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ABSTRACT

The Distributional Effects of Carbon Pricing in Türkiye

As middle income countries grow they see an increase in demand for energy. To avoid extreme climate change as these countries develop, there will be a need to decarbonise the increased energy consumption as they grow. We use the PRICES microsimulation model to examine the impact of carbon pricing across the income distribution in Türkiye. In particular we assess the joint distributional impact of combining both carbon taxation with revenue recycling. We evaluate both the relative performance of existing excise duties and additional carbon taxation. Despite the relative large change in the tax rate, replacing excise duties with carbon related excise duties has a relatively small distributional impact, with carbon taxes slightly less regressive than excised duties. Additional carbon taxes equivalent to €30 per tCO2 are regressive, increasing inequality. However we find that revenue recycling has a greater impact on inequality than the tax itself, with targeted instruments reducing inequality, while flatter instruments when combing with the carbon tax do not fully compensate for the increased inequality from the carbon tax. Although the carbon tax reduced emissions, revenue recycling mitigated this impact with a trade off between redistribution and emissions reduction.

JEL Classification: Q58, C15

Keywords: carbon pricing, middle income countries, revenue recycling, microsimulation

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The Distributional Effects of Carbon Pricing in Türkiye

1. Introduction

As middle income countries grow they see an increase in demand for energy and consumer durables (Kahn and Lall 2022). To avoid extreme climate change as these countries develop, there will be a need to decarbonise the increased energy consumption as they grow.[1] Carbon pricing can be a useful tool to incentivise this change (Dorband et al., 2019). However the regressive nature of these instruments can result in increased inequalities, negative attitudes and political pressure to the use of these tools (Dechezleprêtre et al., 2022). In this paper we paper we will examine the distributional impact of the introduction of carbon pricing in a large middle income country, Türkiye and evaluate the impact of a range of revenue recycling instruments.

Türkiye is a middle income country with medium emissions per person, however given its economic growth and industrial structure it is trending towards high emissions per person as it moves towards being a high income country by 2050. [2] Globally, in terms of carbon dioxide emissions, Turkey ranked 14th in 2023, with an emission amount of 432.08 million tons, compared to 316.19 million tons in 2010[3]. The energy sector is the primary contributor to these emissions, accounting for around 70% of the total, largely due to the extensive use of coal and natural gas in electricity generation (Ministry of Environment and Urbanization, 2021). Türkiye's per capita energy consumption has risen from 0.94 tonnes of oil equivalent (toe) in 1990 to 1.73 toe in 2019, still behind northern Mediterranean countries like France and Spain. Although Türkiye has committed to reducing emissions by 41% by 2030 and achieving net-zero by 2053, its reliance on fossil fuels continues to be a major barrier to meeting climate goals (Ministry of Environment and Urbanization, 2021). Despite significant progress in renewable energy generation, which accounted for 54% of Türkiye's electricity in 2023, fossil fuels remain dominant in the energy mix (Ministry of Energy and Natural Resources, 2023). Decarbonising coal based electricity is a key goal of national strategy (Aliabadi, 2020). In this context, we investigate how transitioning from excise duties on energy to a carbon tax could help address income disparities by lessening the disproportionate burden on households.

After a period of a reducing reliance on high emissions from coal, the pressures on energy security resulting from the Ukraine war has seen a reversal of this trend, resulting in the Climate Action Tracker finding that the emissions reduction strategy is "Critically Insufficient" [4] and has fallen nine places to 56 in the Climate Change Performance Index[5]. Delivering on reduced emissions while reducing the energy usage gap requires new strategies if Türkiye is to deliver upon its stated goals of its NDC (Nationally Defined Contribution), it will need to implement stronger policies to incentivise this transition. Carbon pricing is one of the important tools within the decarbonisation toolkit for reducing greenhouse gas (GHG) emissions, but comes with negative distributional implications (Ohlendorf et al., 2021). In this paper we evaluate the distributional implications of carbon pricing in Türkiye, considering in particular the transition

[1] https://cepr.org/voxeu/columns/collapse-revisited-climate-change-and-development-middle-income-countries
[2] https://worldemissions.io/
[3] https://www.statista.com/statistics/270499/co2-emissions-in-selected-countries/
[4] https://climateactiontracker.org/countries/turkey/
[5] https://ccpi.org/country/tur/

and enhancement of existing indirect taxation on fuels and the importantly the joint distributional impact of the revenue recycling.

Research on the distributional effects of carbon pricing shows it disproportionately impacts low-income households due to their higher spending on energy-intensive goods (Zhang et al., 2023; Chepeliev et al., 2021; Frondel and Schubert, 2021; Li et al., 2018; Yan and Yang, 2021; Shei et al., 2024). Carbon taxes increase direct fuel costs and indirect costs for carbon-intensive goods, often resulting in regressive effects (Böhringer et al., 2019. For example, Kerkhof et al. (2008) found a 7% tax burden for low-income families in Denmark compared to 4% for high-income ones. However, Tiezzi (2005) demonstrated a progressive impact in Italy, with welfare losses of 0.2% for the poorest and 9.2% for the richest. Regional disparities are also significant, with studies exploring rural-urban differences (Callan et al., 2009). Revenue recycling mechanisms can offset regressive impacts, as shown in Thailand (Saelim, 2019) and Mexico (Renner, 2018), where revenues fund direct transfers or social programs. Coady et al. (2017) further suggest that removing fossil fuel subsidies and recycling savings can reduce inequality in developing countries.

Research on carbon pricing and energy taxes in Türkiye and their effects on income distribution is scarce in comparison to other countries. Some papers have used general equilibrium models to study the macroeconomic effects of carbon pricing (Akın-Olcum & Yeldan, 2013; Karapinar et al., 2019), or focused on citizens' willingness to pay for emissions reduction (Ertor-Akyazı et al., 2012). Among studies on household contributions to carbon reduction in Turkey, only Gevrek and Uyduranoglu (2015) mention "carbon tax" and explore public preferences for policies, including green taxes. Coruh et al., 2024) considered the drivers of carbon emissions at a household level impact of carbon emissions in Türkiye. Using a bespoke survey, Bülbül et al., (2023) considered behavioural drivers of carbon emissions in Türkiye. However, neither decomposed their results across the distribution. Uzar & Eyuboglu, (2019) considered the distributional drivers of the production of carbon emissions, but not the distributional impact of carbon pricing, From a distributional perspective of carbon pricing itself in Türkiye, the OECD employment outlook, (2024) considered the distributional impacts of energy related excise duties in Türkiye between 2012 and 2021. Steckel et al. (2021) in a comparative paper studied the effects of carbon pricing in eight Asian countries, including Türkiye, that invest heavily in coal, with a focus on climate change mitigation and income distribution. The paper focused on carbon pricing but with a relatively low emphasis on revenue recycling or the behavioural response to carbon pricing.

Given the extensive literature on carbon pricing, there remains a gap in studies focusing on low- and middle-income countries like Türkiye, where the dynamics of carbon taxation and its real-world implementation differ from those in high-income countries. Most existing research on middle income countries emphasizes theoretical analyses of carbon taxes rather than examining their interaction with existing policies or addressing practical challenges such as revenue recycling or addresses the behavioural impact of these potential reforms interacted with the income distribution. This paper aims to fill these gaps by analyzing various carbon pricing options, their distributional impacts, and the potential for revenue recycling in Türkiye. By considering Türkiye's unique energy reliance, tax structures, and socio-economic context, the study contributes to the broader policy discourse, offering a practical justification for carbon taxation and demonstrating how revenue recycling could make such a policy more equitable and politically feasible.

This study employs the PRICES microsimulation model (O'Donoghue et al., 2023) to examine the impact of carbon price changes across the income distribution in Türkiye.. The model utilizes household budget survey data, structured to include detailed expenditure patterns, self-produced consumption (where relevant), and socio-economic characteristics. It estimates budget elasticities through Engel curves and budget share equations, enabling the calculation of LES-based price elasticities (O'Donoghue et al., 2023; Creedy, 1999). The PRICES model also integrates policy-specific algorithms tailored for different national contexts and provides comprehensive tools for welfare and distributional analysis, making it well-suited for evaluating the effects of carbon pricing and related fiscal policies.

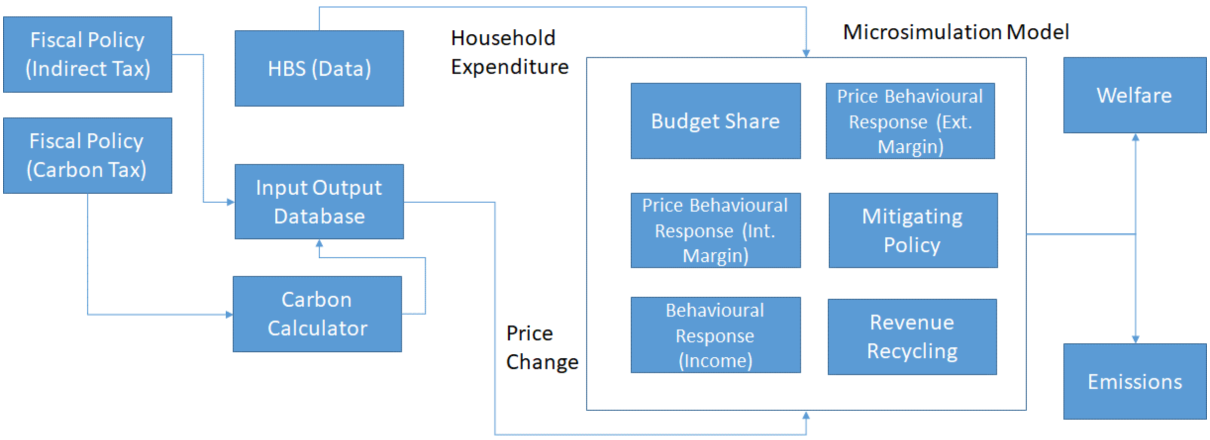
In this study, we use Turkey's 2019 harmonized household budget survey. For carbon taxation, we use a 2016 Input-Output table from the World Input Output Database (WIOD) to assess indirect effects (See Can, 2025 for a richer discussion of these data sources). The analysis looks at both direct emissions from households and those embedded in the goods and services they consume, aiming to understand potential public support or opposition to carbon pricing policies. Section II describes the data and methodology used. The results are explored in Section III with Section IV concluding and providing some policy implications.

2. Methodology

In this paper our aim is to assess the distributional implications of a variety of different energy related carbon tax options for Türkiye incorporating revenue recycling. Doing this requires a methodological framework (Figure 1) that contains

- the distribution of fuel expenditures in order to calculate direct carbon emissions
- a macro framework such as an Input-Output model that incorporates the energy usage in the production of other goods and services consumed by households
- a carbon calculator to model the direct and indirect carbon emissions of these energy expenditures
- a policy module that can allow for the simulation of existing indirect taxation, new carbon taxation and mitigation policies utilising recycled revenue
- a behavioural module that can simulate the behavioural response to both price changes induced by changes in carbon and indirect taxation and income changes resulting from revenue recycling.

Figure 1. Microsimulation Model Framework



Modelling the distributional impact of a carbon tax requires therefore both micro units and a simulation framework, known as a microsimulation model (Hynes and O'Donoghue, 2014; O'Donoghue, 2021)

Modelling Carbon Emissions

In order to model carbon emissions we have to convert fuel expenditure expressed in value terms to volume terms. This requires information on both the emissions per unit of energy (measured in kilowatt-hours) and the cost per kilowatt-hour. Drawing upon data from the OECD Effective Carbon Rates (ECRs) database[6], we calculate the Excise Duty per Turkish Lira and per TCO2 for different fuels in Türkiye (Can, 2025). Effective carbon rates account for implicit fossil fuel subsidies offered through preferential excise or carbon tax rates, ensuring that total ECRs are always non-negative.

Table 1 provides the calculation for Türkiye. Solid fuels produce higher emissions per kWh compared to liquid fuels, and liquid fuels have higher emissions than gaseous fuels. However, wood is the cheapest per kWh, while petrol and diesel has the highest cost per kWh. After the conversion, fire wood and then coal incurs the highest carbon tax per unit of expenditure due to its high emission factor and low cost per kWh. Petrol, despite not having the lowest emission factor, has the lowest carbon intensity per unit of expenditure because of its already high price per kWh. Excise duties are currently only levied on petrol, diesel and natural gas, albeit the natural gas excise duty is a fraction of the petrol and diesel rates.

The EU establishes standardized minimum excise duty rates for all energy products (mineral oil, natural gas and coal) utilized in heating, transportation, and electricity generation[7].In Türkiye, excise duty is not applied to electricity, natural gas, town gas, liquefied hydrocarbons (such as butane), liquid fuel, or coal; however, it is imposed on diesel, petroleum, and other fuels used for personal transportation.

PRICES Model

This PRICES model (Prices, Revenue Recycling, Indirect Taxation, Carbon, Expenditure Simulation model), is consistent with the theoretical framework outlined in Figure 1 (O'Donoghue et al., 2024). It is structured into four primary components, each represented in a column. The first column on the left highlights changes external to the model, such as fiscal policy, inflation, or energy policy. The second column contains the three datasets that the model uses to simulate the effects of these external changes on the population. The third column, which is framed, includes modules that adjust the input microdata to account for the external changes. The fourth and final column presents the main outputs of the model. Each column's elements are distinguished by color: light blue represents the datasets, mid-shade blue indicates components currently implemented in the model, grey marks components not yet implemented, and dark blue represents the model's outputs.

The PRICES model employs an Input-Output model to assess the indirect effects of carbon pricing on consumer goods, capturing the overall impact of the carbon price. After determining price changes for various expenditure categories, data from the Household Budget Survey (HBS) is used to calculate household-specific tax payments. By aggregating these tax payments across households, the revenue available for funding mitigation strategies through revenue

[6] The OECD ECR database tracks carbon prices from carbon taxes, emissions trading systems (ETSs), and fuel excise taxes applied to energy consumption. The dataset includes 72 countries that accounted for about 80% of global greenhouse gas (GHG) emissions in 2021.

[7] https://taxation-customs.ec.europa.eu/taxation/excise-duties/excise-duties-energy_en

recycling is estimated. Additionally, information on direct tax liabilities and benefit payments from income data allows for further exploration of possible mitigation measures.

To incorporate household behavioural responses to changes in price and income, the PRICES model features a basic demand system. Price variations affect consumption behaviour through own-price and cross-price effects (intensive margin), while revenue recycling and mitigation measures influence consumption through income effects (income behavioural response). The parameters derived from the demand system are used to evaluate the welfare impacts and changes in emissions.

Moreover, changes in prices motivate households, businesses, and governments to adapt their behaviour and invest in new assets, such as electric vehicles, energy-efficient heating systems, and solar panels. However, modelling general equilibrium (GE) effects and changes at a broader level requires specialized models. The discussion section provides an overview of the role of GE models and explains how these effects, as well as models of technology adoption, will be incorporated into the PRICES model.

Table 1. Calculating a Carbon Emissions per TLira of fuel expenditure in Türkiye (2019)

Fuel	tCO2 per kwh	Excise Duty Rate per tCO2	Price per kwh	Price per tCO2	Excise Duty Rate per TLR	VAT rate	tCO2 per unit (local currency)
Liquid Fuel	0.00026	0.0	0.626	2419.7	0.000	0.18	0.00042
Natural Gas	0.0002	16.0	0.196	969.5	0.017	0.18	0.00102
Coal	0.0004	0.0	0.373	925.0	0.000	0.18	0.00107
Wood	0.00011	0.0	0.065	160.9	0.000	0.18	0.00170
Electricity	0.0004	0.0	0.000	0.0	0.000	0.18	0.00038
Petrol	0.00027	745.0	0.702	2630.8	0.283	0.18	0.00040
Diesel	0.00025	1066.5	0.632	2534.0	0.421	0.18	0.00042

Source: Household budget survey.
Source: OECD ECR (2018) adjusted by CPI.

Data

The PRICES model relies on two primary data sources: the World Input-Output Database (WIOD) (Timmer et al., 2015) and the Household Budget Survey (HBS). When simulating complex mitigation strategies, a third dataset is used to provide detailed information on incomes, taxes, and benefits.

HBS datasets offer granular details on household expenditures by item, along with demographic, socioeconomic, and income information. This particular application uses the 2019 HBS data from Türkiye. For applications that require insights into inter-industry relationships, the model uses the 2016 WIOD data and its environmental extension, which includes industry-specific CO2 emissions (as outlined by Corsatea et al., 2019). The WIOD covers monetary flows across 56 industries in 44 countries and is supplemented with environmental and socioeconomic accounts.

Modelling the effects of energy price changes on household living costs involves both direct impacts (changes in the prices of energy consumed by households) and indirect impacts (price changes in inputs used to produce other goods and services that households consume). A change in input prices can influence the production costs of goods and services, which may then be partially passed on to consumers. The PRICES model can simulate energy price fluctuations resulting from carbon pricing and assess their direct and indirect effects on the prices of goods and services consumed by households.

To capture the indirect effects of producer price changes and carbon taxes, the model uses an input-output (IO) table to trace how price changes propagate through the economy and affect households. The IO modeling approach, originally developed by Leontief (1951), is thoroughly discussed in Miller and Blair (2009).

By incorporating environmental extensions, IO and MRIO models can track the environmental effects of production through global supply chains, creating Environmentally Extended-MRIO (EE-MRIO) models. These extensions link emissions or resource use to the production of each sector in each region. In the context of carbon emissions, EE-MRIO models allow for the assessment of indirect emissions embedded in the production of goods and services.

The central equation of an IO model, also called a Leontief quantity model, is the *Leontief inverse matrix* $(\boldsymbol{I}-\boldsymbol{A})^{-1}$, where $\boldsymbol{I}$ is the identity matrix and $\boldsymbol{A}$ is the technology matrix. The Leontief inverse gives the direct and indirect inter industry requirements for the economy:

$$x = (\boldsymbol{I}-\boldsymbol{A})^{-1}.\boldsymbol{d} \qquad (1)$$

Where $\boldsymbol{d}$ is a vector of final demand.

To convert an Input-Output (IO) model into an Environmentally Extended Input-Output (EE-IO) model, a carbon intensity vector is required. This vector captures the amount of carbon emissions produced by an industry per monetary unit of its output. By multiplying this vector with the Leontief inverse, we derive a new vector that represents the carbon intensity of each monetary unit of industry output (E_ind). This accounts for emissions produced directly by the industry as well as those emitted by all upstream industries involved in the supply chain.

Using input-output bridging techniques, we can translate the carbon emissions tied to industry outputs into the indirect emissions associated with products consumed by households ($\boldsymbol{E}_{ind}$). To calculate total emissions at the household level, we combine data on household fuel consumption with the carbon intensity of each fuel type, generating a vector that represents the household's direct carbon emissions ($\boldsymbol{E}_{dirHH}$). By summing the direct and indirect emissions, we obtain the total carbon emissions related to household consumption ($\boldsymbol{E}_{HH}$):

$$\boldsymbol{E}_{HH} = \boldsymbol{E}_{dirHH} + \boldsymbol{E}_{indHH} \tag{2}$$

This approach provides a comprehensive measure of the carbon footprint associated with household consumption, considering both the direct emissions from fuel use and the indirect emissions from the production of consumed goods and services.

The PRICES framework calculates CO2 emissions produced by energy industries in each country and tracks energy usage across various industries. This method specifically addresses energy-related emissions, allowing for the simulation of carbon taxes based on energy consumption.

To estimate household carbon footprints, the model combines data from the World Input-Output Database (WIOD) and the Household Budget Survey (HBS). The HBS provides detailed expenditure data categorized by consumption purposes (COICOP), while the WIOD offers information on inter-industry flows and final consumption based on industry classifications (ISIC rev. 4 or NACE rev. 2).

Behavioural Estimates

Modeling household behaviour requires a demand system that connects the consumption of a specific good to its price, the prices of other goods, household income, and household characteristics.

The goal of a demand system is to analyze household spending patterns on related groups of items, which allows for the estimation of price and income elasticities and consumer welfare. This approach has been widely used since Stone's (1954) linear expenditure system (LES). Typically, the expenditure share serves as the dependent variable in such models. However, due to limited price variability, some adjustments to the approach are necessary. In our application, we adopt a simpler method based on Stone's Linear Expenditure System, as described in Creedy (1998). Instead of estimating a complex system of demand equations, Creedy (1998) builds on a method by Frisch (1959), which expresses own and cross-price elasticities (η_i), budget shares (w_j) and the Frisch marginal utility of income parameter (ξ) for directly additive utility functions[8] in terms of total expenditure elasticities. This approach offers a more straightforward way to analyze consumption behaviour and estimate the impacts of price changes on household expenditure. Own-and cross-price elasticities can be described as follows:

$$\eta_{ij} = -\eta_i w_j \left(1 + \frac{\eta_j}{\xi}\right) + \frac{\eta_i \delta_{ij}}{\xi}, \tag{6}$$

where $\delta_{ij} = 1$ if i = j, 0 otherwise.

[8]See Creedy (1998) for more details.

The total expenditure elasticity (η_i) can be defined:

$$\eta_i = 1 + \frac{dw_i}{dC}\frac{C}{w_i} = 1 + (\beta_i + 2\gamma_i \ln C)/w_i \qquad (7)$$

where C is total consumption expenditure. We estimate β_i and γ_i using OLS regression and the same specification as in equation (5). Further, to allow for differences in behaviour across population groups, we calculate w_i and C for 10 population groups[9]. We omitted subscripts for population groups in equation (7) to improve readability. The Frisch parameter (ξ), can be defined as the elasticity with respect to total per capita nominal consumption spending of the marginal utility of the last dollar optimally spent.

Table 2 presents the budget and price elasticities obtained from the Linear Expenditure System (LES) using our dataset. The results show that for essential goods such as food, fuel, and clothing, as well as for tobacco and recreation, the budget elasticities are lower. This indicates that expenditures on these items are less responsive to changes in income (or total expenditure), suggesting they are necessities. Similarly, health and communication services have budget elasticities below 1, implying that spending on these items does not increase significantly as income rises. In contrast, most other consumption categories exhibit a budget elasticity close to 1, indicating a proportional relationship with changes in income.

On the other hand, expenditures on private education and durable goods show budget elasticities well above 1. This suggests that spending on these categories is more heavily concentrated among households with higher levels of expenditure, making them more of a luxury rather than a necessity.

There is a direct relationship between budget and price elasticities, resulting in a strong correlation between imputed own-price elasticities and budget elasticities. Goods with low budget elasticities, such as necessities link heating fuels and electricity, tend to be relatively insensitive to price changes. Although cross-price elasticities are not included in the report, they are generally smaller in magnitude compared to own-price elasticities, indicating that the substitution effects between different categories of goods are less pronounced.

[9] The ten population groups represent five population groups for two income groups. The population groups are singles, single person with children, couple without children, couples with children, and other households. The two income groups are below and above median income.

Table 2. Budget and Own Price Elasticities for Energy and Transport

	Budget Elasticities	Own Price Elasticities
Heating Fuels	1.52	-0.91
Electricity	0.87	-0.52
Motor Fuels	0.47	-0.29
Public Transport	0.71	-0.43

Source: Household budget survey.

3. Results

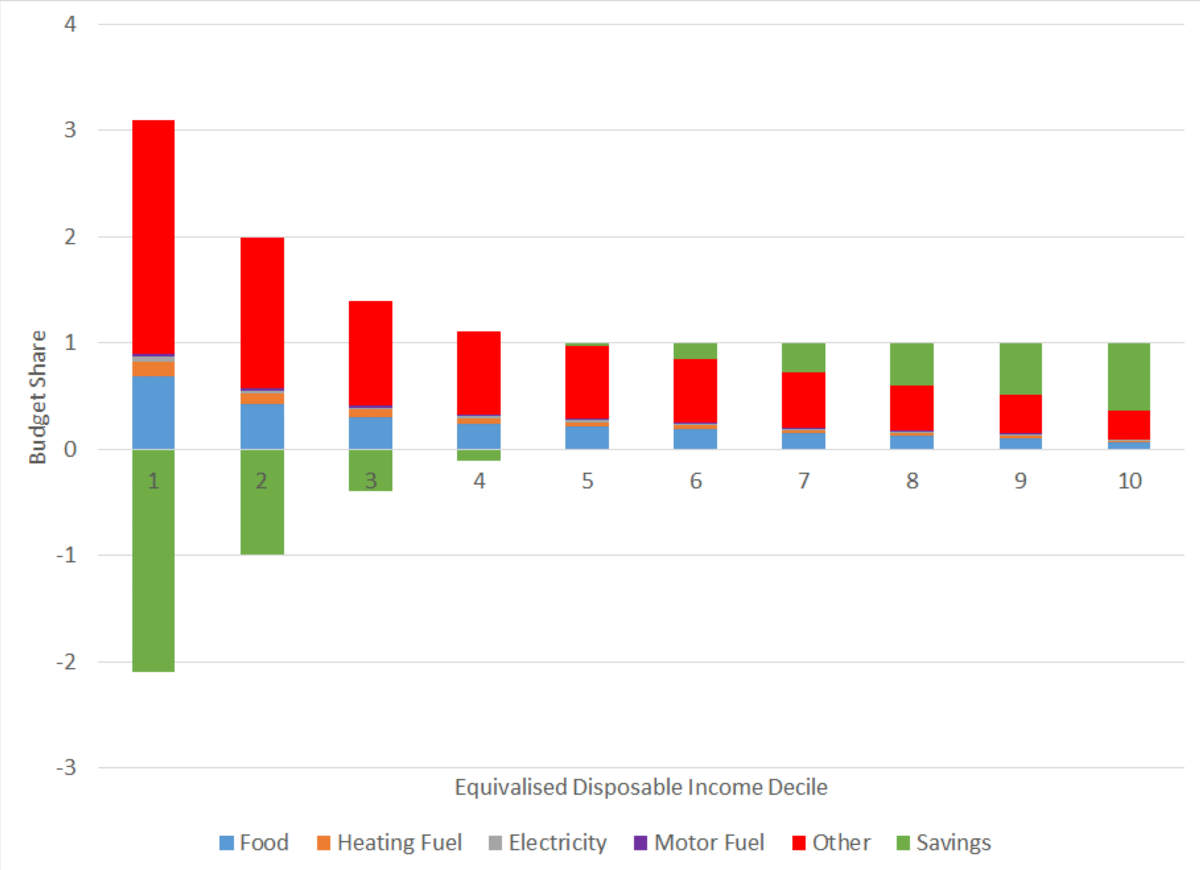
Expenditure Drivers of Carbon Pricing

Carbon pricing assigns a monetary cost to carbon emissions, encouraging individuals and businesses to adopt low-carbon practices by making polluting activities more expensive. For households, this policy holds significant implications for daily budgets given the scale and location of direct and indirect energy expenditure. Directly, it impacts expenditures on fuels used for heating and transportation. Indirectly, it raises the prices of goods and services by increasing production costs tied to CO_2 emissions.

Figure 2 shows households' expenditures on motor fuel, heating fuels, and electricity as a share of disposable income across equivalized income deciles. Figure 2 shows the proportion of household income spent on fuel, heating, and electricity by income group, adjusted for household size. This figure provides several key insights. Firstly, the lowest-income households dedicating a larger share of their income to energy consumption compared to higher-income households. As income deciles increase, the percentage of disposable income spent on energy decreases noticeably.

Second, we examine how much households spend on motor fuel, heating fuels, and electricity as well as food and other expenditures, together with their savings or dissavings. The "other" category has the highest share in each decile with a declining share of food consumption over the distribution, reflecting its role as a necessity. As figure 2 shows negative savings rates for low-income households, where expenditures exceed income, total expenditures are higher than income. In terms of energy, domestic fuels have the highest share, followed by motor fuels and electricity which have a similar share. While the share of each declines with income, the share is relatively much higher for home fuels and electricity at the bottom of the distribution, as necessities similar to food.

Figure 2. Household expenditures on fuel and other energy, as a percentage of income, by income decile (Türkiye)



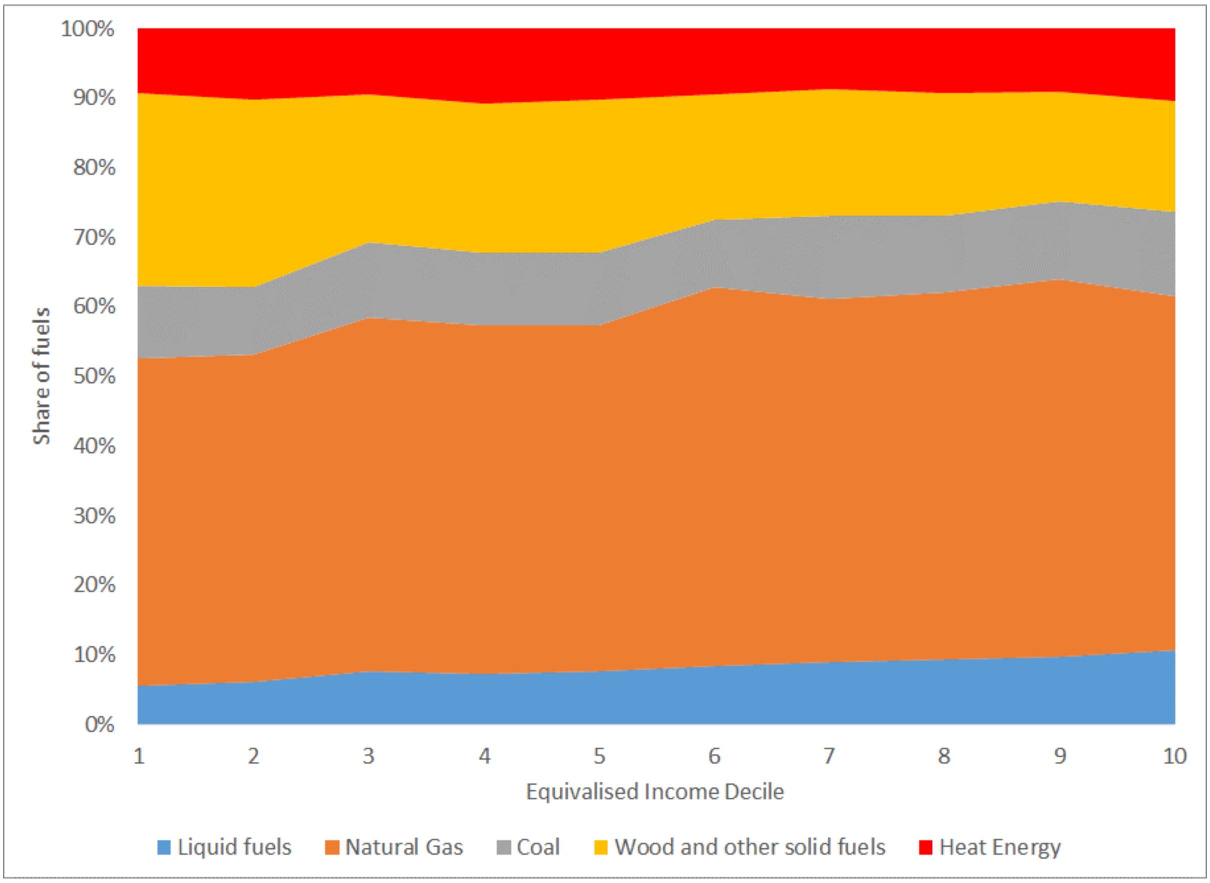
Source: Household budget survey.

Distribution of Carbon Emissions

As emissions vary depending on the type of fuel used, with solid fuels like coal or firewood emitting more CO2 than liquid fuels or natural gas, total direct carbon dioxide equivalent emissions are driven by both the total emissions and the composition of energy sources.Figure 3 illustrates the share of fuels across the income distribution, highlighting the proportion of income spent on energy sources such as liquid fuels, natural gas, coal, heat energy, and wood, which varies in its impact on income groups. In general natural gas is the dominant energy source at over 50%, followed by wood and other solid fuels at about 20% and with the other sources (liquid fuel, coal and heat energy) having a similar average budget share. Distributionally, wood and other solid fuels are highly concentrated in the bottom of the distribution, being 75% higher in the bottom decile relative to the top decile.

Lower-income households often rely on heating systems that use wood, which, despite being accessible in small quantities. Liquid fuels are most concentrated at the top of the distribution, with the share in the top decile about twice that of the bottom, while the energy shares of the others are about 15% higher at the top than the bottom.

Figure 3. Share of Fuels over the income distribution

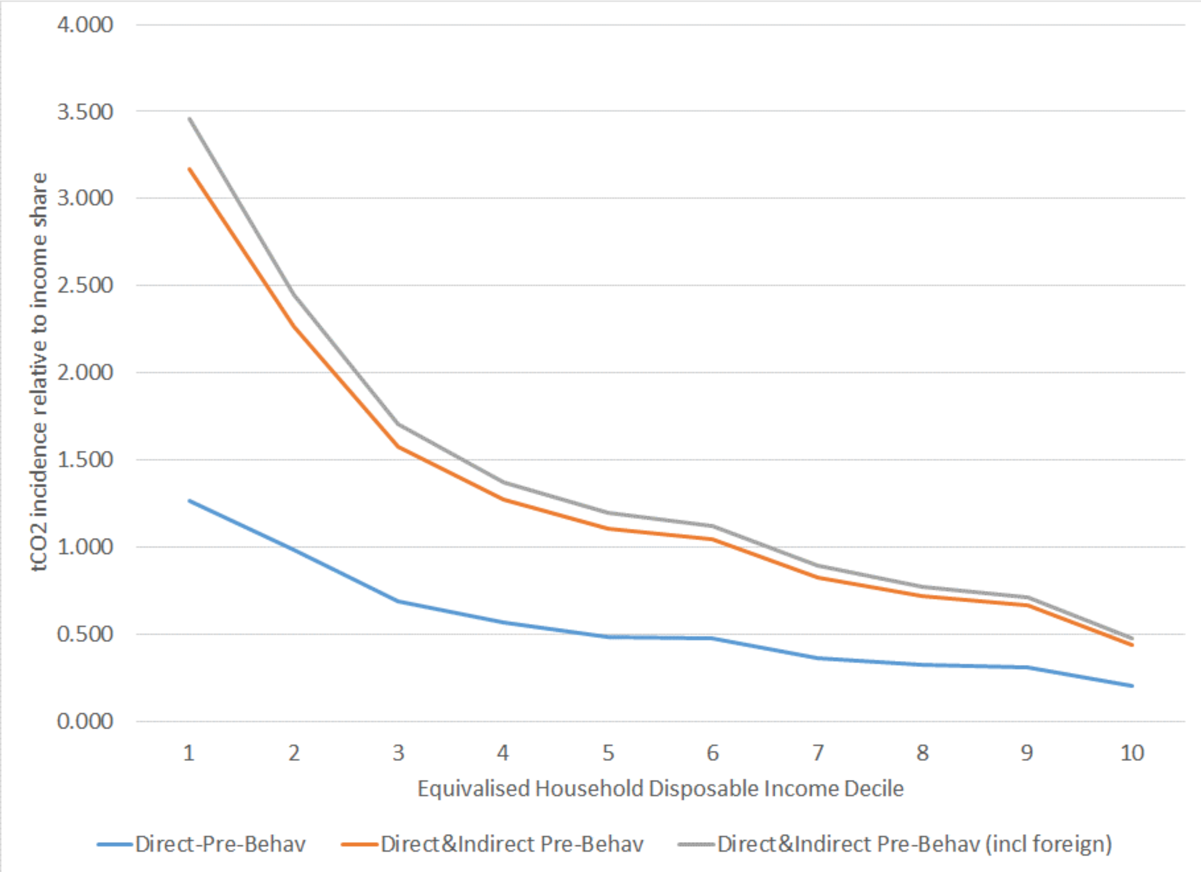


Source: Household budget survey.

Household carbon emissions result both from energy consumed directly by households and energy but also create carbon emissions indirectly We use the World Input-Output Database (WIOD) in order to model indirect emissions,.By incorporating carbon intensity data for each industry, the model can quantify the indirect emissions linked to household consumption of other goods and services.

Figure 4 shows how carbon dioxide emissions vary across equivalised disposable income deciles. CO2 per household measures total emissions, including direct emissions from fuel use and indirect emissions from consumed goods and services. As you move from lower to higher income deciles, CO2 per household typically decreases, reflecting lower direct, indirect, and imported emissions. Figure 4 shows the relationship between carbon dioxide emissions (tCO2) relative to income by household income decile. The table expresses income in terms of the ratio of the average income in the decile relative to the mean. The figure reports, the average tCO2 per household relative to this share, so in effect tCO2 per euro multiplied by mean income. Reflecting the high share of other expenditure sources and the low budget share of energy, most of the emissions (c. 60%) are indirect emissions, with emissions coming from imported goods and services at about 7% and about 40% of emissions coming from direct emissions from household energy consumption. Emissions expressed relative to income are regressive with a much higher budget share relative to income at the bottom of the distribution compared with the top. Indirect emissions are slightly more concentrated at the bottom of the distribution compared with direct emissions, while imported emissions are relatively flat across the distribution. The differential savings rate is a particularly important driver of this patterns, with the lower savings and dissavings, which may be attributed partially to measurement error result in a higher total budget shares relative to income

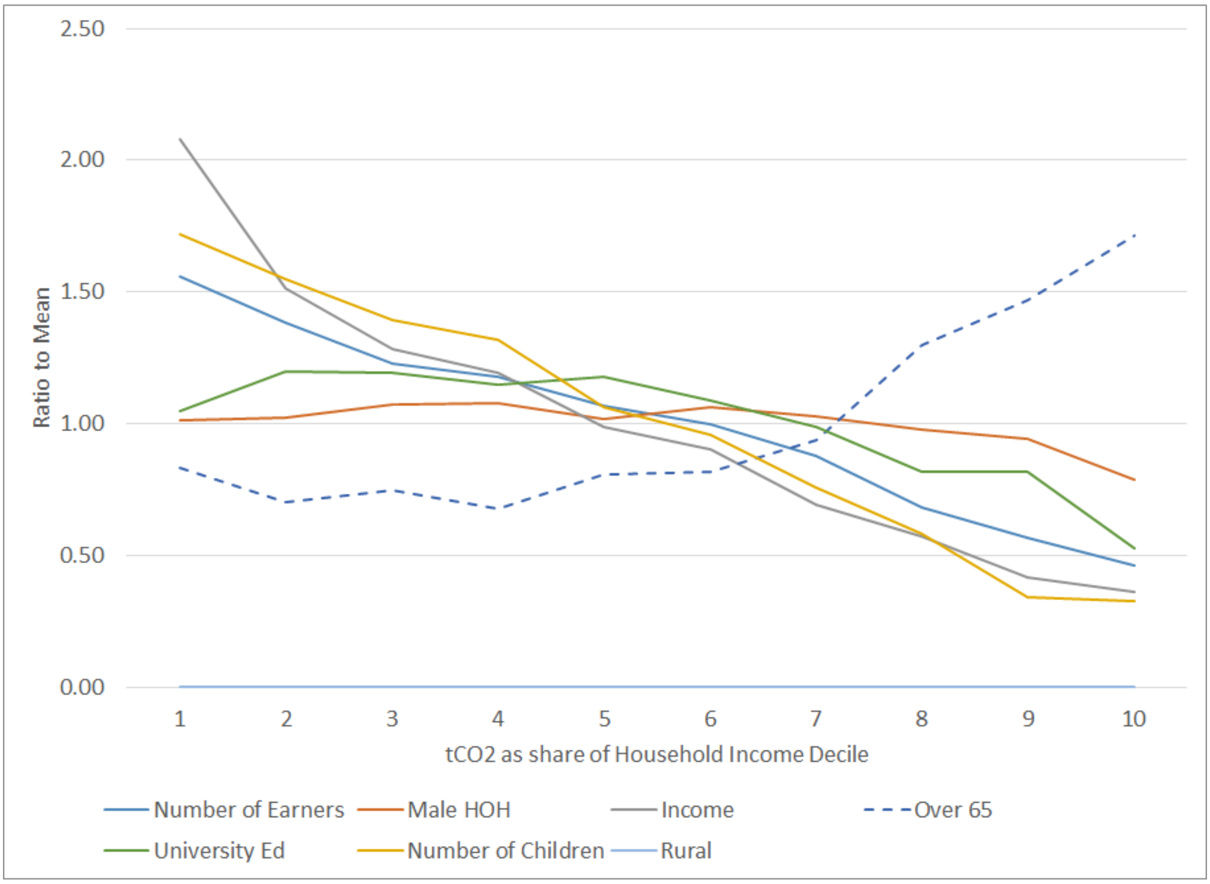
Figure 4. Emissions intensity (tCO2 per household income share) from household consumption, tCO2 per household across the income distribution (Türkiye)



Note: Average emissions across the income distribution, with tCO2 expressed as a share of income share (average income per decile relative to the mean) Estimates follow the "consumer responsibility" principle, accounting for all household consumption, including both domestically produced and imported goods.
Source: WIOD Input-Output database as well as household budget survey.

Emissions vary not only vertically across the income distribution, but also horizontally across different household groups. Figure 5 captures these horizontal differences by expressing the ratio of the household group category relative to the average. The higher the ratio, the higher a group is represented in that decile. The figure is expressed in terms of decile of carbon intensity or the ratio of carbon emissions per unit of household disposable income. There are two trends. There is a higher share of over 65s in households with higher carbon intensities. The other variables are concentrated in households with lower carbon intensities. A number of the variables are associated with higher incomes, the number of earners, the household head being male or being university educated. As the emissions intensity falls with income as outlined above due to both higher direct emissions shares and lower savings, it is not surprising to find variables associated with higher incomes having lower carbon intensities. The number of children per household is also associated with relatively lower emissions shares.

Figure 5. Household characteristics by decile of carbon intensity (CO2 per household income) (Ratio to the mean) (Türkiye)



Note: The ratios compare socio-economic characteristics between high-emitting and low-emitting households (based on emissions as a percentage of household income) in the following ways: For the number of earners and children in the household, the ratio represents the average number of earners and children per household. For other categories, the ratio indicates the number of households located in rural areas, those headed by males, those led by individuals with tertiary education, or those headed by pensioners.

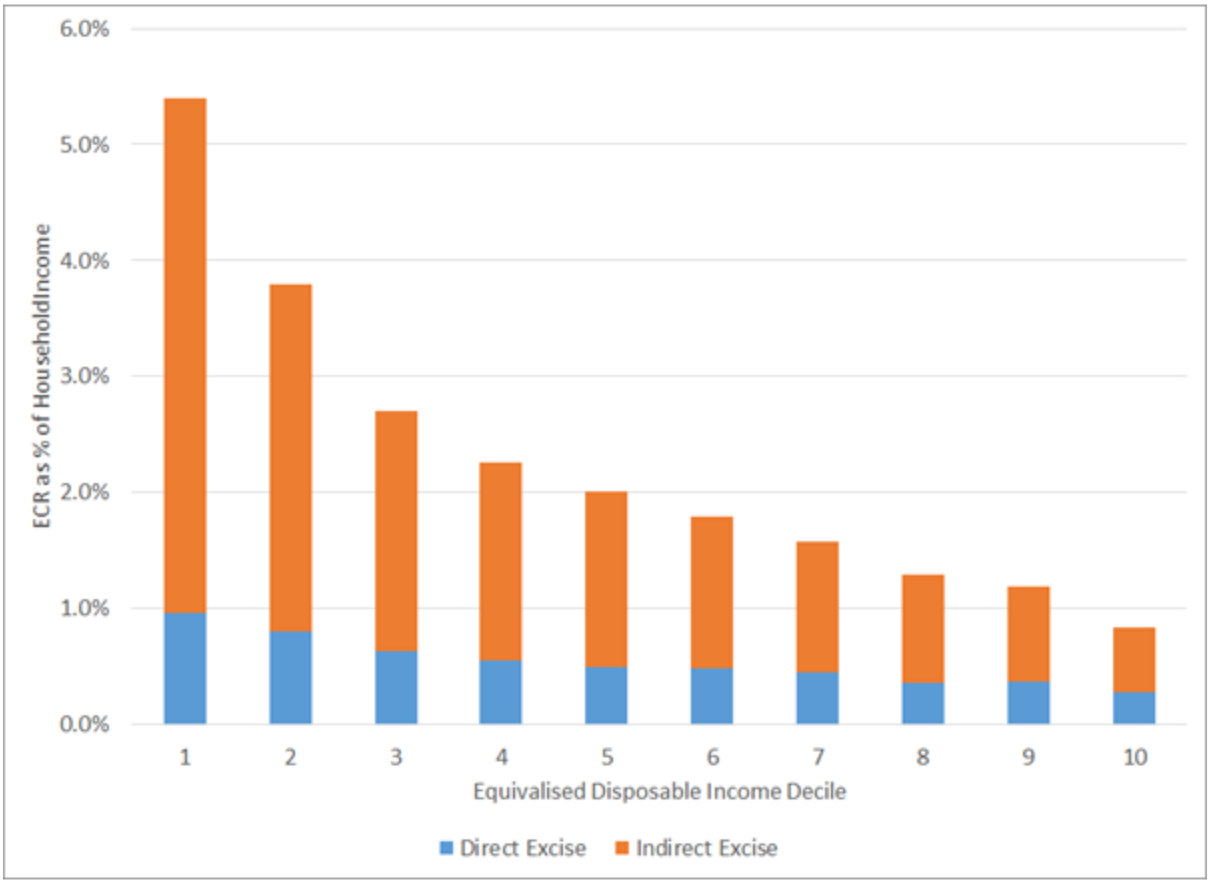
Source: Calculations utilizing emissions factors from the IEA for various fuels, along with data from the WIOD Input-Output database and household budget surveys conducted in 2015.

Converting Excise Duties to Carbon Taxation

Excise duties are an existing source of target indirect taxes on fuels as well as alcohol and tobacco. However as noted in table 1, the are highly non-linear with significant differential taxation on motor fuels relative to home fuels. Much of the move towards carbon taxation has seen a move away from excise duties (Elgouacem et al., 2024). Drawing upon the OECD Effective Carbon Rate database we report in Figure 6, fuel related excise duties as a percentage of household income across the income distribution. Given the higher share of non-energy expenditures, the highest share of excise duties relates to duties arising from fuel inputs to other goods and services purchased rather than excise duties associated with household fuel purchases.

Reflecting the distributional incidence of motor fuel expenditures, we see in Figure 6 the proportion of a household's income spent on excise duties across the income distribution. The decile representing the lowest-income households has the highest Excise Duty as a percentage of household income (ECR%) and then declining over the income distribution. This occurs in part, because lower-income households tend to allocate a larger portion of their income to motor fuels. This is a characteristic of regressive taxes, where the tax burden decreases as income increases (Linden et al., 2024; OECD, 2020). However the distributional incidence of excise duties is driven primarily because of excise duties associated with expenditures on other goods and services. As the carbon intensity is not that different between households in terms of the expenditure mix, the main reason for this difference is the difference the relationship between expenditure and income, savings. The proportion of indirect excise duties as a share of household income is higher and decreases for higher income groups, because wealthier households, having higher incomes, spend a smaller share of their income on taxed goods. This indicates that indirect taxes place a greater burden on lower-income groups.

Figure 6. Excise Duties as a percentage of disposable income by equivalised disposable income deciles, 2021



Source: ealculations using IEA emissions factors for different fuels, WIOD Input-Output database as well as household budget surveys (2015).
Note: ECR - Effective Carbon Rate. Excise – Excise Duties; CT Carbon Tax; ETS – Emissions Trading Scheme. D prefix means Direct; I prefix means Indirect.

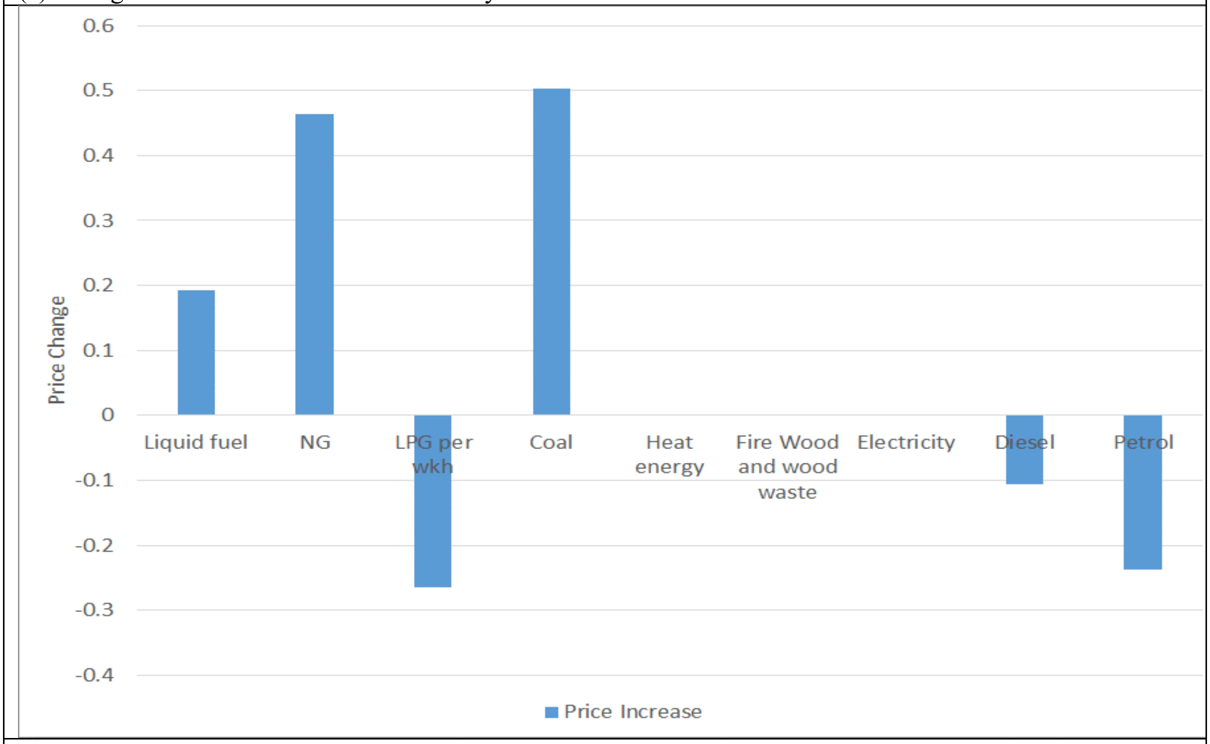
In Figure 7.a, we simulate a scenario where excise duties are replaced by a carbon tax, generating the same revenue prior to any behavioural response. As excise duties are levied only on petrol, diesel and LPG, a move to a revenue neutral carbon tax, would see a reduction in the tax rate on these fuels, with a corresponding increase in coal, natural gas and liquid heating fuels. Change in price from revenue neutrality shows coal and Natural Gas (NG) show the largest price increases, reflecting their high carbon emissions per unit of energy, with coal being the most carbon-intensive. Liquid fuel experiences moderate price increases, indicating significant but lesser impacts compared to coal and NG. LPG per kWh shows a notable price reduction, likely due to policy adjustments such as subsidies or tax exemptions. Petrol and diesel exhibit negative price changes, possibly resulting from compensatory mechanisms or structural market shifts to mitigate consumer impacts. Firewood and wood waste remain largely unaffected, reflecting their renewable nature and low carbon intensity. Similarly, heat energy show minimal price changes, potentially due to lower carbon intensity in generation or offsetting policy mechanisms like renewable energy subsidies.

Figure 7.b describes the change in revenue or two scenarios, (i) where there is revenue neutrality and (ii) where there is emissions neutrality after the switch from excise duties. These scenarios are simulated post behavioural response. Revenue neutrality means that the revenue from the increased carbon price is redistributed or offset to prevent a net financial burden on the economy or specific income groups. Without behavioural responses, the simulation is relatively trivial, however with a behavioural response using a demand system, we adjust the tax and run the behavioural simulation until neutrality is achieved. Emissions neutrality means that the emissions after the carbon tax is levied is the same (ie. within 2%) of the previous emissions total under existing excise duties. However as there is change in the nature of taxation, with greater taxation on heating fuels. The carbon tax rate is adjusted in 2% steps until neutrality (either revenue or emissions neutrality is achieved. In terms of revenue change, the revenue neutrality reform sees a shift in the revenue raising down the income distribution as fuels which have a higher budget share amongst the poorest have a higher tax rate, while motor fuels which are less targeted at the top, have a reduced tax rate.

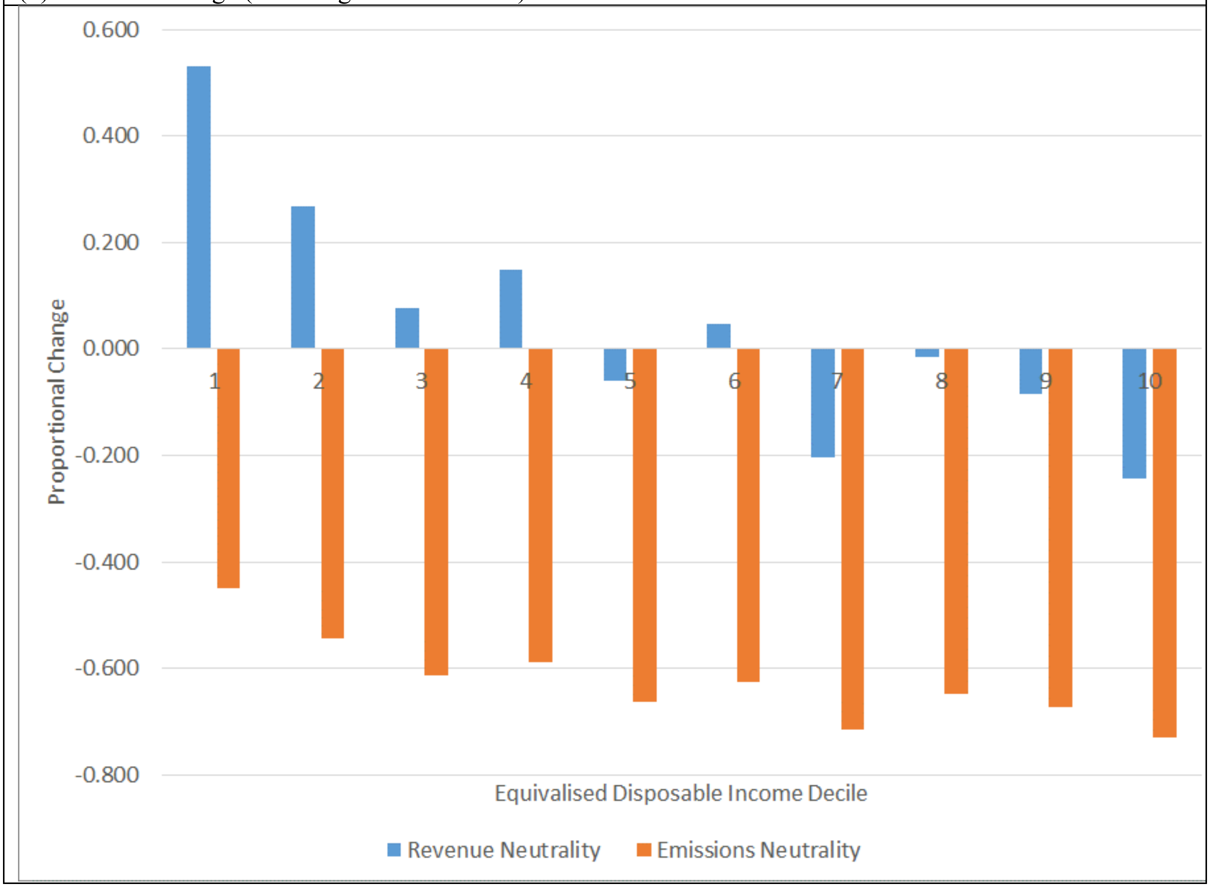
Figure 7.c reports the change in emissions that result from the switch in taxation. The emissions neutrality sees a minor shift in emission up the distribution reflecting the change in taxation. However the revenue neutrality scenario sees a reduction in emissions across the distribution, with a slight skewness towards the bottom of the distribution. This is a result of the price elasticity on heating fuels being higher than motor fuels and with former increasing and the latter decreasing.

Figure 7. Distributional Impact of Moving from Excise Duties to Carbon Taxes

(a) Change in Price from Revenue Neutrality



(b) Revenue Change (% Change in in Revenue)



(c) Emissions Change

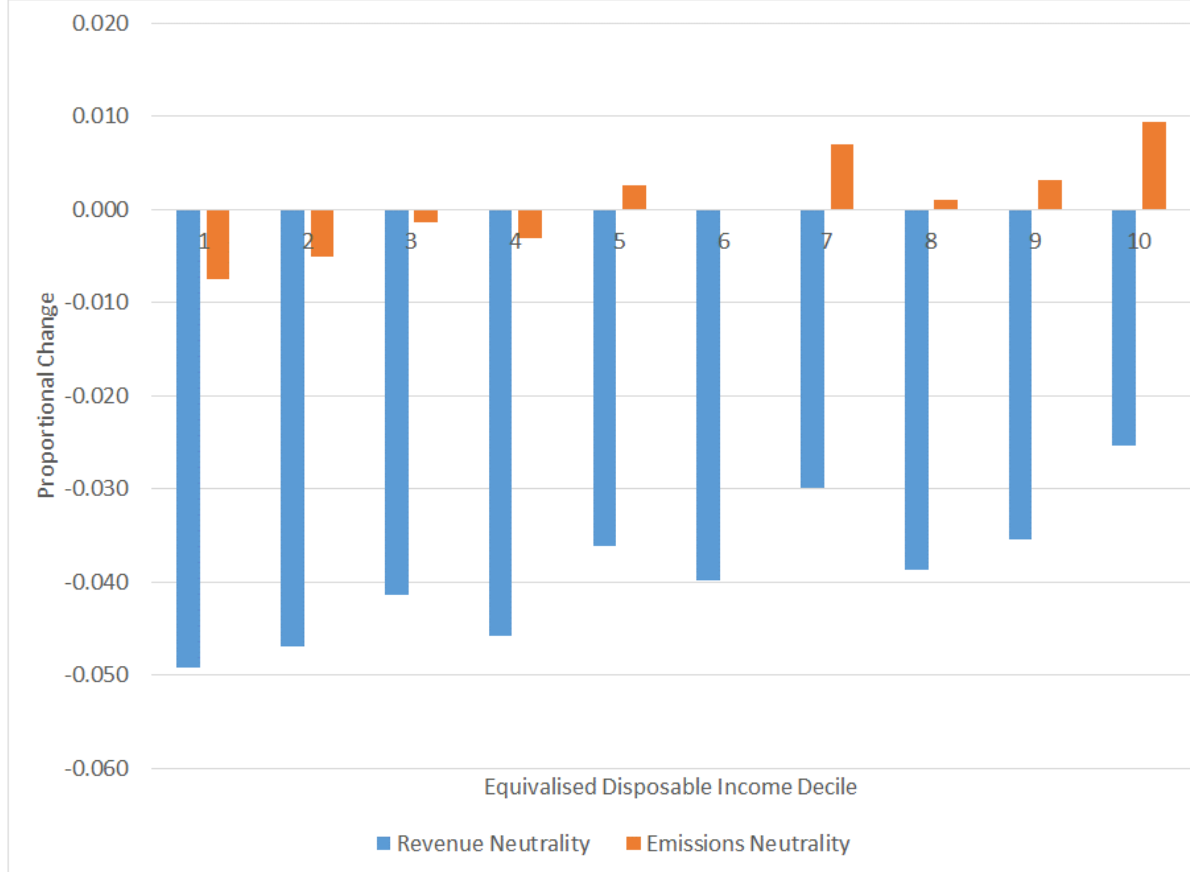


Table 3 provide some inequality statistics in relation to the scenarios considered. Gini Pre-tax remains constant at 0.40 across all scenarios, indicating no change in pre-tax income inequality. Gini Post-Carbon tax shows a slight increase (0.40 to 0.42) in the ED-CT (RN) scenario, indicating a marginal rise in inequality due to the tax. Other scenarios, ED-CT (EN) and CT30, show a small impact on inequality. Average Tax Rate (ATR) has the negative value in ED (-0.45) suggests a redistribution of the tax burden that may benefit lower-income groups, while the other scenarios show minor positive or near-zero changes. The Tax Concentration Coefficient refers slightly higher values in ED-CT (RN) and ED-CT (EN) suggest that the tax burden is somewhat concentrated among certain income groups, though the concentration remains low across all scenarios.

Table 3. Decomposition of Drivers of Distributional Impact of Climate Change

	ED	ED-CT (RN)	ED-CT (EN)
Gini Pre-tax	0.403	0.403	0.403
Gini Post - tax	0.419	0.400	0.400
Average Tax rate (ATR)	-0.45	-0.01	-0.01
Tax Concentration Coefficient (C)	0.10	0.12	0.11
Carbon Tax Regressivity (K)	-0.31	-0.28	-0.29
Carbon Tax Suits Index (S)	-0.31	-0.29	-0.29
Carbon Tax Redistribution (RS*100)	-0.02	0.003	0.004
Emissions (tCO2)	8.68	8.40	8.71
Revenue Surplus/Deficit % of Expenditure		0.000	0.24

Notes: G = Gini index of equivalized household Expenditure ; Gt = Gini index of equivalized household expenditure minus equivalized household carbon tax ; K = Kakwani = C - Gt ; S = Suits index; RS = Reynolds-Smolensky = G - Gt; Calculations are based on equivalized household expenditure.
Scenarios – redistributive impact of ED –Excise Duties; ED-CT – Excise Duty to Carbon tax conversion; CT30 - Carbon tax of €30 per tCO_2; RN – Revenue Neutrality; EN – Emissions Neutrality

Introducing a Carbon Tax

We now consider separately how an entirely new carbon tax would function. We utilise a nominal tax of €30 per ton similar to that used by Steckel et al., (2021) and Linden et al. (2024). The carbon tax is slightly inequality increasing, with a similar regressivity as the shift from excise duties to carbon taxation.

Table 4. Decomposition of Drivers of Distributional Impact of Climate Change

	CT30
Gini Pre-tax	0.403
Gini Post - tax	0.406
Average Tax rate (ATR)	0.009
Tax Concentration Coefficient (C)	0.110
Carbon Tax Regressivity (K)	-0.293
Carbon Tax Suits Index (S)	-0.299
Carbon Tax Redistribution (RS*100)	-0.003

Notes: G = Gini index of equivalized household Expenditure ; Gt = Gini index of equivalized household expenditure minus equivalized household carbon tax ; K = Kakwani = C - Gt ; S = Suits index; RS = Reynolds-Smolensky = G - Gt; Calculations are based on equivalized household expenditure.
Scenarios – redistributive impact of ED –Excise Duties; ED-CT – Excise Duty to Carbon tax conversion; CT30 - Carbon tax of €30 per tCO_2; RN – Revenue Neutrality; EN – Emissions Neutrality

Revenue Neutral Mitigation Measures

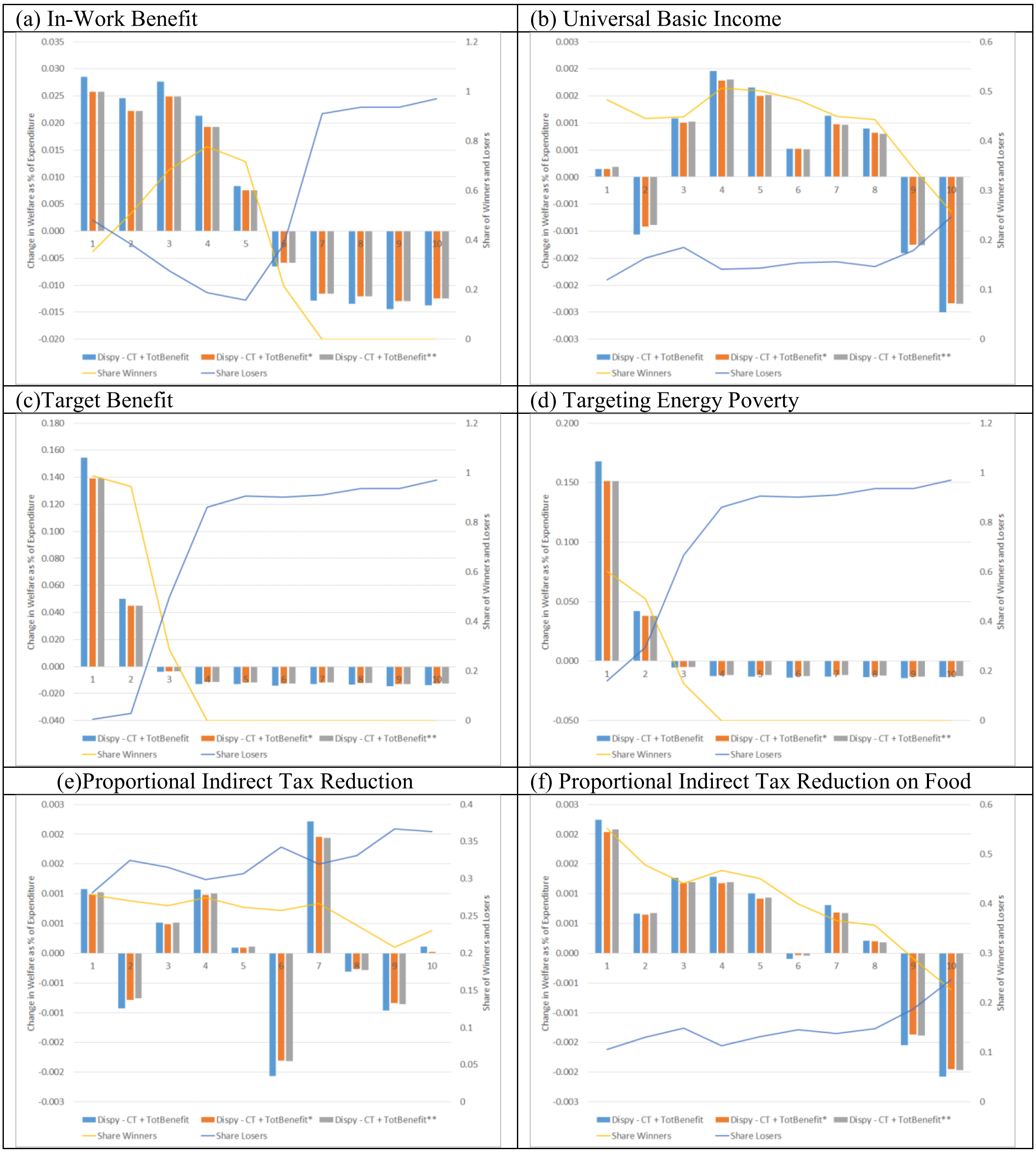
The carbon tax generates significant revenue, which is crucial for determining its distributional impact through revenue recycling. Figure 8 illustrates the impact on household welfare without revenue recycling, showing that the carbon tax burden increases with expenditure levels. However, the adjusted total impact is slightly smaller, as lower-income households spend less on taxed fuels.

We evaluate six potential mitigation measures funded through revenue recycling:

- In-Work Benefit: Supports low-income employed individuals, tapering off as incomes rise.
- Universal Basic Income (UBI): A flat-rate payment to all adults.
- Targeted Benefit for Low-Income Households: Provides support to those below the poverty line.
- Targeted Benefit for Fuel-Poor Households: Targets households facing high energy costs.
- Proportional Reduction in Indirect Taxes: Uses carbon tax revenues to reduce all indirect taxes.
- Proportional Reduction in Food-Related Indirect Taxes: Reduces taxes on food consumption.
- Proportional Reduction in Income Taxes: Lowers income taxes.
- Increase in Solar Panel Refit Tariff: Boosts support for solar panel installations.

Each measure is modelled as part of a revenue-neutral reform, where all carbon tax revenue is redistributed to households. The analysis aims to balance emissions reductions with equity across income groups, identifying strategies to mitigate the regressive effects of the carbon tax.

Figure 8. Net Distributional Impact of a Carbon Tax with Revenue Recycling (as % of Expenditure)



Note:

1. Dispy – CT + Measure: Net Impact Pre Behavioural Response; Dispy – CT + Measure *: Net Impact Post Price Behavioural Response; Dispy – CT + Measure **: Net Impact Post Income Behavioural Response
2. Deciles: Equivalised Expenditure

Figure 8 presents several analytical measures, categorized by equivalised expenditure, to assess the impacts of a carbon tax and various revenue recycling measures:

- Expenditure minus carbon tax plus Measure: Net Impact Pre-Behavioural Response
- Expenditure minus carbon tax plus Measure: Net Impact Post Price Behavioural Response*
- Expenditure minus carbon tax plus Measure*: Net Impact Post Income Behavioural Response**
- Share of Winners and Losers (with "winners" defined as those whose post-tax expenditure increases by more than 0.5%, accounting for both price and budget elasticity adjustments, and "losers" defined similarly for losses).

Two types of behavioural responses are accounted for:

- Price Response: Reflects changes in household expenditure resulting from price increases due to the carbon tax.
- Income Response: Reflects changes in expenditure driven by shifts in income from the redistribution of carbon tax revenue, influenced by the budget elasticity.

In-Work Benefits (5.a): The analysis shows that the greatest gains as a percentage of expenditure occur in the lower deciles, while losses are concentrated in the top half of the distribution. This measure targets individuals who earn less than twice the poverty line and are employed. As a result, it significantly benefits those at the lower end of the distribution, but those unable to work do not receive benefits. The price response helps to offset some of the initial income loss caused by the carbon tax, while the income response is modest, leading to an overall progressive net impact.

Universal Basic Income (5.b): This approach produces less extreme gains and losses compared to the in-work benefit, but a broader base of beneficiaries, especially in the lower three quarters of the distribution, except for the second decile, albeit the average difference across all deciles is so small, this conclusion is not important. The flat-rate nature of the UBI results in a more evenly distributed benefit, making it a more inclusive but less targeted approach to redistribution.

Means-Tested Benefits Targeted at Those Below the Poverty Line (5.c) and Energy Poverty Targeted Benefit (5.d): These measures achieve the highest gains for the poorest households, with winners concentrated heavily at the bottom of the expenditure distribution. However, the significant degree of targeting introduces concerns about creating "unemployment traps," where the incentives to seek or maintain employment are reduced due to the sharp tapering of benefits.

Reduction in Indirect Taxes (5.e): This method has the least pronounced distributional impact among the measures considered.

Reduction in Food-Related Indirect Taxes (5.f): When revenue recycling is directed specifically at reducing taxes on food, there is a higher proportion of winners among lower-income households. This measure is especially beneficial for those at the bottom of the distribution, as food makes up a larger share of their overall spending.

Redistributive Impact

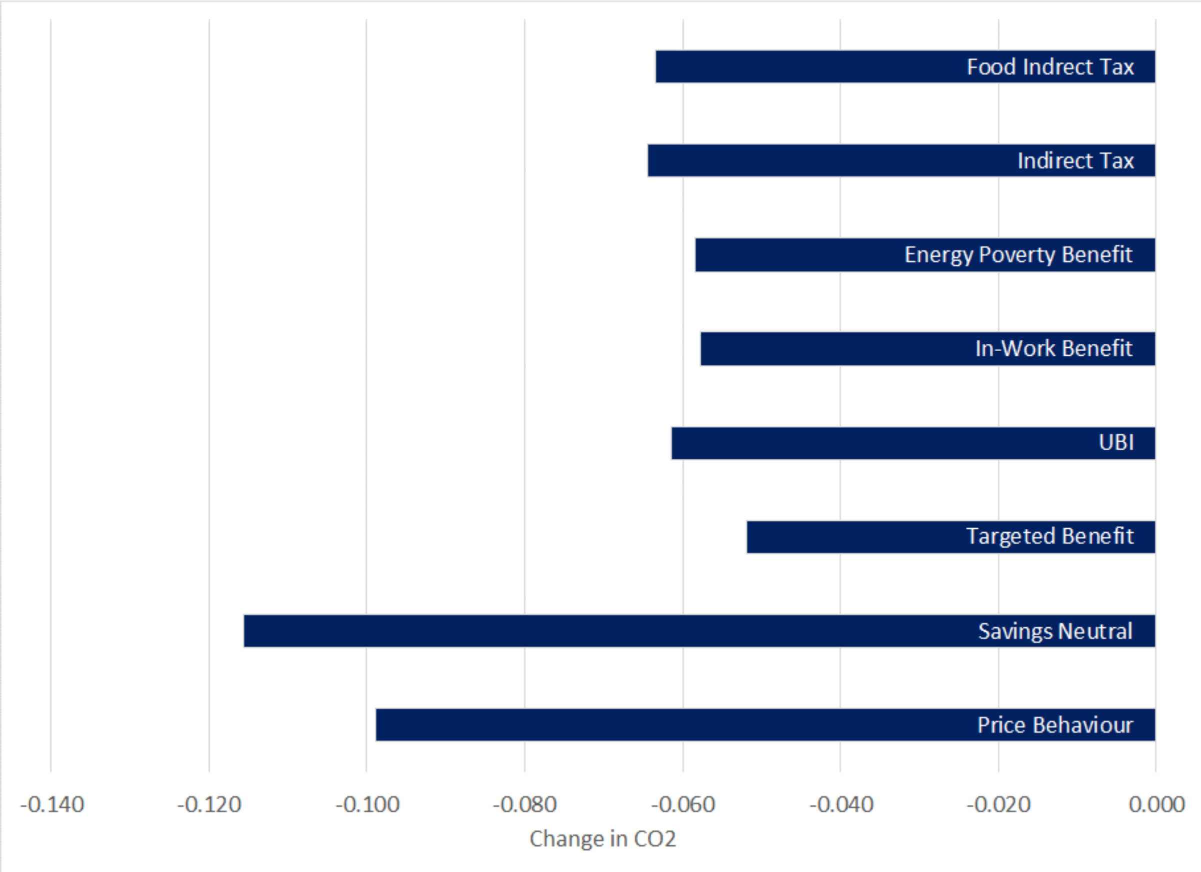
The overall redistributive effects of these measures are quantified by examining changes in the Gini coefficient of equivalised expenditure before and after the carbon tax and revenue recycling (Figure 9). The carbon tax by itself increases income inequality. Comparing measure by measure, we find that the redistributional impact of the combined revenue recycling and carbon tax is greater than carbon tax by itself:

a. Targeted Benefits: Using carbon tax revenues to increase targeted benefits (such as those for low-income or energy-poor households) is the most effective approach in reducing inequality, as reflected in a more substantial reduction in the Gini coefficient. However, this approach may reduce incentives to work due to its highly targeted nature.
b. In-Work Benefits: This approach is also progressive, as it focuses on low-income earners, but it excludes those who are not employed. It strikes a balance between supporting lower-income workers and preserving work incentives.
c. Reducing Indirect Taxes: Using recycled revenues to lower indirect taxes has the least progressive effect, as it provides a more evenly distributed benefit across all income groups. While it offers some relief to lower-income households due to their spending patterns, it is not as effective in reducing overall inequality.

Figure 9. Change in Gini for different Revenue Recycling Options (by behavioural change)

Figure 10 illustrates the changes in greenhouse gas (GHG) emissions resulting from the combined effects of the carbon tax and various revenue recycling strategies. It shows two scenarios for price-related impacts without revenue recycling: one based on a basic price elasticity and another assuming a fixed savings rate. The basic price elasticity scenario captures how households adjust their consumption in response to increased prices due to the carbon tax, resulting in a GHG emissions reduction of about 10% and slightly less if we assumed the savings rate was constant. Revenue recycling reduces the emissions reduction by about one third, with the most redistributive instruments such as the targeted and energy poverty benefit reducing emissions by slightly less than less targeted revenue recycling. This is because financial gains by poorer households result in proportionally higher energy demands.

Figure 10. Environmental Impact – change in greenhouse gas emissions.



4. Conclusions

This paper assesses the distributional effects of carbon pricing in Türkiye using various instruments, including Excise Duties, Carbon Taxes, and the EU Emissions Trading Scheme using the PRICES model, which is based on the Household Budget Survey and the World Input-Output Database.

Essential energy consumption represents a significant expenditure, especially for low-income households, highlighting regressive spending trends across different income levels. The direct impact of carbon pricing on household finances depends on the fuels used for heating and transportation, while the indirect impact relates to the emissions linked to other goods and services. Carbon footprints differ substantially among households, with higher-income households generally emitting less as a proportion of their income.

This paper goes beyond the state of the art for middle income countries by analysing not only the gross distributional impact of carbon pricing but also the net impact of carbon pricing together with different tools to recycle revenue. Additional carbon taxes equivalent to €30 per tCO_2 are regressive, increasing inequality. Carbon pricing reforms therefore tend to exhibit regressive characteristics, disproportionately impacting lower-income households in relation to their earnings. Middle-class households also experienced significant effects, indicating that carbon pricing affects a wide segment of the population. However we find that revenue recycling has a greater impact on inequality than the tax itself, with targeted instruments reducing inequality, while flatter instruments when combing with the carbon tax do not fully compensate for the increased inequality from the carbon tax. Decisions regarding the allocation of carbon pricing revenues back to households as part of broader policy frameworks can help alleviate losses and shape distributional outcomes. However, the design of these policies is crucial. Simple compensation methods, may not be efficient and could divert funds from other essential programs.

Additional carbon taxes equivalent to €30 per tCO2 are regressive, increasing inequality. However we find that revenue recycling has a greater impact on inequality than the tax itself, with targeted instruments reducing inequality, while flatter instruments when combing with the carbon tax do not fully compensate for the increased inequality from the carbon tax. While much of the international literature focuses on theoretical carbon prices, we also consider how potential carbon pricing would interact with existing instruments which indirectly price carbon such as Excise Duties. We evaluate both the relative performance of existing excise duties and additional carbon taxation. Despite the relative large change in the tax rate, replacing excise duties with carbon related excise duties has a relatively small distributional impact, with carbon taxes slightly less regressive than excised duties.

In addition as the objective of carbon pricing is to incentivise changed behaviour, we incorporate the behavioural impact of introducing carbon pricing and the consequential reduction in carbon emissions. Although the carbon tax reduced emissions, revenue recycling mitigated this impact with a trade-off between redistribution and emissions reduction.

Middle income countries like Türkiye will be amongst the biggest source of carbon emissions over the next decade. It is critical that appropriate mechanisms are introduced to incentivise a shift away from carbon emissions. Recent geopolitical events have highlighted challenges where energy security issues incentivised a reversal in shift away coal power electricity generation. Given the regressive nature of carbon pricing, it is essential both from an equity point of view and from a political economy point of view to co-design combined energy pricing and mitigation measures to aid a just transition. It requires more combined energy and social policy analyses undertaken in this paper so that more refined policies can be develop that deliver multiple carbon reduction and equity sensitive reforms.

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