing (Carattini et al., 2018; World Bank, 2019). Compensation should be timely and may need to be suitably targeted to make it cost-effective, notably in a context of tightening fiscal space. Suitably designed, compensation for households can increase political support for carbon pricing by easing concerns over impacts on living costs (Beiser-McGrath and Bernauer, 2019).

The paper makes three main contributions to this debate and to the literature. First, we undertake the first comprehensive distributional analysis of carbon pricing for Lithuania, an EU country and OECD member with lower GDP and higher poverty rates than in comparator countries. Previous studies have analysed carbon-pricing burdens in upper-middle-income countries (e.g. Renner (2018) for Mexico, Rosas-Flores et al. (2017) for Peru), but there is limited evidence for countries that transitioned to the high-income group of countries relatively recently (e.g., Antosiewicz et al. (2022) in Poland). Second, we carefully examine options for compensating households, providing a richer assessment of revenue recycling than is typical in the literature, quantifying gains and losses, and estimating the number of gainers and losers, as key metrics related to voter support. We analyse seven different compensation policies, including cash transfers and tax reductions that commonly feature in policy debates. Third, we account for recent price and income changes to make results more realistic and, arguably, more policy relevant in the context of rapid changes in the cost of living. Much of the literature on the distributional impacts of carbon charges considers hypothetical carbon prices that are specified in

<sup>1</sup> In 2024, the at-risk-of-poverty rate in Lithuania is 21.5 %, the third highest level in the EU after Bulgaria at 21.7 % and Latvia at 21.6 %, and compares to an EU-27 average of 16.2 % (Eurostat, n.d.).

nominal terms, evaluating their impact using income and consumption data that is between 5 and 10 years old. In periods of moderate to high inflation, such analysis can quickly become outdated and can be a blunt guide for policy. In the discussion, we compare household burdens from carbon pricing with those from other price increases, which are unrelated but sometimes confounded in public and political debates.

The remainder of the paper is structured as follows. Section 2 briefly sketches the policy context for carbon taxes. Section 3 gives an overview of past assessments of their distributional impact. Section 4 lays out the methodology and describes the data. Section 5 presents results, distinguishing between (i) direct effects of carbon pricing on households' living standards (via their fuel consumption), (ii) indirect effects (via consumption of other goods and services with different carbon content), and (iii) effects of household compensation that can be financed from carbon-tax revenues. Section 6 compares burdens resulting from the carbon tax, with those from the recent cost of living crisis.

## 2. Carbon tax: policy context and distributional effects

Carbon taxes were first introduced in Finland in 1990 and in Norway in 1991. In 2025, 53 national and 40 subnational jurisdictions operated 110 carbon pricing schemes (World Bank, n.d.). In Europe, 20 countries had implemented a carbon tax in 2021 with rates ranging from 75 cent/tonne of CO<sub>2</sub> in Ukraine to 120 Euro/tonne in Switzerland. The OECD's (2022) Tax Policy Reforms report notes that "promoting environmental sustainability has become increasingly central to the policy goals of taxing energy and vehicle use", and successive editions provide additional details on new or higher carbon taxes that are planned or were recently adopted (e.g., in Austria, Canada, Iceland, Ireland, Netherlands).

The European Green Deal, approved in 2020, is a set of policy initiatives with the overarching goal of a climate-neutral EU by 2050. In light of this ambition, the 2021 European Climate Law set an interim emissions reduction target of 55 % by 2030 (compared with 1990 levels). In order to meet this target, the European Commission has developed a set of proposals, also known as the Fit for 55 package, putting in place new climate policy initiatives in line with the increased ambition of the Green Deal. Fit for 55 comprises numerous legislative proposals and climate policy initiatives including, but not limited to, the taxation of energy and the extension of carbon pricing to transportation and residential sectors.

In accordance with EU-level commitments, Lithuania has targeted net-zero emissions by 2050. Achieving this will require considerable acceleration of emissions reductions, including by reversing detrimental emissions trends in the transport sector. Indeed, emissions from private vehicles and road freight have grown steadily and fuel taxes in Lithuania are among the lowest in the EU. Lithuania's expanding domestic renewable energy production helps to reduce its reliance on electricity imports. But decarbonising the economy through electrification will also significantly increase electricity demand; Energy efficiency is therefore key and will require a package of ambitious climate policies (OECD, 2021a, OECD, 2021b).

Until recently, Lithuania did not operate an explicit carbon tax. CO<sub>2</sub> emissions from energy use were partly priced, through the EU Emissions Trading System (ETS) and through (comparatively low) fuel excise taxes.<sup>2</sup> In May 2023, the Lithuanian Government signed into law a tax based on the carbon intensity of fuels that is to be phased in from 2025. It is to start at 10 Euros per tonne of CO<sub>2</sub> and rise by 10 Euro each year, to 60 Euros per tonne in 2030. In addition to being the target carbon-tax rate in the specific Lithuanian reform, 60 Euros per ton also corresponded to a low to midpoint estimate for the social cost of carbon in 2020 and a low-end estimate for 2030. As such, it is an informative benchmark value as countries seek to narrow or eliminate the gap

<sup>2</sup> (OECD, 2023), e.g. <https://stat.link/2s67g0>.

between the private and social cost of carbon. More recent and forward-looking studies mostly support significantly higher values, however, illustrating the sizeable gaps between current policies and those needed to meet mitigation targets.<sup>3</sup>

While carbon pricing is central to climate mitigation efforts in numerous countries, some governments have responded to cost-of-living concerns by recently easing or suspending environmental tax measures. For instance, Portugal suspended a proposed carbon-tax increase in carbon tax and Austria delayed the introduction of its carbon tax until October 2022. Already at an earlier stage, the French government withdrew a planned carbon-price increase and froze any further increases, following strong resistance from some groups of voters, notably in rural areas (the ‘Yellow Vest’ movement that formed in late 2018). Throughout the EU and OECD areas, concerns over high and increasing living costs have remained prominent in recent years.

There is a common conjecture that, without revenue recycling, carbon pricing is regressive in high-income countries (Klenert and Mat- tauch, 2016). However, home fuel and electricity taxation tend to be more regressive than fuel taxation in the transport sector (Büchs et al., 2021), which can be progressive, especially in countries with moderate car ownership and well-developed public transport systems (Wang et al., 2016). In the EU, average impacts of a given carbon-tax rate on the cost of living are much larger in lower-GDP, primarily Central and Eastern European countries (Feindt et al., 2021; Linden et al., 2024).<sup>4</sup> Taxation of both direct and indirect emissions, associated to the production of goods and services, tends to be less regressive than taxing direct emissions only (Ohlendorf et al., 2020; OECD, 2024).

In countries with lower GDP levels, larger shares of households are unable to satisfy their energy needs (Flues and van Dender, 2017), and carbon pricing is therefore less regressive. In poorer countries, progressive impacts are possible, as the carbon intensity of consumption baskets is low, and energy can be difficult to access or unaffordable for large shares of the population, and heating fuels may be less important due to climatic conditions (Ohlendorf et al., 2020; Dorband et al., 2019; OECD, 2024).

The literature on net impacts, accounting also for revenue recycling, points to the quantitative importance of revenue recycling for overall distributional outcomes.<sup>5</sup> Lump-sum transfers financed through carbon pricing are progressive and poverty-reducing (Berry, 2019; Klenert et al., 2018; Owen and Barrett, 2020; OECD, 2024). Depending on their reach, more targeted social welfare payments also support low-income earners and reduce inequality, but they can achieve effective compensation at lower fiscal cost (Callan et al., 2009). Across-the-board income tax cuts benefit the top and are regressive in their mechanical impact (Goulder, 1995), but can have progressive impacts if they lead to higher employment (Rausch et al., 2011). Recycling carbon-tax revenues through preferential rates of value-added tax (VAT) for specific goods, e. g. on public transport, can redistribute between income groups and regions (Brännlund and Nordström, 2004). Energy cheques tend to reduce fuel poverty (Berry, 2019), while public transport vouchers can be progressive and achieve sizeable emission reductions (Büchs et al., 2021). Support for retrofitting residential buildings is progressive if it is

targeted to the least efficient dwellings (Bourgeois et al., 2021), and if support is likely to be taken up by low-income earners (e.g., if it is provided in the form of direct grants, instead of subsidised loans).

A number of countries implemented explicit compensation policies financed through carbon tax revenues (Immervoll H., 2024). In Ireland, the carbon tax includes a commitment to use the revenues to prevent fuel poverty and ensure a just transition. The carbon tax introduced in British Columbia, Canada, in 2008 was accompanied by a revenue-neutral tax shift that cuts other taxes and provides for direct transfers to households (Murray and Rivers, 2015). Switzerland earmarks one third of carbon-tax revenues for programmes to support a green transition and reduce energy consumption, with the remainder redistributed through lower health insurance premiums (Bureau et al., 2019). Austria introduced a “climate bonus” paid to residents at different rates depending on access to the public transportation network (Budgetdienst, 2022). At the EU-level, countries have been designing Social Climate Plans, detailing how a share of revenues from the EU-ETS can be used to compensate vulnerable households (European Parliament and Council of the European Union, 2023).

### 3. Methodology and data

We use a microsimulation approach to capture the heterogeneous impact of carbon taxation on households represented in detailed microdata (O’Donoghue, 2021a,b). We use two main data sources, the World Input-Output Database (WIOD) and the Lithuania portion of the EU Household Budget Survey (HBS). The section starts by describing the input-output analysis underpinning carbon-intensity estimates for each product category. WIOD is then combined with HBS data to estimate carbon-tax burdens at the household level.<sup>6</sup>

We model a uniform carbon tax on all sectors within the country. This is a simplification, as the current version of Lithuania’s carbon-tax reform does not cover installations already subject to emissions trading (EU-ETS). An assessment of a uniform carbon tax is nevertheless informative, as EU-ETS does not yet include the transport and buildings sectors, where the effects of carbon taxes on prices are expected to be especially sizeable. By 2030, carbon prices will, to varying extents, also rise for ETS sectors, even if not through explicit carbon taxes, but due to the removal of emission allowances and tightening emission caps. Given current policy trajectories and a growing urgency about countries’ failure to meet emission targets required for the key 1.5 and 2-degree commitments, an average carbon price of 60 EUR/tonne of CO<sub>2</sub> arguably presents a reasonable lower-bound value in 2030.

The reference period of the policy introduction and simulation is relevant. Available data refer to earlier periods. However, household circumstances, preferences and prices, and as resulting consumption patterns, change over time. Our modelling relies on available household expenditure microdata (HBS, 2015). For the simulations, we uprate price data to account for the major recent price changes up until July 2,

<sup>3</sup> The US government currently relies on a mean value of USD 51/tCO<sub>2</sub> (Interagency Working Group on Social Cost of Greenhouse Gases (IWG), 2021), a recent report by the European Commission (2021) suggests a central value of EUR 100/tCO<sub>2</sub> through to 2030, while a recent comprehensive review indicates a preferred mean estimate of USD185/tCO<sub>2</sub>, at 2020 prices (Rennert et al., 2022). See also (Network for Greening the Financial System, 2023; Tol, 2023).

<sup>4</sup> As a result, findings point to regressive impacts of uniform EU-wide carbon taxation (Feindt et al., 2021).

<sup>5</sup> This also holds for policies that raise effective carbon prices through a withdrawal of energy subsidies (Durand-Lasserre et al., 2015).

<sup>6</sup> A previous analysis of a carbon tax in Lithuania was published as a working paper (Immervoll, O’Donoghue, Linden and Sologon, 2023). The distributional impact estimates presented here differ from those in the working-paper version for several reasons. Most importantly, the primary dataset here is the Lithuania Household Budget Survey, while the working paper uses the Survey on Income and Living Conditions with expenditure patterns imputed, rather than observed. The working paper also attempts to account for household behavioural responses, mainly for methodological illustration. Behavioural modelling is not included here.

022.<sup>7</sup> Relatedly, observed income levels are uprated via income inflators, and separately for each income quantile. This approach is standard in the literature, to side-step challenges involved in more ambitious now-casting approaches (Immervoll et al., 2005; O'Donoghue and Loughrey, 2014; Sologon et al., 2022). Indeed, now-casting of microdata can be informative when the objective is to approximate aggregate measures of inequality. They involve a range of data adjustments, however, which can be problematic when the resulting data are used as input into further modelling or analysis. Essentially, extensive data manipulations can obscure distributional results from the policy modelling that are of primary interest. A description of our approach can be found in the appendix.

### 3.1. Computing household carbon footprints

Modelling the CO<sub>2</sub> emissions linked to all forms of household consumption requires data on households' (energy) expenditure, economy-wide data that capture carbon emissions by sector, and production linkages between sectors. Emissions associated to household consumption can be written as  $E_{HH} = E_{dirHH} + E_{indHH}$ , where  $E_{dirHH}$  gives the direct emissions associated to households' fuel consumption, and  $E_{indHH}$  gives the indirect (embedded) emissions associated with households' consumption of all other goods and services.

We compute direct emissions ( $E_{dirHH}$ ) by sourcing energy prices and carbon intensity factors for each fuel consumed by households. For each fuel type, expenditure is then divided by its price to estimate the quantity of energy consumed, and multiplied by its carbon intensity factor. We differentiate between heating oil, gas, district heat, firewood, coal, diesel and petrol<sup>8</sup>.

We compute indirect emissions using the Input Output (IO) methodology (Miller and Blair, 2009; Leontieff, 1951) and data from the WIOD's Multi-region input-output (MRIO) tables with 2014 as a reference year. MRIO datasets map monetary flows between  $n$  sectors and  $m$  regions,  $Z \in R^{(m \cdot n) \times (m \cdot n)}$ . A final demand vector  $Y \in R^{(m \cdot n) \times (m \cdot n)}$  captures the final demand for each industry output in each region. The technology matrix,  $A \in R^{(m \cdot n) \times (m \cdot n)}$ , contains all input coefficients for all sectors in all regions. Using the technology matrix, we calculate the Leontief inverse matrix,  $L = (I - A)^{-1}$ , which gives the economy-wide input requirements of output  $o$ ,  $o = f(I - A)^{-1} = f(I + A + A^2 + \dots + A^n)$ .

To compute carbon emissions associated with industries' outputs, we multiply the Leontief inverse matrix with a vector capturing industry-level CO<sub>2</sub> emissions, resulting in an environmentally-extended Multi-regional Input-Output (EE-MRIO) model (see Kitzes (2013) for an introduction to EE-MRIO modelling). Briefly, let  $E \in R^{(1 \cdot p)}$  denote a vector of emissions for each sector and region, where  $p = m \cdot n$ . We compute CO<sub>2</sub> emissions per monetary unit of the sector's output by dividing  $E$  entry-wise by the corresponding sector's output. Finally, we compute households' indirect emissions. Emission vectors are sometimes provided alongside MRIO models. In the case of the WIOD, this emission vector consists of a value of total CO<sub>2</sub> emissions per euro of industry output per region, and includes energy-based, progress-based, and fugitive emissions. In this paper, we simulate a carbon tax on energy-based emissions only. Therefore, rather than using the full EE

<sup>7</sup> We use June 2022 as a reference period for this analysis because it reflects prices at the peak of the cost of living crisis in Lithuania (HCIP inflation was highest in 2022) and represents a mid-year estimate, thereby following the convention in the literature.

<sup>8</sup> We source natural gas and electricity prices from Eurostat, prices of oil products (Diesel, Petrol, Heating oil) from the European Commission Weekly Oil Bulletin, and fire wood and coal prices were provided by the Lithuanian Statistical Office upon request. We take district heating prices from Werner (2017). Carbon Intensity factors are sourced from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and Werner (2017) for district heat.

provided by WIOD, we compute carbon emissions for each fuel type. We then compute the carbon emissions of each industry's output as a function of industry inputs.<sup>9</sup> Finally, we match the HBS expenditure groups<sup>10</sup> in COICOP to WIOD industries in NACE rév. 2 using bridging matrices provided by Cai and Vanduyck (2020),<sup>11</sup> enabling us to compute indirect carbon emissions at the household level ( $E_{indHH}$ ).

### 3.2. Revenue recycling

Carbon-tax revenues can be used to finance compensation to households. Such revenue recycling can ease a regressive distributional impact of carbon taxation, and could even render it progressive (Klenert et al., 2018). Popular proposals include uniform lump-sum transfers, reductions in consumption, labour, or capital taxes, or subsidies to accelerate household adoption of low-carbon heating and transportation technologies. In this paper, we draw on HBS data to simulate options for recycling carbon-tax revenues to finance various cash transfers or tax reductions. Past studies demonstrate that distributional impact of revenue recycling can be bigger than that of the carbon tax (Fremstad and Paul, 2019). We therefore explore this channel in detail, simulating a total of seven different compensation options; per capita transfers, per capita transfers targeted to rural households, a reduction in energy excise duties, a reduction in energy excise duties with remaining revenues used for per capita transfers, a transfer aimed at closing the energy-poverty gap with remaining revenues returned as per capita transfers, a reduction in food value added taxes (VAT), and a reduction in all indirect tax liabilities.<sup>12</sup>

## 4. Results

At carbon tax levels that countries currently apply or discuss, the impact on household living costs can be significant, as can their distributional effects. At the outset, it is useful to put the resulting burdens into context, however. In Lithuania, the impact on living costs would be much smaller than the effects of high inflation rates seen in this country, and across the OECD, since 2021. A carbon tax at 60 EUR/tonne as currently discussed would increase the consumer price index by less than 4 % in total.

### 4.1. Consumption patterns across the income distribution

The impact on different population groups depends upon various factors, including notably the distribution of expenditures across the income spectrum. Carbon taxes affect household budgets directly through fuel consumption, and indirectly via the consumption of other

<sup>9</sup> Given difficulties in measuring process-based and fugitive emissions, we view it as more realistic to simulate a carbon tax levied in relation to energy consumption. A challenge with this approach pertains to the high volatility in the energy mix consumed by industries. In Lithuania in particular, the energy mix produced by energy industries within the country and used by industries has changed substantially since 2014 (the WIOD reference year). To attenuate the impact of changes in the Lithuanian energy sectors, we approximate energy industries' fuel mix through the average fuel mix across EU energy industries, sourced from UNIDO MINSTAT.

<sup>10</sup> Expenditure categories are Food and Non-alcoholic beverages, Alcoholic beverages, Tobacco, Clothing and footwear, Heating fuels, Electricity, Rents, Household services, Health, Private transport, Public transport, Communication, Recreation and culture, Education, Restaurants and hotels, Other goods and services, Childcare costs, Motor fuels, Durable goods.

<sup>11</sup> Further detail on the procedure is provided in O'Donoghue et al. (2023).

<sup>12</sup> The options considered are frequently discussed as policy options and have been implemented in various countries. For example, households were compensated for increased living costs through per capita transfers in Canada, through geographically targeted transfers in Austria, through excise tax reductions in Finland, and through energy poverty benefits in France.

goods and services that give rise to CO<sub>2</sub> emissions during the production process.

The direct incidence of carbon taxes across households is shaped by the pattern of fuel expenditures. Domestic heating fuels are ‘necessities’ in the sense of the term as commonly used by economists, i.e. people will buy them regardless of income and low-income households tend to devote larger shares of their total income and expenditures to heating fuels than better-off households. An opposite pattern can emerge for motor fuels, reflecting higher rates of car ownership among middle and higher-income households.

Fig. 1 plots the distribution of fuel expenditures in Lithuania, along with electricity, accounting for price changes up until mid-2022. Spending shares for heating fuel are highest in income deciles 3, 4, and 5. Overall, spending on heating fuels and electricity is regressive. Expenditure on domestic fuels in particular is substantial across the income distribution. Nevertheless, shares are lower in the poorest 2 deciles compared to deciles 3 and 4, which may be related to budget constraints and the poorest households needing to prioritize other essentials over adequate heating. Expenditures on electricity are substantially lower than for heating fuel in all deciles, and follow a mildly regressive pattern overall. Spending on motor fuels is top-heavy, with smaller spending on this item in the bottom 30 % but a higher share than heating fuels at the top. Taken together, overall fossil-fuel (and energy) expenditure is broadly flat in Lithuania, albeit following a slight inverted U-shape.

Fuel prices and the composition of fuel consumption also drive distributional outcomes. Population groups that use higher-emitting “dirtier” fuels will see a greater absolute impact of carbon taxes on prices. The relative price change depends also on initial prices, with cheaper fuels affected more strongly by a given carbon tax per unit. As is commonly the case, motor fuels in Lithuania are more expensive (due to higher taxation) than domestic fuels (Fig. 2, Panel A). As a result, the energy usage and emissions per unit of fuel expenditure are higher for domestic fuels (which account for a large share of spending for low-

income people) than for motor fuels (mostly consumed by higher-income groups). Domestic fuels include high shares of solid fuels (coal, coke, firewood), which have much higher emissions than liquid fuels. Emission factors are lower for natural gas (Fig. 2, Panel B).

Like the direct burden from fuel expenditure, the distribution of the indirect burden from carbon taxes on everything else is also driven by a range of factors, and their net effect is difficult to anticipate. Budget shares for goods other than fuel can be comparatively “flat”, with similar shares of total expenditures across income groups. But since poorer households save less, they spend a higher proportion of their income than better-off households. A relatively flat indirect impact of carbon taxes across households with low and high spending can therefore translate into a distributionally regressive impact across the income spectrum (with carbon tax burdens making up a larger share of income for low-income groups).

#### 4.2. Distributional impact across income groups

The carbon tax incidence is shaped by (i) the distributional patterns of households’ fuel expenditures, and (ii) the indirect effects of a 60 EUR carbon tax on the cost of other goods, based on emissions released during production in different parts of the value chain.

Fig. 3 decomposes the carbon-tax burden into components related to domestic and motor fuels, and indirect emissions. The carbon-tax burden on domestic fuels (ca. 1.8 % of household income on average across all income groups) is much higher than for motor fuels (less than 0.5 % on average). This reflects the higher expenditure on heating, as well as the higher emissions per euro of domestic fuel. In line with fuel expenditure profiles, the direct carbon tax burden for domestic fuels is concentrated in the bottom half (regressive), while carbon taxes on motor fuels are more progressive. The direct burden on households from overall fuel expenditures is regressive.

At just over +1 % of household income on average, the costs from indirect emissions related to the domestic production of other goods and

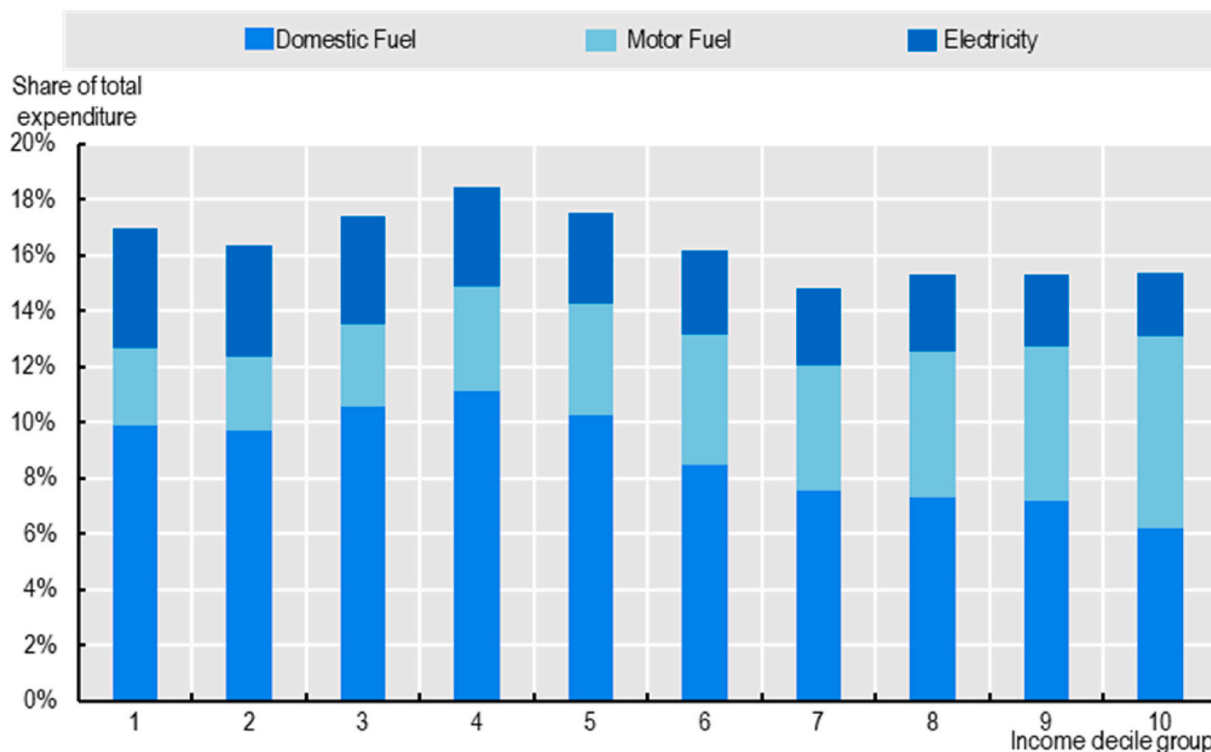
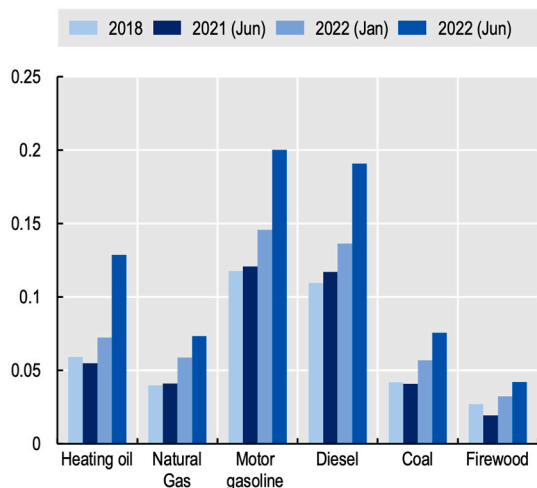


Fig. 1. High-income households spend large shares of their budgets on energy - Lithuania, approximations for 2022.

Note: Domestic fuel includes expenditure on gas (natural gas and town gas), liquified hydrocarbons, liquid fuels, heat energy, coal and other solid fuels. Motor fuels include expenditure on diesel and petrol for transportation. Source: Household budget survey, combined with 2022 price data.

A. Prices in Lithuania, EUR per kWh



B. CO<sub>2</sub> emissions, tonnes per unit, 1=average

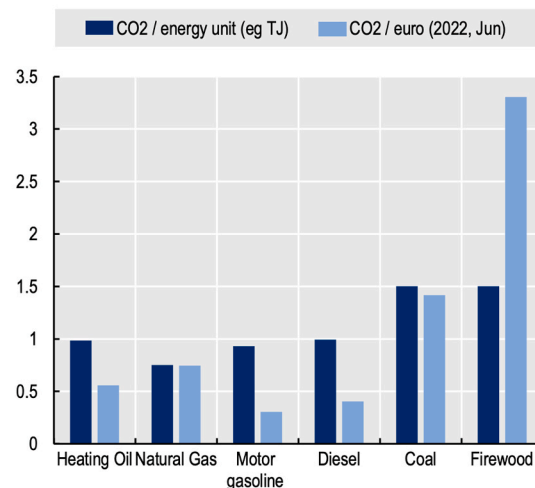


Fig. 2. Fuel prices and CO<sub>2</sub> emissions A. Prices in Lithuania, EUR per kWh B. CO<sub>2</sub> emissions, tonnes per unit (1 = average). Note: Firewood also includes wood waste. Source: Author calculations using UNFCCC, Eurostat, EC Weekly Oil Bulletin.

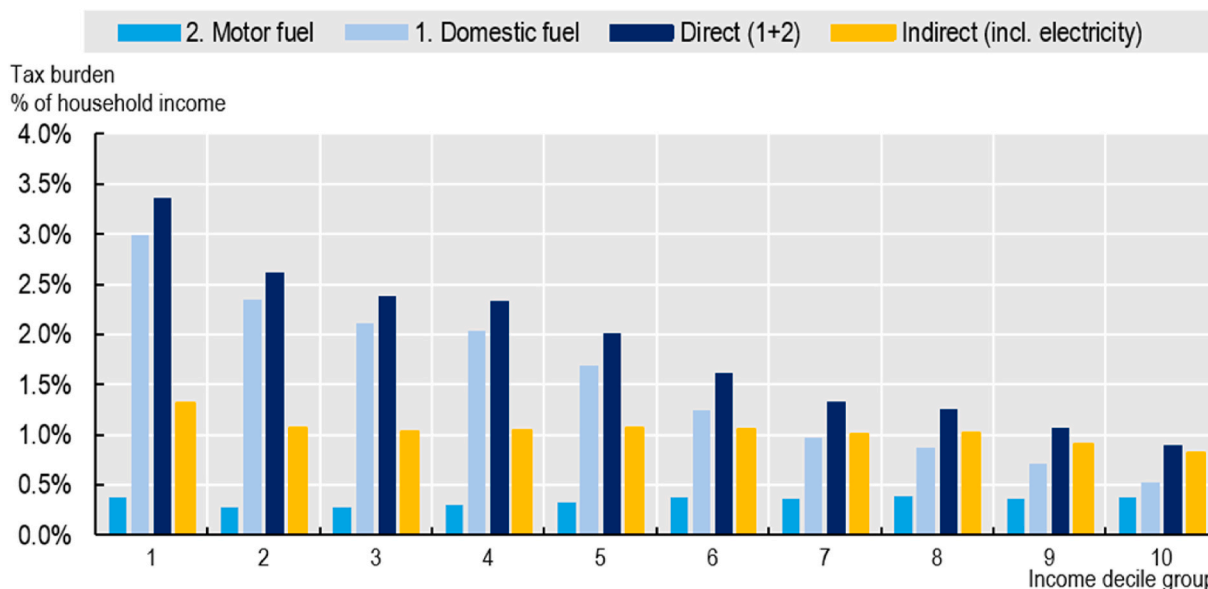


Fig. 3. Components of a EUR 60/t carbon tax (% of household disposable income). Source: Authors' calculations using data on household expenditure, emission levels and industry inputs and outputs.

services are lower than the direct component, but remain important, as households spend much more on non-energy than on fossil fuel overall. This highlights the quantitative importance of accounting for all consumption categories, and a careful Input-Output analysis. The scale of the indirect effect is partly driven by spending on electricity, and the carbon intensity of electricity generation, with the largest contributions due to food and electricity consumption. Although the lowest-income households spend greater shares of total expenditure on electricity than higher-income groups (Fig. 2), the carbon content of electricity is lower than for other energy sources, and overall indirect effects (including also electricity) are essentially flat as a share of income.

Overall carbon-tax burdens are regressive, with around 3.5 % of income for the bottom half of the distribution, and 2.15 % for the top half – they are also largest for decile 1, and smallest for decile 10 (see Fig. 4). As noted, multiple drivers and country idiosyncrasies shape this result. There is no a-priori reason to expect it to apply more generally and carry over to other country settings.

4.3. Revenue recycling

The carbon tax generates revenue, which can be used to shape its overall distributive impact via revenue recycling. Such revenue recycling can alleviate distributional concerns of carbon pricing and increase their public acceptability (Klenert et al., 2018). The policies financed with carbon tax revenues measures as part of a broader carbon-tax policy package however also produce gains or losses for different income groups and each revenue recycling option has strengths and weaknesses (Nachtigall et al., 2022). We consider seven stylised compensation measures. Table 4 in the appendix provides a non-exhaustive list of compensation options considered in the literature. All are budget-neutral and can thus be fully financed through the carbon tax.

Option (1) is a stylised per capita transfer, paid at the same individual rate to all residents. Similar to a universal basic income, a per capita payment is often less redistributive than established social

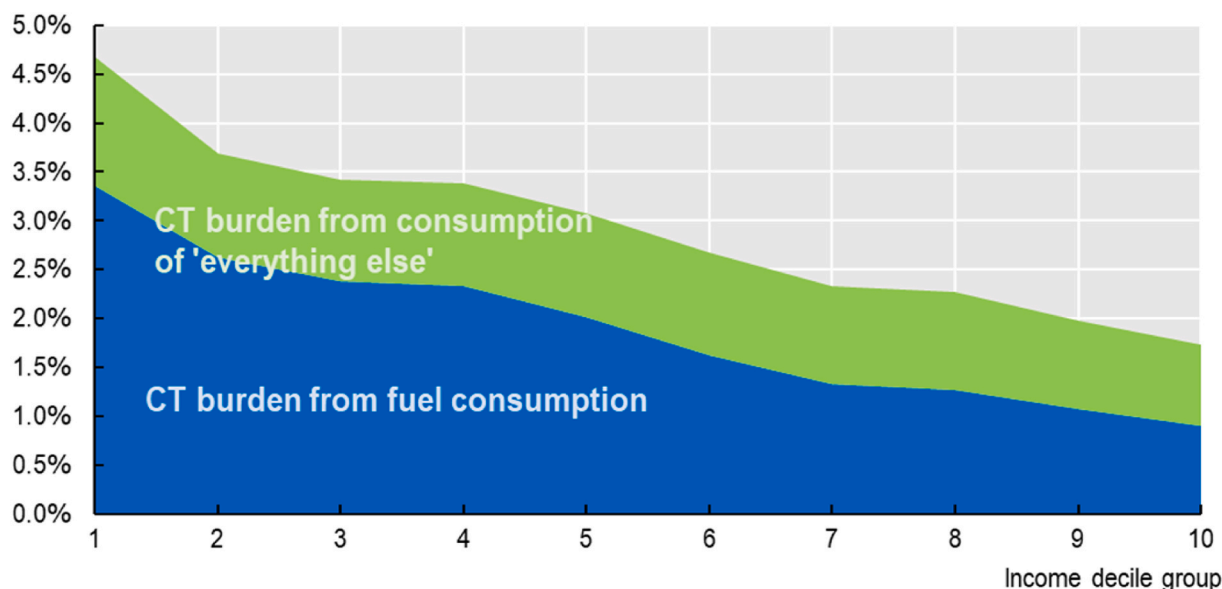


Fig. 4. Incidence of a EUR 60/t carbon tax (% of household disposable income).  
Source: Authors' calculations using data on household expenditure, emission levels and industry inputs and outputs.

transfers. When conceived as a standalone benefit that replaces other transfers, a basic income is difficult to finance without a substantial tax increase (Browne and Immervoll, 2017). However, in the context of a carbon tax, per capita compensation can be an attractive option, as it is built around a novel revenue source, and can be introduced “on top of” existing transfers, without needing to substitute for them. It is also simple to communicate and, as everyone receives a recurring payment, it may act as a signal that the carbon tax aims to alleviate climate change, without creating an additional overall burden for households. The universal lump-sum payment to everybody is indeed sometimes argued to be the optimal revenue recycling option (Klenert et al., 2018).

Alternatively, carbon-tax revenues can be used to compensate households more selectively, e.g. by adapting/expanding existing policies or introducing new targeted support payments.

Option (2) is a cut in food VAT rates. Because food is a necessity and purchased by everyone, this option distributes resources across all households but provides most support to low-income households relative to their income, as they devote bigger shares of their budget to food.

Option (3) is a per capita transfer to households in rural areas only. Because of higher energy needs due to reliance on personal transportation and larger, often detached, houses, rural households are particularly likely to be disproportionately affected by a carbon tax.

Option (4) is a reduction in excise taxes levied on energy, to mitigate the effect of the carbon tax on energy prices. Such rebalancing of the tax burden has been implemented in some countries, for instance in Finland, France, and Germany (OECD, 2024). As it reduces the carbon price for some emissions, it also weakens the overall incentives for emission reductions. And because excise duties are commonly levied on motor fuels, but not on domestic fuels, this primarily directs resources towards higher earners. The tax base of the carbon tax is much broader than that of energy excise duties, therefore the revenues generated by a carbon tax exceed those needed to eliminate energy excise duties. Remaining revenues are returned to households on a per capita basis under Option (5).

Option (6) is designed to address energy poverty, a particularly salient concern with carbon taxation, and especially in Lithuania. The transfer is designed to close the energy poverty gap, defined as energy expenditure exceeding twice the median energy income share (before the carbon tax), following the ‘High Share’ definition of energy poverty (see Menyhért (2024) for a comparison of energy poverty definitions). Because carbon tax revenues are more than sufficient to close this energy

poverty gap for all households, the remaining revenues are returned as per capita transfers.

Finally, Option (7) is a general and proportional reduction in the indirect tax liability, including Value added tax, excise duties, and *valorem* taxes for all products.

For each option, Fig. 5 reports two measures of gains/losses by income group; average gain or loss of a carbon tax with revenue recycling, and the share of individuals with net gains.<sup>13</sup>

As a baseline, Fig. 5, Panel (a) first shows household losses in the absence of any compensating transfers, to facilitate assessing the impact of revenue recycling. The results elaborate Fig. 4 by showing also the variation of impacts within income deciles, and can be interpreted as a scenario where the government does not spend the carbon-tax revenue. The revenues are sizeable (ca. €560 million or 0.75 % of GDP according to our calculations) and provide the government with considerable scope to cushion losses and shape the distributional profile as part of a broader policy package.

When all carbon-tax revenues are channelled back to individuals via a per capita transfer (Fig. 5, Panel (b)), most people are better off than without the carbon-tax package. Revenues are sufficient for financing a per-capita transfer of 16 Euros per month. Most households in the bottom decile gain, and at least half do throughout deciles 1 to 4. Low-income households pay smaller absolute amounts in carbon tax than the better-off, because they spend less. However, substantial heterogeneity in fuel consumption among low-income households implies that a significant share of low-income households still loses out under per capita transfers. As a percentage of household income, gains quickly decline as one moves up the income spectrum. Even for high-income earners in the top decile, the per capita payment substantially reduces the average net carbon-tax burdens (compare Panels (a) and (b)).

Lowering VAT on food (Fig. 5, Panel (c)) has a neutral impact and on average neutralizes the impacts of the carbon tax across income deciles. Lower gains for the poorest and higher gains for the richest compared to a per-capita payment also reflect in the share of reform winners, with higher shares of reform winners in all deciles except the lowest. Recycling revenues through reduced VAT rates on food therefore

<sup>13</sup> A household is considered to be reform winners if their net gains exceed 0.5 % of their disposable income.

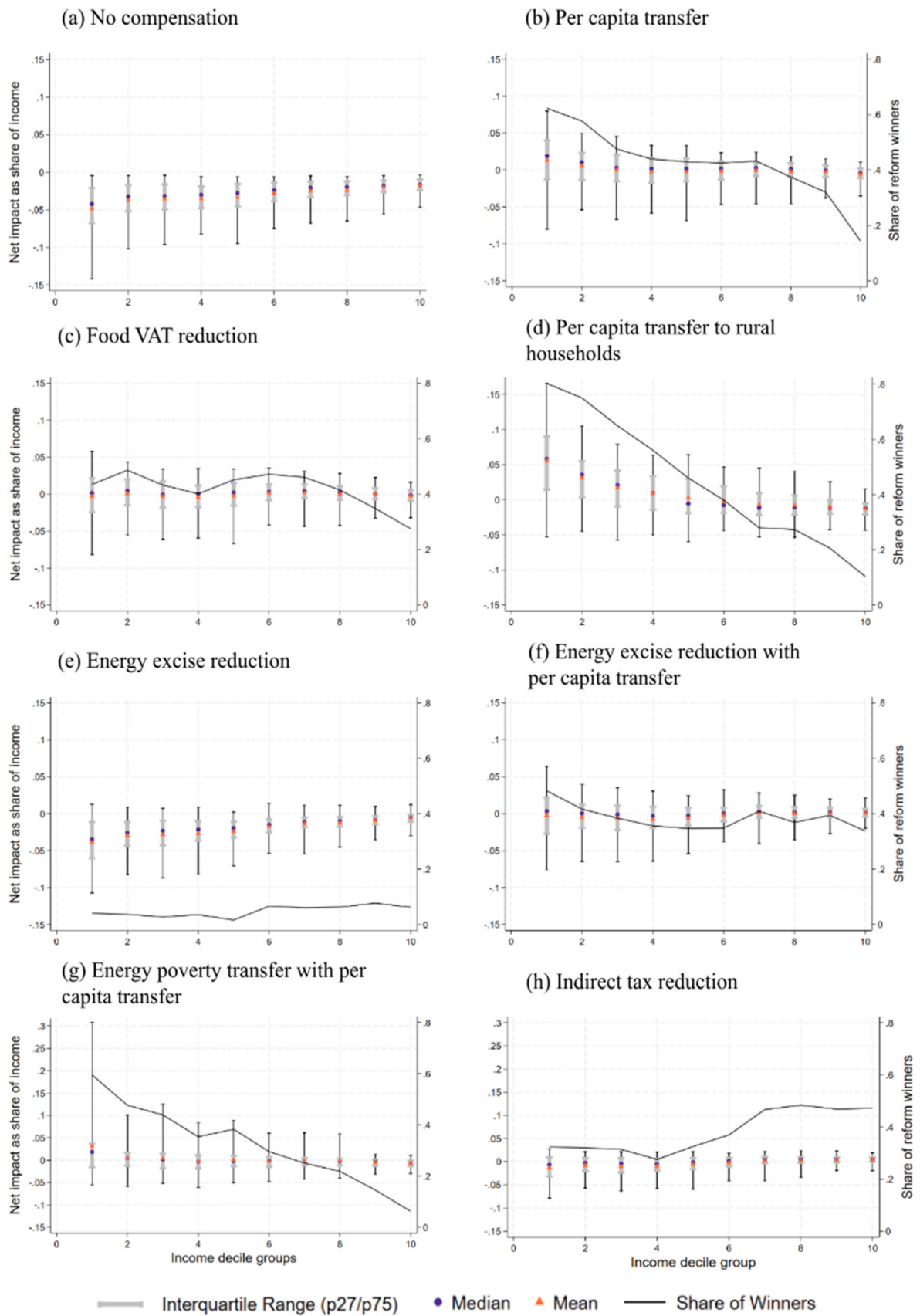


Fig. 5. Carbon tax package with revenue recycling – Gains and losses by income decile.

compensates households relatively well across the entire income spectrum, but it provides less support to the poorest than in the per capita scenario.

The per capita transfer scenario examined in Panel (b) is very simple and its distributional properties could be further tailored, e.g. by making it taxable, or by differentiating payments across groups, to approximately account for higher energy dependence (in a similar spirit as in the revenue recycling scheme in Austria noted above). Targeting transfers to rural households can mitigate high carbon tax burdens if rural households require more energy for heating and mobility. Rural households generally have poorer access to public transportation infrastructure and lower carbon heating options, such as district heating or gas networks. Panel (d) shows a per capita transfer to rural households.<sup>14</sup> In Lithuania, low-income households are primarily concentrated in rural areas, with 90 % of households in the lowest decile living in rural areas, as compared to below 20 % among high income households. The average impact of the carbon tax on the cost of the consumption basket in rural areas is twice as high (ca. 4 %) as in urban areas (ca. 2 %). When compensation payments are targeted entirely to households outside of cities, a higher share of low-income households gains from the reform compared to untargeted payments (compare Panel (b) and (d)). The per capita transfer to rural households is noticeably more progressive with the majority of households in deciles 1 to 5 gaining from this reform, though the overall share of gainers is slightly below that with untargeted payments (38.5 % against 41.8 %). Transfers to rural households may therefore be politically attractive, particularly if impacts on low-income households are a concern (Dechezleprêtre et al., 2022).<sup>15</sup>

Using revenues to lower energy excise taxes is regressive as shown in Panel (e) because existing excise taxes are levied on motor fuels but not domestic fuels or electricity. The tax base for energy taxes is much narrower than that of a carbon tax, but energy excise rates are higher than average carbon tax rates. A small share of carbon tax revenues would therefore be sufficient to reduce excise tax rates to zero. The remaining revenues can be returned to households as per capita transfers. The impact of this reform is shown in Panel (f) and smoothens average losses across income groups.

Another approach to mitigating the impact of a carbon tax on energy expenditure is to identify households that struggle to meet their energy needs, and that are therefore deemed energy poor. While there is no generally agreed definition of energy poverty (Menyhárt, 2024), targeting compensation to the energy poor is sometimes suggested in the public and political discourse (European Parliament and Council of the European Union, 2023; Berry, 2019). Panel (g) shows a progressive impact of targeting households with energy-to-income shares that are greater than twice the population median. In fact, the reform impact is broadly flat and only slightly progressive when comparing decile averages, but it leads to substantial gains for some low-income households (note the adjusted vertical axis in the two panels).

The patterns of gains and losses of a proportional reduction of all indirect taxes (VAT, excise, and ad valorem taxes) shown in panel (h) is slightly regressive, with net losses for approximately two thirds of households with incomes below the median, and just over half of high-income households winning. While most low-income households are net losers under this reform, the broad-based reduction in indirect tax rates

means that net carbon-tax burdens are reduced for all households (comparing panel (a) to panel (h)).

## 5. Discussion – carbon taxes when price levels are volatile

Our results show a significant impact of a €60 per ton carbon tax on the cost of living in Lithuania. The carbon tax-induced price rise further adds to price hikes for energy and other goods during the cost-of-living crisis. Indeed, the recent high-inflation period heightened concerns over rising prices, and energy prices in particular, and the impact of carbon prices on the cost of living is a major source of public opposition to price-based climate mitigation (Dechezleprêtre et al., 2022; Douenne, 2020). Despite this link between rising prices and concerns about carbon pricing, few studies compared the impacts of carbon prices and the recent inflationary period on the cost of living.<sup>16</sup>

The aftermath of the COVID-19 crisis and Russia's war against Ukraine resulted in the highest price increases in the EU in decades. Initially, the price surge was driven by rising energy and freight costs and supply-chain disruptions (Michail et al., 2022) but these later spilled over to multiple industries and most goods (OECD, 2022a, OECD, 2022b). In Lithuania, price inflation peaked in the third quarter of 2022. At the end of 2024, inflation in Lithuania has stabilized at 1.5 % relative to 2023. Simultaneously, income growth in Lithuania has been substantial over the last decade. Between 2021 and 2024, wages and salaries increased by between 35 % and 54 %, with the lowest wage growth registered in the 'Other service activities' sector and the highest growth registered in the 'Administrative and support service activities' sector.

Fig. 6 shows that the cost-of-living impact of a €60 per ton of CO<sub>2</sub> carbon tax is small compared to both income and price growth. On average, HICP changes between 2021 and 2024 are ten times as large as estimated price changes from the carbon tax. For most Lithuanian households, income growth outpaced inflation (wages and salaries grew by 46 % on average, not shown in Fig. 6) and many Lithuanian households therefore became richer over the period. This would still be true if a carbon tax of €60 per ton of CO<sub>2</sub> were implemented.

While the average impact of a carbon price on overall price levels is clearly small compared to HICP changes, changes in the cost of living differ substantially across income groups. This paper found a regressive carbon tax that impacts domestic fuel and electricity prices most. Similarly, Sologon et al. (2025) found that inflation in Lithuania between 2021 and 2022 was regressive and that domestic fuel and electricity prices increased most. For some households, and likely many pensioners and low-income households, the combined price change may make heating and electricity unaffordable. Comparatively small impacts of a carbon price may therefore plausibly encounter public opposition, even if burdens may not be noticed by the average household. Such opposition may, e.g., be driven by the fact that the carbon tax is directly under the governments' control, unlike many of the forces that triggered the cost of living crisis. Disadvantaged people, who suffer the largest combined increase in their cost of living, may also be more likely than the average household to voice opposition (Büchs et al., 2024). As shown in this paper, compensating households through revenue recycling provide powerful levers for compensating households, and future research could identify households that are disproportionately impacted by both inflation and carbon pricing.

## 6. Conclusion and policy implications

There is broad consensus that setting a price for carbon is a necessary part of urgent strategies to avert catastrophic climate change. Carbon pricing is economically efficient, as it promotes emission reductions in a

<sup>14</sup> We consider households to live in rural areas if they live in thinly populated or intermediate density areas, using the 'Degree of urbanisation (DEGURBA)' classification.

<sup>15</sup> Compensating those with the greatest carbon-price burdens, compensating the poor, and avoiding regressive impacts of carbon pricing were all identified as important predictors of public support for climate policy (Dechezleprêtre et al., 2022). Transfers to rural households perform well on all of these dimensions. It should be noted however that they exclude urban households which form a substantial share of the Lithuania population.

<sup>16</sup> To our knowledge, only Konradt et al. (2024) compare the average impact of a €150 per ton of \$CO<sub>2</sub>\$ tax to cost of living crisis in 2022 in the euro area, finding that such a carbon price would have comparatively small impacts.

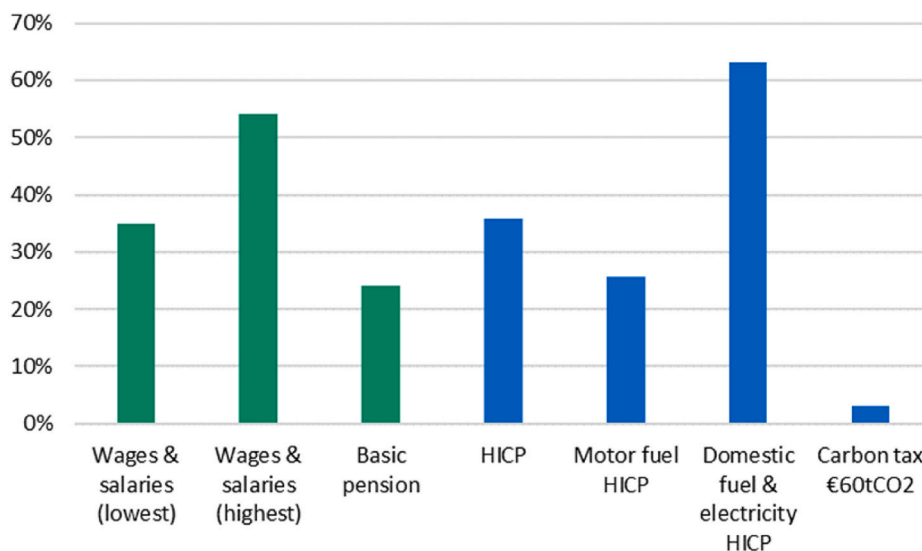


Fig. 6. Selected price and income changes after 2021.

Note: The impact of the EUR 60/t carbon tax on the average cost of a consumption basket is found by estimating the resulting price increases. Wage and salary changes refer to the period from 2021 Q1 to 2024 Q2. Harmonized index of consumer price (HICP) changes refer to the period between January 2021 and September 2024. Basic pension changes refer to period between 2021 and 2023.

cost-effective way that leverages, rather than hinders, entrepreneurship, markets and innovation. At the same time, there is a view that public support for carbon taxes is limited, largely because of perceived welfare losses and distributional concerns, and also in view of exceptionally high and volatile energy prices in recent years. These concerns highlight the need for careful distributional analyses that support policy design, and the communication of the benefits and costs of a green transition.

In this paper, we use a rich set of available data and policy models to assess the effect of a €60 per ton carbon tax in Lithuania, along with compensatory government transfers financed through carbon-tax revenues. The context of Lithuania is a challenging one for carbon pricing and is therefore of particular interest. It is a former transition country that has achieved high-income status relatively recently. Lithuania faces similar pressures to reduce emissions and increase carbon prices as other EU countries, but average household incomes are lower and poverty rates are higher. The climate is comparatively cold and, while Lithuanian households are sufficiently rich to prioritize energy consumption over other essentials, such as food, energy budget shares remain high, particularly among low-income households.

Results in this paper confirm that, without compensation measures, a carbon tax is regressive. For instance, the “direct” burden from the emissions associated with households’ own fuel consumption, sums to about 3.3 % of household income for the bottom income decile, compared to less than 1 % for the richest 10 %. “Indirect” burdens, associated to emissions released in the production of all other goods and services, are sizeable but essentially “flat”, with averages of around 1 % of incomes in all income groups.

We study seven specific revenue recycling options for compensating households. In line with previous research, we find that carbon tax revenues give the government substantial leverage for shaping distributional outcomes of a carbon-price reform (Klenert et al., 2018). It is possible to avoid detrimental distributional impacts, but compensation strategies need to be designed carefully. Recycling revenues in the form of per capita payments, particularly if they are targeted to rural or energy-poor households, renders the overall reform progressive, with bigger gains for lower-income households. By contrast, using carbon-tax

revenues to reduce other indirect taxes is regressive, and reducing VAT for food has a broadly proportional impact. We show that all revenue neutral policy packages create large numbers of winners and losers, even among households with similar income levels. The per capita transfers produce the largest share of reform winners, particularly among low-income households. Tax cuts create more winners among high-income households, but fewer overall. Results suggest that combining tax cuts with per-capita transfers can make the overall impact progressive, but this may not hold if only part of the carbon-tax revenue is available for compensating households.

We contextualize carbon tax burdens by comparing associated price changes to (unrelated) price increases and income trends during the recent cost-of-living crisis. The impact of a €60 per ton carbon tax on households’ living costs is much smaller (ca. 3 %) than cumulative inflation during the 2021–2024 period (ca. 36 %). Inflation led to particularly fast price increases for domestic fuels, highlighting that, without specific support measures, low-income households may be left behind. Yet, despite very high inflation, wage and salary growth outpaced prices and, even with the proposed carbon tax, real incomes grew for many Lithuanian households. This comparison is relevant because burdens from carbon pricing and unrelated price increases are sometimes confounded in public debates and may weaken support for price-based mitigation approaches.

The modelling approach combines different data sources to derive patterns of household burdens that are needed for distributional analysis. As all modelling, it nevertheless abstracts from certain parts of reality, and these limitations suggest possible priorities for future research. Importantly, carbon taxes have effects beyond those on consumption expenditures by altering the incomes of the owners of the different factors of production, including natural resources, “brown industry” equity and labour (Rausch et al., 2011; Metcalf and Stock, 2020; Metcalf G., 2021) by changing the pace and direction of innovation (Dechezleprêtre and Kruse, 2022; Dechezleprêtre and Sato, 2017; Dechezleprêtre et al., 2023), and by affecting jobs in high-carbon industries (Metcalf and Stock, 2020; OECD, 2021a,b,c,d; OECD, 2024). Further, households adjust their consumption behaviour following price

changes, affecting the distributional outcomes of a carbon tax (Ohlendorf et al., 2020). These effects are not considered here. Finally, a complete assessment of the distributional impacts of carbon pricing should include the cost of *inaction* or, vice versa, the benefits of mitigation (Tovar Reaños and Lynch, 2022), and the research agenda for distributional assessments is closely linked to the broader evolving evidence on the economic impact of climate change, and of policies to avert it. A key question concerns the counterfactual that is adopted in distributional studies. The status quo, as adopted in this paper, can be a natural starting point, and the scale of economic damages from climate change remains uncertain (Auffhammer, 2018; Howard and Sterner, 2022). They are, however, by definition of the same order of magnitude as carbon prices that internalise the negative externalities of greenhouse-gas emissions.

### CRedit authorship contribution statement

**Herwig Immervoll:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis. **Jules Linden:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation,

Conceptualization. **Cathal O'Donoghue:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Denisa M. Sologon:** Writing – review & editing, Supervision, Software, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## 7. Appendix

### A.1. Data adjustments

To make the simulations more realistic and relevant in the context of a high-inflation environment, we adjust the historical expenditure and income data underpinning the analysis. Currently available HBS data are from 2015; more recent data have recently become available but they relate to the COVID period and are therefore not representative of key consumption patterns. We make adjustments to bring population totals and structure up to a more recent period and, crucially, to account for price and income changes.

2020 is the most recent year for which population totals are available and we use this information to account for changes as shown in Table 2. Even though the 2015–2020 time interval is short, population changes for some age groups were substantial in Lithuania, due to ageing and (historical and current) migration patterns. Lithuania has fewer than 3 million residents, its population is decreasing and projected to decline by 200,000 by 2030 (OECD, 2021a,b,c,d). Historically, migration remained outward, with young people, in particular, leaving Lithuania. This trend has reversed recently, with net positive migration flows since 2019 (OECD, 2021a,b,c,d). From 2015 to 2020, most working age groups declined while older age cohorts aged (60+) expanded, with greater relative increases for older groups. To approximate 2022 population totals, we subsequently apply twice the average annual growth rate over the 2015–2020 period. The resulting factors are used to reweigh observations in the micro-data depending on their age group.

Total inflation over the 2015–22 period was 54 %, with 2021–2022 accounting for more than half (32 percentage points) of this change. Food, drink and tobacco, fuels, restaurants and transport increased at a higher rate than the mean. The impact is comparatively small; price increases observed over the 2021–2022 period were more than ten times as high as the increase that would result from a carbon tax of EUR 60/tonne, using July 2022 price levels as reference.

Nominal incomes grew faster than prices between 2015 and 2020 (by 60 %, a real increase of almost 40 %). We uprate disposable incomes by a quantile specific factor reflecting this average change. In reality, some of the change in disposable income will have been due to market income changes among workers, some due to employment changes and some due to changes in policy, notably those that impact on pensions and other government transfers. Although it is possible to approximately account for this granularity, it is beyond the scope of this paper. It is preferable to await new data rather than attempting to undertake complex, cumbersome and potentially in-transparent adjustments of the rich income distributions captured in the data.

Our approach can be summarized in five steps.

- 1) We group HBS expenditure items into COICOP groupings (see Table 2) and we source the corresponding Harmonized Index of Consumer Prices (HICP) from Eurostat.
- 2) We compute HICP changes between January 2015 and July 2022 per expenditure grouping and uprate household expenditures observed in the EU-HBS 2015 using HICP changes (see Table 2).
- 3) We source income uprating factors (2015–2020) for each household disposable income quantile and uprate disposable income for each household using the uprating factor differentiating income growth per quantile (see Table 3).
- 4) We adjust the population weights to reflect changes in the demographic composition of the population (by age) (see Table 1).
- 5) To compute the carbon emissions associated with fuel expenditure, we source price data for July 2022 for each energy commodity (gas, liquid fuel, solid fuels, district heat, diesel, petrol) and fuel emission factors. The prices were sourced from the European Commission Weekly Oil Bulletin and provided by the Lithuanian Statistics Office upon request. We use the 2006 IPCC emission factors for each unit of fuel.

A.3. Change in cost of living and prices

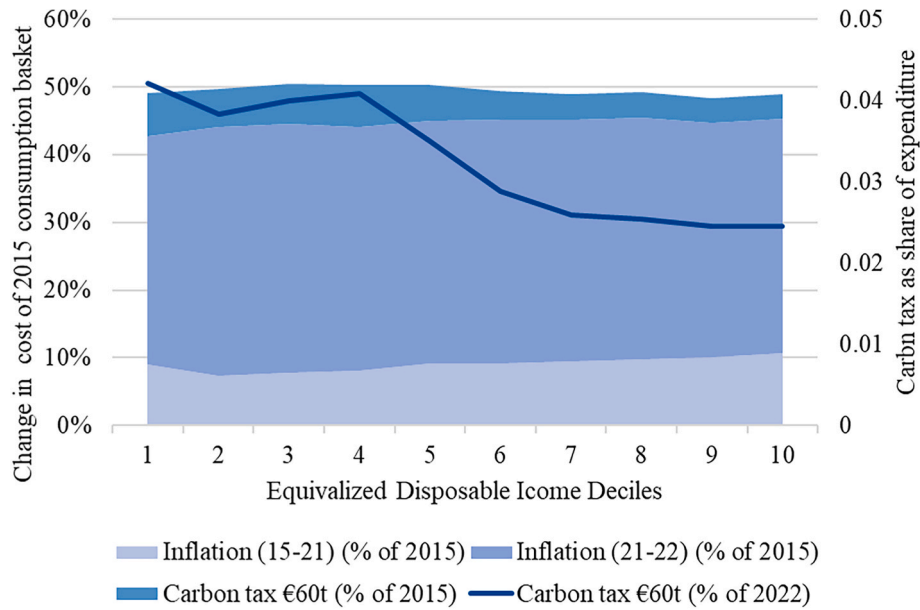


Fig. 1. Change in the cost of living between 2015 and 2022.

Table 1  
Population change Lithuania - 2020.

	2015	2020	Change
0-4	150984	145590	0.964
5-9	139381	144512	1.037
10-14	134240	132642	0.988
15-19	166270	130926	0.787
20-24	201515	154360	0.766
25-29	195615	185376	0.948
30-34	178111	187446	1.052
35-39	176352	171793	0.974
40 - 44	197732	174252	0.881
45 - 49	207820	195470	0.941
50 - 54	225192	201308	0.894
55 - 59	213239	217731	1.021
60 - 64	170639	196708	1.153
65 - 69	145259	154540	1.064
70 - 74	131531	126480	0.962
75 - 79	120539	110410	0.916
80 - 84	85932	90739	1.056
85 - 89	47321	51559	1.090
90 - 94	14902	18624	1.250
95 - 99	1978	3364	1.701
100 +	358	639	1.250
<b>Total</b>	<b>2904910</b>	<b>2793986</b>	<b>0.962</b>

**Table 2**  
HICP changes from January 2015 to July 2022 by COICOP grouping.

COICOP	Expenditure group	HICP Jan. 2015	HICP Jul. 2022	HICP change
1	Food	100.17	149.85	1.496
2	Alcoholic beverages, tobacco and narcotics	99.51	144.05	1.448
2.3	Tobacco	98.98	157.28	1.589
3	Clothing and footwear	94.27	100.72	1.068
4.1	Actual rentals for housing	88.76	155.35	1.75
4.4	Water supply and miscellaneous services relating to the dwelling	99.95	116.54	1.166
4.5.1	Electricity	100.00	188.44	1.884
4.5.3	Liquid fuels	96.73	172.65	1.785
4.5.2	Gas	105.85	180.42	1.705
4.5.4	Solid fuels	105.88	227.71	2.15
4.5.5	Heat energy	110.43	144.44	1.31
5	Furnishings, household equipment and routine household maintenance	99.50	126.11	1.267
6	Health	98.64	132.10	1.339
7.2	Operation of personal transport equipment	95.49	156.18	1.636
7.2.2.1	Petrol	90.55	164.92	1.821
7.2.2.2	Diesel	94.63	177.22	1.873
7.3	Transport services	96.83	135.68	1.401
8	Communications	99.74	98.93	0.992
9	Recreation and culture	98.60	125.05	1.268
10	Education	98.98	137.45	1.389
11	Restaurants and hotels	97.49	156.57	1.606
13	Miscellaneous goods and services	99.66	138.31	1.388
13.3.1	Child care services	100.00	128.96	1.29

Source: Eurostat (n.d.). *Harmonized Index of Consumer Prices (HICP) – Monthly Index* [Data set]. Retrieved June 6, 2025, from [https://ec.europa.eu/eurostat/databrowser/view/PRC\\_HICP\\_MIDX\\_custom\\_2780946/default/table](https://ec.europa.eu/eurostat/databrowser/view/PRC_HICP_MIDX_custom_2780946/default/table)

**Table 3**  
Mean disposable income (in euro) and income growth by disposable income quantile (2015–2020).

Year/Quantile	Quantile 1 (Lowest)	Quantile 2	Quantile 3	Quantile 4	Quantile 5 (Highest)
2015	2678.20	5396	8944.20	13,645.40	26,602.90
2020	4508	8891	14,083	20,834	41,595
Change	0.683	0.648	0.575	0.527	0.564

Reference: Eurostat (n.d.). *Mean and median economic resources of households by income, consumption and wealth quantiles – experimental statistics* [Data set]. Retrieved October 17, 2024, from [https://ec.europa.eu/eurostat/databrowser/view/icw\\_res\\_02\\_custom\\_13349710/default/table](https://ec.europa.eu/eurostat/databrowser/view/icw_res_02_custom_13349710/default/table).

**Table 4**  
Overview of existing distributional studies using microsimulation: Scope and modelling choices.

Author	Country coverage	Scope	Distributional impact	Distributional metric	Taxes considered	Multi-regional IO model	Revenue recycling	Data matching
Pearson and Smith (1991)	United Kingdom (some results for EU12)	country	Regressive	Expenditure	Carbon tax	Country IO	(1) Lump-sum; (2) lower income tax	no
Symons et al. (2002)	5 EU	country	Mixed	Income	Direct and indirect	no	no	no
Dorband et al. (2019)	87 low and middle-income	country	Progressive	Income	Transportation fuel	yes	no	no
Vogt-Schilb et al. (2019)	Latin America & Caribbean	cross-country	Progressive	Expenditure	Direct and indirect	yes	(1) Higher cash-transfers, (2) Higher coverage	no
Büchs et al. (2021)	27 EU	EU-level	Regressive across EU	Income	Direct and indirect	yes	(1) fuel rebates; (2) green vouchers + infrastructure	no
Feindt et al. (2021)	23 EU	EU-level, country	Progressive across country/regressive across EU	Expenditure	Direct and indirect	yes	(1) National/EU lump sum; (2) Targeted to poor	no
Callan et al. (2009)	Ireland	country	Regressive	Net cost	Direct and indirect	yes	(1) Social welfare payments, child benefit, (2) tax credit, tax rate decrease	no
Bourgeois et al. (2021)	France	country	Regressive	Income	Carbon tax	no	(1) Lump-sum, (2) Subsidies	No, specialized dataset
Reaños (2021)	Ireland	country	Regressive	Income	Carbon tax	no	Lump-sum	Yes, Stone Index

(continued on next page)

Table 4 (continued)

Author	Country coverage	Scope	Distributional impact	Distributional metric	Taxes considered	Multi-regional IO model	Revenue recycling	Data matching
Douenne (2020)	France	country	Regressive	Income and Expenditure	Domestic and Transport fuels	no	(1) Lump-sum, (2) Geographical and Fuel targeted	Statistical matching
Vandyck et al. (2021)	11 EU	Cross-country	regressive	Income	Direct and indirect	yes	(1) Lump-sum, (2) Social benefit index, (3) Wage index	EUROMOD-ITT, imputation and statistical matching
Többen et al. (2023)	Germany	Country	regressive	Income	Carbon tax	no	(1) Purchasing power target, (2) Energy poverty target, (3) renewable energy levy abolition	Synthetic dataset using iterative proportional fitting and random forests

## Data availability

The authors do not have permission to share data.

## References

- Antosiewicz, M., Fuentes, J., Lewandowski, P., Witajewski-Baltvilks, J., 2022. Distributional effects of emission pricing in a carbon-intensive economy: the case of Poland. *Energy Policy* 160, 112678. <https://doi.org/10.1016/j.enpol.2021.112678>.
- Auffhammer, M., 2018. Quantifying economic damages from climate change. *J. Econ. Perspect.* 32 (4), 33–52. <https://doi.org/10.1257/jep.32.4.33>.
- Baranzini, A., Goldemberg, J., Speck, S., 2000. A future for carbon taxes. *Ecol. Econ.* 32 (3), 395–412. [https://doi.org/10.1016/s0921-8009\(99\)00122-6](https://doi.org/10.1016/s0921-8009(99)00122-6).
- Baumol, W.J., Oates, W.E., 1988. *The Theory of Environmental Policy*. Cambridge University Press, Cambridge.
- Beiser-McGrath, L.F., Bernauer, T., 2019. Could revenue recycling make effective carbon taxation politically feasible? *Sci. Adv.* 2019 (9), 5.
- Berry, A., 2019. The distributional effects of a carbon tax and its impact on fuel poverty: a microsimulation study in the French context. *Energy Policy* 124, 81–94. <https://doi.org/10.1016/j.enpol.2018.09.021>.
- Bourgeois, C., Giraudet, L.-G., Quirion, P., 2021. Lump-sum vs. energy-efficiency subsidy recycling of carbon tax revenue in the residential sector: a French assessment. *Ecol. Econ.* 184, 107006. <https://doi.org/10.1016/j.ecolecon.2021.107006>.
- Brännlund, R., Nordström, J., 2004. Carbon tax simulations using a household demand model. *Eur. Econ. Rev.* 48 (1), 211–233. [https://doi.org/10.1016/s0014-2921\(02\)00263-5](https://doi.org/10.1016/s0014-2921(02)00263-5).
- Browne, J., Immervoll, H., 2017. Mechanics of replacing benefit systems with a basic income: comparative results from a microsimulation approach. *J. Econ. Inequal.* 15 (4), 325–344. <https://doi.org/10.1007/s10888-017-9366-6>.
- Büchs, M., Bardsley, N., Duwe, S., 2011. Who bears the brunt? Distributional effects of climate change mitigation policies. *Crit. Soc. Policy* 31 (2), 285–307. <https://doi.org/10.1177/0261018310396036>.
- Büchs, M., Bastianelli, E., Schnepf, S.V., 2024. Public opposition to fuel taxes in Europe: how important is social disadvantage and how do welfare regimes compare? *J. Eur. Soc. Pol.* 34 (5), 495–510.
- Büchs, M., Ivanova, D., Schnepf, S., 2021. Fairness, effectiveness, and needs satisfaction: new options for designing climate policies. *Environ. Res. Lett.* 16 (12), 124026. <https://doi.org/10.1088/1748-9326/ac2cb1>.
- Budgetdienst, 2022. Verteilungswirkung des ersten und zweiten Teils der Ökosozialen Steuerreform. Parliament of the Republic of Austria.
- Budolfson, M., Dennig, F., Errickson, F., Feindt, S., Ferranna, M., Fleurbaey, M., Zuber, S., 2021. Climate action with revenue recycling has benefits for poverty, inequality and well-being. *Nat. Clim. Change* 11 (12), 1111–1116. <https://doi.org/10.1038/s41558-021-01217-0>.
- Bureau, D., Henriot, F., Schubert, K., 2019. Pour le climat : une taxe juste, pas juste une taxe. *Notes du conseil d'analyse économique*, n° 50 (2), 1. <https://doi.org/10.3917/naec.050.0001>.
- Cai, M., Vandyck, T., 2020. Bridging between economy-wide activity and household-level consumption data: matrices for European countries. *Data Brief* 30 (105395). <https://doi.org/10.1016/j.dib.2020.105395>.
- Callan, T., Lyons, S., Scott, S., Tol, R., Verde, S., 2009. The distributional implications of a carbon tax in Ireland. *Energy Policy* 37 (2), 407–412. <https://doi.org/10.1016/j.enpol.2008.08.034>.
- Carattini, S., Carvalho, M., Fankhauser, S., 2018. Overcoming public resistance to carbon taxes. *WIREs Climate Change* 9 (5). <https://doi.org/10.1002/wcc.531>.
- Dasgupta, S., Laplante, B., Wang, H., Wheeler, D., 2002. Confronting the environmental Kuznets curve. *J. Econ. Perspect.* 16 (1), 147–168.
- Dechezleprêtre, A., Kruse, T., 2022. The effect of climate policy on innovation and economic performance along the supply chain: a firm- and sector-level analysis. In: OECD Environment Working Papers. OECD Publishing, Paris. <https://doi.org/10.1787/3569283a-en>.
- Dechezleprêtre, A., Sato, M., 2017. The impacts of environmental regulations on competitiveness. *Rev. Environ. Econ. Pol.* 11 (2), 183–206. <https://doi.org/10.1093/reep/rex013>.
- Dechezleprêtre, A., Fabre, A., Kruse, T., Planterose, B., Sanchez Chico, A., Stantcheva, S., 2022. Fighting climate change: international attitudes toward climate policies. In: OECD Economics Department Working Papers. OECD Publishing, Paris. <https://doi.org/10.1787/3406f29a-en>.
- Dechezleprêtre, A., Nachtigall, D., Venmans, F., 2023. The joint impact of the European Union emissions trading system on carbon emissions and economic performance. *J. Environ. Econ. Manag.* 118, 102758. <https://doi.org/10.1016/j.jeem.2022.102758>.
- Dorband, I., Jakob, M., Kalkuhl, M., Steckel, J., 2019. Poverty and distributional effects of carbon pricing in low- and middle-income countries – a global comparative analysis. *World Dev.* 115, 246–257. <https://doi.org/10.1016/j.worlddev.2018.11.015>.
- Douenne, T., 2020. The vertical and horizontal distributive effects of energy taxes: a case study of a French policy. *Energy J.* 41 (3).
- Durand-Lasserre, O., Campagnolo, L., Chateau, J., Dellink, R., 2015. Modelling of distributional impacts of energy subsidy reforms: an illustration with Indonesia. In: OECD Environment Working Papers, 2015. OECD Publishing, Paris. <https://doi.org/10.1787/5js4k0scrq5-en>.
- European Commission, 2021. *Green Taxation and Other Economic Instruments - Internalising Environmental Costs to Make the Polluter Pay*.
- European Parliament and Council of the European Union, 2023. Regulation (EU) 2023/955 of the European parliament and of the Council of 10 May 2023 establishing a social climate fund and amending regulation (EU) 2021/1060. *Orkesterjournalen L* 130 (16), 1–51, 5.2023. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R0955>.
- Eurostat (n.d.). People at risk of poverty or social exclusion by age and sex - EU-SILC survey. Retrieved June 5, 2025, from [https://ec.europa.eu/eurostat/databrowser/view/tessi010/default/table?lang=en&category=t\\_iloc\\_t\\_iloc\\_ip.t\\_iloc\\_li](https://ec.europa.eu/eurostat/databrowser/view/tessi010/default/table?lang=en&category=t_iloc_t_iloc_ip.t_iloc_li).
- Feindt, S., Kornek, U., Labeaga, J., Sterner, T., Ward, H., 2021. Understanding regressivity: challenges and opportunities of European carbon pricing. *Energy Econ.* 103, 105550. <https://doi.org/10.1016/j.eneco.2021.105550>.
- Flues, F., van Dender, K., 2017. The impact of energy taxes on the affordability of domestic energy. In: OECD Taxation Working Papers. OECD Publishing, Paris. <https://doi.org/10.1787/08705547-en>.
- Fremstad, A., Paul, M., 2019. The impact of a carbon tax on inequality. *Ecol. Econ.* 163, 88–97.
- Goulder, L.H., 1995. Environmental taxation and the double dividend: a reader's guide. *Int. Tax Publ. Finance* 2, 157–183.
- High-Level Commission on Carbon Prices, 2017. Report of the high-level commission on carbon prices. High-Level Commission on Carbon Prices. Washington DC. Retrieved 03 28, 2022, from [https://static1.squarespace.com/static/54ff9e5ce4b0a53decccfb4c/t/59b7f2409f8dce5316811916/1505227332748/CarbonPricing\\_FullReport.pdf](https://static1.squarespace.com/static/54ff9e5ce4b0a53decccfb4c/t/59b7f2409f8dce5316811916/1505227332748/CarbonPricing_FullReport.pdf).
- Howard, P.H., Sterner, T., 2022. Between two worlds: methodological and subjective differences in climate impact meta-analyses. *Resources for the Future Working Paper* 22 (10).
- Immervoll, H., 2024. Financing social protection in OECD countries: role and uses of revenue earmarking. In: OECD Social, Employment and Migration Working Papers. OECD Publishing, Paris. <https://doi.org/10.1787/0d53155c-en>.
- Immervoll, H.L., Mustonen, E., Riihelä, M., 2005. Accounting for population changes in tax-benefit microsimulation models. A note on static data 'ageing' techniques. *EUROMOD Working Paper* 7 (5).
- Immervoll, H., Linden, J., O'Donoghue, C., Sologon, D., 2023. Who pays for higher carbon prices? Illustration for Lithuania and a research agenda. *OECD Social, Employment and Migration Working Papers*, p. 283.
- Interagency Working Group on Social Cost of Greenhouse Gases (IWG), 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide: Interim Estimates under Executive Order 13990.
- IPCC, 2006. *THE IPCC. Guidelines for national greenhouse gas inventories*, prepared by the national green-house gas inventories programme.

- Ivanova, D., Vita, G., Steen-Olsen, K., Stadler, K., Melo, P.C., Wood, R., Hertwich, E.G., 2017. Mapping the carbon footprint of EU regions. *Environ. Res. Lett.* 12 (5), 054013.
- Kitzes, J., 2013. An introduction to environmentally-extended input-output analysis. *Resources* 2 (4), 489–503. <https://doi.org/10.3390/resources2040489>.
- Klenert, D., Mattauch, L., 2016. How to make a carbon tax reform progressive: the role of subsistence consumption. *Econ. Lett.* 138, 100–103. <https://doi.org/10.1016/j.econlet.2015.11.019>.
- Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., Stern, N., 2018. Making carbon pricing work for citizens. *Nat. Clim. Change* 8 (8), 669–677. <https://doi.org/10.1038/s41558-018-0201-2>.
- Konradt, M., McGregor, T., Toscani, M.F., 2024. Carbon Prices and Inflation in the Euro Area, 24/31. IMF WP/.
- Leontieff, W.W., 1951. Input-output economics. *Sci. Am.* 185, 15–21.
- Linden, J., O'Donoghue, C., Sologon, D.M., 2024. The many faces of carbon tax regressivity—why carbon taxes are not always regressive for the same reason. *Energy Policy* 192.
- Menyhárt, B., 2024. Energy poverty in the European Union. The art of kaleidoscopic measurement. *Energy Policy* 190, 114160.
- Metcalf, G., 2021. Carbon taxes in theory and practice. *Annual Review of Resource Economics* 13 (1), 245–265. <https://doi.org/10.1146/annurev-resource-102519-113630>.
- Metcalf, G., Stock, J., 2020. The Macroeconomic Impact of Europe's Carbon Taxes. National Bureau of Economic Research, Cambridge, MA. <https://doi.org/10.3386/w27488>.
- Michail, N.A., Melas, K.D., Cleanthous, L., 2022. The relationship between shipping freight rates and inflation in the Euro Area. *Int. Econ.* 172, 40–49.
- Miller, R., Blair, P., 2009. Input-Output Analysis. Cambridge University Press. <https://doi.org/10.1017/cbo9780511626982>.
- Murray, B., Rivers, N., 2015. British Columbia's revenue-neutral carbon tax: a review of the latest "grand experiment" in environmental policy. *Energy Policy* 674–683.
- Nachtigall, D., Ellis, J., Errendal, S., 2022. Carbon pricing and COVID-19: policy changes, challenges and design options in OECD and G20 countries. In: OECD Environment Working Papers. OECD Publishing, Paris. <https://doi.org/10.1787/8f030bcc-en>.
- Network for Greening the Financial System, 2023. NGFS Scenarios for Central Banks and Supervisors. NGFS, Paris.
- Nordhaus, W.D., 1991. A sketch of the economics of the greenhouse effect. *American Economic Review* 81 (2), 146–150.
- O'Donoghue, C., 2021a. Practical Microsimulation Modelling. Oxford University Press. <https://doi.org/10.1093/oso/9780198852872.001.0001>.
- O'Donoghue, C., 2021b. Practical Microsimulation Modelling. Oxford University Press.
- O'Donoghue, C., Amjad, B., Linden, J., Lustig, N., Sologon, D., Wang, Y., 2023. The Distributional Impact of Price Inflation in Pakistan: A Case Study of a New Price Focused Microsimulation Framework. PRICES.
- O'Donoghue, C., Loughrey, J., 2014. Nowcasting in microsimulation models: a methodological survey. *J. Artif. Soc. Soc. Simulat.* 17 (4). <https://doi.org/10.18564/jasss.2635>.
- OECD, 2021a. Assessing the Economic Impacts of Environmental Policies: Evidence from a Decade of OECD Research. OECD Publishing, Paris. <https://doi.org/10.1787/bf2fb156-en>.
- OECD, 2021b. OECD environmental performance reviews: Lithuania 2021. In: OECD Environmental Performance Reviews. OECD Publishing, Paris. <https://doi.org/10.1787/48d82b17-en>.
- OECD, 2021c. Quarterly National Accounts. <https://doi.org/10.1787/4f3988d0-en>, 2021 Issue 3. 2021/3.
- OECD, 2021d. Statistical Insights: consumption shifts and inflation measurement during COVID-19. <https://www.oecd.org/fr/sdd/prix-ppa/statistical-insights-consumption-shifts-and-inflation-measurement-during-covid-19.htm>.
- OECD, 2022a. Coping with the Cost-Of-Living Crisis: Income Support for Working-Age Individuals and Their Families. OECD. Retrieved from. <https://oe.cd/inflation-income-support>.
- OECD, 2022b. OECD economic outlook, interim report september 2022: paying the price of war. 2022/1. <https://doi.org/10.1787/ae8c39ec-en>.
- OECD, 2022c. Tax Policy Reforms 2022: OECD and Selected Partner Economies. <https://doi.org/10.1787/067c593d-en>.
- OECD, 2022d. Towards a Sustainable Recovery? Carbon Pricing Policy Changes during COVID-19. OECD, Paris. Retrieved from. <http://oecd.org/coronavirus>.
- OECD, 2023. Effective carbon rates 2023: pricing greenhouse gas emissions through taxes and emissions trading. In: OECD Series on Carbon Pricing and Energy Taxation. OECD Publishing, Paris. <https://doi.org/10.1787/b84d5b36-en>.
- OECD, 2024. Who pays for higher carbon prices? Mitigating climate change and adverse distributional effects. In: OECD Employment Outlook 2024: the Net-Zero Transition and the Labour Market. OECD Publishing, Paris. <https://doi.org/10.1787/9138d7e3-en>.
- Ohlendorf, N., Jakob, M., Minx, J., Schröder, C., Steckel, J., 2020. Distributional impacts of carbon pricing: a meta-analysis. *Environ. Resour. Econ.* 78 (1), 1–42. <https://doi.org/10.1007/s10640-020-00521-1>.
- Owen, A., Barrett, J., 2020. Reducing inequality resulting from UK low-carbon policy. *Clim. Policy* 20 (10), 1193–1208. <https://doi.org/10.1080/14693062.2020.1773754>.
- Pearson, M., Smith, S., 1991. The European Carbon Tax: an Assessment of the European Commission's Proposals. Institute for Fiscal Studies. Retrieved from. <https://discovery.ucl.ac.uk/id/eprint/17288/1/17288.pdf>.
- Pigou, A.C., 1920. *The Economics of Welfare*. Macmillan, London.
- Rausch, S., Metcalf, G., Reilly, J., 2011. Distributional impacts of carbon pricing: a general equilibrium approach with micro-data for households. *Energy Econ.* 33, S20–S33. <https://doi.org/10.1016/j.eneco.2011.07.023>.
- Reaños, M.A., 2021. Fuel for poverty: a model for the relationship between income and fuel poverty. Evidence from Irish microdata. *Energy Policy* 156, 112444.
- Renner, S., 2018. Poverty and distributional effects of a carbon tax in Mexico. *Energy Policy* 112, 98–110.
- Rennert, K., Errickson, F., Prest, B., Rennels, L., Newell, R., Pizer, W., Anthoff, D., 2022. Comprehensive evidence implies a higher social cost of CO<sub>2</sub>. *Nature* 610 (7933), 687–692. <https://doi.org/10.1038/s41586-022-05224-9>.
- Rosas-Flores, J.A., Bakhat, M.R.-F., Zayas, J., 2017. Distributional effects of subsidy removal and implementation of carbon taxes in Mexican households. *Energy Econ.* 61, 21–28.
- Sologon, D., O'Donoghue, C., Kyzyma, I., Li, J., Linden, J., Wagener, R., 2022. The COVID-19 resilience of a continental welfare regime - nowcasting the distributional impact of the crisis. *J. Econ. Inequal.* 20 (4), 777–809. <https://doi.org/10.1007/s10888-021-09524-4>.
- Sologon, D.M., O'Donoghue, C., Kyzyma, I., Loughrey, J., Linden, J., 2025. Distributional impact of soaring prices in Europe: A cross-national decomposition of inflation's regressivity and progressivity. *Rev. Income Wealth* 71 (2), e70010. <https://doi.org/10.1111/roiw.70010>.
- Symons, E., Speck, S., Proops, J., 2002. The distributional effects of carbon and energy taxes: the cases of France, Spain, Italy, Germany and UK. *Eur. Environ.* 12 (4), 203–212. <https://doi.org/10.1002/eet.293>.
- Tatham, M., Peters, Y., 2022. Fueling opposition? Yellow vests, urban elites, and fuel taxation. *J. Eur. Publ. Pol.* 1–25. <https://doi.org/10.1080/13501763.2022.2148172>.
- Többen, J., Pichler, P.P., Jaccard, I.S., Kratena, K., Moran, D., Zheng, H., Weisz, H., 2023. Unequal carbon tax impacts on 38 million German households: assessing spatial and socio-economic hotspots. *Environ. Res.: Climate*.
- Tol, R., 2023. Social cost of carbon estimates have increased over time. *Nat. Clim. Change* 13 (6), 532–536. <https://doi.org/10.1038/s41558-023-01680-x>.
- Tovar Reaños, M., Lynch, M., 2022. The benefits of action on implementing carbon taxation in Ireland: a demand system approach. *J. Environ. Plann. Manag.* 1–25. <https://doi.org/10.1080/09640568.2021.2006157>.
- Vanduyck, T., Weitzel, M., Wojtowicz, K., Los Santos, L.R., Maftai, A., Riscado, S., 2021. Climate policy design, competitiveness and income distribution: a macro-micro assessment for 11 EU countries. *Energy Econ.* 103, 105538.
- Vogt-Schilb, A., Walsh, B., Feng, K., Di Capua, L., Daniela, Z., Marcos, R., Hubacek, K., 2019. Cash transfers for pro-poor carbon taxes in Latin America and the Caribbean. *Nat. Sustain.* 941–948. <https://doi.org/10.1038/s41893-019-0385-0>.
- Wang, Q., Hubacek, K., Feng, K., Wei, Y.-M., Liang, Q.-M., 2016. Distributional effects of carbon taxation. *Appl. Energy* 184, 1123–1131. <https://doi.org/10.1016/j.apenergy.2016.06.083>.
- Werner, S., 2017. International review of district heating and cooling. *Energy* 137, 617–631.
- World Bank, 2019. Using carbon tax revenues. Technical Note 16.
- World Bank. (n.d.). Carbon Pricing Dashboard. Retrieved June 5, 2025, from <https://carbonpricingdashboard.worldbank.org/>.