Supported by:

November 2023

DISTRIBUTIONAL IMPACT OF CARBON PRICING IN CENTRAL AND EASTERN EUROPE

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Distributional Impact of Carbon Pricing in Central and Eastern Europe

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Acknowledgements:

This project is part of the European Climate Initiative (EUKI). EUKI is a project financing instrument by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). The EUKI competition for project ideas is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It is the overarching goal of the EUKI to foster climate cooperation within the European Union (EU) in order to mitigate greenhouse gas emissions.

The authors would like to thank Radu Răuță, Claudia Tufiși, Caterina Oproiu, and Corina Lazăr for their contributions to this project and this report.

Suggested quotation:

Energy Policy Group (2023), Distributional Impact of Carbon Pricing in Central and Eastern Europe

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Executive Summary

Carbon pricing is widely seen as an effective policy option to pursue reductions in GHG emissions. Either through carbon taxes or emissions trading systems (cap and trade), carbon pricing reduces the negative externality of GHG emissions. By putting a price on emissions, economic agents can incorporate this cost in their investment, production, and consumption decisions. In time, this leads to lower emissions. At the same time, this policy can have negative effects on the economy and households, associated with the additional cost of emissions. The negative effects can be alleviated or even reversed through revenue redistribution. The sums collected by Governments can be directed toward investment in low-emissions alternatives and support for low-income households. The European Union's Emissions Trading System represents a significant example of carbon pricing. It covers emissions from industry and electricity generation and has been effective at achieving emissions reductions. Recently, a separate Emissions Trading System has been introduced for buildings and road transport (ETS2), with the aim of generating similar results in these sectors. There is concern that ETS2 may affect low-income households and the economy in general by purposely increasing the prices of emissions-intensive goods. To address this, the EU also adopted the Social Climate Fund, which uses part of the revenue collected by auctioning emissions allowances to finance investments in low-carbon technologies and support for low-income households.

In this context, this paper adds to the extensive body of evidence on the economic impact of carbon pricing with revenue redistribution. It presents the results of a simulation model of a hypothetical carbon tax in Bulgaria, Germany, Hungary, Poland, and Romania. The macroeconomic impact is evaluated by calculating the effects of this carbon tax on GDP and employment by sector. At micro level, the focus is on welfare losses across deciles and energy poverty, before and after revenue redistribution.

The carbon tax is set through the dynamic stochastic general equilibrium model MEMO at the level required to induce emissions reductions of 40% by 2032 compared to 2022. The tax ranges from 2.95 USD/tonne of CO2 in Romania to 14.57 USD in Hungary in 2022 and goes up to 15.91 USD in Romania and 73.65 USD in Hungary in 2032. This stylized tax is then applied to all sectors of the economy and the model estimates the impact on GDP and employment.

At the macro level, a dynamic stochastic general equilibrium model MEMO is used to evaluate the effects on GDP and employment. The results of the macroeconomic modelling show a small negative impact on GDP for the period until 2032. In the cases of Germany, Bulgaria and Romania, the observed negative deviations are negligibly small, and even in Poland, which would see the largest effect on GDP (around 1%), economic growth would still be strong over the observed period. In terms of the labor market, the carbon price barely affects employment rates by 2032. The expansion of low-carbon sectors would likely offset the losses in employment in carbon-intensive sectors.

At micro level, the effect on households is calculated using the QUAIDS demand system estimation model, applied to the Household Budget Survey data for the five countries. The variable of interest is welfare loss – the additional income, as a percentage of the initial consumption, needed for a household to maintain the same level of consumption after the introduction of the carbon tax.

Overall, before redistribution, the carbon tax seems to display minor regressive tendencies – the welfare loss is slightly higher for lower income households (around 1 percentage point). This means that the relative burden imposed by the tax on households belonging to the lower income deciles in all five countries is higher than the burden for more affluent households.

Looking at country level, Hungary has the highest welfare losses in 2032, calculated as the mean loss for the population (followed by Poland), while Bulgaria has the smallest (followed by Romania). Germany stands in the middle of the distribution of average losses in 2032. Nevertheless, the five countries are comparable, with their losses mainly ranging between 0.9% and 2.6% of total expenditure.

The revenues collected from the carbon tax can be redistributed. Three scenarios for redistribution were tested: (1) a lump-sum transfer scenario that redistributes the revenues equally to all households, (2) a price subsidy scenario where revenues are used to alleviate the welfare effects of the price increases for lower income households, and (3) a double-dividend scenario in which revenues are used to reduce other distortionary taxes.

Based on these scenarios, we observed that carbon pricing can improve the welfare of the least affluent when coupled with the right redistribution strategy. This is the case for all five countries in the price subsidy or the lump-sum scenarios. In particular, this is relevant for countries with relatively high welfare losses, such as Hungary or Germany. Furthermore, lower-income countries, such as Romania and Bulgaria, also see the average losses of the lowest deciles reduced dramatically - in some cases, they even gain after redistribution.

The impact of carbon pricing on energy poverty can also be estimated. In most countries, the carbon tax with redistribution through price subsidy or lump sum strategies results in slightly lower energy poverty rates than in the baseline. However, the results seem to indicate that the impact on energy poverty is rather small, whether positive or negative, if the carbon tax is complemented by revenue recycling.

We conclude that carbon pricing with revenue redistribution represents a desirable policy option for decarbonization. It can induce rapid emissions reduction, with relatively low negative impacts on GDP and employment and potentially positive impacts on welfare in low-income households. If designed together with other policies, promoting low carbon alternatives and providing income support to households, carbon pricing can be effective at lowering emissions, spurring investment in low emissions technologies and behavior change while reducing energy poverty. At the same time, governments need to focus on the implementation of carbon prices and revenue redistribution to ensure support reaches the households that need it most, particularly in countries with historically low EU funds absorption rates and ineffective social welfare policies.

Introduction

To deliver on the commitments under the Paris Agreement and mitigate the worst effects of climate change, all EU Member States need to continue reducing GHG emissions. At EU level, the goal is to reduce emissions by 55% by 2030 compared to 1990, and to reach net zero emissions by 2050. All member states and all sectors need to contribute to this goal. Carbon pricing with income redistribution is widely seen as an effective and fair way of achieving emissions reductions (IMF, 2019). Without carbon pricing, the carbon emissions resulting from the production and consumption of goods generate costs that are borne by society in general and not by their producers or consumers. A carbon price aims to incorporate those costs into the prices of emission-intensive goods and thus make less emissions-intensive goods relatively cheaper. This is expected to encourage people to change their consumption behavior away from carbon-intensive goods and toward low-carbon alternatives. Carbon pricing is politically sensitive because, in the short run, it may hurt the economy of a country. At micro level, it may negatively affect the welfare of households, which would face higher prices for the goods they currently consume. This is particularly relevant for energy, which is responsible for the highest share of total emissions and therefore would see a price increase proportional to its carbon intensity. At EU level, 34 million citizens are already experiencing energy poverty. An economy-wide carbon pricing mechanism risks exacerbating this situation by increasing the prices of carbon intensive goods. Moreover, carbon pricing may also be regressive, i.e. hurt low-income households disproportionately, as consumption represents a higher share of their income. To overcome this risk, carbon pricing is often proposed together with revenue redistribution mechanisms. The revenues collected through carbon pricing would be substantial at the beginning of such a scheme and they could fund income support measures and investment in lower-carbon alternatives for the worst affected households. This can achieve emissions reductions, help alleviate poverty, and accelerate the deployment of low-carbon technologies, all at the same time.

The main types of carbon pricing are Emissions Trading Systems (also called cap-and-trade) and carbon taxes.

Emissions Trading Systems (ETS) establish a declining cap on allowed emissions and require polluters to purchase and trade emissions allowances at prices set by supply and demand. The current EU ETS covers the industrial, aviation and power sectors, and has recently been expanded to the maritime sector. The EU is also preparing to implement an ETS for the buildings and road transport (BRT) sectors (ETS2). Under the ETS2, suppliers of fuels for BRT will have to purchase emissions allowances, with the total number of available allowances gradually decreasing over time. This would expose households to a carbon price and should thus incentivize them to seek lower carbon alternatives. To mitigate the potential impact on lower-income households, a Social Climate Fund (SCF) will be set up to finance temporary income support measures, as well investments for reducing GHG emissions from heating and transport. Each member state will have to develop a social climate plan (SCP) describing how revenues will be disbursed.

Carbon taxes, on the other hand, establish a price of carbon and impose it on certain polluting economic activities through the tax system. There are several countries operating carbon taxes, including the Scandinavian countries, Switzerland, and others.

Both types of carbon pricing have been shown to be effective, provided that the carbon price is high enough to create a strong incentive for polluters to seek lower-carbon alternatives (Köppl and Schratzenstaller, 2022). At the same time, carbon taxes tend to be simpler to manage as they can be implemented through existing tax systems.

To further investigate the economic and social feasibility of carbon pricing, we simulate a stylized general carbon tax, evaluating its impact on the economy and the welfare of the population in five countries: Bulgaria, Germany, Hungary, Poland, and Romania.

This general carbon tax is significantly different from existing carbon pricing at EU level (ETS) and represents a theoretical exercise, evaluating the impact of the most comprehensive solution to the externality: taxing all embedded emissions at the level of the consumer. This tax is applied for the entire economy and comes on top of the already exiting ETS price applicable to power generation, heavy industry, and aviation. The carbon tax is conceptualized as the additional cost of GHG emissions embedded in consumption goods that can deliver the emissions reductions in line with a trajectory for climate neutrality by 2050. We study the impact of such a tax – proportional to the carbon content of all consumption goods – on macroeconomic indicators, on consumer welfare, and expenditure patterns. In addition, we look at several revenue recycling options.

This simulation aims to add to the body of evidence on the effects of carbon pricing and inform policy makers on the potential impact of an idealized policy, abstracting away from any issues of implementation. In reality, a carbon pricing scheme would be less comprehensive and the associated impact less pronounced than in the simulation presented in this study. In addition, we consider that the carbon tax would be passed through entirely to consumers, whereas in reality, due to competitive pressure, this may not be the case.

Problem statement and literature review

This section will review existing literature on the effectiveness of carbon pricing at household level and revenue recycling in more general terms. The focus will be on reviewing evidence on the following points:

- Whether a carbon price is effective for reducing emissions at household level;
- Whether a carbon price has negative economic, welfare and distributional impacts;
- Whether potential negative impacts can be mitigated through revenue recycling.

The World Bank (2022) models a carbon tax for the non-ETS sectors in Bulgaria, Croatia, Poland, and Romania. It includes two scenarios: (1) low-ambition starting at €15/ton in 2021 and reaching €50 in 2030, and (2) Paris-aligned starting at €45/ton and reaching €90 in 2030. Both scenarios result in reduced GHG emissions - the low-ambition scenario generates between 5 and 7% reductions compared to the baseline, while the Paris-aligned scenario has more divergent results ranging from 22% in Poland to 9% in Romania. If the revenues are used to reduce labor taxes, the GDP impact of the carbon tax would be positive in the short run and neutral in the longer run under both scenarios. In terms of employment, Bulgaria, Croatia, and Romania would see net job growth under both scenarios, while for Poland the presence of a large coal base makes results less homogenous (some regions are affected negatively while others positively).

The European Commission (EC) evaluated potential impacts of carbon pricing through cap and trade in its impact assessment on the possible extension of the ETS to BRT (European Commission, 2021). The document reviews the experience of several jurisdictions and finds mostly positive evidence in terms of effectiveness of carbon pricing. The EC's modelling shows significant emissions reductions across the range of carbon prices assumed – from €30/ton to €150/ton. The reductions by 2030 compared to the baseline range between 2.9% in buildings and 1.8% in road transport at the lower end, and 11.7% in buildings and 7.8% in road transport at the higher end. In terms of distributional impacts, the EC confirms the higher impact on low-income households even in high income countries – as their share of expenditure for heating and cooling of buildings is higher and the price elasticity of their demand is lower. However, the regressivity would not be significant for road transport, where expenditure patterns and price elasticities are less clearly linked to income.

Stenning et al. (2020) conducted a macroeconomic simulation on, among others, the introduction of a separate ETS for the BRT sectors with prices linked to existing ETS and presented the impacts on emissions in 2030, as well as distributional effects. They find limited additional emissions reductions compared to the baseline scenario – around 5% by 2030 for heating and less than 1% for road transport. As for distributional effects, the carbon price would lead to an increase of 6% in heating expenditure for the low-income households and only a 1% reduction in demand. This assumes an elasticity of 0.21 (an increase of 1% in price generates 0.21% decrease in consumption). For road transport, the expenditure of the lowest quartile household goes up by 3% and demand is reduced by 1%. The elasticity assumed is 0.30. They conclude that an ETS on the BRT sectors would not be the most effective tool for reducing emissions significantly. The BRT sectors tend to have lock-in effects – the equipment used has a long lifetime and switching is costly. This makes demand response to a carbon price relatively rigid, especially for lower income households for whom BRT are essential services. In the study, revenue recycling options are used to replace various taxes. This has positive effects on GDP but does not mitigate the impact on lower income households. In the actual EU policy proposal, the SCF is a relevant tool to compensate such households for the increases in BRT costs.

Maj et al. (2021) find that significant results in terms of emissions reduction of –40% would require a price of €170/ton and show that a mix of complementary policies would be best suited to obtain the desired objectives. They also find the BRT sectors to have low price elasticities, which implies that the high upfront costs of low-carbon alternatives are the main barrier to switching technologies and fuels. This means that the policy would be regressive in the absence of revenue recycling. On the other hand, revenue recycling is seen as weakening the effectiveness of carbon pricing though rebound effects.

ETS2 – Emissions Trading in the Buildings and Road Transport Sectors and the Social Climate Fund (SCF)

The European Union recently adopted a form of carbon pricing with revenue redistribution – ETS2 and the SCF - which should start in 2026. While different from the carbon tax simulated in this study, some effects are likely to be similar. The theory of change of ETS2 is similar to any cap and trade system – a cap on total emissions is created that decreases at a known rate and emissions allowances are auctioned to market players who are obliged to purchase them based on their emission intensity. This creates the incentive to lower emissions at the least cost, while the revenues collected can be invested back into climate positive projects. In the long-term, the artificially induced scarcity of emissions allowances means that their price will increase, until no more allowances are released into the system.

The ETS2 covers suppliers of fuels for the BRT sectors. The political sensitivity of ETS2 stems from the direct and visible impact on consumers, the difficulty of switching to low carbon alternatives and the potential regressivity – lower income households tend to spend a higher share of their income on housing related energy expenditure (less clear for road transport). On the supply side, a successful ETS2 would see GHG emissions from the BRT sectors decrease at the expected rate due to investments in low-carbon technology and innovation. On the demand side, emissions would decrease through investments in energy efficiency or low carbon technologies, partially funded with the revenues created by auctioning allowances. To cushion the immediate impact on the most vulnerable households, some of the ETS2 revenues would also be used for temporary income support.

Görlach et al. (2021) examine several design options for the ETS2 and SCF by assessing distributional impacts, both between MSs and between different income groups at EU level. At a price of €50/ton, the findings confirm the risk of regressivity of the introduction the ETS2, in the absence of compensation. The losses range from 0.5% of income in the lowest decile to 0.3% in the highest. When revenue recycling is introduced under two scenarios – equal per capita allocation at EU level or at MS level – the policy becomes progressive. The six lowest income deciles would experience net gains from ETS2 with recycling. The analysis goes further and identifies high-intensity consumers as those within the first three income deciles that have energy expenditure as a share of income higher than one standard deviation above the median. There are 6.2 million people who meet this criterion in the EU and most of them live in Bulgaria, Hungary, Poland, and Romania. Compensating all these consumers would require less than 10% of the revenue generated by the ETS2 - around 25% of revenues would be enough to compensate all such energy-intensive consumers in the EU. This, of course, assumes that such accurate targeting is feasible and cost-effective from an administrative point of view.

Held, Leisinger and Runkel (2022) assess the ETS2 and SCF based on criteria of equity and effectiveness. Using a static model, they find that the SCF would ensure a significant redistribution towards poorer MSs, with Romania and Bulgaria being the top recipients on a per capita basis. In addition, at a EUA price of €55, they find similar impacts within income quintiles at MS level. In all MSs, the impact as a percentage of expenditure is below 2%, but higher in low-income MSs. However, within countries the differences between quintiles are insignificant. They also find the SCF to be sufficient to cover the lower-income quintiles – 25% of the revenues (about half of the SCF allocation under the EC proposal) would be enough to compensate the first two quintiles in all MSs.

Gore (2022) conducts a static microsimulation based on HBS data to assess the cumulative impacts of the Energy Taxation Directive (ETD) reform and introduction of the ETSs and SCF. At €45/ton and looking at EU-wide expenditure deciles, the ETS2 would be slightly regressive, with welfare losses below 1% (shares of expenditures). The various revenue recycling options compensate for that significantly. One option – 25% of ETS2 revenues plus new ETD revenues targeted to the poorest 50% - creates welfare gains for the lowest decile of around €100 per household per year. If all ETS2 revenues would be directed at the poorest 50% of all households, the policy becomes strongly progressive.

Berghmans (2022) also finds CEE countries to be most affected by the cumulative effects of the ETD reform and the introduction of the ETS2. The results of the static simulation using HBS data and a €45/ton carbon tax show that Poland (2.1%) and Hungary (1.6%) would see the highest welfare losses. These losses could be mitigated by recycling 25% or all of the revenues collected through ETS, with most countries no longer having average welfare losses (except Poland and Germany).

Braungardt et al. (2022) analyze the adequacy of the SCF and confirm that the impact of the ETS2 is regressive especially for the buildings sector, where lower income households spend a higher share of their income on heating. The SCF, as proposed by the EC, contains a significant inter-MS redistribution effect, but this effect is reduced drastically at higher EUA prices, if the total envelope remains constant. Otherwise, the SCF seems to be sufficient to compensate vulnerable households for the additional BRT related costs. The targeting of such households is seen as a significant implementation challenge.

As shown through this brief literature review, the evidence on the effectiveness of carbon pricing and its social impact is mixed, and the heterogeneity in terms of methodology and data used makes the various findings difficult to compare. Overall, the potential regressive effects of an ETS for BRT are largely confirmed, while the impact on lower income households can be, if we ignore the implementation complexities, adequately mitigated by the SCF. The next section presents the results of simulating an idealized carbon tax, using a novel model, in terms of the macro- and micro-economic impact in five countries: Germany, Poland, Hungary, Bulgaria and Romania.

Methodology and data

To evaluate the potential impacts of implementing economy-wide carbon pricing, we utilized a comprehensive, data-driven approach that incorporates a wide range of factors to accurately predict macroeconomic and microeconomic consequences. The analysis begins by modelling individual carbon price levels for each country, aiming for a 40% reduction in national CO_2 emissions by 2032 compared to 2022, considering each nation's unique circumstances.

The model then calculates the necessary carbon price for each nation to achieve this emissions reduction target, considering factors such as the country's macroeconomic situation, carbon intensity, trade structure, energy mix, and the relative effectiveness of various mitigation strategies. Carbon prices are assumed to rise linearly over the modelled period. These predicted carbon price levels are then used to determine the potential deviations in macroeconomic indicators, such as GDP, employment, and sector-specific value added (including agriculture, manufacturing, and services), from a baseline scenario without carbon pricing between 2022 and 2032.

To examine the effects on households of the carbon price derived from the macroeconomic model, the study measures changes in welfare across various income groups and energy poverty levels, which are important indicators of social equity. Utilizing national household budget survey data and a microsimulation model, the analysis estimates the additional financial burden (welfare losses) on households by determining how much more each income group, from the poorest 10% to the wealthiest 10%, would need to earn on average to maintain their pre-carbon-price consumption levels. This assessment takes into account the carbon intensity of household consumption, the resulting cost increases due to carbon pricing, and the anticipated shifts in consumption patterns based on microsimulations that consider price changes, price elasticities of demand, and potential behavioral adjustments.

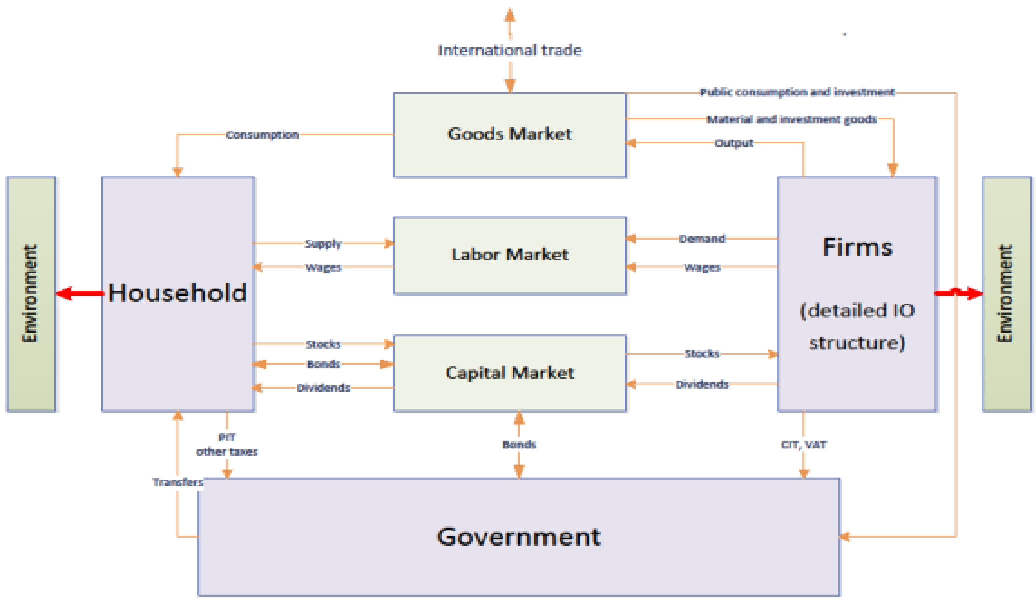
The analysis also models how different revenue redistribution mechanisms could alter welfare losses and energy poverty rates, considering various policy instruments and their effectiveness. The study assumes three main scenarios for redistribution: 1) a lump-sum scenario where each household receives an equal amount of funds, 2) a price subsidy scenario where revenues are redistributed inversely proportional to household budgets, providing greater benefits to poorer households and 3) a double-dividend scenario in which other distortionary taxes (such as labor or consumption taxes) are reduced, promoting economic efficiency.

In this section, the modelling methodology is described in detail for both the macroeconomic and household level approach.

Macroeconomic simulation

For the assessment of the policy package we used the dynamic stochastic general equilibrium model MEMO, developed at the Institute for Structural Research (Antosiewicz and Kowal, 2016). The model combines two strands of research – input-output and general equilibrium modelling. The main agents of the model and their interrelations are depicted in Figure 1.

Figure 1: The MEMO model



Source: Antosiewicz et al., 2022.

The model consists of the household sector, which maximizes utility from consumption and leisure, the firm sector which maximizes profits, the government sector which collects various taxes and finances public consumption, and a foreign sector responsible for trade with the rest of the world. The main features of the model include division of the firms into sectors calibrated to input-output matrix, search and matching on the labor market to model transition of workers between sectors and endogenous adaptation of technology related to energy use.

The sector structure of the model is calibrated using the 2015 (1) Bulgarian, (2) Hungarian, (3) German, (4) Polish and (5) Romanian industry by industry input-output matrix from the OECD statistics database which uses the International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4. In the model we distinguish the following sectors and products:

- Agriculture and Forestry;
- Mining of Coal;
- Mining of Crude Oil;
- Mining of Gas;
- Mining of Other;
- Manufacturing Industry,
- Manufacturing of Refined Petroleum Products;
- Energy;
- Construction;

- ◊ Transport;
- ◊ Market Services;
- ◊ Public Services.

The technical details such as exact equations, calibration and solution methods of the MEMO model can be found in the research report by Antosiewicz and Kowal (2016). The exact specification of the model used in this study slightly differs from the model described in the aforementioned research report, as we tailored it to the needs of the current assessment.

Model structure

Antosiewicz et al. (2022) lay down the main structure of the model. The model assumes a small open economy with four agents: (a) households, (b) firms, (c) government, and (d) the foreign demand sector. These agents interact in three markets: (1) labor (2) capital, and (3) goods market.

Households

There are many identical households in this economy that conform to a representative household that chooses consumption from maximizing an inter-temporal Constant Relative Risk Aversion (CRRA) utility function. There is no leisure in the utility function. The usual budget constraint applies. The household uses labor income, firms' profits, the return from previous savings to pay consumption, value added and income taxes, quadratic search costs in the labor market expressed in terms of consumption good. The working age population is divided between employed and unemployed workers.

Firms

The model is composed of the 12 sectors described in the previous section. It must include raw materials and energy sectors, given the nature of our problem (the macroeconomic effects of a carbon tax). The calibration of the production function and the relations across sectors come directly form the input-output matrix.

Following Figure 1, firms produce a basic sectoral good under monopolistic competition, employing capital, labor, materials and energy as production factors. There are trading firms that purchase this good and sell it to domestic and foreign sectoral markets. The agents that buy this good are: (i) (as intermediate demand) producers of basic goods (in each sector); (ii) (sectoral) export firms, which distribute domestic production in foreign markets; and (iii) three types of domestic final goods producers, providing investment, government, and private consumption goods. Final production is traded on the goods market with households, basic producers and government in accordance with the flows established from the input/output matrix.

$$KLEM_t^s = \left[(1-\theta_{M,t}^s)^{\frac{1}{\epsilon_M^S}} (KLE_t^s)^{\frac{\epsilon_M^S - 1}{\epsilon_M^S}} + (\theta_{M,t}^s)^{\frac{1}{\epsilon_M^S}} (M_t^s)^{\frac{\epsilon_M^S - 1}{\epsilon_M^S}} \right]^{\frac{\epsilon_M^S}{\epsilon_M^S - 1}}$$

$$Y_t^s = e^{\xi_t^Y} \times KLEM_t^s$$

where KLEM is an aggregate production factor that uses capital (K), labor (L), electricity (E) and materials (M). This is constructed using CES aggregator between *K* and *E*, then we add *L*, and finally *M*. Where Y_t^s represents output of sector s at time t, $\theta_{M,t}^s$ represents the share of materials in the production process of the basic good and ϵ_M^s is the elasticity of substitution between materials and the capital labour-electricity (KLE) composite production factor. ξ_t^Y is an economy-wide productivity shock that we use to calibrate the dynamics properties of the model.

Materials play a key role in the model to estimate the CO_2 emissions. Intermediate material used in sector s, M_t^s is obtained from a composite of fuels ($FUELS_t^s$) and a composite of all other intermediate inputs.

$$M_t^s = \left[(\theta_{FLS,t}^s)^{\frac{1}{\epsilon_{MF}}} (FUELS_t^s)^{\frac{\epsilon_{MF}-1}{\epsilon_{MF}}} + (\theta_{MO,t}^s)^{\frac{1}{\epsilon_{MF}}} (\theta_{MO,t}^s)^{\frac{\varepsilon_{MF-1}}{\varepsilon_{MF}}}\right]$$

Where $\theta_{FLS,t}^s$ and $\theta_{MO,t}^s$ denote the share of fuels and other material in the intermediate input, with $\theta_{FLS,t}^s + \theta_{MO,t}^s = 1$, while ε_{MF} represents the elasticity of substitution between inputs. In turn, combining materials $M_{i,t}^s$ in a Leontief production function generates the composite MO_t^s, used for all the basic goods sector:

$$M_{i,t}^s = \theta_{i,t}^s MO_t^s$$

where $\theta_{i,t}^s$ (with $\sum_{i\in s}\theta_{i,t}^s$=1) denotes the shares of intermediate good *i* in overall material consumption in sector *s*. Note that this specification allows for the introduction of energy material input into the composite MO. For the purpose of calibration, energy only enters in the production of electricity and raw materials, to replicate the high volatility of these two energy inputs observed in the data.

Raw materials intermediate goods (different from fuels, e.g. coal, oil gas, etc.), use raw materials in a Leontief production function. In the case of fuels, a CES aggregator combine all the relevant types of fuels needed for their production.

$$FUELS_t^s = \left[\sum_{k\in FLS} (\theta_{k,t}^s)^{\frac{1}{\epsilon_{FLS}^S}} (M_{k,t}^s)^{\frac{\epsilon_{FLS}^s}{\varepsilon_{FLS}^S-1}}\right]^{\frac{\epsilon_{FLS}^s}{\epsilon_{FLS}^s}}$$

Where $\{FLS\}$ is the set of fuels, $M_{k,t}^s$ denotes input of k-th type of fuel, $\theta_{k,t}^s$ is the share of k-th fuel type in fuels intermediate input composite, and ϵ_{FLS}^s denotes the elasticity of substituting between different fuels in sector *s*.

In summary, the set of intermediate sectoral input, $M_{i,t}^s$, is the union of the sets of all intermediate inputs, raw materials different than fuels, and fuels. Since, this is a small open economy, $M_{i,t}^s$ is a composite good produced with inputs made at home ($M_{i,H,t}^s$) and abroad ($M_{i,F,t}^s$), combined according to the Armington aggregator. The final basic good in sector s, $\underline{Y}_t^s$ is a composite made of intermediate goods produced in the way just described. The final firm produces the final good using the Dixit-Stiglitz aggregator and selling it in a perfectly competitive market.

$$\underline{Y}_t^s = \left(\int_0^1 (Y_t^s(i))^{\frac{p^s}{p^s-1}} di\right)^{\frac{p^s-1}{p^s}}$$

Where parameter p^s sets the markup.

Firms make capital accumulation decisions in a way which maximizes the profit.

The government collects value added tax, corporate income tax, labor income tax, some specific taxes and CO_2 emission tax. The revenue is spent on public goods, transfers to households and interests on public debt.

Given the small open economy assumption, the economy is price taker in international markets for exports and imports. There is open capital account, which defines external assets (debt) accumulation.

Firms and households produce CO_2. Firms in sector *s* produce CO_2^s as a by-product while using intermediate goods.

Formally:

$$CO_2^s = \theta_{H,CO2,t}^s \times Y_t^s + \sum_{j \in T} \theta_{j,CO2,t}^s \times (M_{j,H,t}^s + M_{j,F,t}^s)$$

where $\theta_{H,CO2,t}^s$ defines the amount of CO_2 in sector s by using j-type material produced in home (H) or foreign country (F). The main assumption is that only fuels consumption generates CO_2, in other words $\theta_{H,CO2,t}^s \neq 0$) for $j \in \{FLS\}$. Moreover, chemical processes other than fuel combustion can also produce CO_2. We assume that such CO_2 emission is proportional to the amount of goods and services produced in a given sector and is controlled by the parameter $\theta_{H,CO2,t}^s$. Similarly, the amount of CO_2 emitted by households is equal:

$$CO_2^{CNS} = \sum_{j \in t} \theta_{j,CO2,t}^{CNS} \times M_{j,t}^{CNS}$$

On the labor market, sectoral supply and total demand for labor Wages in the model are sector specific. They are determined in general equilibrium, and hence they react to changes in sectoral demand induced by climate policy. The sectoral demand for labor is determined in the optimization of representative firms in all sectors. To model labor supply curves at sectoral level, we assume existence of an intermediary between representative worker and sectoral firms that allocates workers to different sectors using Constant Elasticity of Substitution technology. In addition, we let the intermediary decide on the total number of vacancies in the economy, which we use to determine unemployment rate.

The intermediary optimization problem is given by

$$V_t^L = \pi_t^L + \lambda_{t+1} V_{t+1}^L$$

Subject to:

$$\pi_t^L = \sum_s w_t^s n_t^s - w_t N_t - v_{Vac} Vac_t$$

$$N_t = \omega_N \left(\sum_s \omega_N^s \left(n_t^s\right)^{\frac{\varepsilon_L - 1}{\varepsilon_L}} \right)^{\frac{\varepsilon_L}{\varepsilon_L - 1}}$$

$$N_t = (1 - \delta_L) N_{t-1} + \Phi_t Vac_t$$

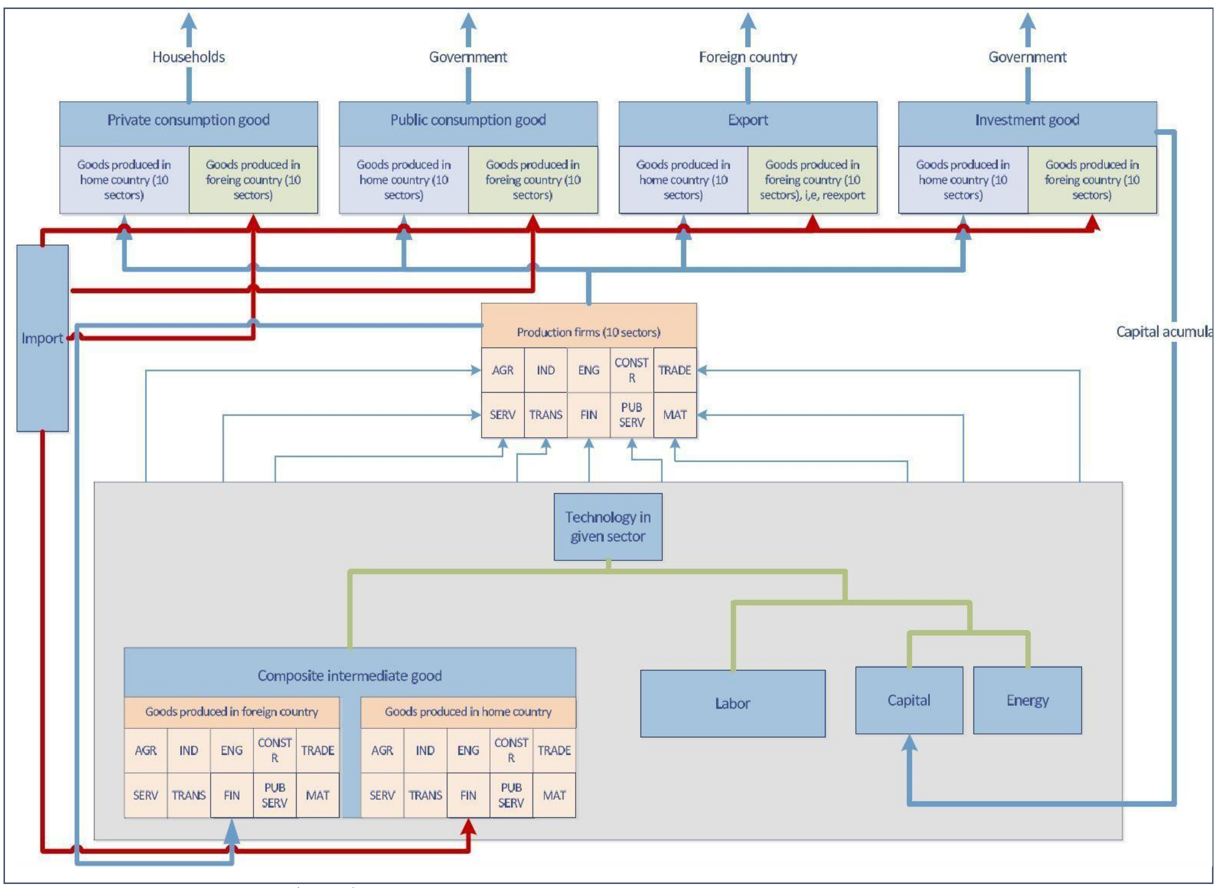
Where V_t^L is the discounted sum of profits, π_t^L is the profit in period t, λ_{t+1} is the discount factor (determined endogenously based on the interest rate), w_t^s is wage in sector s, n_t^s is the supply of workers in sector s, w_t is the aggregate wage (received by representative worker) and N_t is the total demand for labour, v_{Vac} is the cost of having an open vacancy (which could be interpreted as a search cost), Vac_t is the number of open vacancies, ω_N and ω_N^s are parameters calibrated to ensure that number of workers in each sector and total number of workers are the same as in input-output matrices, ε_L is the elasticity of transformation between sectors, δ_L is a job destruction rate (exogenous in the model) and Φ_t is the probability of filling the vacancy. The intermediary takes aggregate wage (w_t), sectoral wages (w_t^s) and probability of filling the vacancy (Φ_t) as given and decides on total demand for labour (N_t), its allocation across sectors (i.e. supply of labor at a sectoral level, n_t^s) and total number of vacancies (Vac_t).

Input-Output sectors structure and emissions

There are several distinct sets of parameters whose values need to be calculated. The main one is the parameters governing the firm and production side of the model. These parameters can be further specified as those which govern the value added[1] structure of the sectors, investment and compensation of employees in each sector, the intermediate use structure which considers domestically produced and imported goods and final use structure which also takes into account domestically produced and imported goods. A scheme of the production structure is shown in Figure 2. Each firm operates a production function which utilizes a nested CES (constant elasticity of substitution) specification to combine the factors of production. In the first stage the firm combines capital and energy, the second stage consists of adding labor, whereas in the final stage this bundle is combined with materials (intermediate use). The material bundle is composed of products of each sector, which are further disaggregated into the imported and domestically produced part. On the use side, the goods produced by each sector are purchased by the household as private consumption, by the government as public consumption, by firms as investment or they can be exported.

In order to calibrate the firm side of the model we use the input-output (IO) matrix from the OECD statistics database. This is a 36 activity by 36 activity matrix which uses the International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4. However, for the purpose of this study we have disaggregated some sectors and products which are collapsed into a single activity in the OECD matrix.

Figure 2: Production process in MEMO model



Source: Antosiewicz & Kowal (2016)

[1] It is defined as the value of output minus the value of purchased inputs (Abel et al., 2011)

In the first step the OECD IO matrix is aggregated into the following sectors: 1) AGR: Agriculture, forestry and fishing; 2) MIN_ENE: Mining of energy products; 3) MIN_OTH: Mining of metal and other ores; 4) RPP: Manufacturing of refined petroleum products; 5) IND: Remaining manufacturing industry; 6) ENERGY: Electricity, gas, water supply and sewerage; 7) CONSTR: Construction; 8) TRANS: Transport; 9) SERV: Market services; 10) PBL: Public services. Table 1 summarizes this sector aggregation. In the second step we conduct a disaggregation of several sectors related to fossil fuels and the electricity sector using the highly disaggregated IO matrix and data from the International Energy Agency regarding electricity generation by source.

Table 1: Aggregation of sectors from OECD IO matrix

ISIC Rev.4 code	Sector	Aggregation
TTL_01T03	Agriculture, forestry and fishing	AGR
TTL_05T06	Mining and extraction of energy producing products	MIN_ENE
TTL_07T08	Mining and quarrying of non-energy producing products	MIN_OTH
TTL_09	Mining support service activities	MIN_OTH
TTL_10T12	Food products, beverages and tobacco	IND
TTL_13T15	Textiles, wearing apparel, leather and related products	IND
TTL_16	Wood and of products of wood and cork (except furniture)	IND
TTL_17T18	Paper products and printing	IND
TTL_19	Coke and refined petroleum products	RPP
TTL_20T21	Chemicals and pharmaceutical products	IND
TTL_22	Rubber and plastics products	IND
TTL_23	Other non-metallic mineral products	IND
TTL_24	Manufacture of basic metals	IND
TTL_25	Fabricated metal products, except machinery and equipment	IND
TTL_26	Computer, electronic and optical products	IND
TTL_27	Electrical equipment	IND
TTL_28	Machinery and equipment n.e.c.	IND
TTL_29	Motor vehicles, trailers and semi-trailers	IND
TTL_30	Other transport equipment	IND
TTL_31T33	Other manufacturing; repair and installation of machinery and equipment	IND
TTL_35T39	Electricity, gas, water supply, sewerage, waste and remediation services	ENERGY
TTL_41T43	Construction	CONSTR
TTL_45T47	Wholesale and retail trade; repair of motor vehicles	SERV
TTL_49T53	Transportation and storage	TRANS
TTL_55T56	Accommodation and food services	SERV
TTL_58T60	Publishing, audiovisual and broadcasting activities	SERV
TTL_61	Telecommunications	SERV
TTL_62T63	IT and other information services	SERV

TTL_64T66	Financial and insurance activities	SERV
TTL_68	Real estate activities	SERV
TTL_69T82	Other business sector services	SERV
TTL_84	Public administration and defence; compulsory social security	PBL
TTL_85	Education	PBL
TTL_86T88	Human health and social work	PBL
TTL_90T96	Arts, entertainment, recreation and other service activities	PBL
TTL_97T98	Private households with employed persons	PBL

Source: own elaborations.

In MEMO we directly model CO_2 emissions from the use of fossil fuels: coal, oil and gas. The volume of carbon emissions in a particular sector is modelled as a linear function of the use of these fuels, with coefficients set to match sector data regarding emissions. We do not model directly other, non-carbon emissions, such as those resulting from industrial processes, waste processing, agriculture or captures in the forestry sector. Such emissions are treated in an indirect way in the post-processing phase of the modelling exercises. In case of running a carbon tax simulation, the agents in the model only react to the fossil fuel emissions which are modelled directly and do not, for example, reduce output in the agriculture sector to cut non-carbon emissions.

Microeconomic simulation

The second part of the methodology involves using information from the macroeconomic model, MEMO, and feeding it to a microeconomic model that estimates a demand system for the five countries of interest, which estimates the Quadratic Almost Ideal Demand System (QUAIDS).

Demand system estimation

From a microeconomic perspective, calculating the incidence of a carbon pricing instrument requires calculating all the changes in prices that occur in an economy as a response to a change in the carbon tax rate, followed by calculating the welfare effects of these changes on households (West and Williams, 2004). Changes in the price of carbon directly influence only a limited number of carbon-intensive industries, such as transportation or power generation, however, its indirect effects are more subtle but potentially more important for some categories of the population. For example, if an increase in the price of carbon leads to a higher price of gasoline, this could affect the price of goods produced in industries which are relying on road transportation, and thus on gasoline as an intermediary input.

To accurately estimate the effect of changes in the price of carbon on the consumption choices of households, and thus to capture both direct and indirect responses, we estimate the demand system for each of the five countries studied in this project. This dynamic approach is essential to precisely estimate the regressivity of carbon taxation, without omitting or over-inflating the indirect effects. In practice, estimating a demand system requires at least two major simplifying assumptions: (1) that the burden of taxes on labour falls exclusively on workers and not on firms, and (2) the supply of goods is perfectly elastic, with the burden of the tax falling exclusively on consumers. While these assumptions could seem unrealistic, they are standard in the existing literature (Metcalf, 2009), and have limited implications for the accuracy and reliability of the modelling results.

We estimate the Quadratic Almost Ideal Demand System (QUAIDS), introduced by Banks, Blundell and Lewbel, 1997. This model extends and generalizes the Almost Ideal Demand System (AIDS) developed by Deaton and Muelbauer (1980) by allowing for non-linear Engel curves through the introduction of a quadratic logarithmic income term. This extension does not require any strong assumptions about household preferences, which prevents or at least reduces the chance of model specification bias

(Douenne, 2020). Moreover, its ability to estimate non-linear Engel curves is essential for studying the distributional effects of carbon pricing in developed countries, where non-linearity is expected (Tovar Reaños and Wölfing, 2018). While other demand systems have been proposed recently, QUAIDS remains the most widely-used demand system, especially in the case of analyzing the distributional effects of carbon pricing across a variety of scenarios (Rosas-Flores *et al.*, 2017; Renner, 2018; Aggarwal *et al.*, 2021; Moz-Christofoletti and Pereda, 2021; Okonkwo, 2021).

QUAIDS estimation

To estimate the QUAIDS, we consider the consumer demand for a given set consisting of k different goods, under the constraint of having the budget m. The process of determining k and m is irrelevant for the purpose of estimating the demand system. The model is based on the indirect utility function given by:

$$ln\ ln\ V(p,m) = \left[\left\{\frac{ln\ ln\ m - ln\ ln\ a(p)}{b(p)}\right\}^{-1} + \lambda(p)\right]^{-1}$$

where $ln\ ln\ a(p)$ is the transcendental logarithm function:

$$ln\ ln\ a(p) = \ \alpha_0 + \sum_{i=1}^{k} \alpha_i\ ln\ ln\ p_i + \frac{1}{2}\sum_{i=1}^{k}\ \ \sum_{j=1}^{k} \gamma_{ij}\ ln\ ln\ p_i\ ln\ ln\ p_k$$

with p_i is the price of good i, with $i = 1,2, \dots\dots, k. b(p)$ is the Cobb-Douglas price aggregator:

$$b(p) = \prod_{i=1}^{k} {p_i}^{\beta_i}$$

and

$$\lambda(p) = \sum_{i=1}^{k} \lambda_i\ ln\ ln\ p_i$$

Following the consumer theory, adding-up, homogeneity and Slutsky symmetry requirements, we get:

$$\sum_{i=1}^{k} \alpha_i = 1, \sum_{i=1}^{k} \beta_i = 0\,, \qquad \sum_{j=1}^{k} \gamma_{ij} = 0\,, \sum_{i=1}^{k} \lambda_i = 0\ and\ \Upsilon_{ij} = \Upsilon_{ji}$$

Furthermore, if we take q_i to be the quantity of the good i consumed by households, and $p_i q_i$ to be the expenditure for the same good, then $w_{i=}(p_i q_i)/m$. Following Roy's identity applied to the indirect utility function, we obtain the expenditure share equation for good i:

$$w_{i=}\alpha_i + \sum_{j=1}^{k} \Upsilon_{ij}\ ln\ ln\ p_j\ + \beta_i\left\{\frac{m}{a(p)}\right\} + \frac{\lambda_i}{b(p)}\left[ln\ ln\ \left\{\frac{m}{a(p)}\right\}\right]^2 +\ u_i\,, i = 1, \dots, k$$

where $\alpha_{i,}\beta_i, \lambda_i$ and Υ_{ij} are the parameters estimated by the model, and u_i is the error term.

There are at least two methods to introduce demographic heterogeneity in the demand system. One of them is the scaling approach introduced by Ray (1983), and the other is the translating approach of Pollak and Wales (1981). The scaling approach allows the level and slope of total expenditure to depend upon demographic variables, while the translating approach is more restrictive, allowing for nonlinearity only in the expenditure terms through the price aggregator (Lecocq and Robin, 2015).

In this research, we follow the more conservative translating approach. Consequently, demographic heterogeneity of households enters the model via the α terms:

$$\alpha^h = As^h, A = (\alpha_i')$$

where s^h is the set of sociodemographic variables.

Estimation of unit values

The biggest challenge for accurately estimating the QUAIDS for the five countries studied in this research project is the lack of data on both household market prices, and data on quantities at the household level. Usually, the only option for computing unit values would be to make general assumptions about the unobserved properties of the goods bought by household i, and to use, therefore, more general price indices. However, even if we disregard potential issues of endogeneity, the level of variability between the estimated unit values is extremely low, which can lead to biased estimates, as well as to contradictions with consumer choice theory (Dagsvik and Brubakk, 1998; Atella, Menon and Perali, 2004; Coondoo, Majumder and Ray, 2004).

To overcome this low variance in unit values, we follow the method pioneered by Menon, Perali and Tomassi (2017) for computing the synthetic Stone-Lewbel price indices (Lewbel, 1989).

While QUAIDS is consistent with consumer choice theory, there are reasons to suspect that expenditures and prices are endogenous, especially when working with estimated unit values as approximations of market prices (Vigani and Dudu, 2021). Endogeneity might be present due to multiple reasons: the fact that expenditures on individual goods might be jointly endogenous given that they are by definition individually endogenous, the fact that we deal with unobserved features of commodities such as quality or durability, or even due to measurement error (Lecocq and Robin, 2015).

In dealing with the endogeneity challenge, we make use of an important property of QUAIDS, conditional linearity: it is linear in all parameters, conditional on a set of functions of independent variables and parameters. Assuming conditional linearity, Browning and Meghir (1991) introduced a new estimator for AIDS (different from the simple OLS and SUR estimators), which has been extended for QUAIDS by Blundell and Robin (1999). This ILLS estimator is computationally efficient, relies on fewer and less restrictive assumption, and is tailor-made for data structured such as the ones found in household surveys. In addition, the ILLS estimator is compatible with a larger number of control variables, which could prevent endogeneity. To further deal with the challenge of endogeneity, we make use of instrumental variable techniques commonly used in demand system estimation (Hausman, 1978). Instrumental variables for both prices and expenditures can be used to augment our regressions. We thus estimate the reduced form of the total expenditure of the household, x^h, and for the price vector p^h, arriving at the error term $\hat{v}_i^h$. The initial error term, u_i^h is subsequently orthogonally decomposed in:

$$u_i^h = \hat{v}_i^h p_i + \varepsilon_i^h, with\ E(x^h, p^h), \forall\ i, h$$

The instrument used for expenditures in the reduced form regression is, alongside the sociodemographic variables s^h, household disposable income (Douenne, 2020), while for prices we make use of one-year lagged unit values (Vigani and Dudu, 2021).

Demand elasticities

Estimates from the QUAIDS model are used to compute the income and price elasticities with respect to each bundle of goods i. To compute these elasticities, we differentiate the expenditure share equation from the QUAIDS model with respect to the logarithm of expenditures $ln\ ln\ m$, and the logarithm of price of the same good $ln\ ln\ p$. From this we obtain:

$$\mu_i = \frac{\partial w_i}{\partial\ ln\ ln\ m} = \beta_i + \frac{2\lambda_i}{b(p)}\left\{ln\ ln\ \left[\frac{m}{a(p)}\right]\right\}$$

$$\mu_{ij} = \frac{\partial w_i}{\partial \ ln \ ln \ p_j} = Y_{ij} - \mu_i \left(\alpha_j + \sum_k Y_{jk} \ ln \ ln \ p_k \right) - \frac{\lambda_i \beta_j}{b(p)} \left\{ ln \ ln \ \left[\frac{m}{a(p)} \right] \right\}^2$$

Consequently, given that $e_i = \frac{\mu_i}{w_i} + 1$, we get the Marshallian price elasticities:

$$e_{ij}^U = \frac{\mu_{ij}}{w_i} - \delta_{ij}$$

and the Hicksian price elasticities, derived from the Slutsky equation:

$$e_{ij}^C = e_{ij}^U + e_i w_j$$

Limitations

Estimates from the QUAIDS are used to predict welfare changes, using the compensating variation as the parameter of choice. In this regard, measuring the compensating variation requires simulating the size of a tax, through the changes in the relative prices of the categories of goods that were analyzed through the QUAIDS. The size of the tax is inferred from the MEMO macro-model described in the first part of this chapter, and the relative price changes are determined by using the average carbon content of the six categories of goods and services in the micro-model. Therefore, the estimates could be inconsistent if there is a high degree of variation in terms of greenhouse gas emissions within each category of goods and services. For example, if certain households consume food that emits more CO_2, that group would bias the estimates. Future research should critically engage with this assumption.

Secondly, using the HBSs requires minimal modifications to the data collected by the national institutes of statistics, including rounding up decimals and correcting small errors (i.e., typos). While this is unlikely to bias the estimates, subsequent studies should check whether homogenized versions of the HBSs, collected by Eurostat, are in line with the early releases by the national statistics offices.

Finally, the QUAIDS model only acknowledges changes in demand pattern, omitting, when estimated for a longer period of time, supply responses (i.e., what companies do when faced with a tax). Therefore, our results, which estimate changes in expenditure patterns until 2032, should be understood not as causal, but as descriptive of a trend. Ceteris paribus, if a carbon tax were introduced, people would shift their personal budget, in the long run, in the manner estimated through our model.

Carbon tax characteristics

We assess the distributional and welfare effects of stylized direct carbon taxes applied cross-sectorally to all the major components of a national economy between 2022 and 2032, proportional to the average carbon content of each of the sectors. These taxes can be interpreted as broad nationwide policies that raise the price for carbon intensive goods and services based on their level of emissions of greenhouse gases. For example, a tax of EUR 10/tCO_2 will affect the relative price of car fuels (e.g., diesel) more than the price of electricity, as the latter is, on average, less carbon-intensive per unit of output. Taxes using different benchmarks for different sectors or fuels, rather than a uniform rule (e.g., a tax of EUR 20/tCO_2 in the power sector, but EUR 30/tCO_2 for the transport sector), are beyond the scope of this study. Nevertheless, such taxes appear to be, by design, less efficient in providing effective long-term abatement strategies for firms (Kuneman, 2022).

Carbon footprints

To accurately describe the mechanisms through which such stylized, direct carbon taxes propagate across the economy, we derive sector-specific carbon footprints from existing literature, which usually relies on multi-regional environmentally-extended input-output models such as the EXIOBASE (Dorband *et al.*, 2019). The carbon footprints of the six sectors for each of the five countries are presented in Table 2. These carbon footprints are valid for the baseline year 2022, with the rest of the carbon footprints being endogenously determined in the model by following the emission reduction pathway induced by the carbon taxes. In terms of measurement, we utilize the level of emissions per capita which can be immediately corroborated with data on population and GDP to derive the level of emissions per unit of output, if needed. Results are collected from existing literature, rather than computed separately. The results of our data collection procedure are in line with existing literature which studies the distribution of carbon footprints across countries in the European Union (Ivanova *et al.*, 2017; Ivanova and Wood, 2020). One limitation of this approach is that we assume no technological change in the periods between 2022 and 2032 through any channel other than demand reduction, which could bias our results upwards.

Table 2: Yearly carbon footprints of goods and services

Country	Food-kgCO2 /household	Others-kgCO2 /household	Electricity-kgCO2 /household	Transport fuels-kgCO2 /household	Transport-kgCO2 /household	Energy-kgCO2 /household	Total emissions per household - kgCO2
Bulgaria	693,6	1.468,80	3.124,80	2.325,60	1.140,00	3.861,60	12.611
Germany	1.391,78	1.632,16	4.397,54	5.732,76	981,72	4.402,60	18.535
Hungary	1.120,80	1.665,60	2,680,08	3,828,05	645,6	4.579,20	14.527
Poland	1.471,12	2.351,12	4.455,96	2.825,80	806,56	7.205,08	19.113
Romania	964,17	1.344,06	1.165,90	2.777,20	571,16	2.528,78	9.394

Source: own calculations

Carbon footprints were collected from papers that conducted an environmentally extended multiregional input-output (MRIO) analysis combining the use of regionally disaggregated demand from consumer expenditure surveys and product carbon intensities from the EXIOBASE database. EXIOBASE provides national carbon intensities across 200 product sectors and is detailed bilaterally by places of origin, which enables us to estimate both indirect emissions embodied in the supply chains of household purchases and the direct emissions occurring when households burn fuels themselves. Additionally, the structure of the EXIOBASE and the imputation strategy usually associated with computing carbon footprints ensure that we only consider emissions from activities that are undertaken within the boundaries of each jurisdiction (as estimated numerically in the input-output tables), with exports being counted for the country where the commodities are actually consumed. Using this proxy methods for inferring carbon footprints has been validated by recent research, as imputed values align with even test estimates produced by directly using The Emissions Database for Global Atmospheric Research provided by the European Commission's Joint Research Centre.

Drawing on these data sources suggests that our analysis is robust to potential pitfalls on using only national-level production data, as that could conflate the place of production with the place of consumption for our commodity categories. In practice, that would imply, for example in the case of Germany, that our estimates of losses would incur prices paid by Germans for goods consumed outside Germany, which would not be reasonable given that any tax regime is applied domestically.

However, we need to acknowledge, a limited, yet relevant potential sensitivity of the analysis for countries or within-country regions for which the import-export regime has either varied substantially in the previous years or might experience a systematic change in the period of interest for our study (i.e., 2022-2032). This means that if the input-output tables from which our carbon footprints have been estimated characterize the export pattern of the jurisdiction in a systematically different manner than that under which the jurisdiction will operate at some point, our carbon footprints might be biased[2].

Carbon tax levels

The precise tax levels for each country and each year are obtained from the DSGE macro-model, ensuring that effects on trade, domestic restructuring, and sectoral changes are accounted for in the first stage of the quantitative modelling exercise (Antosiewicz *et al.*, 2022). Furthermore, the simulated tax is endogenously determined to ensure the European-wide deep decarbonization objectives outlined under the European Green Deal framework. One essential element of our analysis is that taxes are distinctively computed for all five countries, resulting in five series of results that use inputs narrowly tailored to local conditions and needs. More precisely, we model an incremental tax whose annual levels are decided as to smoothen the emission reduction pathways, with a final reduction rate of 40% by the end of 2032, compared to the baseline year. The initial and the final carbon tax levels for the five sampled countries are displayed in Table 3, below.

Table 3: Carbon tax values

Country	Value in $ / tonne CO_2 in 2022	Value in $ / tonne CO_2 in 2032
Bulgaria	4,52	22,58
Germany	3,97	20,51
Hungary	14,57	73,54
Poland	7,26	36,42
Romania	2,95	15,17

Source: own calculations.

The differences in the tax levels between otherwise similar countries can be traced back to the economic structure of each state. A more precise characterization of the MEMO macro-model can be seen in the previous chapter.

Demand system estimation

Based on these carbon tax scenarios in the selected CEE countries, we employ five distinct versions of the *quadratic almost ideal demand system* (QUAIDS) model to estimate the behavioral changes of households once the new pricing mechanism enters into force. We run the model for multiple periods (i.e., years), with the outputs of each run of the QUAIDS model becoming the new inputs for the next period. Furthermore, we assume that uncertainty is linearly additive, which ensures that results from 2032 can be compared to

[2] However, the sign of the bias is immediately computable: if we expect a country to become more export-oriented, ceteris paribus, we should expect fewer emissions associated with domestic households; the opposite is true for countries that might become more import-oriented.

the baseline of 2022, as long as contextual anchors and time-sensitive elements (e.g., price trends, technological shocks) are accounted for in the interpretation.

Overall, our microsimulation results establish behavioral trends for the entire population of the five countries. More precisely, we reveal the new patterns of expenditure when carbon taxes are introduced, which align with the microeconomic consumer theory. Our particular way of implementing the model allows us to observe the evolution of expenditure patterns that account for how different redistribution and tax regime affect consumption in the long run. Simply put, we assume that once a tax is introduced, every consumer recalibrates the budget in accordance with the new relative prices, preferences, and budget constraint.

QUAIDS has been thoroughly used in the literature discussing energy taxes worldwide, as it is a flexible class of models that respect consumer theory and impose very little restrictions on behavior (Banks, Blundell and Lewbel, 1997; Poi, 2012; Douenne, 2020; Moz-Christofoletti and Pereda, 2021; Liu, Gong and Qin, 2022).

Data on expenditure patterns

The QUAIDS model relies on analyzing microdata for the five countries in the sample (i.e., Bulgaria, Germany, Hungary, Poland, and Romania) collected through the national Household Budget Surveys (HBSs). The HBSs are national, representative surveys focusing mainly on household expenditure patterns on many goods and services. Therefore, all the analyses performed for the five countries take into account the latest version of the HBSs available at the national level and take as a baseline the 2015 version of the same surveys available through Eurostat. This choice maximizes temporal variation in expenditure patterns across and within income categories in the population and for the price indices used as inputs in the model.

Despite variation resulting from different inputs (i.e., different expenditure data, price indices, and carbon tax values), the five demand systems are intrinsically comparable as they maintain the exact model specification. Therefore, differences between countries can continuously be tracked to the differences in the inputs of the QUAIDS specification and not to variations in the model itself.

Variable construction

As the raw versions of the HBSs are designed in order for national authorities to compile weightings for critical macroeconomic indicators, such as consumer price indices, the level of granularity across expenditure categories is too high for performing an interpretable welfare analysis. Consequently, the HBSs expenditure groups were restructured into six cross-cutting categories that are relevant when analyzing energy taxes, particularly taxes on the carbon content of goods and services.

The six encompassing categories are food, other non-energy goods and services (e.g., education, healthcare), electricity, transport fuels, transport services (e.g., public transport, plane tickets, and other energy goods (e.g., natural gas, coal—essentially describing heating and cooling). The decision to model not only energy-related goods and services, but also other major consumer products can be justified by the fact that for average households, energy constitutes only one of the essential categories of expenditure/consumption. Without correctly understanding the interactions between energy and other needs of final consumers, one cannot discern the actual welfare costs incurred by different sections of the population once a new tax is introduced. Table 4 outlines the association underlying the process of restructuring the raw HBS datasets, which follows the COICOP classification:

Table 4: Structure of variables for micro-analysis

Variable in the welfare analysis	Corresponding HBS categories	Expenditures according to COICOP classification
Food	food	COICOP 01
Others	alcohol, clothing, housing, education, health, communication, recreation, restaurants, miscellaneous	COICOP 02, COICOP 03, COICOP 04, COICOP 06, COICOP 08, COICOP 09, COICOP 10, COICOP 11, COICOP 12
Electricity	electricity	COICOP 04.5.1.0
Transport fuels	Diesel, gasoline, LPG for vehicles	COICOP 07.2.2.1, COICOP 07.2.2.2, COICOP 07.2.2.3
Transport services	transport	COICOP 07
Other energy	Natural gas, charcoal, firewood, LPG for heating	COICOP 04.5.2.1, COICOP 04.5.2.2, COICOP 04.5.4.1, COICOP 04.5.4.9

Source: own elaborations.

Consumption levels

Our model uses each household's total consumption level as a proxy measure for income (Metcalf, 2009). While this is common in the existing literature studying the distributional and welfare effects of carbon pricing, especially in developed countries, other proxies could be valuable and provide new insights. For example, using lifetime income instead of annual consumption levels is known to reduce the overall regressive tendencies of the carbon tax, as measured through demand system estimation-based models. This is a consequence of the permanent income hypothesis (Friedman, 1957), which assumes that households smoothen their consumption pattern across their entire lifespan. While a comparative discussion of the results coming from different proxies is interesting, we are limited by data availability. Recent research has also attempted to use disposable income as an instrument for total consumption, removing issues of endogeneity from the QUAIDS.

Robustness and sensitivity of results

The QUAIDS micro-model, by using similarly constructed categories of expenditure and a coherent model specification produces results with a high degree of internal and construct validity. In terms of the sensitivity of the results produced by the model, it is worthy to note that estimating QUAIDS involves numerical optimization rather than the identification of a unique analytical solution. Consequently, the precise estimate used to compute elasticities and derive welfare losses depends on the model specification, and on the carbon tax level provided by the MEMO macro-model. Therefore, it is generally correct to assume, for policymakers, that the validity of the micro and macro results are interdependent.

Data on prices of goods and services

Demand-system estimation involves relating information about expenditure patterns (as provided by the HBSs) with information about the prices paid by households for different goods and services (in this case, the six variables described in Table 4). As the five HBSs do not provide individualized price information, we rely on national aggregate price indices for the six categories of goods and services provided by the national institutes of statistics and Eurostat. Generally, the price indices are provided monthly, guaranteeing the existence of multiple prices for each consumption category. As two of our consumption categories are highly correlated (i.e., transport and transport fuel), we rely on a common price aggregator that avoids the possibility of the QUAIDS not functioning for technical reasons.

The baseline for computing the price indices is January 2015, with changes being monitored on at least a quarterly basis, and the evolution of the price indices in each country being part of the five country profiles. The choice of the baseline year-month is irrelevant for the results, as the model only uses within-category variation, regardless of the starting point.

Welfare and distributional effects

Definitions

Generally, distributional effects refer to any expenditure-related outcomes heterogeneously distributed within the same population (Pizer and Sexton, 2017). For example, if households belonging to different expenditure deciles must pay different shares of their budget on the same tax, that tax displays distributional effects regardless of which households pays more. Consequently, regressivity and progressivity tendencies displayed by a stylized carbon tax are both understood as distributional effects, with the former being considered an adverse form of distributional effect (Fullerton, 2011). As regressivity is considered more significant from a political perspective (Carattini *et al.*, 2017; Klenert *et al.*, 2018; Maestre-Andrés, Drews and van den Bergh, 2019), we focus our analysis on regressive tendencies induced by carbon pricing. The study of distributional effects is complemented by the calculation of precise welfare effects, with the latter used to numerically characterize the magnitude of the former.

Measurement of welfare effects

Welfare losses are measured at the household level and averaged across income deciles to enable a comprehensive discussion of redistributive policies, using the compensating variation (CV) (Chipman and Moore, 1980). The compensating variation is the adjustment in income that returns the consumer to the original utility after an economic change has occurred, such as the introduction of a new tax. If the CV is positive, we infer there are welfare losses, while if the CV is negative, we infer there are welfare gains. The actual value of the CV for each household can be understood as follows: a 0.12 CV would indicate that in order for a household to reach its initial levels of utility, its income should grow by 12%. On the other hand, a -0.09 CV indicates that a household can afford to lose 9% of its income and, by doing so, return to the initial level of utility. By extension, a neutral policy is one that induces a CV of 0. Consequently, redistributive policies are conceptualized as measures that reduce welfare losses for at least a section of the population (Cronin, Fullerton and Sexton, 2016; Rausch and Schwarz, 2016). While this is not necessary, under this definition, redistribution is also likely to affect the distribution of welfare losses, potentially dealing with challenges such as regressivity and subsequently reducing inequality.

Redistribution scenarios

This section discusses the effects of three redistribution strategies:

A **lump-sum transfer** scenario that redistributes the revenues collected from the carbon tax toward the population. The transfer size does not depend on the socio-demographic characteristics of households or their estimated welfare losses. Instead, the government gives the same amount of money to each household. Intuitively, this reduces the welfare losses of all the households. Households that benefit the most from this redistribution scheme are those whose absolute size of welfare losses is higher than the average share of the budget spent by all households on the tax. Accordingly, this reduces welfare losses for a significant population share in highly unequal societies. Nevertheless, given that affluent households also receive a transfer, the adverse distributional effects of the tax are likely not addressed by this redistribution scheme.

A **price subsidy** scenario in which the government uses the revenues collected from the carbon tax to alleviate the welfare effects of the price increases for less affluent households. While this complex policy depends on the design, implementation, and monitoring of national and local authorities, we use a stylized version of this approach as part of our micro-modeling strategy. From the taxes collected from all households, the ones in the lower deciles get a price subsidy thus reducing their welfare losses. As such, we model this as a transfer, inversely proportional to the total budget of the households but proportional to the deviation in welfare losses of each household vis-à-vis their expected loss per decile, for all deciles. In this scenario, all household benefit from the subsidy, but poorer households benefit disproportionately more. We expect this scenario to significantly improve the distributional effects of carbon pricing, as it focuses precisely on the poor households disproportionately affected.

A **double-dividend** scenario in which the government uses carbon tax revenues to make the reduction of other distortionary taxes feasible. A complex analysis of which taxes could be optimally reduced is beyond this project's scope, as it would require complete fiscal models of an open economy. Instead, deriving our insights from the literature, we assume that any tax reduction is proportional to the size of the income sources in households (e.g., wages). Therefore, we model this scenario as a transfer contingent on the household's total expenditure budget, an assumption which is contingent on the reasonable assumption that richer households earn and spend, in absolute terms, more than poorer households. This could be conceptualized as an income tax rebate. Regarding distributional and welfare expectations, we predict this scenario will improve aggregate social welfare but will most likely maintain some of the adverse distributional effects of carbon pricing, particularly from households in the bottom deciles. The reason for these expectations is that tax rebates, when not tailored to a particular group, have potential adverse distributional effects. Moreover, under certain unequal distributions of expenditure within a country, this scenario could in fact increase overall levels of inequality.

Table 5: Redistribution scenarios

Scenario	Type of transfer	Expected distributional effects	Expected welfare effects
Lump-sum	Equal share of total revenue	(Mildly) Reduces regressivity	Reduces losses for every household
Double dividend	Share of revenue proportional to total budget	Increases regressivity	Reduces losses, especially for more affluent households and the middle class
Price subsidy	Share of revenue inversely proportional to losses	(Strongly) Reduces regressivity	Reduces losses, especially for less affluent households

Source: own elaborations.

In all three revenue redistribution scenarios, the funds needed by the government to initiate the transfers to the population are generated by the carbon tax. The welfare gains calculated post-redistribution (and implicitly also post-tax) measure the net-CV resulting from the two effects compared to the baseline scenario (i.e., no tax, no redistribution in the last period of the study, 2032).

In all three scenarios, some households still bear the burden of financing the redistribution scheme. Therefore, compared to their initial state, some households will be net winners, and some will be net losers. The results of the model describe, for each country, the distribution of this policy effort, showcasing which sections of the population will be better off and which will be worse off after the carbon tax is implemented and its revenues recycled, compared to the initial state before the tax is levied.

The transfer size depends intrinsically on the size of the carbon tax, as revenues are a function of how much the entire population must pay to the government. The total revenue size, which is subsequently used for implementing the three scenarios, can be seen in Table 6 below.

Table 6: Carbon tax revenues in the first and last year of the forecasted period

Country	Revenues in 2022 (million EUR)	Revenues in 2032 (million EUR)
Bulgaria	876.75	2,672.92
Germany	3,211.85	9,878.64
Hungary	734.16	2,214.25
Poland	2,319.71	6,982.13
Romania	337.18	1,040.34

Source: own calculations.

Finally, Table 7 shows the approximate value of the different types of transfers that would be received by households in the lowest income decile in each country, based on the three redistribution schemes.

Table 7: Value of the redistributive transfer in 2022 for the 1st decile per household

Country	Lump-sum transfer (EUR)	Double dividend (EUR)	Price subsidy (EUR)
Bulgaria	301,2	144,5	364,4
Germany	783,2	601,4	910,6
Hungary	172,3	122,2	203,4
Poland	178,8	140,3	211,3
Romania	72,4	44,3	101,5

Source: own calculations.

Using the described methodology and data sources, this report proceeds to present the results of the simulation in the five countries, estimating macro and microeconomic effects of the carbon tax.

Country reports

Bulgaria

Context

Bulgaria is one of the most energy- and carbon-intensive countries in the EU. In 2019, Bulgaria used 2.9 times more energy and emitted 3.4 times more CO2 per unit of GDP as compared to the EU average. In fact, Bulgaria emitted 22% more CO2 per EUR 1000 of GDP than Poland, a country much more reliant on coal for power generation than Bulgaria. Meanwhile, CO2 emissions measured on a per capita basis are slightly lower than the EU average mainly due to the lower living standards and the higher level of energy poverty (Vladimirov, Rangelova and Dimitrova, 2022). There are a number of major challenges for decarbonizing the Bulgarian economy that require special attention.

One of these challenges is Bulgaria's failure to commit to decarbonizing its power sector by accelerating coal phase-out. Most recently, the government decided to begin talks to renegotiate its commitment in the National Recovery and Resilience Plan to reduce GHG missions from the power sector by 40% by 2026 vs 2019, in view of maintaining coal power plants in the system at least until 2038. Maintaining coal plants beyond 2030 risks leading to the disbursement of even higher coal subsidies, without which national coal power plants cannot be commercially viable. Meanwhile, severe regulatory and administrative barriers have hindered the uptake of renewable energy sources in the electricity sector and the existing political and economic framework fails to incentivize power sector decentralization and instead enables utility-scale projects (Center for the Study of Democracy, 2022).

The growing role of services in the Bulgarian economy has not translated into a bigger decarbonization push, mainly due to the central role of carbon-intensive transportation and the lack of low-carbon alternatives. This sector has the lion's share of national demand for oil and petroleum products – 85%. In addition, the current transportation policies lack focus on decarbonizing the sector's commercial segment.

Bulgaria's industrial sector is the second largest sector in terms of value-added (17%), employment (18%), and share of final energy demand in the country (27%). Its importance in the national economy comes together with high fossil energy intensity, CO2 emissions, and a general vulnerability to fossil fuel price volatility. Across the four sectors (industry, services, households, and agriculture), industry requires the largest amounts of natural gas and solid fossil fuels. It consumes 60% of the coal and 70% of the natural gas in Bulgaria's final energy demand. Meanwhile, industrial energy efficiency in Bulgaria is among the lowest in the EU.

The sector's dependence on natural gas in different manufacturing processes not only poses a hurdle for Bulgaria's green transition but in light of Russia's invasion of Ukraine also exposes the Bulgarian economy to high geopolitical and geoeconomic risks. High natural gas and CO2 costs could become strong economic incentives for industrial energy consumers to decarbonize the manufacturing processes and boost efficiency. The deep decarbonization of the industry sector requires a structural shift in all industrial production processes, especially in chemicals, iron, steelmaking, cement and ceramics, which still have a dominant role and have poor sustainability performance (Center for the Study of Democracy, 2021). Additionally, it requires a reorientation of the economy towards lighter industries with higher added value.

In the buildings sector, the high share of renewable energy in final energy consumption among households conceals the excessive reliance on firewood for heating, the most important component of the energy demand in the sector. The dependence on firewood comes together with severe environmental sustainability and air pollution risks revealing the enormous energy poverty challenges that have become in themselves a brake on the energy transition process. Despite the large spending on energy efficiency programs for residential and public buildings implemented so far, the actual impact in terms of renovation rate and depth has been negligible. The government grant scheme for multi-family residential buildings between 2015 and 2019 has had a limited scope of around 2000 buildings. Moreover, the actual renovation has been shallow, mostly focusing on wall and rooftop insulations and no measures targeting net-zero energy buildings (Center for the Study of Democracy, 2020).

Bulgaria's overall energy policies lack a high decarbonization ambition and are not aligned with the EU goals under the Green Deal and the "Fit-for-55" package which Bulgaria is currently not officially supporting. It delayed the publication of a long-term low carbon strategy by almost two years and when appropriate plans were announced, the government faced an im¬mediate backlash from the industrial sector. The least costly decarbonization pathway for Bulgaria requires accelerated electrification, in combination with deep decarbonization of the electricity sector and a strong focus on energy efficiency and economic transformation towards lighter industries and services with higher added value (Rangelova et al., 2021).

Energy Poverty

The magnitude of energy poverty in Bulgaria makes it a primary energy and climate security risk. According to Eurostat survey data, it has the largest share of people who are unable to keep their homes adequately warm in the EU. As of 2020, this concerned 28% of Bulgarian households, down from 67% in 2010, yet a staggering 20 percentage points above the EU average. The improvements made over the past decade have primarily been an effect of overall economic development, rather than targeted government policies to tackle energy poverty. Such policies have been very limited in scope.

The main roadblock to effective energy poverty mitigation policies in Bulgaria is the absence of a clear legal definition of the phenomenon and of appropriate tools to measure it. How energy poverty is defined can radically change which and how many households would be considered vulnerable. This is mainly due to the interplay between the three key factors that are at the heart of the phenomenon – low income, high energy prices, and low energy efficiency of the home. For Bulgaria, the range of the estimated share of the population that can be considered energy poor is very wide – between 12% (based on the low income/ high energy expenditure method) and 55% (the 10% share of energy in total expenditures method). The 10% indicator is too broad in scope to allow for truly targeted measures. Meanwhile, a more restrictive definition such as the low income/ high expenditure method focuses mainly on poor households in energy inefficient dwellings. It misrepresents poor households that spend little on energy as "energy efficient", while in reality, they may be simply unable to afford their basic energy requirements.

Defining and measuring energy poverty requires going beyond budgetary indicators in favor of a more comprehensive, multi-dimensional approach, which considers a number of high-granularity quantitative indicators. These include a definition of basic energy requirements of households (considering household size, climate zone, the energy efficiency level of the home, the type of heating system used, etc.) and together with additional information on pricing, to derive normative expenditures for meeting these energy requirements. In this case, energy-poor households would be those that would fall below the poverty line after meeting those basic energy requirements.

A key policy related to energy poverty has been the provision of financial aid for covering heating expenses. Only around 300.000 households typically qualify annually for this aid, equivalent to less than 10% of the population. This does not even cover half of the population living below the poverty line – 22%. The size of the aid is also limited, covering only the energy requirements for the heating of one room and minimal usage of electrical appliances. Moreover, this approach provides short-term alleviation but has no structural impact in terms of reducing energy poverty in the long term.

The energy poverty risks exhibit strong correlation with air pollution and health-related issues. Specific measures in large cities such as Sofia and Plovdiv to support a switch to cleaner fuels in residential heating have had limited success. Only a small number of households have switched their heating appliance and many of the approved participants have delayed or cancelled their participation in the program. This measure is also not sufficiently aligned with decarbonization goals, as natural gas is among the available technology options, while low-carbon energy technologies such as solar thermal energy and heat pumps have not been included as an option.

Energy efficiency policies have also had a limited impact. Despite the substantial government funds allocated to energy efficiency projects, the exclusive approach of providing a 100% government grant for buildings renovation, irrespective of the financial situation of households, has reduced the number of projects that could benefit from the government program. At the same time, the regulated electricity market and government efforts to keep electricity prices for households artificially low have reduced the incentive for the middle class to invest in energy efficiency. Hence, the annual renovation rate of the national buildings stock over the past several years has remained below 1%. The depth of renovation has also been limited – mostly to wall and rooftop insulation.

Skyrocketing energy prices and overall inflation amid the war in Ukraine have exacerbated existing vulnerabilities and threaten to bring a larger number of middle-class households closer to or even below the poverty line. In response to the energy crisis, the government has doubled down on price regulation and fuel subsidies without a targeted approach that focuses on the most vulnerable consumers. Meanwhile, energy efficiency measures have been scaled down under the National Recovery and Resilience Plan, which together with the significantly higher cost of construction materials is set to slow the rate of renovation, rather than the necessary acceleration of decarbonization.

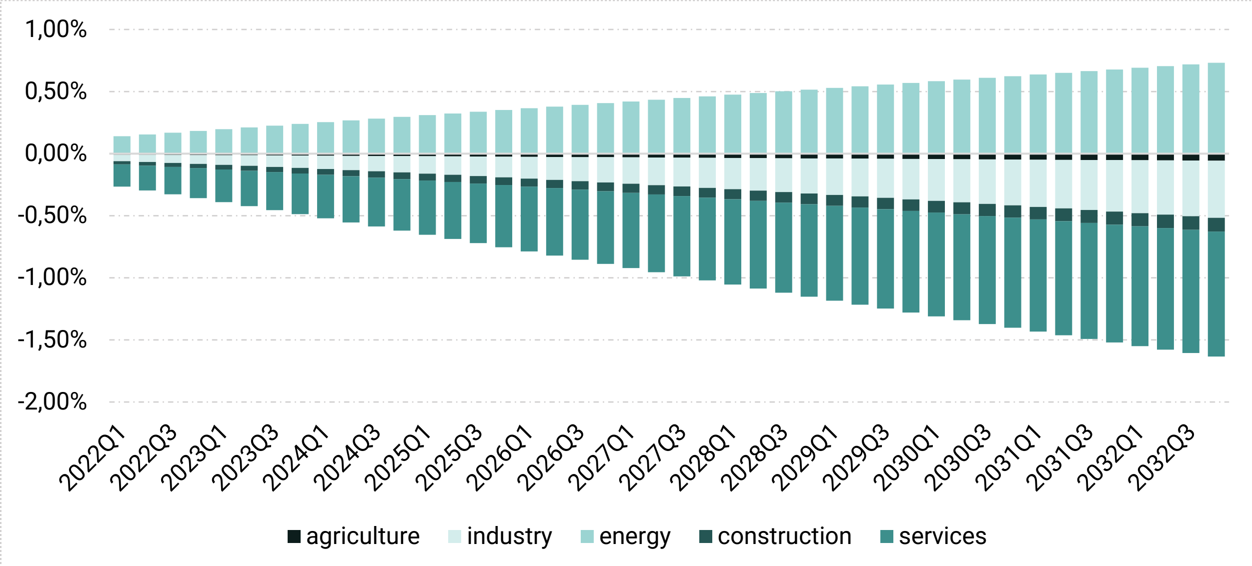
Recent efforts by the government to produce a legal definition for energy poverty are a key step forward. Nevertheless, this definition, expected to be finalized in 2023, is unlikely to be operationalized beyond the context of tailoring government support for energy efficiency measures. There is no political will to create a dedicated institution that would take direct responsibility for this issue, nor does any existing government institution have the political will to take that responsibility.

Results

Macroeconomic impact

Bulgaria's GDP will rise by 22% between 2022 and 2032, according to the OECD projections for the country's economic growth. Introducing a carbon price at the suggested level results in 0.27% lower GDP in 2032 compared to the no-price scenario and the OECD assessment. Similarly, the total value-added across all sectors in Bulgaria would be only marginally lower, 0.9%, albeit the effect varies between sectors. The negative deviation in added value in Bulgaria (see Figure 3) would be mainly driven by the services sector (-1.01%), followed by industry (-0.46%), construction (-0.11%) and agriculture (-0.06%). As the services sector has been growing very strongly in recent years, the expected negative deviations vs the no-carbon-price scenario remains marginal.

Figure 3: Differences in value-added in Bulgaria (% deviation from no-carbon price scenario)

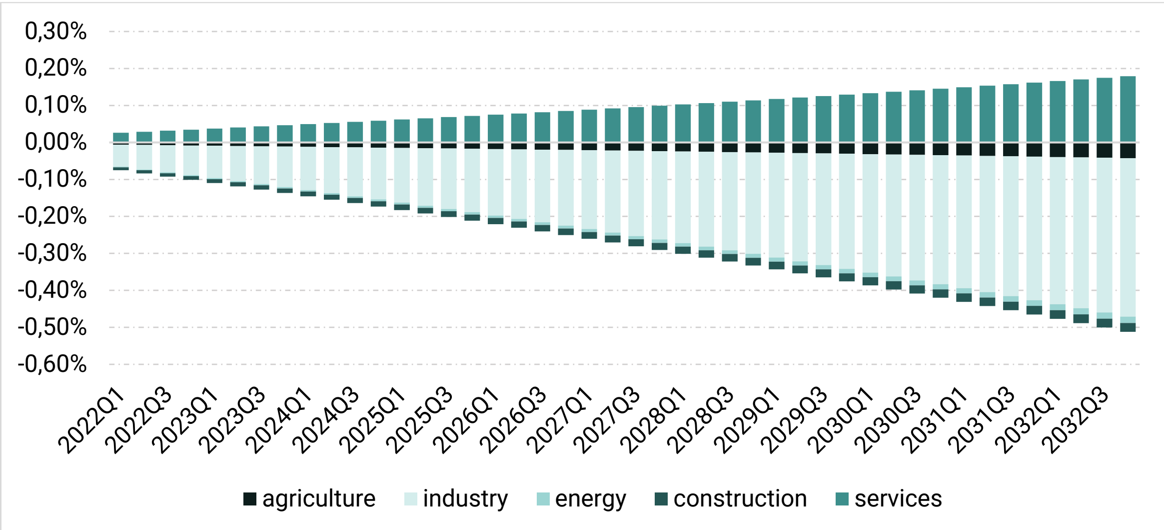


Source: own calculations.

Crucially, Bulgaria's macroeconomic performance will not suffer significantly, but on the contrary the carbon pricing will likely bring notable benefits such as improved labor market conditions and stronger energy security. In addition, the modeling assessment shows a strong positive impact on value added in the energy sector and will contribute to a larger share in the total added value compared to the scenario without a carbon price. A carbon price would further strengthen the competitiveness of the renewable energy industry, which already benefits from low marginal costs, and therefore means a strong shift of resources from the fossil fuel industry to the RES sector, ultimately leading to a higher share of RES in the energy mix. The large gap between renewables' low marginal costs and the high market prices will drive the increase in the sector's added value.

Employment in Bulgaria will also not suffer a major, negative impact from the introduction of a carbon price, as negative deviations from a no-price scenario do not exceed 0.5% in any sector, while employment in services will even grow by roughly 0.18% over the observed period. The growth of this sector coincides with a small negative deviation in comparison to a no-price scenario equal to 0.4% in the industry sector which implies that employment would shift towards higher-skilled labor and higher-value-added segments. These effects can be easily mitigated as Bulgaria already has a low unemployment rate, while the labor shortages in key sectors are a much greater concern. The changes in the labor demand will require widespread and well-coordinated training of workers to help meet the demand for high-skilled labor.

Figure 4: Differences in employment in Bulgaria (% deviation from no-carbon price scenario)



Source: own calculations.

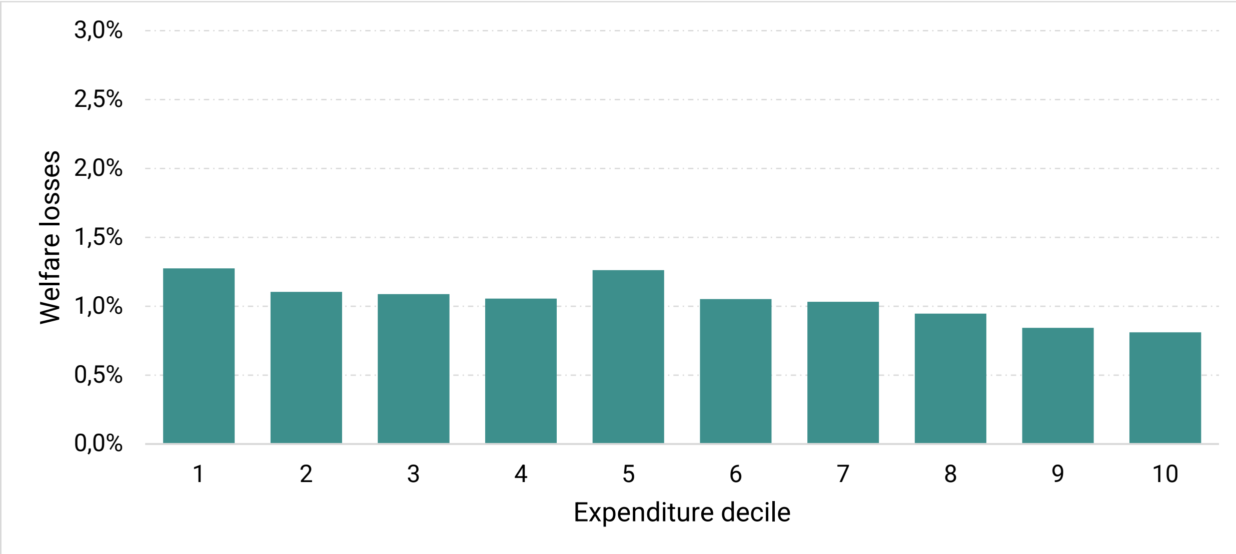
In light of the war in Ukraine and the resulting energy crisis, a carbon price can additionally act as an efficient measure to improve Bulgaria's energy security. Bulgaria is heavily dependent on imports of natural gas, which before the war, came almost exclusively from Russia, putting Bulgaria in a delicate position when Gazprom cut its deliveries in April 2022. The macroeconomic modelling results show that a carbon price would decrease Bulgaria's natural gas imports by a quarter over the next decade, mainly because of the additional pressure on the industry sector to decarbonize. Naturally, diversifying its supply sources for natural gas, as Bulgaria is currently doing, is also critical for improving its energy security. However, this is more of a short-term solution, whereas in the long run, phasing out natural gas from the energy mix is the most sustainable way to achieve better energy and climate security.

Household impact

The results from the microeconomic analysis show that welfare losses for Bulgarian households range between 0.8% and 1.3% with a clear regressive trend. The poorest 10% of Bulgarian households are expected to be most affected by the introduction of a carbon price, as they would have to earn 1.3% more on average to maintain their consumption levels. According to data from the National Statistical Institute, this welfare loss is almost half of what the poorest 10% regularly receive as money transfers from relatives, crucial for making ends meet.

The observed negative trend is likely to be the result of the relatively high share of electricity in household expenditures across all deciles, as well as the high level of social inequality in Bulgaria. Although the margin between the poorest and richest 10% appears to be narrow in absolute terms, the poorest 10% would still be 60% more affected than the richest 10%. As the poorest 10% spend most of their income on bare necessities, this additional price burden would also lead to a disproportionate loss of welfare compared to the richest 10%.

Figure 5: Welfare losses across deciles in 2032, before redistribution

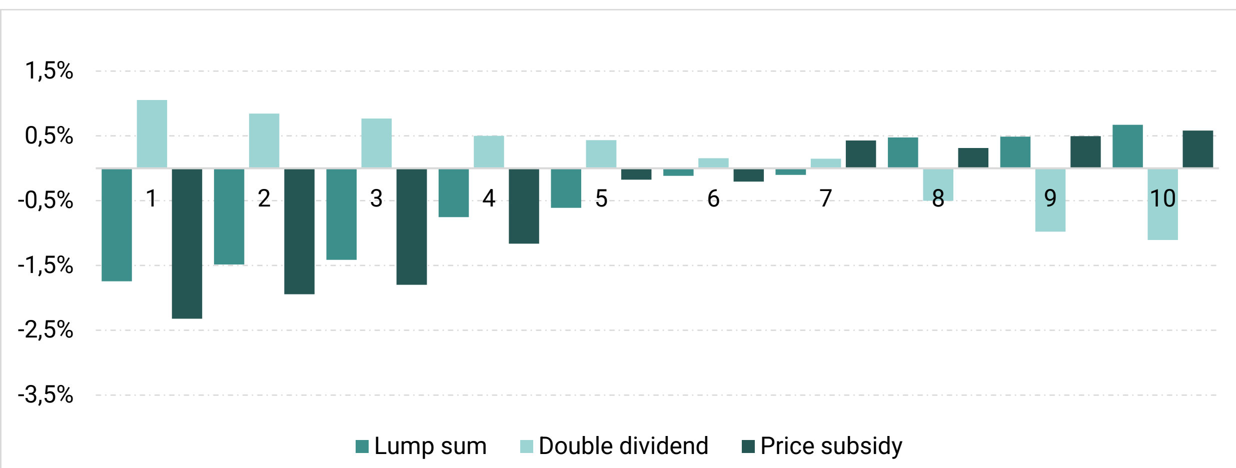


Source: own calculations.

All three scenarios modelled in this study show that the redistribution of the additional tax revenues lead to reduction in welfare losses on the national level, with certain income groups, depending on the scenario, even registering net welfare gains in comparison with a no-carbon-price baseline.

The double-dividend redistribution scenario is assumed to act like an income tax reduction and hence the rebate is directly proportional to income. In this scenario, the poorest 50% still experience welfare losses between 1% and 0.5%, while the richest 30% increase their welfare compared to a no-price scenario. Hence, such a redistribution policy would only exacerbate the regressive tendencies of carbon prices and overall socio-economic inequality.

Figure 6: Welfare losses across deciles in 2032 in the three redistribution scenarios



Source: own calculations.

In the case of a lump-sum redistribution, where each household receives the same amount regardless of their income level, the poorest 50% shift to a net welfare gain compared to the no-carbon-price scenario with the poorest 10% benefitting the most, as they could consume up to 1.7% more with the same income. With the middle class's welfare losses being balanced out and the richest households being the only ones who are still experiencing slight welfare losses, this form of redistribution succeeds in reversing the regressive trend of carbon pricing and improving overall social welfare.

A price subsidy redistribution, where the rebate is inversely proportional to the household's budget, would have a similar effect to the lump-sum rebate but with much greater welfare gains for the poorer segments (2.3% welfare gain for the poorest 10%). The richest 30% experience welfare losses that are almost identical to the lump-sum scenario. Thus, such approach which specifically targets the poorest households is likely to disadvantage the middle class. The administrative burden of such a complex redistribution system also exposes the policy to additional risks associated with national governance gaps, a risk that is particularly potent in Bulgaria. Consequently, there is greater uncertainty as to whether a price subsidy would fully deliver the estimated benefits in a real-life application.

A carbon price without revenue redistribution would increase energy poverty levels in Bulgaria from 17.46% in 2022 to 18.22% in 2032[3]. Nevertheless, in the lump-sum and price subsidy scenarios, energy poverty levels would even fall below the initial levels in 2022. The results reflect the previously discussed welfare changes across deciles in the sense that the double dividend scenario benefits primarily richer households and thus unsurprisingly leads to energy poverty levels that are still above the 2022 ones.

Table 8: Energy poverty levels based on different redistribution scenarios

	Baseline scenario (2022)	Post-tax scenario (2032)	Post-redistribution scenarios (2032)		
			Lump-sum	**Double dividend**	**Price subsidy**
Bulgaria	17.46%	18.22%	16.85%	18.01%	14.05%

Source: own calculations.

The results from the modelling scenarios reveal that a carbon price does not have to lead to welfare losses and higher energy poverty in Bulgaria if it is combined with a well-designed and well-implemented redistribution policy. Due to its relatively easier administrative complexity and its negligibly smaller benefits (compared to a price subsidy), the lump-sum scenario stands out as the most viable option for incentivizing a switch to less carbon-intensive consumption that will additionally leave poorer households better off.

Discussion and recommendations

Even before the introduction of a carbon price, the share of Bulgarian households' total expenditures spent on electricity is significantly larger than in Germany, Hungary, Poland, and Romania. The poorest 10% in

[3] Energy poverty levels are defined as the share of the population whose energy expenditures are below 50% of the national median. This definition focuses specifically on the poorer households, thus failing to fully capture energy poverty among middle class households with low energy efficiency

Bulgaria spend 10% of their income on electricity only while the richest 10% still spend almost 4% on their power bills, which is more than the poorest 10% spend in Germany. The assessment reveals that higher prices lead to a strong reduction in spending on electricity, especially among the poorest. This indicates that when prices increase, poorer households choose to sacrifice their comfort by severely cutting consumption. Bulgaria's only energy poverty reduction policy apart from the social transfers targeting a limited number of households is the regulated power price for household consumers. Keeping prices artificially low for all consumers no matter their income has distorted the market by creating wrong incentives for wasteful power consumption and reducing the attractiveness of individual energy efficiency investments. The regulated electricity prices are also the closest to a redistribution mechanism Bulgaria gets, as the low power tariffs for households are largely financed by the Electricity System Security Fund (ESSF), whose biggest share of revenues comes from the sale of EU ETS allowances.

The same mechanism also indirectly subsidizes coal power plants in Bulgaria. The National Electricity Company (NEC) has pre-defined available capacity quotas for electricity generation from certain producers including from several independent coal-fired power producers at preferential feed-in tariffs to meet the demand from the regulated market. The ETS revenues practically cover the tariff deficit formed between the price NEC pays to buy the availability capacity and the price at which it sells the electricity. These indirect subsidies are set at BGN 1.6 billion for the regulatory period July 2022-July 2023 by the Energy and Water Regulatory Commission. This is almost a third of Bulgaria's total allocation from the Social Climate Fund. Coal power plants are thus artificially maintained in the market at a high cost for the state budget and would be forced to close in a liberalized market, even at lower carbon prices than the recent range of EUR 80-100 per ton of CO_2, as demonstrated also by the present study's modelling results. The issue of electricity market liberalization goes beyond carbon pricing but remains relevant to the revenue redistribution mechanisms and the Social Climate Fund. It also risks affecting public perceptions of carbon pricing, as the planned liberalization of the electricity market and the launch of the ETS II are likely to overlap to some degree. The next two years will be crucial for preparing households for the transition both in terms of informing them about the changes, as well as with a well-designed energy poverty mitigation strategy. The launch of the Social Climate Fund ahead of the introduction of the ETS2 means that the benefits could be felt much earlier if a smart spending program is in place to ensure a smooth transition.

There is a clear distinction to be made between government support for the coverage of basic energy needs and for investments in energy efficiency and renewable energy technologies. The latter covers a much wider target group and requires a carefully tailored approach that combines innovative financing mechanisms that support only a share of the investment costs borne out by households. Funding should be tightly linked with energy efficiency and fuel replacement targets, so that households are incentivized to change their energy behavior limiting wasteful consumption and decarbonizing the fuel mix they use for heating.

At a time when skyrocketing fuel prices threaten to push even more Bulgarian households into energy poverty, an additional carbon price signal risks a strong pushback from society and policymakers alike. The present study provides additional evidence on the macroeconomic and microeconomic impacts of carbon pricing revealing that this additional "tax" would not only have a very small impact on the Bulgarian economy, but would actually incentivize the growth of low-carbon energy alternatives. However, there is an urgent need to introduce a national Social Climate Plan that will feature a redistribution mechanism to reduce the small welfare losses for households from the introduction of a carbon price. Carbon pricing should not be considered in isolation but as part of a broader decarbonization policy toolbox related to the uptake of renewable energy, energy efficiency, low-carbon transportation, and the improvement of energy and climate security.

The assessment identified a number of key priorities, which could reduce energy poverty risks without undermining the decarbonization policy of the government:

- Introducing a carbon price should be used as a primary tool to accelerate the energy transition without hurting Bulgaria's long-term macroeconomic potential or raising energy poverty levels.
- The revenues from the ETS scheme should not support the operation of coal power plants and the below-market ceiling on household power prices but feature in a targeted redistribution plan aiming to expand the coverage of the existing social transfers for mitigating energy poverty. These funds could be reallocated to investments that will accelerate the uptake of renewable energy technologies, the decentralization and modernization of electricity grids and for supporting green innovations. The majority of the ETS2 revenues and the Social Climate Fund should be used for energy poverty reduction measures, focusing on energy efficiency and renewable energy investments.
- The allocation of ETS2 funds toward temporary direct income support for vulnerable households should be directly tied to complementary energy efficiency and fuel replacement measures based on targets for the reduction of energy consumption and the decentralization of power systems in homes.
- Set up a robust scheme for upskilling the labor force to help meet the growing employment demand in high value-added sectors, partially the outcome of carbon pricing shifting capital in low-carbon industries of a new generation.
- Outline dedicated measures that support decarbonization in the services sector, with a focus on boosting sustainable transportation and electrification.
- Formulate a clear strategy for the transformation of the Bulgarian industry that replaces the current lavish energy subsidies with investment support that is also linked with a clear program for reducing energy consumption, boosting circularity in production processes and the uptake of prosumer-based renewable energy solutions.
- Complement the current definition of energy poverty with a clear institutional backing. A dedicated executive agency under the Council of Ministers should manage the implementation of energy poverty policies and measures, which will also keep an up-to-date registry of energy poor consumers in attempt to better tailor measures, keep track of the individual support households receive, and evaluate the effectiveness of the support mechanisms.
- Define a clear strategy for the liberalization of the electricity market, in which regulated prices are replaced with targeted social transfers that are disbursed to the most vulnerable groups fitting the energy poverty definition. The liberalization process should come hand-in-hand with investment schemes for the middle class, which might be out of the scope of the social transfers program but would like to improve energy efficiency and implement low-carbon technologies domestically. The agency should engage power distribution companies in the process by designing additional mechanisms for shared investments with household consumers in the field of, for example, ESCO services.
- Launch a comprehensive public awareness campaign explaining EU's 'Fit-for-55' strategy and the role of carbon pricing for the transformation of the Bulgarian economy. The goal is to counter widespread disinformation narratives that seek to undermine and delay the low-carbon transition and to perpetuate the country's dependence on fossil fuels.

Germany

Context

Since its reunification in 1990, Germany has consistently experienced robust economic growth. This progress has been particularly prominent in the last two decades, with Germany emerging as a primary driving force behind regional economic growth. The nation's growth pattern largely mirrors that of the European Union, with the few recessions it has encountered being linked to exogenous economic shocks impacting the entire Union, such as the Great Recession of 2008-2009. Furthermore, Germany has maintained a stable population, with modest overall increases in the past ten years, although this stability is partly due to higher life expectancy rates rather than rising birth rates.

The interplay between economic growth and population stability has resulted in greenhouse gas emissions remaining relatively unchanged compared to previous decades. However, Germany's emissions intensity has steadily decreased, albeit at a slower pace than the average European Union country. This reduction is attributable to the growth of employment in less energy-intensive industries and improvements in industrial production efficiency, particularly in sectors like automotive manufacturing.

From a policy standpoint, Germany is dedicated to one of the most ambitious energy transition strategies within the European Union. This plan includes a complete coal phase-out by 2038, with ongoing reviews potentially accelerating the timeline. Additionally, Germany has mandated that by 2030, 80% of its energy must be derived from renewable sources, incorporating 30 GW of offshore wind capacity by the end of the decade. Although these targets may appear ambitious, they are crucial for the coordinated efforts of the EU to achieve net-zero emissions by 2030, as mandated by the European Green Deal.

In Germany's energy sector, the country's reliance on energy imports is noteworthy. Despite recent efforts to diversify due to geopolitical factors, Germany still depends on natural gas and oil imports. However, its energy mix includes various carriers: coal and gas are vital, while wind and solar PV have steadily grown and are becoming dominant. Specifically, wind makes up 18%, and solar PV and hydropower nearly 10% each. Agriculture is closely tied to renewable energy advances, but the industry still relies on coal and other solid fossil fuels. As a federal state, Germany's regional differences impact emissions reduction rates, with pollution-heavy industries like chemicals affecting some areas more.

The German economy is service-oriented, with industry playing a significant role in specific regions (e.g., Bavaria's automotive sector). This structure implies that decarbonization strategies must consider diverse greenhouse gas sources and cater to each region's unique features. A one-size-fits-all approach would be sub-optimal and unpopular. Implementing a stringent carbon price requires considering local sensitivities and well-planned complementary social policies.

According to the latest data from Eurostat, Germany is among the countries least affected by energy poverty in 2022 and 2023. Less than 2% of German households have been in arrears on their monthly utility bills, and approximately 1% have experienced disconnections due to financial hardship. Additionally, only 2.5% of German households, although not traditionally considered at risk of energy poverty, reported difficulties in keeping their homes adequately warm. While energy poverty risk may appear relatively mild compared to other countries in East-Central and Southern Europe, it remains a significant concern that nearly 350,000 households face energy poverty risks annually. This number has not declined over the past decade, and some years have even shown substantial increases in the number of affected individuals.

It is important to note that many households experiencing energy poverty do so transiently, meaning they face significant hardship only for a limited period. This suggests a certain level of resilience but also indicates that aggregate statistics may underestimate the actual scope of the problem. Thus, while Germany may have a less severe chronic energy poverty challenge, it faces a more widespread risk of temporary energy poverty. This is particularly concerning because experiencing energy poverty at some point has been shown to be a strong predictor of future energy poverty.

Recent research has identified specific socio-demographic and socio-economic characteristics that are likely associated with an increased risk of energy poverty, including low educational attainment, low labor intensity, rural household location, and housing conditions. These factors have become more significant in recent years due to the high prices of electricity and natural gas in Germany. For example, in 2021, German households paid the highest electricity prices in the European Union and some of the highest gas prices. Importantly, these high prices affected both household and non-household consumers, creating multiple channels through which energy poverty could impact vulnerable populations.

In recent years, concerns about energy poverty have gained prominence in the German political landscape due to several concurrent developments: the increased ambition and stringency of national climate policies, EU-wide objectives and policies (e.g., the EU ETS), as well as exogenous shocks like the COVID-19 public health crisis and geopolitical tensions in Eastern Europe (exacerbated by Russia's recent aggression in Ukraine).

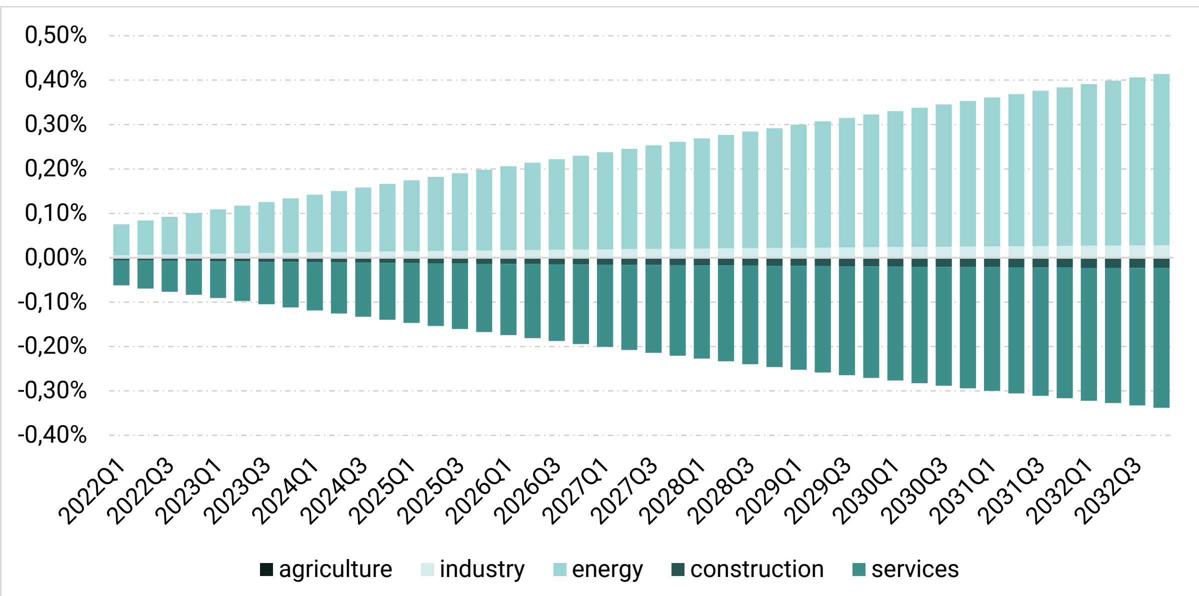
Although German authorities have not yet implemented federal policy packages specifically addressing energy poverty, some argue that this is due to the limited number of households affected. However, German welfare provisions do include energy-related expenses within their broader scope, alleviating some pressure on vulnerable consumers. Notably, such measures typically cover heating expenses rather than electricity consumption. Additionally, more localized policy responses have been implemented, particularly regarding improved energy efficiency standards.

Results

Macroeconomic impact

One of the critical questions concerning the consequences of stringent carbon pricing mechanisms is the effect such a policy would have on Germany's economic growth pathway. While in the absence of any other measure, a carbon tax would have specific distortionary impacts like any other fiscal instrument, our model reveals this to be a manageable challenge. Figure 7 reveals a series of stylized facts that describes the direction and size of the effects induced by a carbon tax on the German economy.

Figure 7: Carbon pricing effects on value-added by sector



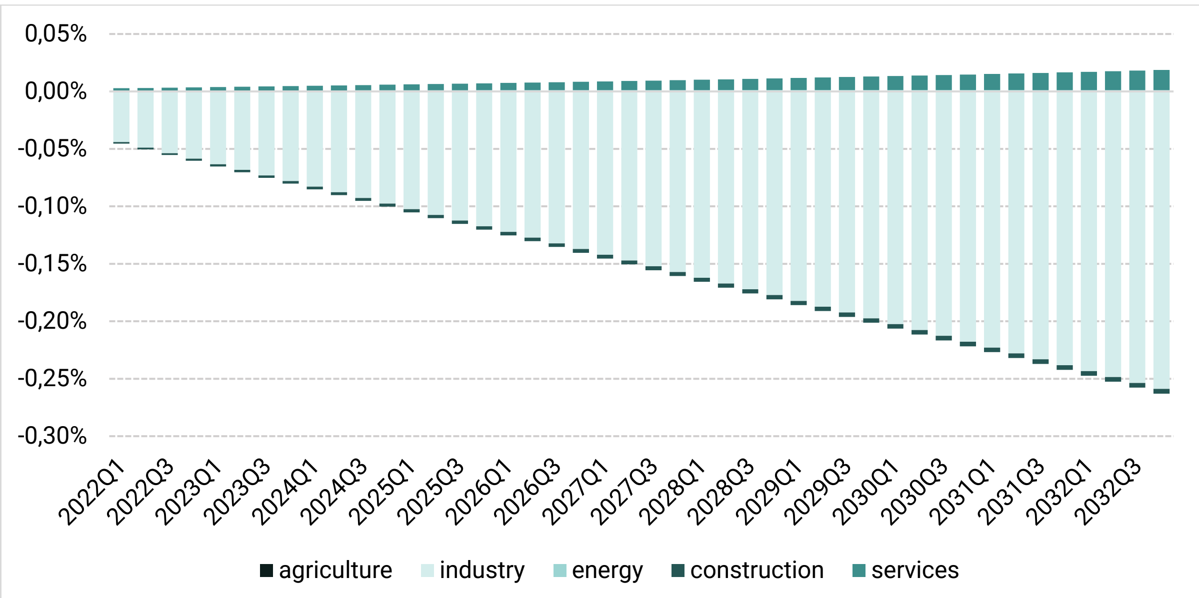
Source: own calculations.

First, some economic sectors (including industrial branches) are likely to be unaffected by the introduction of the policy in terms of their value for the economy. Second, the only sector that appears to be affected by carbon pricing is the services sector. Services are the main contributor to the German economy, both in terms of employment opportunities for the general population and of value-added. While this is an interesting development, possibly related to the reduced dependency on natural gas imports, it is essential to note that this sector is also the most resilient. Therefore, the 0.4% decrease in the value-added by services by 2032 is likely to be compensated either through market mechanisms (i.e., a dynamic restructuring of where the investments in the services sector are directed) or through state-driven incentives.

Finally, the energy sector is expected to grow by around 0.4% in the same period, driven most likely by the growing importance of regional companies in the field of renewable energy. As Germany is committed to becoming carbon-neutral, the carbon tax would therefore contribute to the process of directed technological change.

Regarding the employment effects of carbon taxation in Germany, the overall impact appears to be minimal and concentrated in the industrial sector. However, by the end of 2032, the losses of industry jobs will be less than 0.3% compared to the baseline scenario where the new carbon tax is not implemented (Figure 8).

Figure 8: Carbon pricing effects on employment



Source: own calculations.

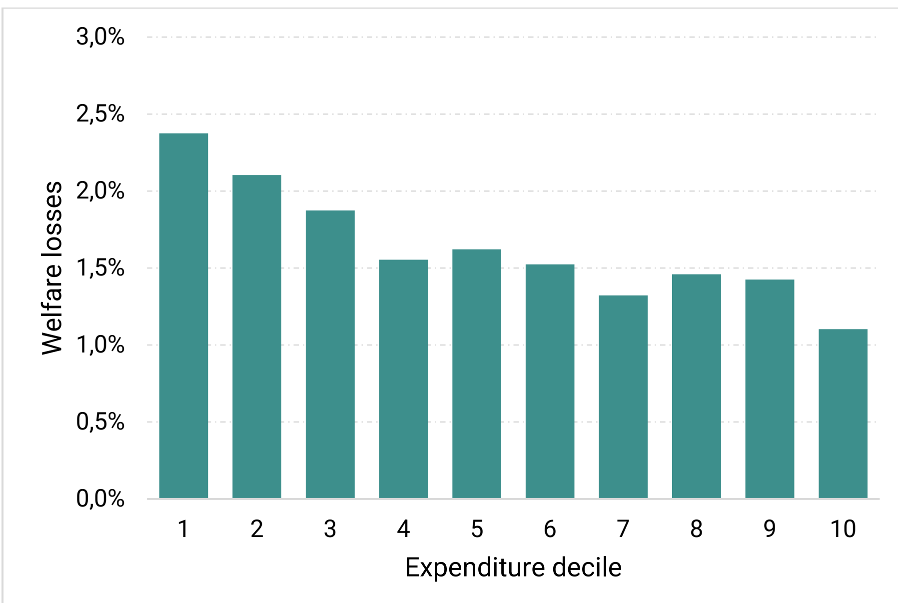
While this is not negligible, as the people losing their job are likely to be concentrated in geographic hotspots, the ability of the German government to compensate them is not under question. Furthermore, referencing the German strategy of assisting workers affected by the coal phaseout as an example of targeted intervention, the carbon tax would not require outstanding efforts from any of Germany's 16 states or the national government. Additionally, while also small, the carbon tax will create new labor opportunities in the service sector. As stated before, this is correlated with the likely growth of the renewable energy firms in Germany over the next decade. While it is unclear whether a correspondence between services and industry could be established, work training programs could facilitate this. Therefore, the stringent carbon tax regime in Germany could be, in the optimistic scenario, an example of market self-adjustment.

The main challenge of Germany's energy transition is ensuring a cost-optimal abatement strategy that improves the ability of domestic firms to maintain their shares and profitability in the European and global markets. Given how decarbonizing industrial processes is central to achieving a net-zero economy in the timeframe set by the European Union, Germany will have to engage in a systematic process of directed technological change that prioritizes the introduction and development of new, market-ready low-emissions goods. This is essential for multiple industrial sectors, but one can immediately think of the chemical and automotive sectors as typical examples of where intervention needs to be well thought out. In the case of Germany, an optimal transition pathway is not only important at the national level but also essential for the economic stability of the European Union. As shown through our macroeconomic modelling strategy, stringent nationwide carbon pricing mechanisms could contribute, sometimes in subtle manners, to addressing this challenge. The reason for which a carbon tax could be necessary is that, with minimal adverse effects on employment structures and sectorial value-added, it helps Germany to reduce its dependency on energy imports, which in recent months has proven to be one of the weaknesses of the German economy. Additionally, the carbon tax is expected to increase the value-added by the energy sector, thus contributing directly to internal diversification, which can only augment the country's technological potential.

Household impact

Figure 9 presents the primary results of the QUAIDS-based microsimulation, highlighting the welfare losses caused by a German nationwide carbon tax applied across all economic sectors from 2022 to 2032. Firstly, without revenue recycling, the tax displays mildly regressive effects. For perspective, the average loss for the poorest 10% of German households is over double that of the wealthiest 10% (i.e., a compensating variation of 0.025 vs. 0.011). There are three categories of losses: high payers (the first three expenditure deciles), medium payers (the following six deciles), and low payers (the top decile).

Figure 9: Welfare losses after the carbon tax

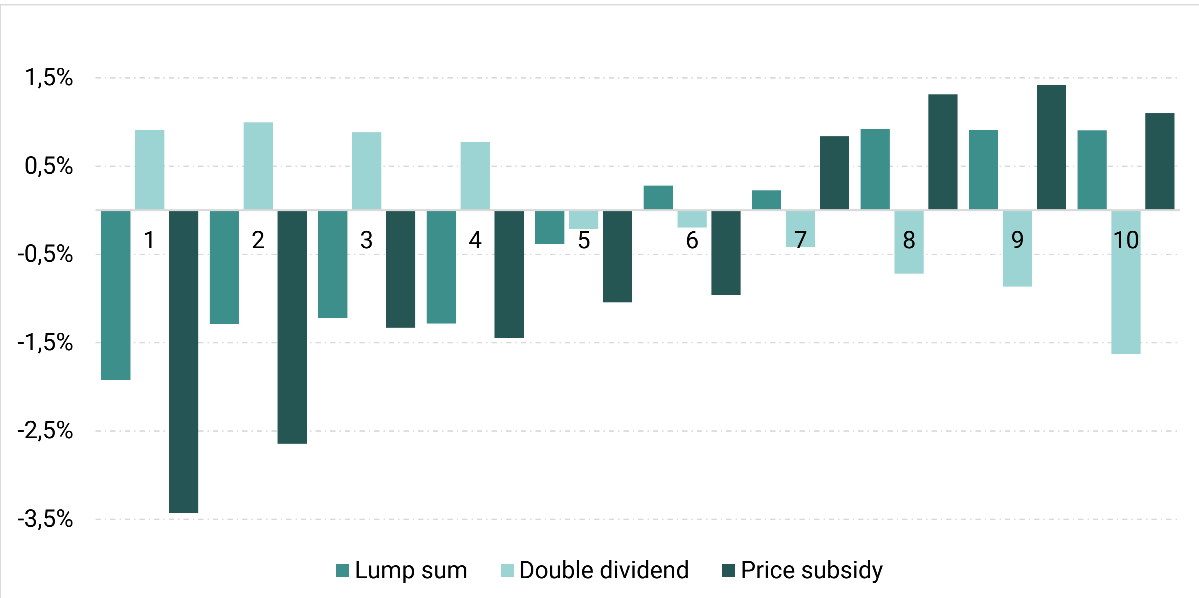


Source: own calculations.

These adverse effects result from a relatively low tax level of 20.51 EUR/tCO2, suggesting that more ambitious carbon pricing mechanisms may produce a larger impact if applied similarly to the entire German economy. The low carbon tax level could also contribute to the variation in welfare losses between deciles, as the average German citizen is unlikely to struggle adapting to the new pricing regime induced by the tax. Secondly, the definition of welfare losses used in this report suggests that all households would need to earn between 1.1% and 2.5% more monthly to maintain their initial consumption levels before the carbon tax. Considering other sources of price inflation, this implies a significant effort for a sizable share of the population (at least t8he bottom 30%), indicating that government intervention targeting the less affluent may be politically and socially desirable. This is particularly relevant due to recent developments in 2022 that have increased inflationary pressure faced by the majority of citizens. However, our data only covers the period before 2020, which could result in a downward bias in our estimate.

Next, Figure 10 illustrates the welfare gains and losses across the German population under the carbon tax and three redistribution scenarios. Each scenario results in different winners and losers by 2032 compared to the baseline scenario before the carbon tax's introduction in 2022. Aggregate social losses decrease substantially in all three cases, confirming that carbon pricing in Germany has minimal impact on less affluent households when the government implements any redistributive policy. This holds true regardless of the policy's specific content.

Figure 10: Post-redistribution welfare gains and losses



Source: own calculations.

The price subsidy scenario is the most effective in reducing welfare losses for less affluent households, especially for the bottom 20%. Under this model of revenue recycling, households belonging to the first six deciles experience net welfare gains, with 60% of the population benefiting. This approach also has the potential to reduce overall inequality in the country. Although the wealthiest 40% become net payers (i.e., net losers), their losses are modest, with a maximum of 1.4% of their monthly income or about 66 EUR.

The lump-sum scenario ensures that the bottom 50% of households incur no losses, becoming the net winners of this policy regime. The net losers of the carbon tax regime are households in the top five deciles, but the total costs of carbon pricing are more evenly distributed. The simplicity of the lump-sum redistribution could be attractive for administrative ease in implementing and monitoring the policy across the German regions.

The double dividend scenario induces very different distributional and welfare effects compared to the other scenarios. In this case, the least affluent remain net losers, but the welfare effects are significantly less pronounced for the aggregate population. The net winners are the most affluent 60%, particularly the top three deciles. Politically, this could be seen as less feasible, as it increases within-country inequality and does not adequately address concerns like energy poverty. Nevertheless, further analysis on the broader effects of this scenario and the potential use of funds from the carbon tax to replace other distortionary taxes should be considered. Additionally, it would be relevant to study whether industry-specific measures would have a broader effect in generating large-scale welfare gains for those at the bottom of the expenditure distribution.

Energy Poverty

Table 9 presents our estimates for energy poverty in Germany, both in the baseline scenarios before carbon taxation in 2022, and at the end of the period studied in 2032. We see that in our baseline case, 8.25% of households are energy poor, a significant number but well below the average values for the European Union or, more specifically, Central and Eastern Europe.

Table 9: Carbon pricing and energy poverty

	Baseline scenario (2022)	Post-tax scenario (2032)	Post-redistribution scenarios (2032)		
			Lump-sum	**Double dividend**	**Price subsidy**
Germany	8.25%	10.93%	8.34%	9.15%	6.02%

Source: own calculations.

However, after implementing the carbon tax, before redistribution, the number increased by 32%, a situation that needs to be managed by the authorities. This management involves deciding which revenue recycling strategy is best suited. All three redistribution scenarios reduce, even marginally, the share of energy poor German households. However, the price subsidy scenario is the most effective, reducing the impact on the share of affected households by almost 27%.

Discussion and recommendations

Currently, Germany has implemented a national carbon pricing policy that mainly applies to oil and natural gas, as the main sectors covered through this carbon market are heating and transportation. Therefore, at least conceptually, this system complements the European Union's Emissions Trading System. Nevertheless, the potential for developing a more stringent carbon price is evident, as both the scope and size of current measures are unlikely to be sufficient to align with the long-term objectives of the European Union.

Introducing such an encompassing carbon tax would have significant results related to Germany's decarbonization efforts. By increasing the costs of certain fossil fuels, our model predicts that until the end of 2032, Germany could reduce its dependency on natural gas imports by around 15%. This would be independent of other policies aimed at decreasing the role of gas, which could further reduce the level of emissions associated with Germany's economic activities through interaction with the carbon price. Moreover, the pace of reduction is similarly impressive, as Germany could rapidly reduce its need for natural gas by more than 5% by the end of 2023. Given situation created by the Russian invasion of Ukraine and the efforts of European countries to reduce their dependency on Russian fuels, this policy appears to be effective and timely.

Based on the results of this study, a number of policy recommendations emerge:

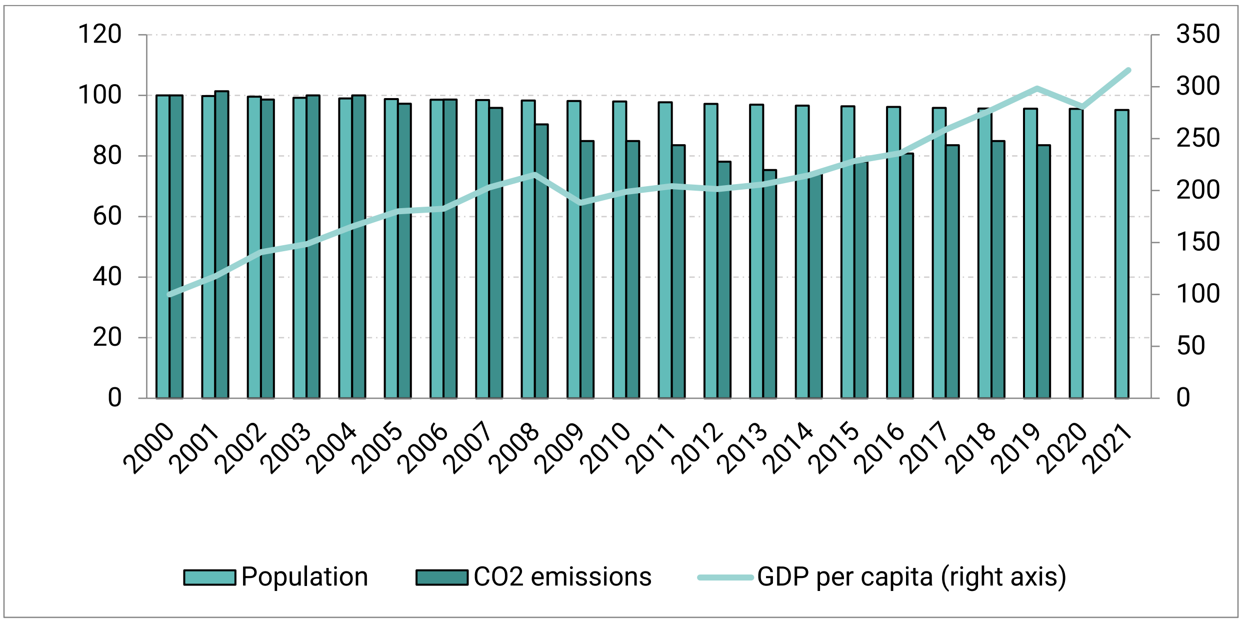
- ◊ Implement a stringent nationwide carbon tax: A carbon tax can help reduce Germany's dependency on natural gas imports, diversify the energy sector, and contribute to achieving the EU's long-term decarbonization objectives.
- ◊ Couple carbon tax with a comprehensive revenue recycling strategy: To address the regressive effects of a carbon tax and minimize welfare losses, revenue generated from the tax should be redistributed through well-designed policies targeting affected households.
- ◊ Adopt a price subsidy approach to redistribution: This scenario is most effective in reducing welfare losses for less affluent households, benefiting 60% of the population, and reducing overall inequality.
- ◊ Develop targeted support programs for energy-poor households: Given the significant increase in energy poverty rates following the carbon tax implementation, targeted support programs should be developed to alleviate energy poverty and ensure access to affordable energy for vulnerable households.
- ◊ Encourage the development of renewable energy sources: Support policies that promote the growth of regionally located renewable energy companies, as they contribute to the decarbonization of the energy sector and create new job opportunities.
- ◊ Invest in retraining and workforce development programs: To counteract job losses in the industrial sector and facilitate market self-adjustment, invest in retraining programs and workforce development initiatives that support workers in transitioning to jobs in the growing renewable energy and services sectors.
- ◊ Support research and development in low-emission technologies: Foster directed technological change by investing in R&D for low-emission technologies, especially in high-emission industries like chemicals and automotive sectors.
- ◊ Monitor and evaluate the carbon tax's impact on various economic sectors: Regularly assess the carbon tax's impact on economic growth, employment, and welfare to inform any necessary adjustments in tax rates or revenue redistribution strategies.
- ◊ Enhance communication and stakeholder engagement: Engage with stakeholders, including businesses and the public, to communicate the benefits of carbon pricing and revenue recycling mechanisms, addressing concerns, and building support for the policy.

Hungary

Context

In the last two decades, Hungary recorded significant GDP growth, with temporary setbacks due to global economic crises. CO_2 emissions have decreased between 2000 and 2014 by almost 26%, however the trend reversed and emissions have since increased to the level recorded in 2010. The Hungarian population decreased by almost 5% between 2000 and 2021, while the employment rate significantly increased during the last decade, at a higher rate than the EU average. Industry and construction have a stronger role in the Hungarian economy compared to the EU average, while the share of services in Hungarian employment represented 68%, slightly lower than in the EU (72.9%).

Figure 11: Changes in GDP per capita, CO_2 emissions and population between 2000 and 2021 (2000=100)



Source: Eurostat.

The residential sector, with its 34% share of final energy consumption is the biggest energy consumer, 51% of which is covered by natural gas and 21% by solid biomass.[4] Oil and petroleum products are predominantly (78%) used in the transport sector. The share of renewable energy in the total final energy consumption is 11% and 21% within household consumption. Solid biomass (mostly firewood) is by far the most important renewable source (79% of final renewable energy consumption), while in the case of household use, they practically cover all renewables (98%). However, this form of energy causes significant air pollution and is predominantly used by low-income households out of necessity.

Nearly half of electricity production and 38% of all primary energy production is covered by nuclear power, produced at a single plant located in Paks. The second most important source of electricity is natural gas,

[4] Hungarian Energy and Public Utility Regulatory Authority (MEKH, 2022); https://mekh.hu/eves-adatok

followed closely by oil and petroleum products. Solid fossil fuels only represent 1% of final consumption and 9% of primary production.

Hungary, in terms of energy sources, relies heavily on imports; 54% of energy sources come from abroad which is more than double the EU average (25.4%). In the case of gas, this is 110% (due to additional exports), 76% of which comes from Russia. The Hungarian government introduced a utility price cut and cap in 2013 and has regulated the prices of household gas to be fixed at a level 25% cheaper than in 2012. Simultaneously, a large share of utility providers has been centralized by the government. By 2022, the cost of gas (and electricity) on the market was multiples of the regulated price, which prompted the government to set up a utility fund – alongside a defense fund – by imposing a new tax on "extra profits" of large firms in certain sectors (e.g.: banking, telecommunication, retail, aviation, etc.). This was followed by further modification of the utility price cap policy to ease its heavy burden on the budget. From 1st of August 2022 domestic consumers must pay a higher price for their consumption that is over the average consumption[5].

The Hungarian government's strategy towards carbon neutrality – which is reflected in the National Energy and Climate Plan (NECP) – is based on scaling up solar and biomass energy and continuing to use nuclear power. However, wind energy is only marginally part of the energy mix (as it is technically banned to install new wind turbines since 2013) and there are serious concerns about too little investment into energy efficiency especially in the residential sector. Furthermore, Hungary's heavy dependence on Russian oil and gas and the government's openly negative stance against EU climate policies may also hinder the needed efforts to reach decarbonization.

Energy poverty

In Hungary multiple factors contribute to the risk of energy poverty. First, the highly inefficient dwelling stock requires high energy consumption. Secondly, while energy prices (except for firewood) are state regulated and has been fixed since 2013, resulting in the cheapest domestic electricity and gas prices in the EU (and sixth and fifth lowest respectively among EU member states in purchasing power standard) in 2021, median incomes are the third lowest among EU member states[6]. Consequently, the share of energy in total expenditure had been among the highest in the EU - before the current energy price boom - and the share of energy expenditure of the poorest households in Hungary was almost twice the EU average in 2018[7]. One-fifth of the population and majority of the lowest income group rely entirely on solid fuels - mostly firewood - to heat their home. Price of firewood has been increasing dynamically - unlike fixed gas prices - and in recent years at an increased rate[8]. Therefore, firewood users have become more vulnerable in the past decade.

According to the Eurostat indicators commonly used to measure energy poverty, 9.7% of the population had arrears on utility bills in 2021 (6.4% is the EU average)[9] while only 5.2% of the population reported experiencing difficulties in keeping their home adequately warm[10]. At the same time, one-fifth of the total population and one-fourth of children lived in a dwelling with a leaking roof, damp walls, floors or

[5] 259/2022. (VII. 21). Government Decree, https://net.jogtar.hu/jogszabaly?docid=a2200259.kor
[6] Eurostat, https://ec.europa.eu/eurostat/databrowser/bookmark/f243f38a-ef0f-4780-9612-90d5094de1d7?lang=en
[7] European Commission, https://eur-lex.europa.eu/resource.html?uri=cellar:8a32875d-0e03-11eb-bc07-01aa75ed71a1.0001.02/DOC_3&format=PDF
[8] Central Statistical Office, https://www.ksh.hu/stadat_files/ara/hu/ara0004.html
[9] EU-SILC, https://ec.europa.eu/eurostat/databrowser/bookmark/4a0bf544-604c-413c-99e2-fc28b95189d7?lang=en
[10] EU-SILC, https://ec.europa.eu/eurostat/databrowser/bookmark/c5caeff6-897b-4e52-b618-8e06bd85fe84?lang=en

foundations[11] in 2020. In the same year, 7.6% of the population was affected by severe housing deprivation[12].

Vulnerable consumers (which is a legal status based on social and health criteria) are eligible for instalment payment of arrears and prepayment meters if they are indebted. The social solid fuel subsidy program provides in-kind support (wood or coal) for low-income households that use solid fuels for heat. The support is only available in settlements with less than 5000 inhabitants. Often low-quality fuels (wet wood or lignite) are provided, and the criteria and distribution mechanism increase inequalities. Municipalities may offer housing subsidies and debt-management services; however these are not universal, centrally controlled measures, and therefore do not reach many households in need.

In 2013 the utility price reduction and caps were introduced in Hungary. These measures reduced gas, electricity and district heating prices and guaranteed price stability for domestic consumers, until the recent changes in August 2022. The price cap reduced the high energy burden of households, consequently the share of population having arrears on utility bills reduced by half in 9 years (though still higher than the EU average). Due to the flat rate and universal nature of the measure, savings of rich households were significantly higher, as their consumption tends to be higher. Currently, households consuming gas and electricity under a specific "average consumption" threshold value (63,645 MJ/year for gas and 2523 kWh/year for electricity) defined by the state are still protected from direct impacts of volatile changes in energy prices, though indirectly they feel the changes through inflation which has been the highest in Hungary among EU states; food prices and the cost of services increase as the commercial sector pays market price for gas and electricity. Households consuming above the threshold, however, need to pay the (near) market price for the excess amount. Based on the data of the Central Statistical Office, 38.5% of households were already using electricity and gas within the current protected (average consumption) range before the partial phasing out of the cap, so they will not be directly affected by the new measure and will continue to pay the same for energy. The rest of households consume outside the subsidy-protected range for at least one energy source: 6.8% of all households for only gas, 33.6% for only electricity and 21% for both[13]. However, households have started to significantly reduce their consumption and/or switch to solid fuels, which means that most households are likely to remain below the threshold, especially for gas.

With the current global energy price increase and re-nationalized energy companies it is questionable how long the state can guarantee fixed energy prices for households that put a large burden on the national budget.

In the last decade generous subsidy programs were introduced for the renovation of privately owned dwellings and for property acquisition, though these have not had any energy efficiency criteria. Low-income households are systematically neglected and/or excluded from larger housing and energy policies. 70% of Hungarian households lack the savings to invest in energy efficiency or to be eligible for the subsidies[14].

Policy context

The Utility Price Reduction (UPR) program, introduced in 2013, is the major policy measure impacting household energy bills, making them independent of market prices. The program, which was in force in this

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[11] EU-SILC, https://ec.europa.eu/eurostat/databrowser/bookmark/fdd9a992-b7de-4b8d-8875-a2e30aeb2515?lang=en

[12] EU-SILC, https://ec.europa.eu/eurostat/databrowser/view/ILC_MDHO06Q/default/table?lang=en&category=livcon.ilc.ilc_md.ilc_mdho

[13] Central Statistical Office, 2023, https://www.ksh.hu/statszemle_archive/all/2023/2023_02/2023_02_118.pdf

[14] Central Statistical Office, 2020

form until August 2022, covers natural gas, electricity, district heating and piped water, so Hungarian households paid much lower prices for energy than households in other EU countries especially in 2021 and the first half of 2022 - although previously there have also been times when Hungarians paid more when global market prices were low.

Currently, the components of household electricity and gas bills consist of the energy price, the system usage/system charges and the VAT. There is therefore no specific energy or carbon tax on households, but with the highest VAT rate in the EU at 27%, this component accounts for a proportionally higher share of their costs than the EU average. Taxes on heating and electricity consumption are currently only included in the energy prices of non-residential consumers (those with a consumption above 1320 kWh), who pay around 1.7 times more per kWh of electricity than residential consumers. In addition, the government introduces a price cap on transport fuels on 15 November 2021 in response to soaring global prices, which was discontinued in 6 December 2022. The tax content is unaffected - but the weak Hungarian currency (forint, HUF) means that Hungary already falls short of the minimum levels required by the 2003 EU directive, which is still in force. Petroleum derivatives are currently taxed in Hungary through excise duty, the minimum value of which is set by the 2003 European Union Directive: 359 euros per thousand liters for petrol (about 143 HUF/l) and 330 euros per thousand liters for diesel (about 132 HUF/l).

There is currently no official definition or indicators of energy poverty in Hungary. There are two documents which make reference to or connect to the term. One is the Hungarian NECP, which states: Hungary will measure the effectiveness of its policy to further reduce heating difficulties by monitoring the share of households spending at least 25% of their income on energy costs (9.8% in 2016). The other one is the Law on Energy Efficiency, which defines the "supported household" as a vulnerable household whose annual energy cost per household for heating the dwelling to 20°C and producing hot water in the dwelling house exceeds 25% of the household's annual income, where the annual energy cost and the household's annual income are the arithmetic average of the energy cost and the average income of the household for the calendar years starting from 2020 and ending at the time of calculation. Also, pursuant to Article 28 of Directive (EU) 2019/944, households in Hungary can register as 'protected consumers' provided they are recipients of certain social benefits (such as care allowance, old age pension, municipal allowance for housing costs). The protected consumer status allows for instalment payment or deferred payment on utility bills (albeit once every calendar year), as well as for the installation of prepaid meters free of charge by their energy provider should they accumulate arrears over 60 days.

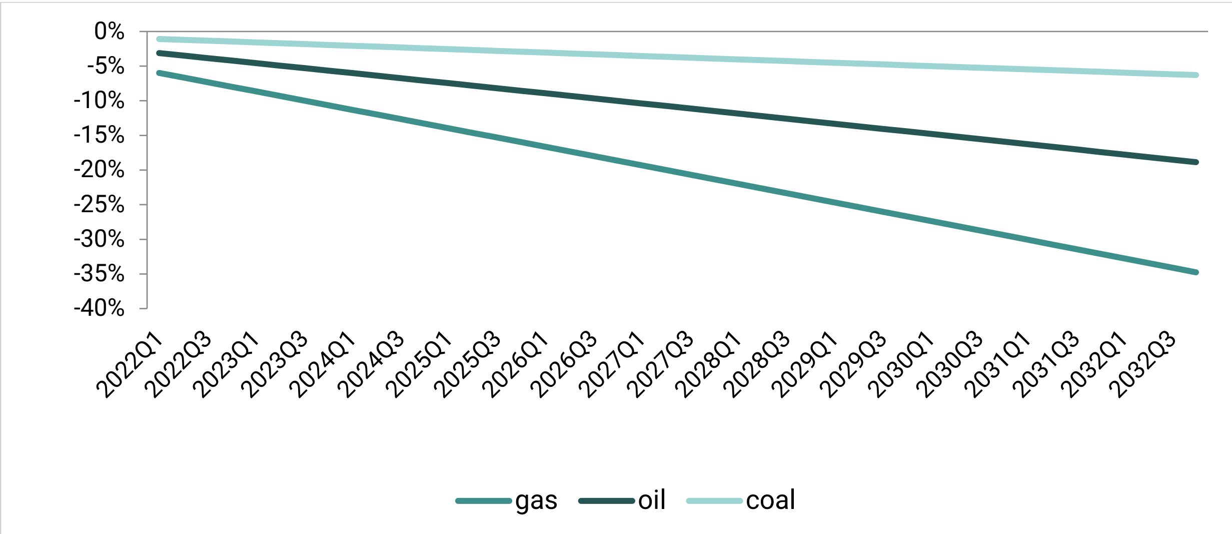
Results

Macroeconomic impact

For Hungary, a carbon tax of $73.54 per ton would be needed to reach the 40% reduction target.

As a result of the macroeconomic modelling, unlike in the other countries studied, the introduction of a carbon tax in Hungary would have a positive impact on GDP at the end of the period analyzed. The introduction of a carbon tax (Figure 12) could contribute to reducing the dependence of the Hungarian economy on imported fossil fuels. If a carbon tax were introduced, gas imports would fall by more than one third (35%) and oil imports by one fifth (19%) by 2034. A carbon tax would already have a significant impact in the short term, reducing gas imports by 13% and oil imports by 7% by 2024. The impact of a carbon tax on coal would be less significant, as the share of coal in Hungary's energy supply is already smaller (7%) than gas (34%) and oil (28%).

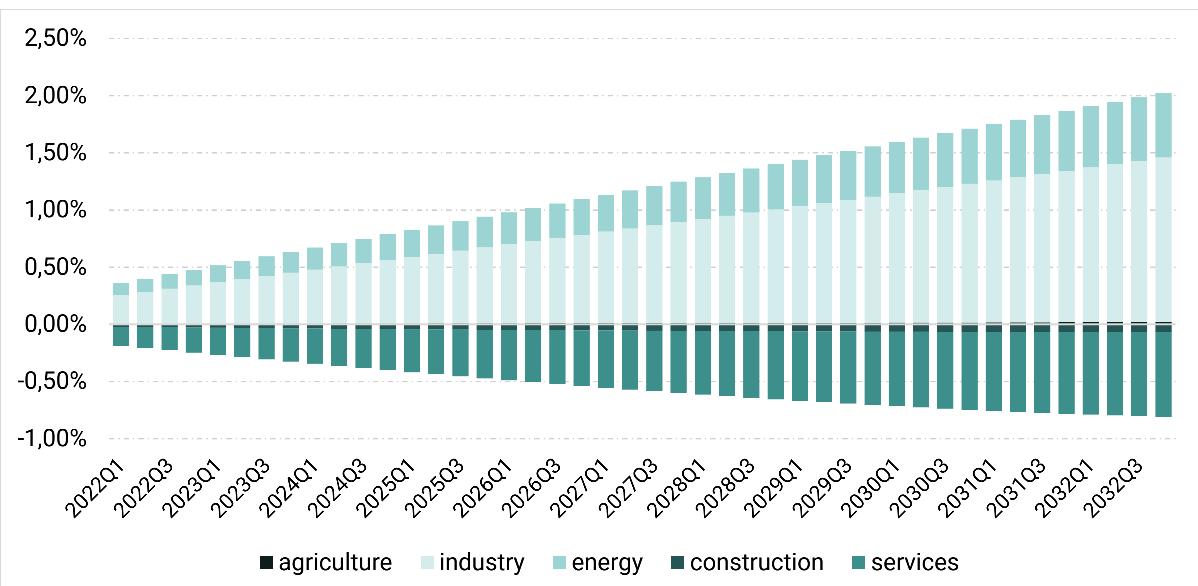
Figure 12: Differences in fuel imports in Hungary (% deviation from no-carbon tax scenario)



Source: own calculations.

We have assessed which of the five key sectors would be at greatest risk of negative impacts on the Hungarian economy from the introduction of a carbon tax (Figure 13). The services sector would be most affected by 2032, albeit the effects is below 1% (-0.74% compared to 2022), followed by construction (-0.07%). Services are a major contributor to Hungarian economic growth, so impacts on this sector should be addressed first. It is important that services have significant economic capacity, high growth potential and the ability to adapt and reorient to new economic conditions - therefore negative impacts can be managed. However, by 2032, impacts on industry (+1.44%) and energy (0.6%) are positive.

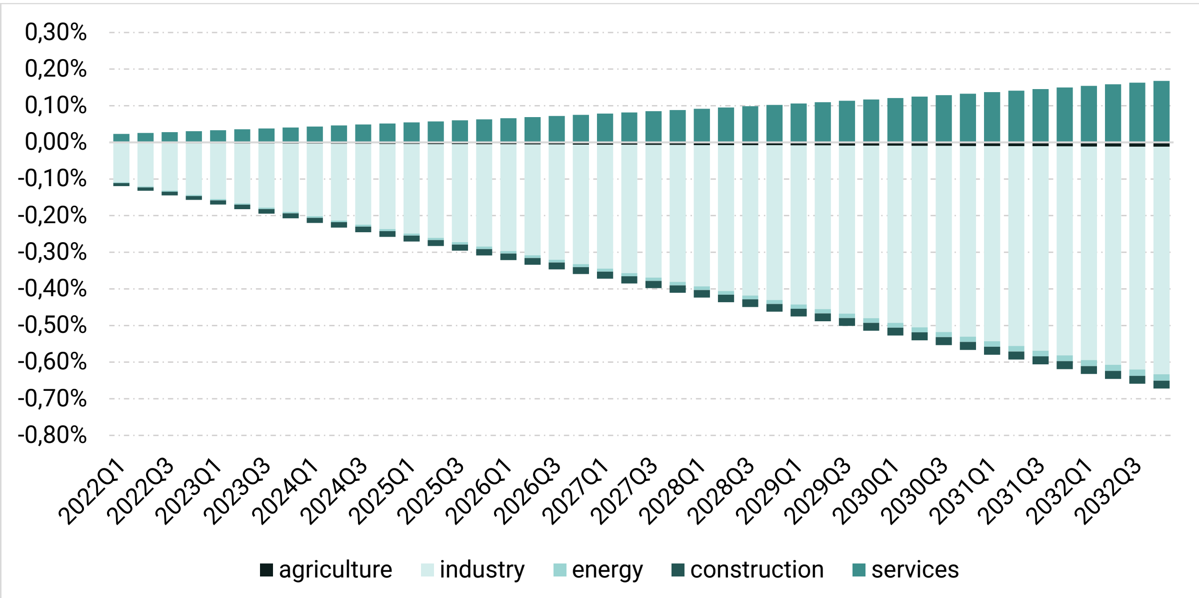
Figure 13: Differences in value-added in Hungary (% deviation from the no-carbon tax scenario)



Source: own calculations.

The labor market effects of the carbon tax in Hungary will be small and manageable until 2032, as employment will fall by 0.1% (Figure 14). The carbon tax impacts are most pronounced in the industrial sector (-0.62%). However, employment in the service sector is expected to increase after the carbon tax (+0.17%). We expect the magnitude of the employment impacts to increase in the long run. Therefore, labor market adjustments resulting from the carbon tax should be addressed, for example, by increasing unemployment benefits and ensuring active labor market policies. Hungary has recently experienced lower unemployment and strong wage growth, but labor shortages in sectors such as construction.

Figure 14: Differences in employment in Hungary (% deviation from the no-carbon tax scenario)

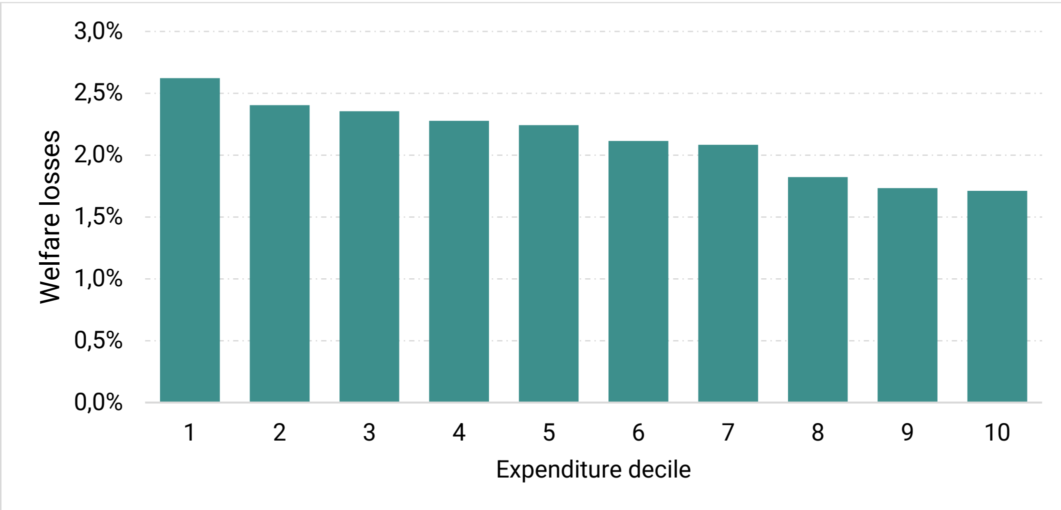


Source: own calculations.

Household impact

Figure 15 shows the incidence of the welfare losses induced by a Hungarian nationwide carbon tax. The first outcome to underline is that in the absence of any revenue redistribution, the tax displays moderate regressive effects: households from lower income deciles are more affected relative to more affluent ones. The average loss of the 10% of poorest Hungarian households is more than 1,6 times higher than that of the wealthiest 10% (i.e., a compensating variation of 0.026 vs. 0.016).

Figure 15: Welfare losses across deciles in 2032 before redistribution

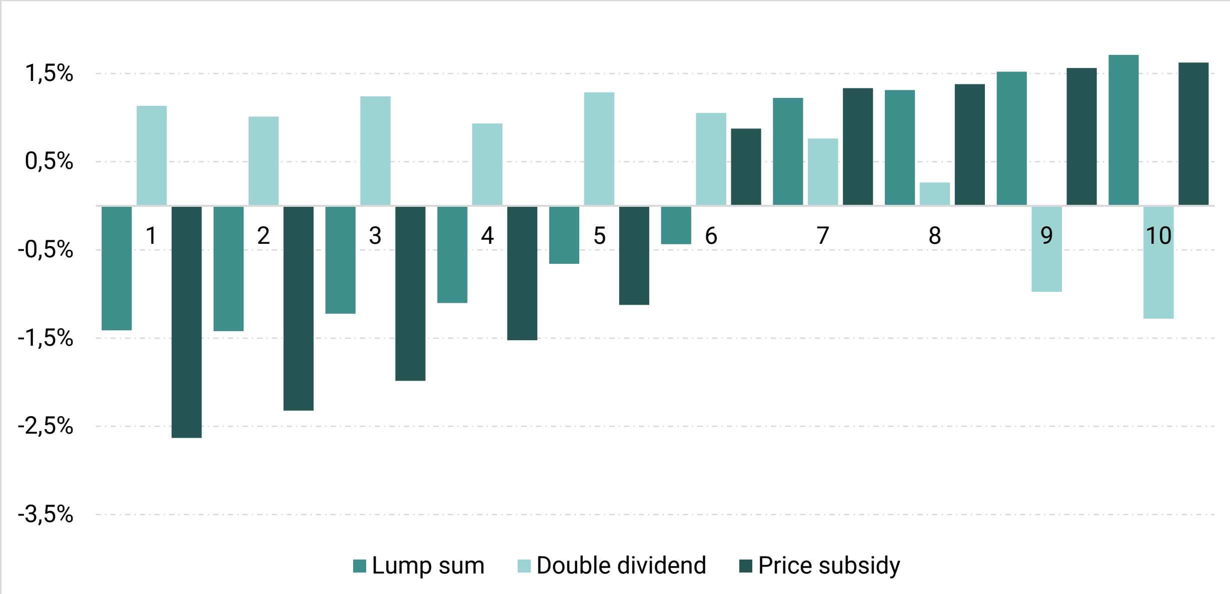


Source: own calculations.

These adverse effects are driven by a tax level of 73,54 \$/tCO_2 (high compared to the other CEE countries). All households would have to earn between 1.7% and 2.7% more monthly to maintain their initial consumption level before introducing the carbon tax. In the presence of other sources of price inflation, this implies a significant effort for a considerable share of the population (especially for the least affluent, bottom 10%), suggesting that a governmental intervention targeting the less affluent might be politically and socially desirable. This is especially relevant given the recent developments in 2022, which have increased the inflationary and energy price pressure faced by most citizens, and that of 2023, where inflation is the highest within the EU.

Figure 16 displays the distribution of welfare losses (CV) across the Hungarian population when considering concurrently the carbon tax and, alternatively, the three redistribution scenarios. As expected, the three scenarios produce different sets of winners and losers by 2032 when compared to the baseline scenario before the introduction of the carbon tax in 2022. Overall losses are reduced substantially in all three cases: while the average CV varies between 0.017 and 0.027 in the baseline scenario, depending on the most affected deciles, we are now seeing a reduced interval bounded upwards by a positive CV of 0.017 (losses incurred in the lump sum scenario by richest decile of the Hungarian society). Therefore, carbon pricing in Hungary is expected to have relatively negligible losses for the less affluent households if the government pursues any form of complementary redistributive policy. However, not all redistribution provides more gains for the less affluent.

Figure 16: Welfare losses across deciles in 2032 after redistribution



Source: own calculations.

The price subsidy scenario is the most advantageous in reducing welfare losses for less affluent households, especially for the bottom 30% of the Hungarian population. Under this model of revenue recycling, households belonging to the first five deciles (which include the median household type and represent, therefore, most of the population) not only see a reduction of losses but become net winners of the new policy regime, as their average CV is negative. Therefore, 50% of the population incurs at least some welfare gains. In simple terms, this means that such households would have more income available for additional expenditures after introducing the carbon tax and this type of redistribution. As the carbon price redirects expenditure towards relatively less carbon-intensive sectors, our model predicts, therefore, that Hungarians will have more money to spend. Finally, while the wealthiest 50% of the population would become the net payers for this policy (i.e., net losers), their losses are modest (the CV is between 0.009 and 0.016). Briefly, the most affluent Hungarian households would lose at most 1.6% of their monthly income.

The lump-sum scenario, like the price subsidy approach to redistribution, ensures that the bottom 60% of the households incur no losses, becoming the net winners of this policy regime. Only people in the seventh income decile and above would occur small welfare losses ranging between CV of 0.012-0.017. Nevertheless, under these conditions, the net losers of the carbon tax regime are households in the top four deciles, representing the wealthier minority of the Hungarian population. The total costs of carbon pricing are distributed more equally between these categories when compared to the price subsidy. However, there would not be a significant difference in the losses of the most affluent households in both the price subsidy and lump-sum scenarios. Thus, the lump-sum scenario would bring less benefits for the poorest at the "same price" for the richest. The lump-sum redistribution would be more easily viable compared to the price subsidy, mainly because it is the simplest one to design, implement, and monitor from the perspective of domestic decision-makers and it also represents a more balanced distribution scenario.

The double dividend scenario induces very different distributional and welfare effects and stands in clear opposition to the two scenarios previously analyzed. In this case 80% of the society would remain net losers of introducing a carbon tax, while the richest 20% would receive significant welfare gains (with a CV between - 0.01 and - 0.013). On average, the poorest 10% of Hungarian households would have an average CV at 0.011, which is less than half of the losses without redistribution. Accordingly, while the poor remain the net losers (i.e., the distributional effects are the same as before redistribution), the welfare effects are significantly less pronounced for the aggregate population. On the other hand, the net winners are the most affluent top two deciles. This would increase inequalities within the country and does not correctly address concerns such as energy poverty at the bottom of the income distribution.

Discussion and recommendations

The biggest decarbonization challenge for the Hungarian economy is its heavy dependence on Russian oil and gas, and the fact that Hungarian society has been disconnected from the gas and electricity market for almost a decade due to governments' flagship policies of utility price caps.

Therefore, carbon pricing is a challenging issue to tackle in Hungary, including the issue of public attitudes. A representative survey in 2019 found that from a range of options the least popular measure was to increase taxes on fossil fuels (oil, coal, natural gas), which Hungarians are rather against (4.6 on a scale of 10)[15].

However, on a macroeconomic scale it has its clear advantages. As a result of our macroeconomic modelling, the introduction of a carbon tax in Hungary would have a positive impact on GDP at the end of the period analyzed. The introduction of a carbon tax could also contribute to reducing the dependence of the Hungarian economy on imported fossil fuels.

However, without the redistribution of carbon tax revenues, the tax displays moderate regressive effects: households from lower income deciles are disproportionately more affected relative to more affluent ones.

The analysis leads us to a number of recommendations:

- ◊ Redistribution of revenues targeting the less affluent is desirable both in terms of reducing emissions and energy poverty. Carbon pricing in Hungary is expected to have relatively negligible losses for the less affluent households if the government pursues any form of complementary redistributive policy. For instance, as transport fuel use is very high among the richest households and elasticity of transport fuels is very low, a carbon tax would generate a high income from transport fuels that can be generously redistributed in a way that it benefits lower income groups (e.g in the form of subsidies) as well as the environment (investment in sustainable public transport).
- ◊ Carbon pricing should not be limited to one (e.g. the power) sector, with other categories of consumption perfectly isolated and exempted from taxation. Our micro-model results reflect a broader carbon pricing scenario, which allows people to adjust their expenditure patterns, reducing the unfavorable adverse effects of one particular (e.g. the electricity) channel.
- ◊ A carbon tax that operates by increasing the price of electricity has regressive tendencies. Therefore, Hungarian policymakers need to encourage a less carbon-intensive power sector, which would be, in turn, less affected by fluctuation in the price of carbon.
- ◊ Large investment and support programs for energy efficiency measures – including deep renovations for residential buildings – must be introduced promptly to assist decarbonization efforts and to help prepare for higher energy prices.

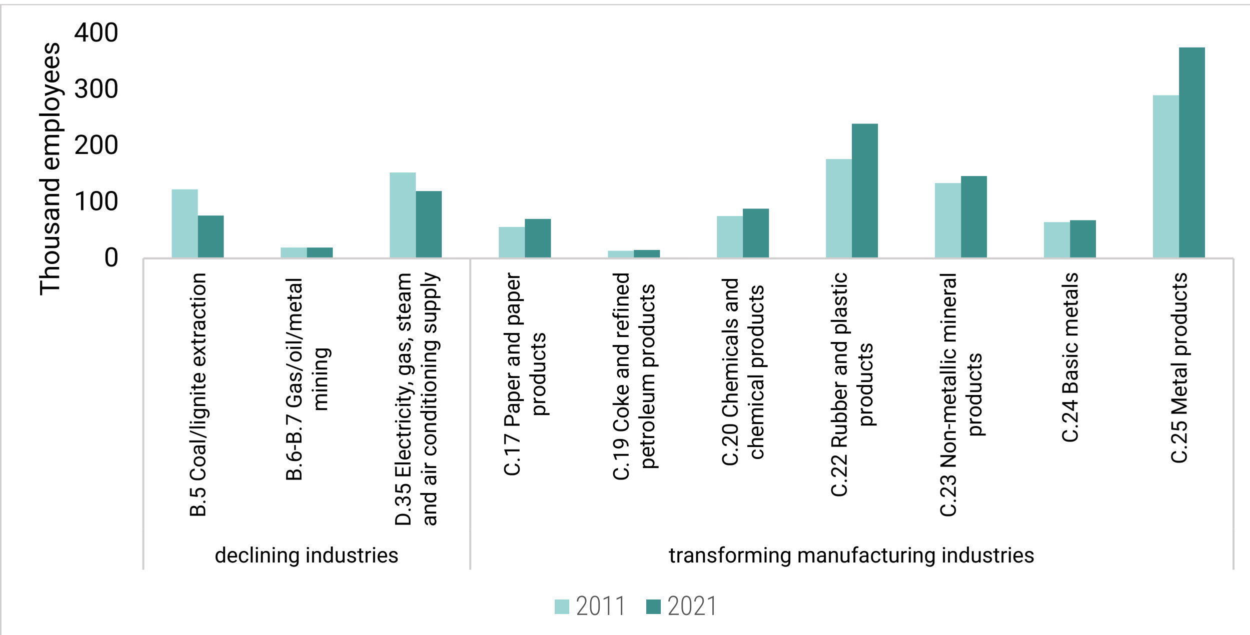
[15] DemNet, 2019; https://demnet.hu/a-magyar-klimapara-eghajlatvaltozas/

Poland

Context

The Polish economy is energy-intensive despite the high pace of economic development. First, the energy-intensive industries still significantly contribute to overall employment (Figure 17), which results from the position of Polish companies in global supply chains. Second, coal still accounts for about 2/3 of produced electricity and heat. Third, decarbonization has only recently become an area of state policy. Social agreements regarding coal mine closures were reached with the mining and energy sector representatives in 2021 and 2022, respectively. With higher energy prices, decarbonization can challenge businesses and households heating homes with fossil fuels.

Figure 17: Employment in carbon-intensive sectors between 2011 and 2021



Source: own elaboration based on Statistics Poland 2011-2021.

The residential sector is strongly reliant on coal. Despite the progress in the domestic energy transition, solid fuels, especially coal, are still used by one-third of households. This problem mainly affects households in rural areas with limited access to gas grids and those deprived of district heating networks in cities. For this reason, decarbonization will pose a severe challenge for households, and it must be accelerated as most of the coal used in the residential sector was imported from Russia before the country's invasion of Ukraine in 2022.

In the last year, the energy poverty level in Poland and the overall vulnerability to this phenomenon have increased. According to the most recent data, in 2021, energy poverty, as measured by the Low-Income High-Costs indicator, affected 11% of the population (1.5 million households). This marks an increase of nearly two percentage points compared to 2020. Furthermore, 400,000 households (3%) were at risk of falling into energy poverty. Among the social groups most exposed to energy poverty were low-income and income-dependent households: pensioners and households receiving social assistance. Energy poverty primarily concerns people living in old houses with individual heating and is more common in rural areas. The effectiveness of various instruments to mitigate energy poverty, such as social benefits (Sokołowski, Frankowski and Mazurkiewicz, 2021), investment support schemes (Sokolowski and Frankowski, 2021), and ad hoc subsidies such as the coal allowance, is limited. In the case of these instruments, policy designers preferred simplicity of implementation over efficiency (e.g. making everyone eligible for the coal benefit regardless of their income). Some policies are also ineffective as they encounter administrative obstacles, which have only recently started to be addressed, such as the lack of investment pre-financing for households in energy poverty.

In Poland, the prices for engine fuel increased last year. Wholesale prices of E-95 gasoline and eco-diesel oil rose by almost 20% within a few months of the start of the Russian military aggression, increasing inflation. The share of households with high transport expenditures and low income was approximately 9% in August 2022, with a significantly higher rate in rural areas at 13% [16]. This measure can be considered a proxy for the level of transport poverty in Poland. In addition, over ¾ of Polish households have at least one car, which is one of the highest indicators in Europe. At the same time, the car fleet is relatively old; hence, carbon pricing and ETS2 can cause tensions, especially in rural areas, where the expenses and age of cars are correspondingly higher.

Poles mostly adopt a transactional approach to climate policies. The population remains enthusiastic about European integration compared to other nations, but at the same time, they would be reluctant to introduce new environmental fees (Sokołowski, Lewandowski and Frankowski, 2023). If so, they would favor using the income of a small group of the wealthiest people (Figure 18). Tax aversion is associated with low trust in state institutions and misbelief about the adverse effects of climate change among significant groups, especially people with right-wing and center political orientations.

Figure 18: Preference regarding burdens to reduce energy consumption in EU-27

Note: Question: Which of the following groups of the population in (our country) do you believe should mainly make more efforts to reduce their energy consumption?

Source: own elaboration based on Eurobarometer (2022).

[16] Own estimates based on the nationwide survey with 10,000 people (August 2022).

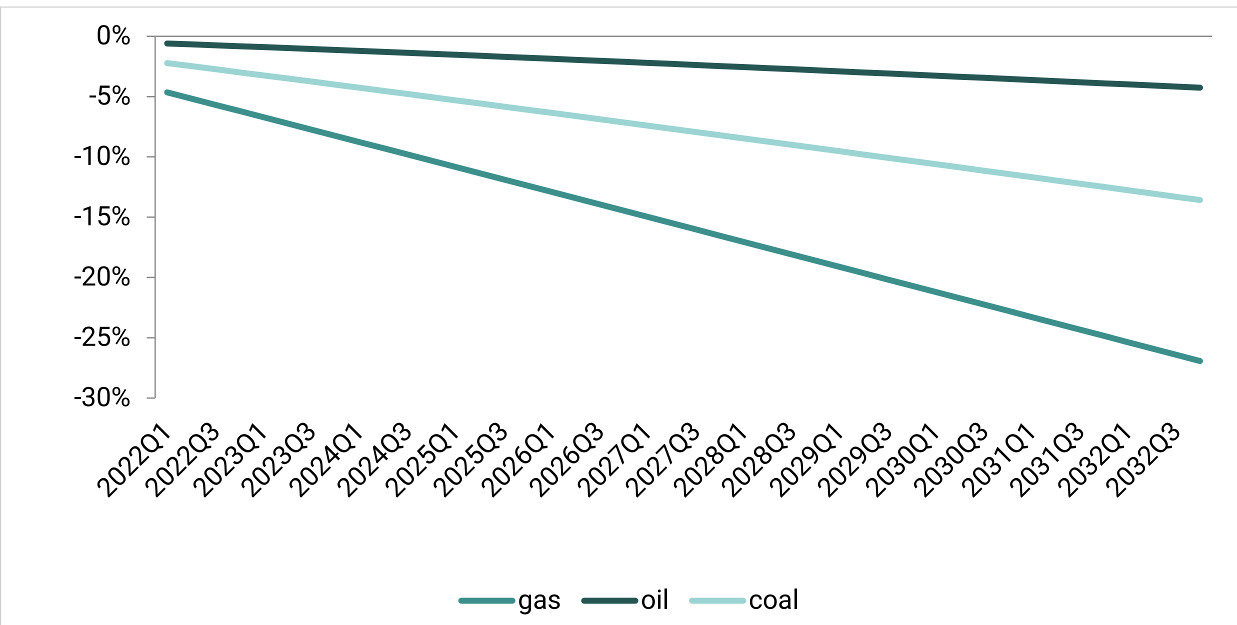
New carbon taxes without safety net adjustments can polarize a strongly divided society. Radical politicians try to take advantage of social concerns about the further increase in energy prices, using opposition to climate policy as a base for gathering political support. An example was a misleading nationwide campaign by state-led energy enterprises in 2021, blaming the climate policy for energy price uptake. In 2023, a report by the C40 Association, which included City of Warsaw (where the mayor is in opposition to the ruling party), recommended that individual consumption restrictions regarding meat, dairy products, buying clothes, cars and air travel. These recommendations were used to antagonize society even four years after initial publication. To debunk such narrations, climate policies must be introduced transparently, and proposed solutions must be understandable, effective, progressive (Dechezleprêtre *et al.*, 2022). They should also protect social groups facing the most challenging situation against radical energy price hikes.

Results

Macroeconomic impact

Introducing a carbon tax would reduce the dependence of the Polish economy on fossil fuel imports. The decrease in fuel consumption would be particularly noticeable in the short term, especially in the case of gas. By 2023, imports of this fuel would decrease by 1/4 compared to the baseline (no tax) scenario (Figure 19). Introducing a carbon tax would require further diversification of supply sources for oil imports. However, these options are possible, as demonstrated by introducing embargoes on Russian fossil fuels (Antosiewicz *et al.*, 2022).

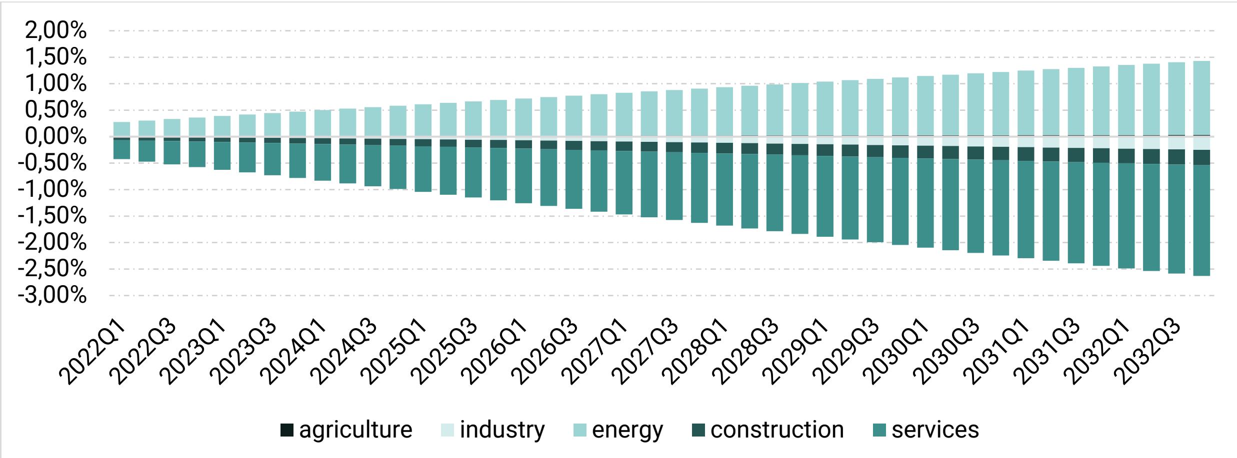
Figure 19: Change in fossil fuel imports after the introduction of a carbon tax (% change from baseline)



Source: own calculations.

The services sector would be most negatively affected by the carbon tax. This is primarily due to the largest share of services in the projected economic growth (2 pp; Figure 20). However, services have greater adaptability to change than other economic sectors. The scale of the challenge is more significant for construction and industry, where decarbonization will put pressure on fixed assets, including production methods and technologies. Steel, cement and chemical plants are already taking steps to reduce CO_2 emissions (as the ETS covers them), but these actions should be further supported by government industrial policy. On the other hand, the added value generated by the energy sector will increase due to the surges in energy prices following the introduction of the climate tax.

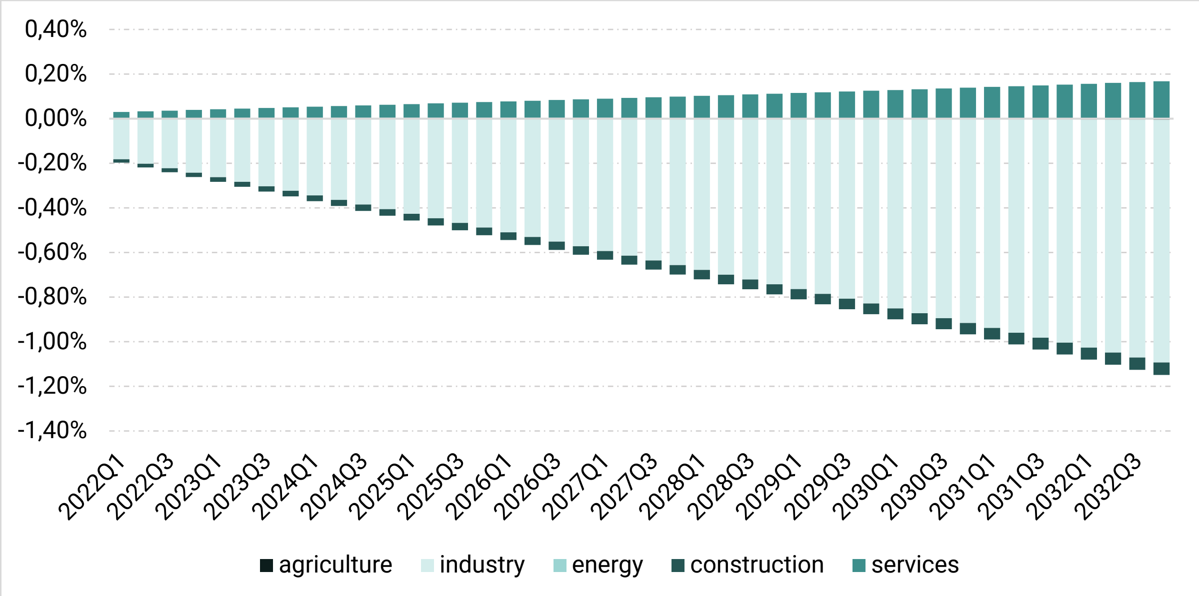
Figure 20: Change in value-added after the introduction of the carbon tax broken by economic sectors (% change from baseline)



Source: own calculations.

A carbon tax in the 2032 horizon would have a limited negative impact on employment. The impact would lead to a decrease of around 1 % compared to the no-tax scenario. The most significant reduction in employment is expected in the industry (1 pp; Figure 21). It is expected that the magnitude of the impact of the carbon tax on employment will increase in the long term. Therefore, labor market adjustments resulting from the carbon tax should be addressed beforehand, applying industrial support for more efficient technologies and labor market policies (e.g. skilling and upskilling). Poland's relatively favorable labor market situation in 2023 would help the transformation caused by introducing the carbon tax. However, a reduction in employment due to the introduction of the carbon tax could more strongly affect local labor markets dependent on the industry, especially after including road transport and the residential sector in the ETS. Such change would reduce demand for the services of energy-intensive industries. Finally, the displacement caused by the introduction of the tax will lead to an increased share of the services sector.

Figure 21: Changes in employment in Poland after the carbon tax by sector (% change from baseline)



Source: own calculations.

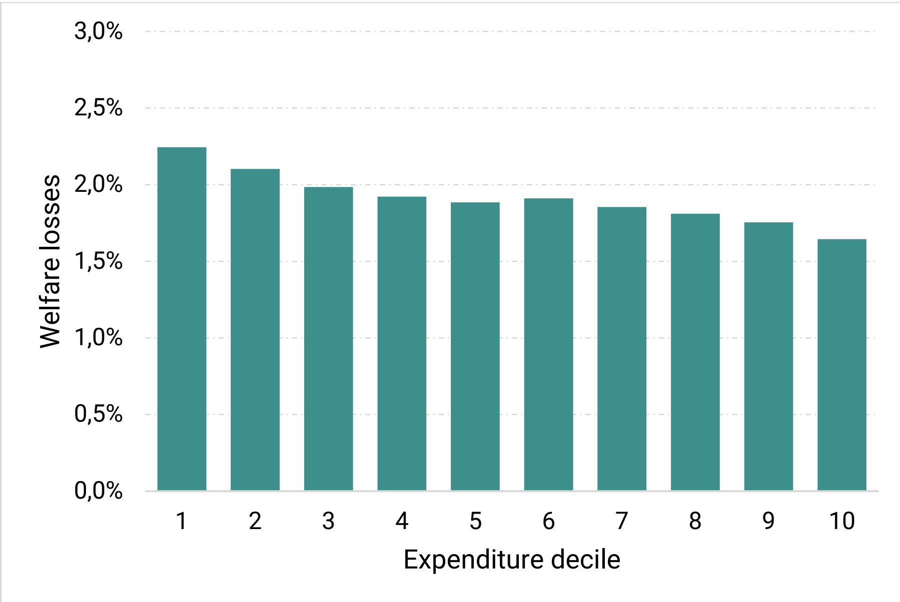
Taxing emissions will primarily affect workers in energy-intensive industries and mining. The mining and energy unions secured the sector's interests through "social agreements" with the government in 2021 (coal mining) and 2022 (lignite mining and energy). For other industries, such agreements still need to be prepared. Mining and energy's relatively strong bargaining position is due to the sector's tradition and geographical concentration, which mobilizes the industry and workers to associate, articulate interests, and exert political pressure (Frankowski, Mazurkiewicz and Sokołowski, 2023). Much less attention is paid to other, more dispersed energy-intensive industries, such as: cement, steel, chemicals, metals, food and transport. The share of these sectors in employment in Poland is higher than in other EU countries.

Taxing emissions will be a significant macroeconomic challenge in regional policy and political economy. Decarbonization may reduce the importance of Silesia as a region concentrating on coal and energy industries (Mazurkiewicz, Frankowski and Sokołowski, 2022). A large part of the announced investments in energy - such as offshore wind or a nuclear power plant – is planned in the northern part of the country. In addition, the potential for locating renewable sources: e.g. wind and solar power, in traditional industrial regions is weaker than in other parts of the country. Decarbonization will also affect existing political sympathies and may position politicians hoping to support workers in energy-intensive industries as opponents of climate policy. Strong regional institutions and support instruments could mitigate these tensions (Vona, 2023).

Household impact

In Poland, the carbon tax will be regressive, meaning that the poorer households will bear a larger share of the costs of the new solutions than the wealthier households. Simulation using the QUAIDS model indicates that, in the perspective of 2032, households in Poland will, on average, face a 2% reduction in their income compared to the scenario without the carbon tax (Figure 22). Households with the highest income (the last three deciles of the income distribution) will experience smaller income losses l compared to the average families in Poland. Notably, the effects of introducing a carbon tax in Poland will be more regressive than in other EU countries (Ohlendorf *et al.*, 2021).

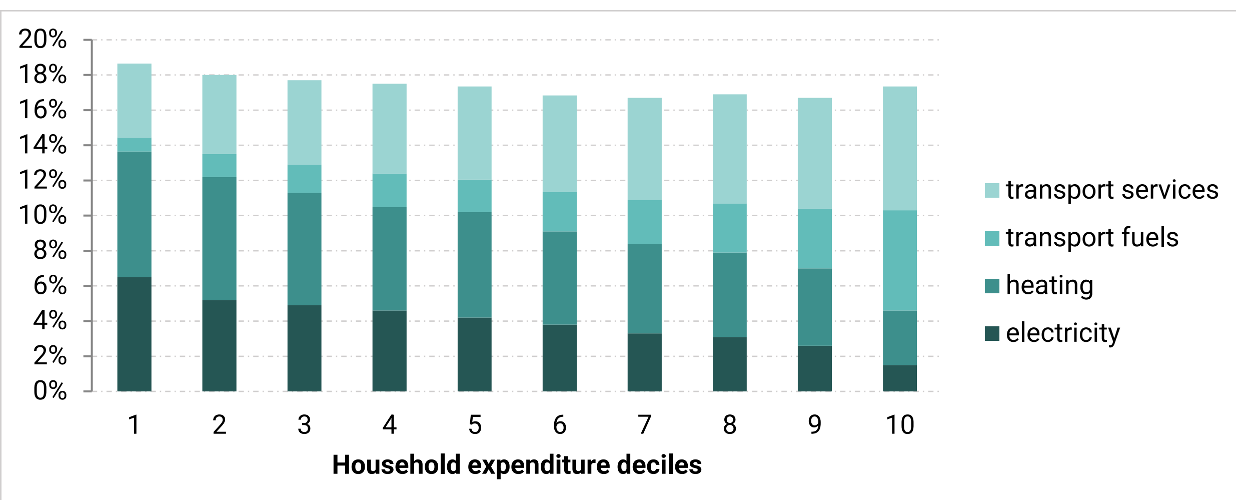
Figure 22: Changes in welfare after carbon taxes by expenditure deciles (%change compared to baseline scenario)



Source: own calculations.

The distributional effects of a carbon tax depend on the quantity and type of energy used. The share of expenditure on the different types of energy used varies in Poland. Less affluent households spend relatively more on electricity and domestic heating than more affluent households (Figure 23). In the case of transport fuels, more affluent households – especially those belonging to the tenth income decile – spend proportionally the most (over 5%). These differences are likely because the less affluent tend to forgo personal transport altogether. However, in the case of heating or electricity use, such a substantial reduction is not as feasible.

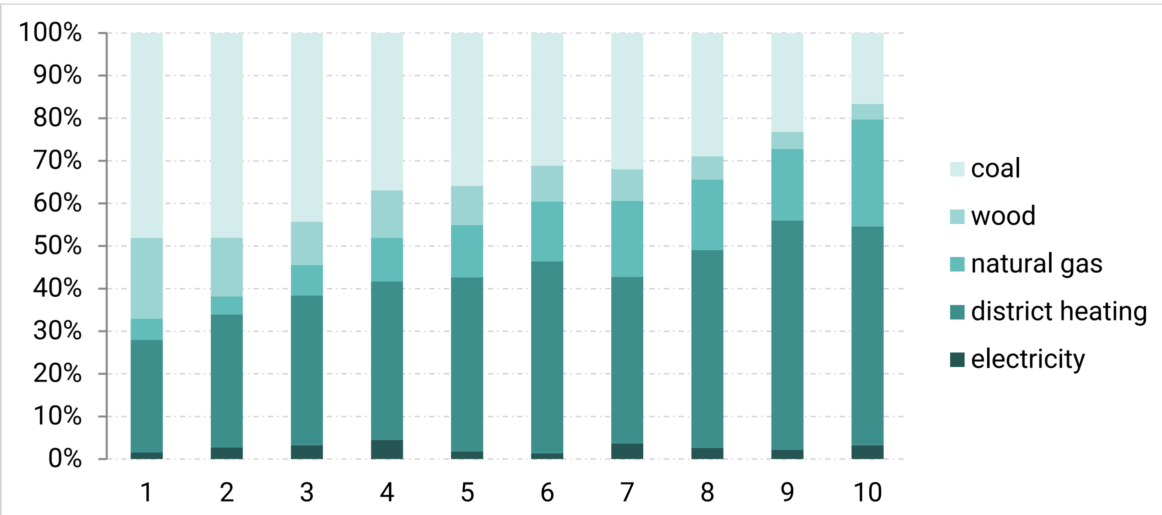
Figure 23: Energy consumption by expenditure decile in Poland



Source: own calculations.

The distributional effects of the carbon tax depend on heating technologies. Less well-off households use solid fuels (Figure 24). Household energy choices are also related to the place of residence and the type of building. The less affluent are more likely to live in rural areas in individually heated single-family houses. Among more affluent residents, who usually live in cities, gas and district heating (primarily coal-fired) are more popular heating sources. In addition, higher heating prices in multi-family buildings are dividend among many households. Housing associations or communities collectively have a greater financial capacity to make the necessary investments, while individual single-family homeowners need to make these investments independently.

Figure 24: Main fuel for home heating by income deciles (%)



Source: own elaboration based on a survey on fuels and energy carriers 2018 (E-GD).

Redistribution of carbon tax revenues is a solution that would reduce inequalities. The effects of redistribution vary depending on the method adopted for transferring carbon tax revenues to households. Unconditional transfers effectively reduce inequality and is the most favorable solution for less wealthy households, in contrast to the reductions in taxation of labor costs (Antosiewicz *et al.*, 2022). The distinction between nominal and relative spending burdens remains crucial for planning redistribution measures. The most affluent households bear the highest costs in absolute terms, but proportionally the largest share of income will be lost by the less wealthy, with the highest energy expenditure. Therefore, introducing a carbon tax will be associated with reductions in consumption of other goods and services that are already on tight budgets.

Simulations indicate that subsidizing energy prices or direct cash transfers would reduce energy poverty to pre-carbon tax levels in Poland. The baseline level of energy poverty was 14.8% in 2022, which would increase to 19.55% in 2032 in the scenario of introducing a carbon tax without redistribution. Redistribution of funds to households would mitigate this negative effect. In the case of Poland, energy price subsidies would be the most effective mechanism for reducing energy poverty. This would be explained by the specific targeting of the least affluent households, who would benefit smaller prices on fossil fuels. This would bring a higher burden on the population with higher-than-average income. Applying the lump-sum scenario would lower the energy poverty level to around 13%. In contrast, the third proposed solution – double dividend scenario – would increase energy poverty to 15%. This redistribution method would not be advantageous to people in energy poverty, or near that level, because many of them depend on pensions or social benefits, income types that are not taxed.

Table 10: Scenarios for energy poverty levels after the introduction of a carbon tax and redistribution mechanisms

Baseline (2021)	Estimated level of fuel poverty after the introduction of the tax without protective mechanisms	Changes in fuel poverty levels in the post-redistribution scenario		
		Direct transfer	Double dividend	Energy price subsidies
14,82%	19,55%	13,34%	15,35%	13,02%

Source: own calculations.

Discussion and recommendations

This study estimates the potential impact of extending climate policy in Poland and tests three mechanisms to reduce inequalities caused by rising energy prices. It also presents the recent data on energy poverty in Poland and estimates the effects of introducing climate taxes on households with different budgets.

A few conclusions and recommendations derived from the present study:

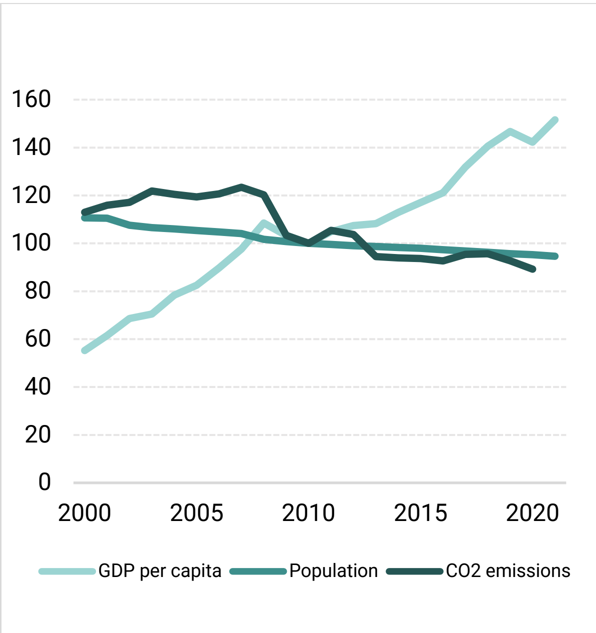
- Assessing the potential distributional effects of new climate policy instruments should be mandatory to avoid generating new inequalities.
- Energy poverty should be better monitored and addressed. Among other things, there should be a discussion on how to maintain or target the allowances introduced in the wake of high energy prices in 2022 and adequately communicate these measures.
- Direct transfers with incentive mechanisms for pro-climate investments should be introduced. At the same time, state policy must not give incentives to perpetuate inefficient technologies, as was the case with the coal benefit in Poland.
- Household investment support should be accompanied with advisory and technical assistance to introduce improvements that reduce energy consumption and costs.

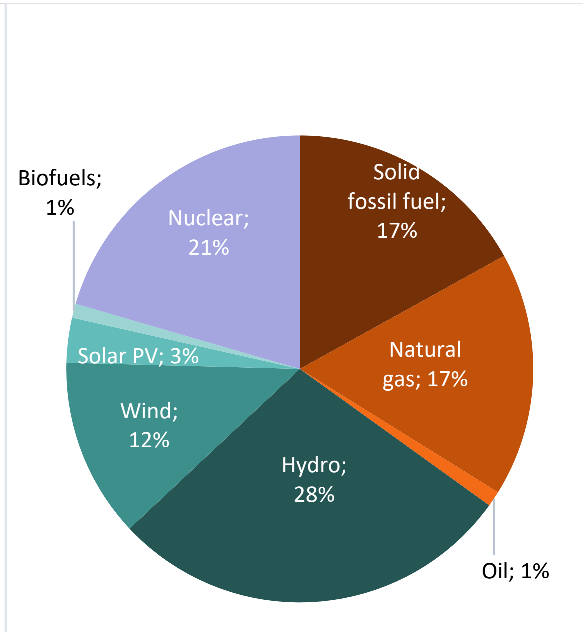
Romania

Context

Romania has seen strong economic growth since 2000. Except for the economic crisis of 2007-2009 and the Covid shock, the country's economy recorded continuous and substantial GDP growth, fueled by consumption, foreign investment into manufacturing and services, EU funds and remittances. The latter increased steeply as emigration accelerated, particularly after EU accession. The period since 2000 has been broadly characterized by an increase in productivity, investment and GDP per capita (Figure 25, left), which are decoupled from GHG emissions.

*Figure 25: **Left**: GDP per capita, population and CO2 emissions in Romania, 2000-2021, chain linked volumes (2010=100); **Right**: Electricity generation by source in 2020*



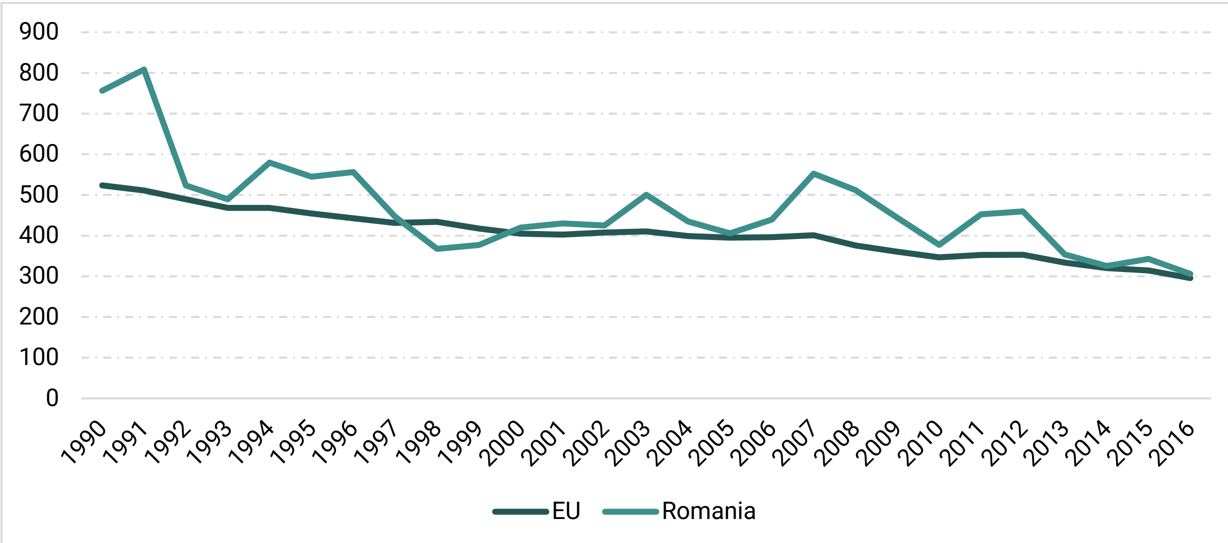


Source: Eurostat.

At the same time, the emission intensity of the economy went down, mostly driven by the shift from the pre-1989 heavy industry dominance to a more service-based economy. In 1990 emissions from fuel combustion and industrial processes were at 148 Mt and 32 Mt respectively. In 2020 the levels dropped significantly to 64 Mt in energy and 13 Mt in industry.

Romania operates a relatively balanced electricity generation mix (Figure 25, right). Solid fossil fuels and natural gas amount to a total of 34%, nuclear for 21%, while renewable generation represents almost half of the electricity generation (hydro 28%, wind 12%, and solar 3%). The current mix generates significantly less CO_2 compared to thirty years ago (Figure 26). In 1990 and 1991 producing one kWh of electricity released 0.8 kg of CO_2, while in 2016 the level dropped to 0.3 kg, similar to the EU average.

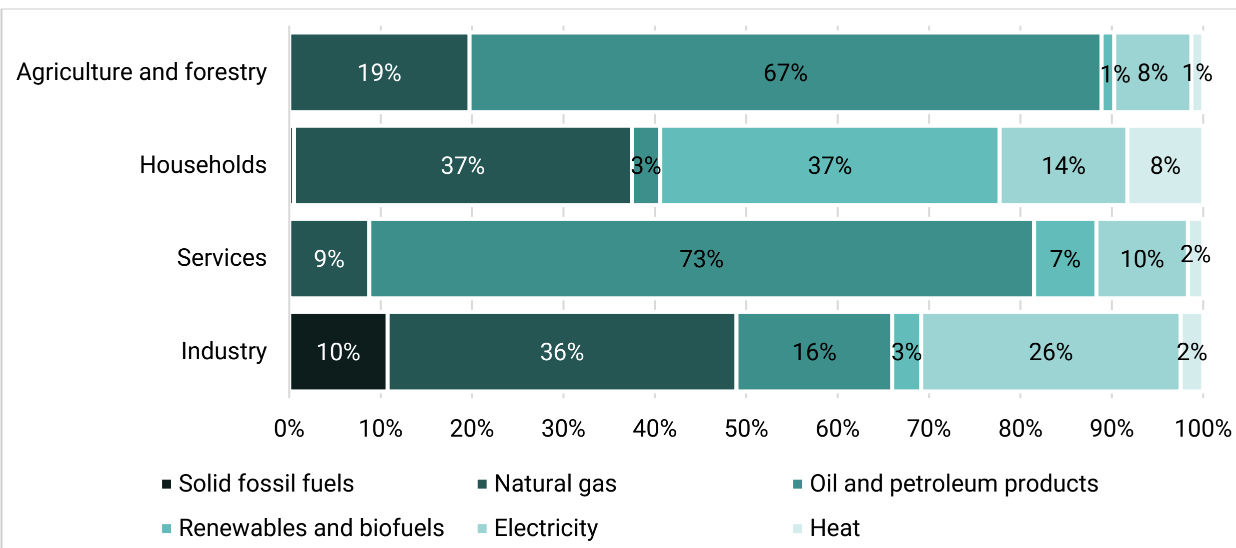
Figure 26: CO_2 intensity of electricity generation (gCO_2/kWh)



Source: European environmental agency.

Looking at energy use by economic sector (Figure 27), oil and petroleum products are heavily relied upon in services (almost 3/4 of final consumption) and in agriculture (2/3). A balanced mix can be observed in the industry sector, while the household sector gets most of its energy needs from biofuels (mostly woody biomass), electricity and heat.

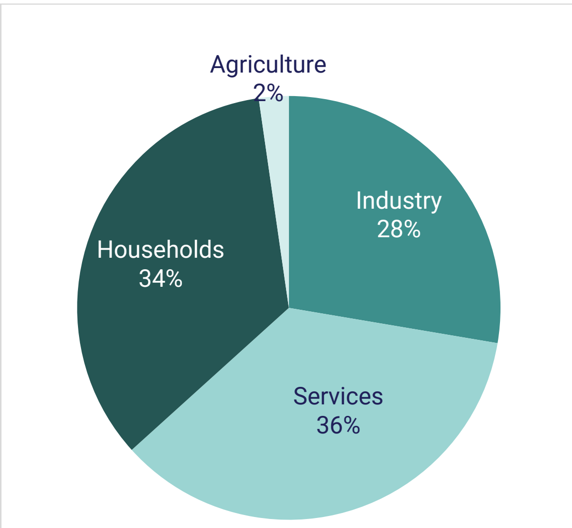
Figure 27: Final energy consumption in 2021

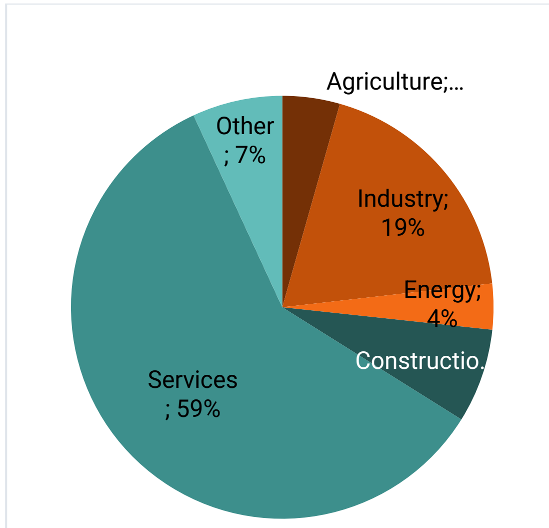


Source: Eurostat.

Households account for a third of the final energy consumption in the country, higher in percentage terms than in 1990, but lower in absolute terms (a decrease from 122 TWh in 1990 to 93 TWh in 2020). Services accounted for 53 TWh in 1990 or 11% of the final energy consumption while in 2020 the figure was 96 TWh or 36% of the total final energy consumption (Figure 28, left). In the services sections, transport accounts for 75 TWh, or 78% of energy used in services.

*Figure 28: **Left**: Final energy consumption by sector, 2020; **Right**: Value added by sector, 2020*





Source: Eurostat.

In recent years, services represent a considerable driver of added value and employment (Figure 28, right). This sector produces 59% of the total added value and employs half of the total workforce. Agriculture employs more than 20% of the workforce. Industry, energy, and construction have lower contributions in terms of value-added (19%, 4%, 7% respectively) and employment (18%, 3%, 9% respectively).

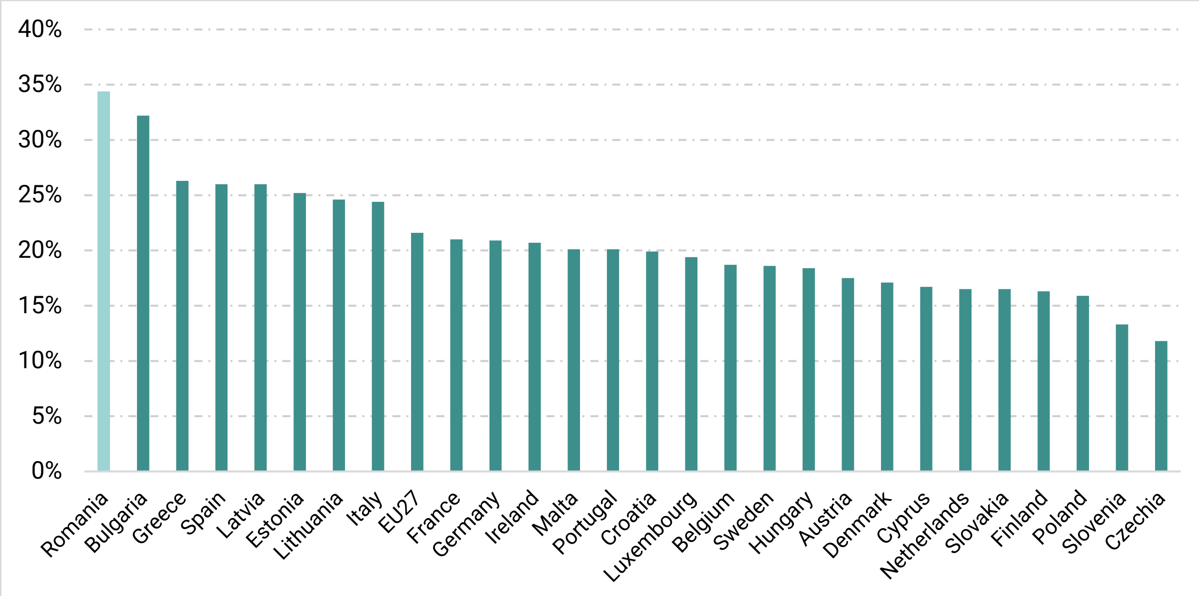
At the same time, compared to the EU average, Romania continues to have a strong industrial base, with the gross value added from industry accounting for a higher share of the GDP than the EU average. Industry, including construction and manufacturing, contribute around 28% to gross value added yearly and employ around 30% of the labor force.

Energy poverty

Among EU members, Romania is one of the countries most affected by poverty and energy poverty. While currently lacking a common EU definition, energy poverty tends to be approximated by looking at several indicators that capture its various dimensions (EPAH, 2022b). The most relevant are the risk of poverty, the inability to keep homes warm, arrears to utility bills, abnormally high or low energy spend.

Romania is the country with the highest share of people at risk of poverty or social exclusion in the EU (Figure 29). The extent to which this translates into energy poverty is not known with precision, but it is safe to assume that this factor is a driver for most other forms of poverty, including energy.

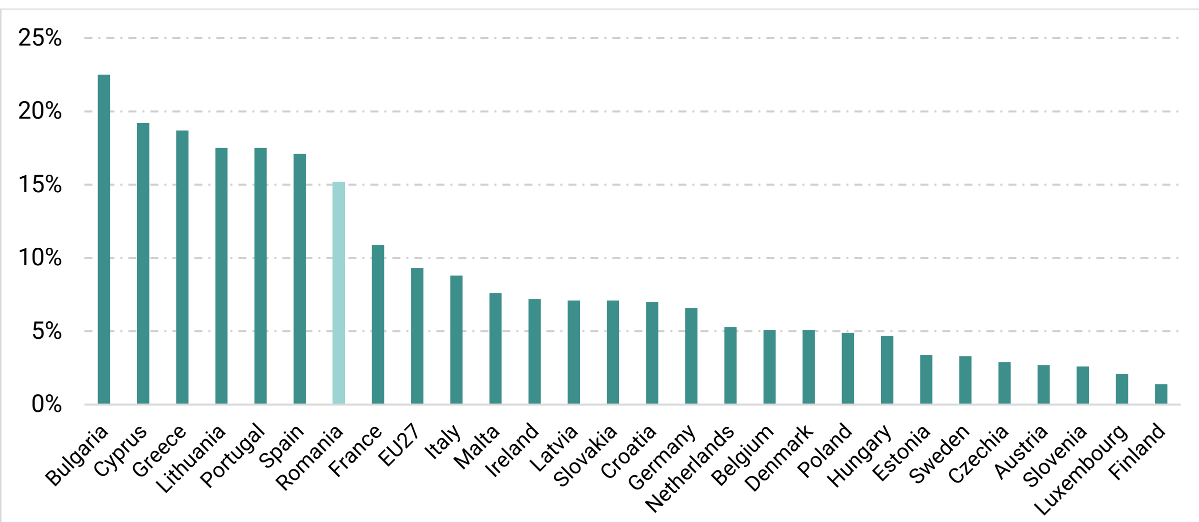
Figure 29: People at risk of poverty or social exclusion, 2020



Source: Eurostat.

With regard to the energy poverty indicators, Romania tends to perform slightly better. The country ranks above the EU average in terms of the percentage of the population that cannot keep their home adequately warm, doing better than higher-income countries like Spain. This may be explained by structural factors such as the reliance on district heating and firewood in Romania, which, until recently at least, enabled many households to heat their homes at relatively low costs.

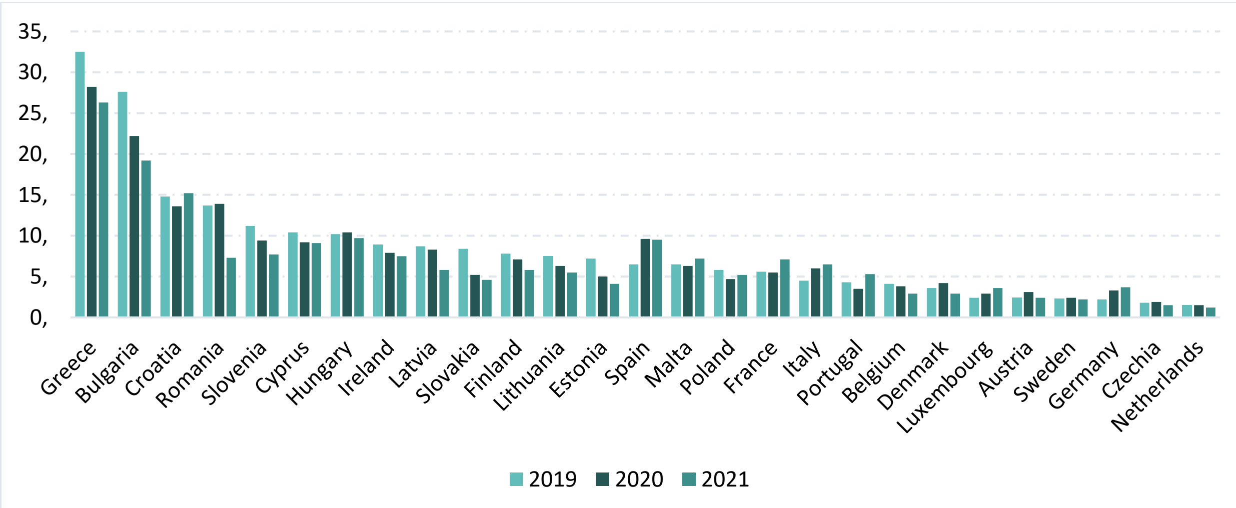
Figure 30: Households that cannot keep home adequately warm, 2021



Source: Eurostat.

Another indicator of energy poverty based on survey data is the percentage of households that have had arrears to utility bills over the past 12 months. In 2021, more than 7% of households in Romania experienced difficulties in paying their utility bills on time because of financial constraints. In the previous two years, the rate was double.

Figure 31: Arrears on utility bills, 2019-2021

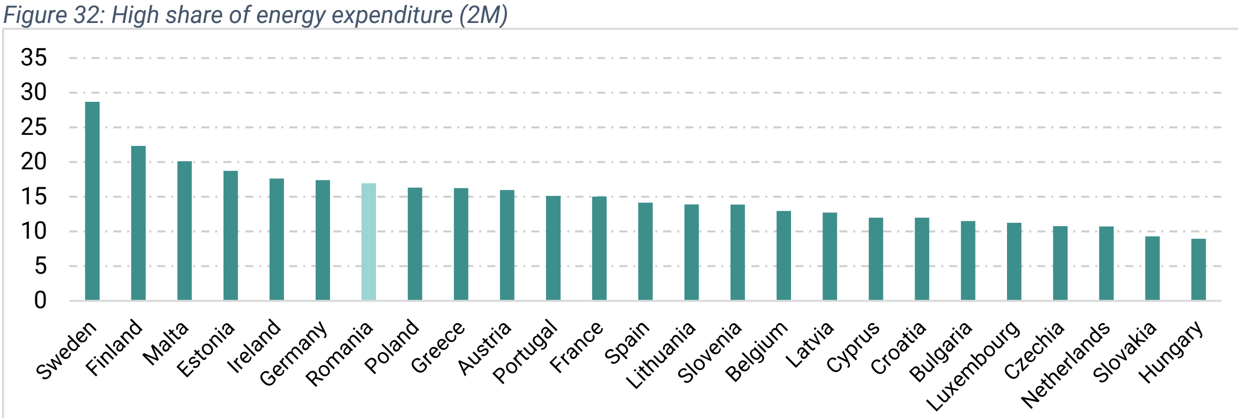


Source: Eurostat.

A distinctive set of indicators that attempt to capture certain dimensions of energy poverty are the ones based on abnormally high shares of expenditure or abnormally low absolute expenditure.

Households that spend significantly higher shares of their income on energy compared to the national median may be experiencing energy poverty, due to low incomes, inefficient housing, or both. In Romania, 17% of households had a share of expenditure on energy more than twice as high as the median of the country in 2015 (the 2M indicator).

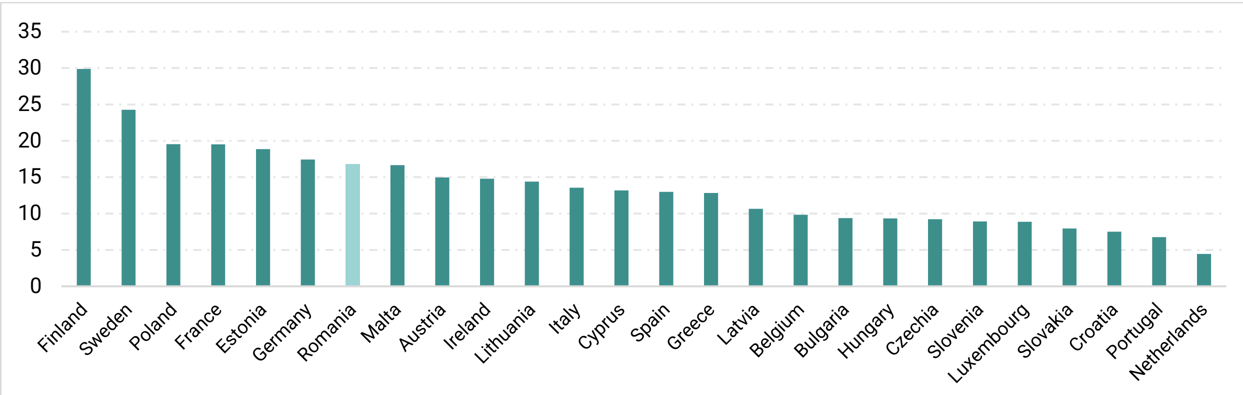
Figure 32: High share of energy expenditure (2M)



Source: EPAH.

Some households experiencing energy poverty may be identified by looking at low absolute expenditure, which may be insufficient to cover the basic energy needs of a typical household. In Romania, 17% of households had a total expenditure on energy that is below half the national median in 2015 (the M/2 indicator). Many households in rural areas have low levels of consumption of electricity and are not connected to the natural gas grid. They use woody biomass for heating, which they often procure informally. The extent to which this amounts to energy poverty is difficult to establish but these households are very likely being captured under the M/2 indicator.

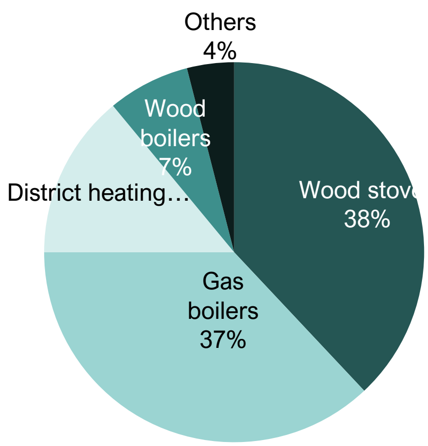
Figure 33: Low absolute energy expenditure (M/2), 2015



Source: EPAH.

There appears to also be a connection between the type of fuel used for heating and poverty. According to Household Budget Survey data for 2019, from the National Institute of Statistics, 2.8 million households use mainly wood-burning stoves for space heating. This technology has a very low efficiency, with a great amount of heat exiting through the chimney.

Figure 34: Main space heating technology used in Romanian households in 2019



Source: National Institute of Statistics: Household Budget Survey data for 2019.

Wood-burning stoves can be replaced by wood burning boilers which can operate on the same fuel but require a significantly higher upfront investment. This is the main reason for which less than 0.5 million homes use wood-burning boilers. According to HBS data in 2019, in the first income decile, namely 10% of all households with the lowest income per capita, more than 80% use wood-burning stoves as the main space heating source. The percentage is ten times lower in the highest-income decile. Out of the 1.28 million households (17% of total) made of wattle and daub in Romania, 89% (1.14 million households) use wood-burning stoves. Therefore, wood-burning stoves are usually found in low-income households with often precarious living conditions.

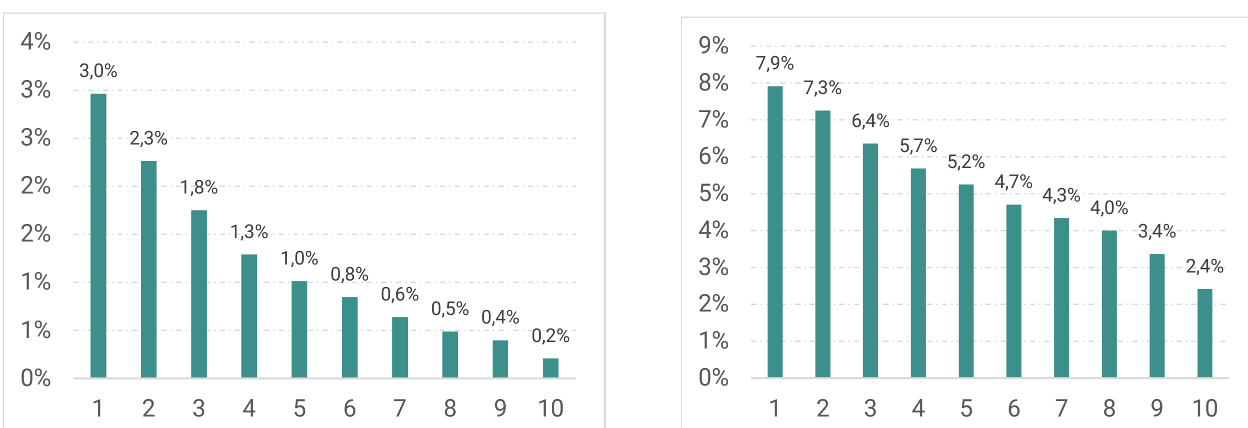
In urban areas the predominant heating technology are gas boilers (58% of urban households), followed by district heating (24%), wood stoves (11%), and others (7%). Rural areas are using primarily wood-burning stoves (68%), gas boilers (14%), wood burning boilers (11%) and others (7%).

In order to further understand how the expenditure on various sources of energy varies between different income levels, we have split Romanian households according to their total consumption expenditures into 10 groups (deciles) and examined the spending patterns on energy sources.

Results based on HBS data for the year 2019 suggests that lower income households have overall different spending patterns that higher income households. For example, when looking at how much Romanian households have spent on electricity, the first decile, allocated 7.9% of their total consumption expenditures on electricity, while higher income households spent a significantly lower share (2.4% in the 10th percentile). Nonetheless, while the share spent on electricity might be larger for lower income households, the amounts are lower in absolute terms (on average a household from the 1st decile spends 87 RON on electricity, while a household from the 10th decile will spend 107 RON).

Another energy source used by lower income households would be LPG for home cooking and heating. As we can observe in the charts below, the first decile spends 2.96% of their total consumption expenditures on LPG, while wealthier households spend around 0.2%.

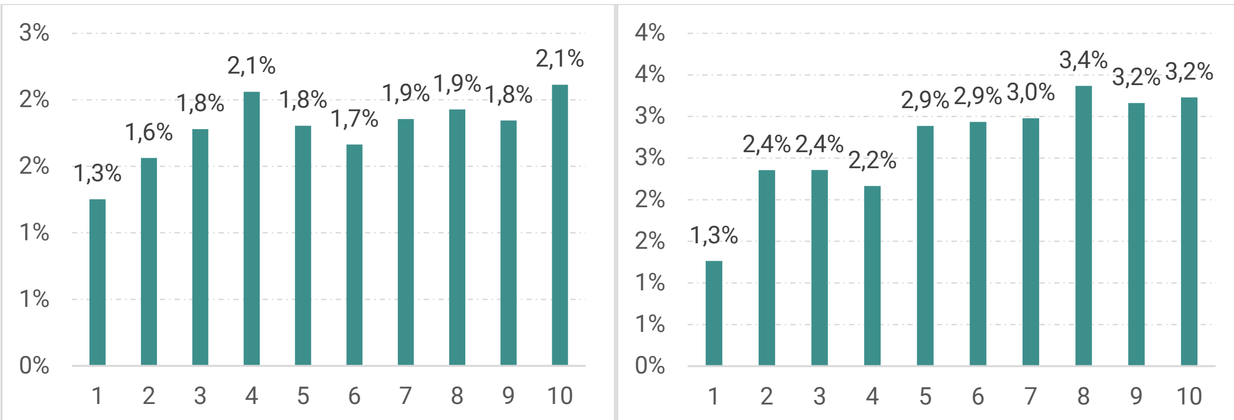
*Figure 35: **Left**: Percent of consumption expenditures spent on LPG for home; **Right**: Percent of all consumption expenditures spent on electricity*



Source: National Institute of Statistics: Household Budget Survey data for 2019.

On the other hand, households which belong to the 10th decile spend more on gasoline (3.23% of their expenditures compared to 1.26% the 1st decile spends), and diesel, since they are more likely to own a car or other vehicles.

*Figure 36: **Left**: Percent of consumption expenditures spent on diesel; **Right**: Percent of consumption expenditures spent on gasoline*

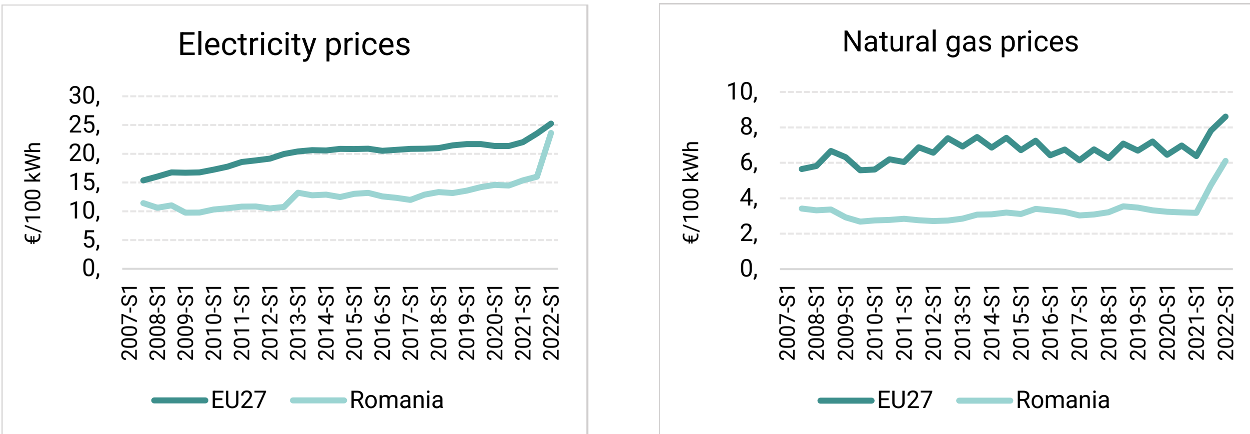


Source: National Institute of Statistics: Household Budget Survey data for 2019.

Overall, in Romania, the drivers of energy poverty for households are typical for a middle-income country. Being at risk-of-poverty, living in households with low labor intensity, being exposed to severe material deprivations (cannot afford to pay rent / loans / bills, adequately heat the house, manage unpredicted expenses with current income) are all dimensions of energy poverty. An estimation from 2017 found that 5.6% of households have informal access to electricity, 32% of households fall into poverty after paying for energy bills, and that 218.698 households (out of a total of about 7.5 million) were benefiting from heating aid during winter (CSD, 2017).

Energy prices are also relevant in the context of poverty. Romania has gone through several cycles of liberalization and regulation, depending on the evolution of prices. Energy markets – power, natural gas and transport fuel tend to be strongly correlated with the rest of the EU, while being constantly lower than EU averages.

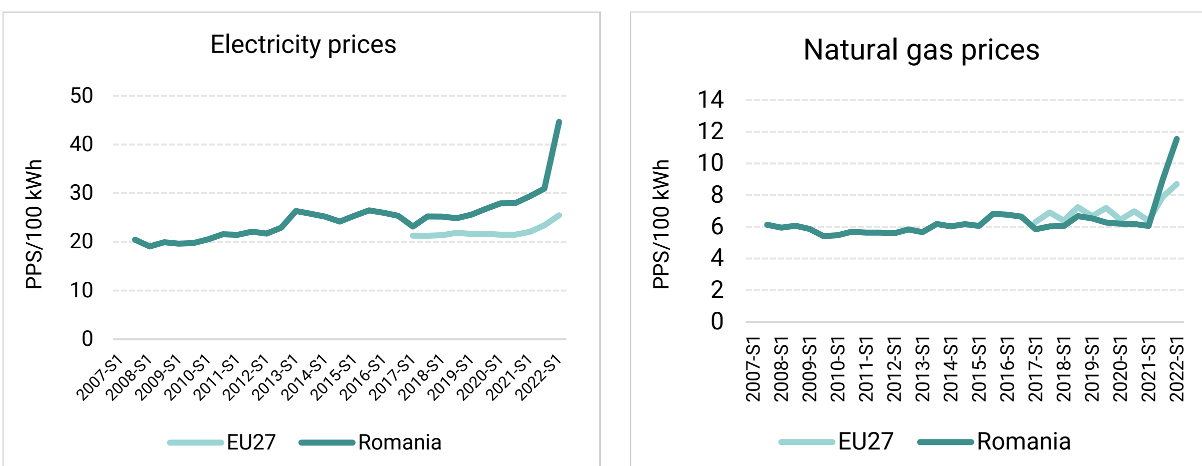
Figure 37: Electricity and natural gas prices for households in euro/100kWh



Source: Eurostat

Romanian households pay higher prices for electricity than the EU average when looking at their purchasing power. The same goes for natural gas, where, despite having some of the lowest prices in the EU, the burden on households tends to be high. In the first semester of 2022, in PPS terms Romania had the highest prices for electricity in the EU, while for gas it ranked 5th.

Figure 38: Electricity and natural gas prices for households in PPA/100kWh



Source: Eurostat.

Carbon taxes would purposely increase prices of emissions-intensive goods, energy being the most relevant. Given the energy poverty situation in Romania, an evaluation of the possible impact of such tax is warranted. However, the revenue redistribution options for income-support as well as the investments into low-carbon alternatives, like renewable energy, electric mobility and heat pumps, need to be included in such assessments to capture the full policy impact.

The lifting of Covid restrictions, the economic recovery that followed and the war in Ukraine pushed power prices to record levels in Romania. In August 2022, a new record on the day-ahead market was set at almost 600 EUR/MWh. Throughout the period, the Romanian Government shielded most categories of consumers from these prices, by fixing the retail price and paying suppliers the difference between the market wholesale price and the administrative retail price. This difference ballooned over the course of 2022 and the Government delayed payments to suppliers and instated windfall profit taxes on the generation side. While this solution contributed to limiting the rise in the inflation rate, this started to be seen as unsustainable (IMF, 2022). New caps and partially regulated wholesale prices were introduced from January 1st, 2023, but the principle has not changed significantly, with most households benefitting from heavily subsidized prices. While not targeted to households experiencing energy poverty, the measure did keep prices at their pre-pandemic level and represented the main intervention that prevented the rise in energy poverty rates.

In Romania, dedicated policies to reduce energy poverty have been relatively ineffective (ORSE, 2022). Until recently, vulnerable consumers were mentioned in the Energy Law (Law 123/2012) and in the regulations of the National Energy Regulator. However, those references were vague and rarely applied. The most concrete targeted measure, historically, has been the heating aid, delivered through local authorities. However, the measure has been ineffective, based on outdated thresholds for eligibility and lengthy bureaucratic procedures. The aid has not been indexed for a long period of time, which means the amount became less and less relevant, as both wages and prices increased, making the measure largely ineffective (CSD, 2017).

In September 2021, a new law was adopted establishing social protection measures for vulnerable energy consumers. Under the new Law, vulnerable consumers are defined as individuals or families who, due to illness, age, insufficient income or isolation from energy sources, would benefit from social protection measures and additional services ensuring their minimum energy needs. An estimated 500,000 households receive up to RON 500 (EUR 100) per month to pay bills during the cold season (between November 1st and March 31st). Non-financial measures include facilities for accessing and connecting to available energy sources necessary to ensure minimum energy needs, such as a ban on disconnection from energy supply sources for certain categories of vulnerable consumers, and transparent and accessible advice and information on energy sources and associated costs.

In 2023, the Government also launched an energy voucher scheme, using EU funds, that targets certain categories of the population that may be at risk of energy poverty. The eligible beneficiaries will be pensioners with incomes below a certain threshold, families with children in difficulty and the beneficiaries of other social policy interventions. The amount would be around 280 euros per household per year.

Currently, the revenues from EU ETS are used by the Environment Fund Administration in several programs, none specifically aimed at reducing energy poverty. The programs with the largest pool of beneficiaries among Romanian households are the *National program for the replacement of used electrical and electronic equipment with more energy-efficient ones* and *the Program to stimulate the renewal of the national car park*. Through the latter, 1 billion RON (218.16 mil. EUR) were spent in 2022 to subsidize the scrapping of 107.000 old vehicles and the acquisition of 53.000 new ones, out of which 10,462 were electric vehicles.

Overall, it can be said that Romania is significantly affected by energy poverty and has had relatively ineffective policies to mitigate it. Given the country's relatively low administrative capacity, targeted measures have been less effective. This was compensated for with repeated and expensive interventions of price regulation for the entire population, with questionable sustainability over time.

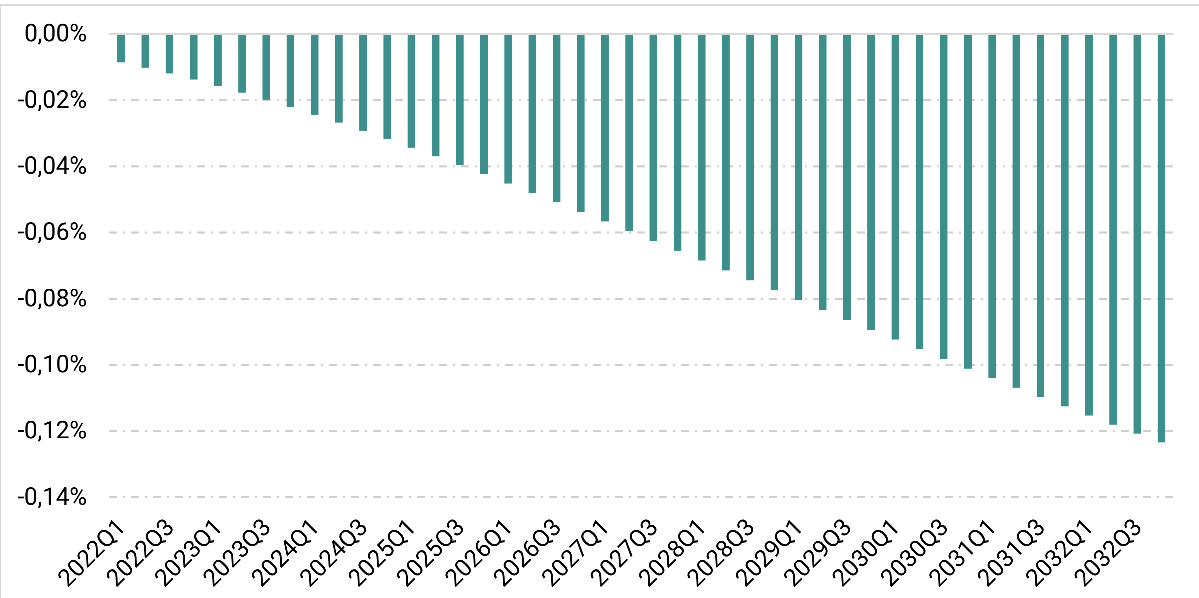
Results

Macroeconomic impact

While empirical evidence is mixed (Köppl and Schratzenstaller, 2022), there are fears that a carbon tax can affect economic growth and employment. The tax directly increases prices for emissions intensive goods, particularly energy, leaving lower disposable income for households and firms. This can lead to lower consumption and investment, which would translate into lower output and employment over the longer term.

However, in countries that implemented carbon taxes there is no evidence of a significant negative economic effects (Metcalf, 2019). This can be partly explained by the availability of lower-emissions alternatives at comparable (or declining/ subsidized) prices – for example switching from coal to gas or renewables. The low economic effect can be also explained by the strategic deployment of the collected revenues, which Governments can use to reduce other, more growth-inhibiting, taxes (such as labor taxes).

Figure 39: Effect of carbon tax on GDP versus baseline (without carbon tax)



Source: own calculations.

Our analysis also finds a limited macroeconomic effect of the modelled carbon tax in Romania; gross domestic product would deviate from a non-tax scenario by a maximum of 0.12%, reached in 2032.

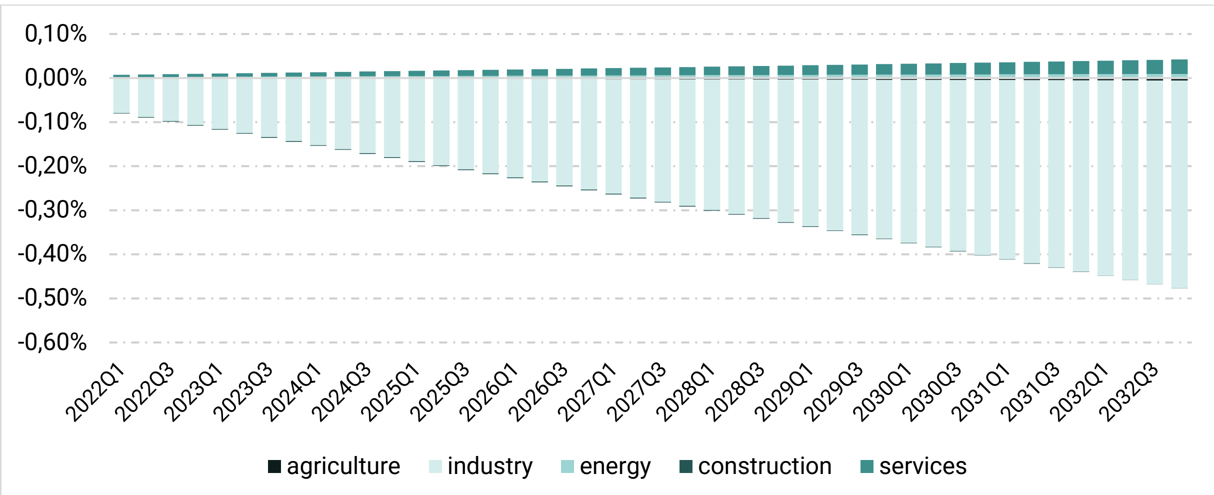
The carbon tax would have different effects on the sectors of the economy. The most affected sectors are industry and services. The added value in industry would see a decrease of 1.17% in 2032 from a projected non-tax scenario, reflecting the carbon intensity of this sector. In services, the impact of transport is the likely driver of the -0.37% deviation associated with the carbon tax. On the other hand, the tax would have a slightly positive impact on the energy sector by an estimated 0.18%. In agriculture and construction, the impacts are negligible.

The cumulated impact that the introduction of a carbon tax would have on the labor market is also relatively low (Figure 40).

The decrease in employment every year until 2032 would be almost zero until 2025 and below 0.02% throughout the entire period.

Industry would see the largest reductions in employment, but even those are below 0.5% of the total workforce. This is again explained by industry being the most emissions intensive sector analyzed here. The impact on other sectors is minimal but positive, for example services would see an estimated .003 increase in employment by 2032. Innovation is not included in the modelling, therefore the negative impact on industry may be even smaller.

Figure 40: Impact of carbon tax on employment by sector in 2032

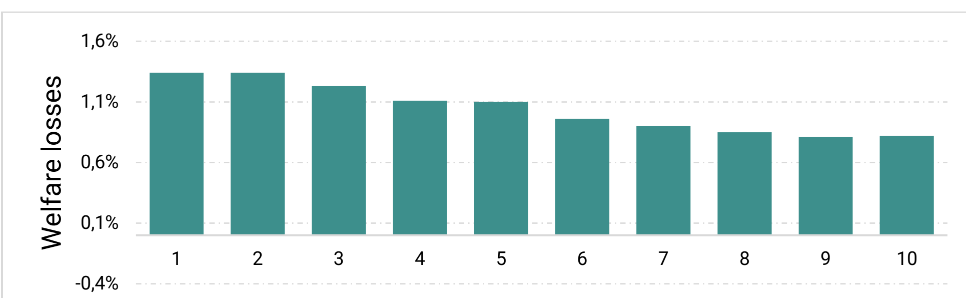


Source: own calculations.

Household impact

Overall, before redistribution, the carbon tax seems to display minor regressive tendencies. This means that the relative burden imposed by the tax on households belonging to the lower income deciles is higher than the burden for more affluent households. In Romania, the highest decile would have a welfare loss of 0.8% compared to almost 1.4% for the bottom decile. The average welfare loss in Romania would be around 1%.

Figure 41: Welfare losses (%) by expenditure decile



Source: own calculations.

The revenues collected from the carbon tax can be redistributed. Three scenarios for redistribution were tested:

Lump-sum transfer - scenario that redistributes the revenues equally for all households. The transfer size does not depend on the socio-demographic characteristics of households or their estimated welfare losses. Instead, the government gives the same amount of money to each household.

Price subsidy - scenario where revenues are used to alleviate the welfare effects of the price increases for lower income households. From the carbon tax collected from all households, the ones in the lower deciles get a price subsidy thus reducing their welfare losses. As such, the transfer is inversely proportional to the total budget of the households and proportional to the welfare losses.

Double-dividend - scenario in which revenues are used to reduce other distortionary taxes. The model uses the assumption that the tax reduction is proportional to household income, therefore acts as income tax rebate. The total revenue collected through the carbon tax is presented in Table 11.

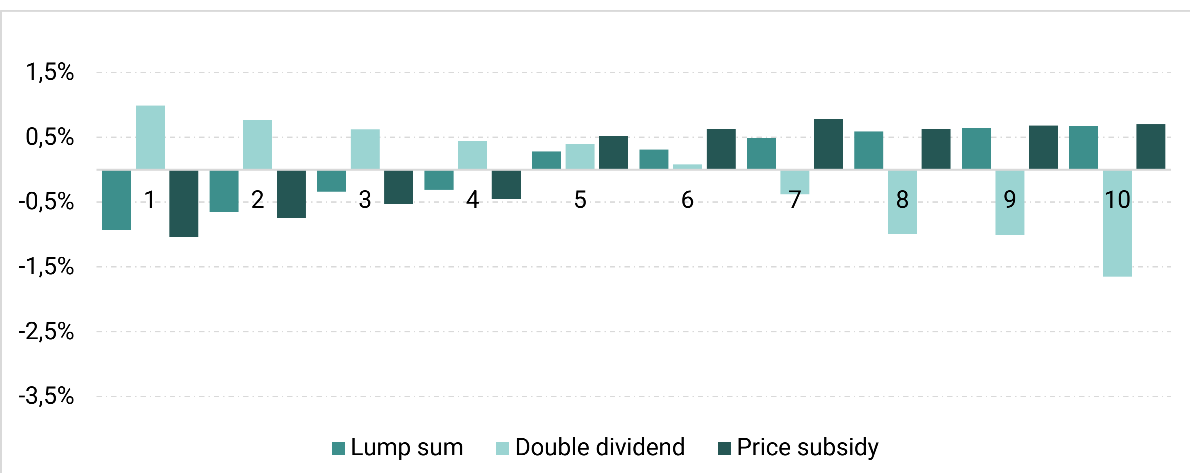
Table 11: Carbon tax revenues in the first and last year of the forecasted period

	Revenues in 2022 (million EUR)	Revenues in 2032 (million EUR)
Romania	337.18	1,040.34

Source: own calculations.

Based on the three scenarios, we observe that carbon pricing can improve the welfare of the least affluent when coupled with the right redistribution strategy (Figure 42). Furthermore, the average losses of the lowest deciles are reduced significantly after redistribution. In addition, some revenue redistribution approaches produce macro effects. For example, reducing other distortionary taxes with the revenues obtained from the carbon tax is likely to have a positive effect on economic growth, but would primarily benefit the more affluent households in the short run.

Figure 42: Impact of the carbon tax on household budgets, by expenditure deciles (positive value represents a welfare gain)



Source: own calculations.

The impact on energy poverty rates can also be estimated. We use one of the indicators of energy poverty built by the EU Energy Poverty Observatory, which also uses HBS data (EPAH, 2022a). The indicator defines energy poor households as those whose total energy expenditure falls below M/2, with M being the median value of the population. Table 12 compares estimates of energy poverty from the 2022 baseline values without a carbon tax with 2032 estimates for a scenario with a carbon tax but without redistribution, as well as for each of the three revenue recycling scenarios in 2032. The carbon tax with redistribution through price subsidy or lump sum results in lower energy poverty rates than in the baseline. The double-dividend scenario is associated with slightly higher rates of energy poverty. However, the results seem to indicate that the impact on energy poverty is rather small, whether positive or negative, if the carbon tax is complemented by revenue recycling.

Table 12: Energy poverty levels before and after tax

	Baseline scenario (2022)	Post-tax scenario (2032)	Post-redistribution scenarios (2032)		
			Lump-sum	**Double dividend**	**Price subsidy**
Romania	18,81%	21,64%	16,75%	18,85%	14,85%

Source: own calculations.

Discussion and recommendations

Carbon pricing is politically sensitive even at the level of the EU. Several MSs, civil society organizations and political leaders have criticized it on the ground of its potential impact on lower income households, particularly given the cost-of-living crisis driven specifically by the high energy prices after the invasion of Ukraine.

For example, the proposal of the EC to introduce ETS2 generated significant controversy, with several stakeholders calling for either changing, postponing, or scrapping it altogether. Trade unions in particular argued that carbon pricing would be ineffective in lowering emissions because of the low price-elasticity of demand, especially for lower income households. Because of the essential character of most emissions intensive goods and low availability of low-carbon alternatives, the argument goes, consumers would not respond to changes in prices by lowering their consumption or switching to alternatives. Instead, since suppliers would pass on the cost to consumers' bills, the latter would be burdened with a higher cost of living.

However, the potential to reduce emissions and mitigate negative effects on the economy and lower income households should not be ignored. For example, a recent World Bank report (World Bank, 2022) discussed two scenarios: (1) low-ambition starting at €15/ton in 2021 and reaching €50 in 2030, and (2) Paris-aligned starting at €45/ton and reaching €90 in 2030. Both scenarios result in reduced GHG emissions - the low-ambition scenario generates between 5 and 7% reductions compared to the baseline, while the Paris-aligned scenario results in a 9% reduction in Romania. If the revenues are used to reduce labor taxes, the GDP impact of the carbon tax would be positive in the short run and neutral in the longer run under both scenarios. In terms of employment, Romania would see net job growth under both scenarios.

The political discussion in Romania on the possibility of introducing carbon pricing at the household level has been marginal. Even the existing ETS for industry and the power sector has been seen domestically as too ambitious and affecting jobs in coal-fired power plants and mines. The Modernisation Fund and article 10c of the ETS directive – which redirect part of the revenue from auctioned allowances under ETS1 improved the political acceptance of carbon pricing, as it was directed mostly at helping ailing coal-fired generators to switch to lower emissions technologies.

The issue of household energy prices tends to be politically sensitive, as illustrated by the generalised retail price cap imposed immediately after the first signs of the post-Covid recovery and then after the war in Ukraine. Hence, the appetite for additional carbon pricing is unlikely to be home-grown in Romania, a country still dealing with poverty and convergence with the EU, where the climate agenda is less prominent. However, the possibility of redistribution at the EU level – through the Social Climate Fund – where Romania may get one of the highest allocations, can be attractive enough compared to the relatively low expected effect on prices, at least in the short term.

The administrative capacity of the country is also relevant to this discussion. The experience with the heating aid, where bureaucracy and lack of coordination made the policy ineffective for several years may be illustrative for the challenges associated with a potential carbon tax. In Romania, social policy suffers from large inclusion and exclusion errors, which may extend to the revenue redistribution component of carbon pricing.

Our economic simulations provide evidence on the macro- and microeconomic impacts of carbon pricing, through a generalized theoretical carbon tax on all consumption goods, at levels required to achieve emissions reductions by 2032 in line with climate neutrality by mid-century. The findings suggest negligible impacts on GDP and employment. At the household level, welfare losses are between 0.8% and 1.4% of expenditure, slightly higher for lower income households. However, they could be mitigated by revenue recycling, particularly by targeting the lower deciles. Importantly, after revenue recycling, low-income households can improve their situation compared to a scenario in which no additional carbon tax would be imposed. In other words, carbon pricing combined with the right revenue recycling mechanisms can even have a progressive redistributive effect. Through adequate targeting, the carbon tax can reduce the rate of energy poverty. In this context, we conclude that carbon pricing can play a complementary role in promoting emission reductions in Romania.

Based on the analysis, our recommendations are:

- Carbon taxes with revenue redistribution should be considered as a complementary policy option to pursue reductions in emissions and energy poverty at the same time.
- Carbon pricing should not be analyzed in isolation. By being exposed to a carbon price, consumers are incentivized to seek lower carbon alternatives that are offered or subsidized through other policies. When considering carbon pricing, the mechanism should be planned and assessed together with other EU and MS level policies, such as energy efficiency, renewable energy expansion, electrification of transport, social benefits and others.
- Carbon pricing generates significant revenues, at least in the beginning. That revenue needs to be redistributed back to specific segments of the population, helping them cope with increased prices and invest to reduce their emissions in the long term, by switching to low carbon alternatives for heating such as heat pumps, insulating their homes or buying electric vehicles.
- The issue of implementation should also be addressed. The targeting required to reduce energy poverty and the impact of carbon pricing on the poorest will be more challenging for countries where existing welfare policies are plagued by large inclusion and exclusion errors such as Romania. Revenues should also be used for improving administrative capacity, particularly in the social policy sector.

Comparative analysis and conclusions

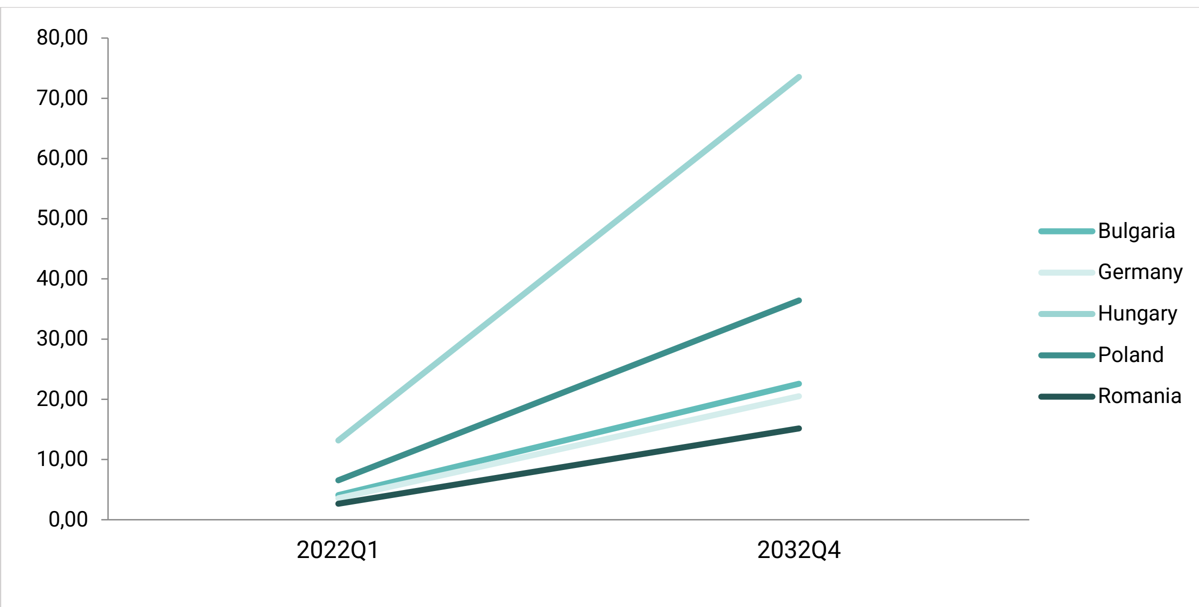
The overall results in the five countries demonstrate that carbon pricing can be effective in achieving emissions reductions, with minor macroeconomic effects, limited or even positive household impact (if coupled with redistribution) and potential reductions in dependency on fossil fuels.

Although some economic sectors may experience a slower growth in employment and economic output, other less carbon-intensive activities would benefit from carbon price-induced shifts in capital and labor. Introducing a carbon price will lead to welfare losses only without a redistribution mechanism. There are a number of fiscal instruments that could not only cut these losses, but improve welfare, especially for less affluent households. Thus, carbon pricing could reduce energy poverty, while accelerating the low-carbon transition.

Comparative macroeconomic impact

As mentioned in the methodology chapter, the analysis of the macroeconomic effects of a carbon price is based on a multi-sector dynamic stochastic general equilibrium (DSGE) model covering Germany, Romania, Hungary, Bulgaria, and Poland. The tax is tailored and optimized by the macro-model for each country in view of reaching a 40% reduction of CO_2 emissions by 2032 vs 2022, taking into account the carbon intensity and energy mix of the national economy, as well as its general macroeconomic situation (Figure 43).

Figure 43: Carbon pricing scenarios (\$/ton CO_2)

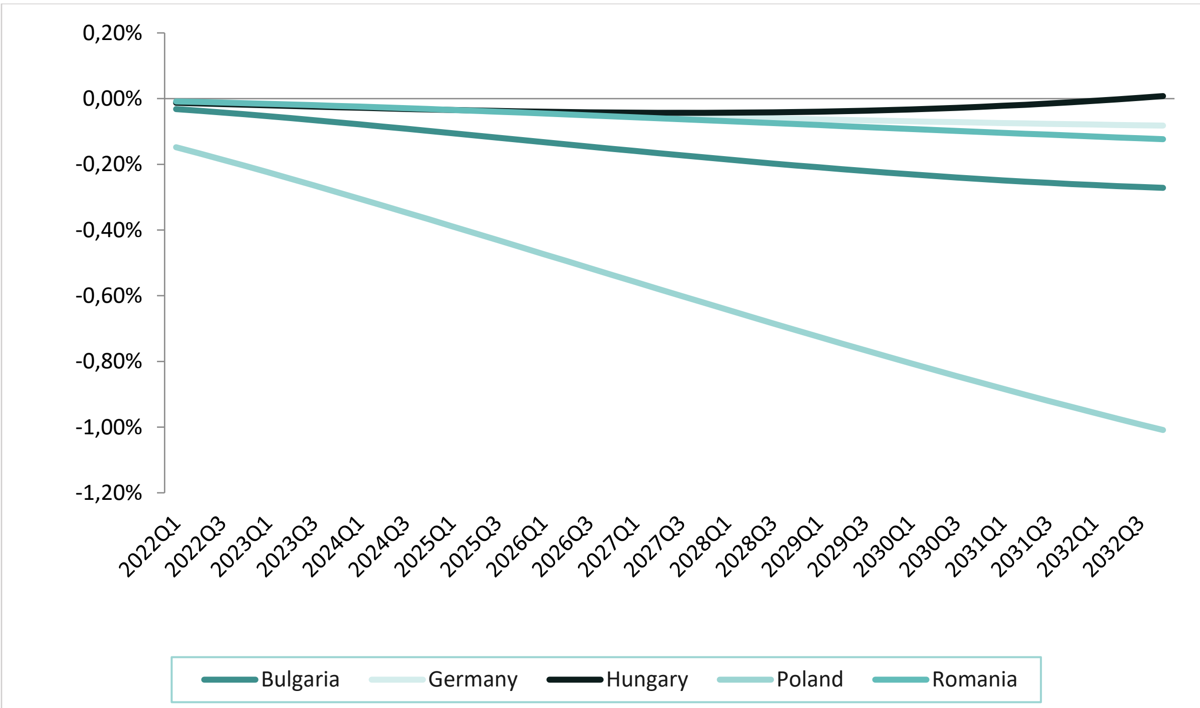


Source: own calculations.

The model results show that the introduction of a carbon price would slow economic growth only marginally. According to the OECD projections, economic growth between 2022 and 2032 will be significantly higher in Bulgaria, Romania, Hungary and Poland, compared to Germany, with the former growing by between 20 and 25%, whereas Germany's economy – by 9% during the same period.

In the cases of Germany, Bulgaria and Romania, the observed negative deviations (See Figure 44) from the OECD forecast are negligibly small, and even in Poland, which would see the largest fall in its GDP with around 1%, economic growth would still be in the double digits over the observed period, despite the carbon price.

Figure 44: Differences in GDP growth (% deviation from the no-carbon price scenario)



Source: own calculations.

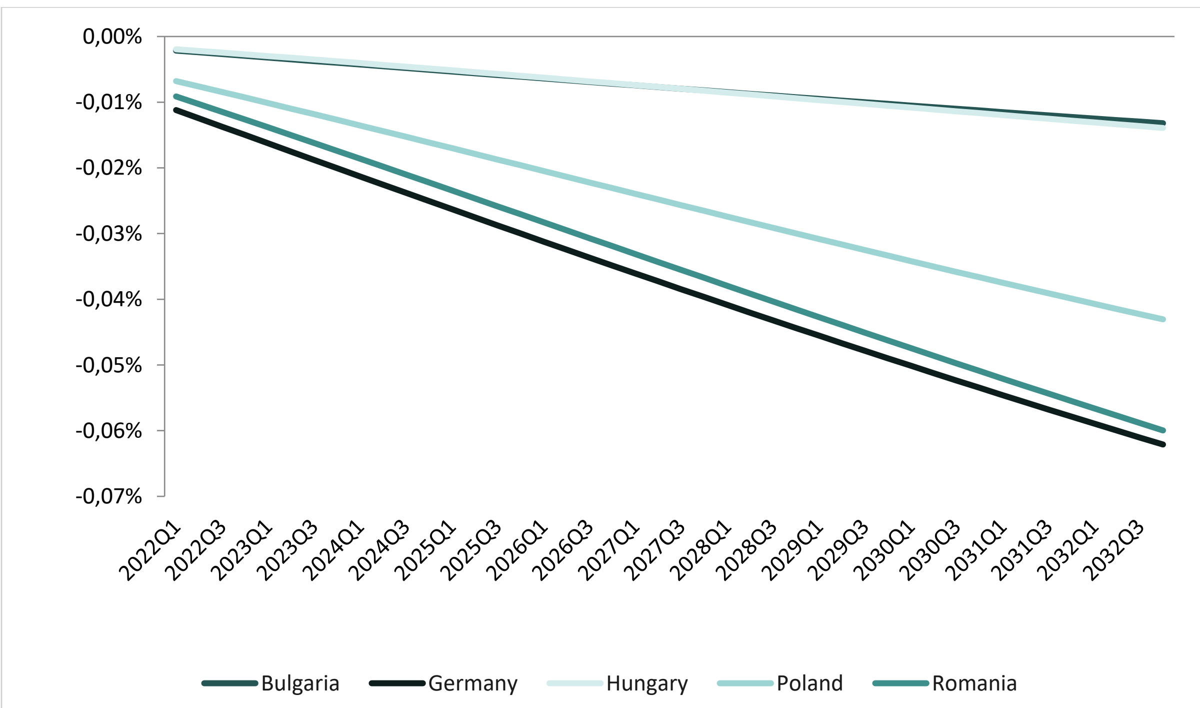
Interestingly, economic growth in Hungary would even accelerate if a carbon price were introduced, albeit only marginally. Consequently, all of the included countries could introduce a carbon price at levels that would reduce carbon emissions by 40% in the next 10 years without harming their economic development potential. Another way of assessing the effects of a carbon price on the economy is to look at how the value-added changes for the whole economy and individually for each sector. In Germany and Hungary, a carbon price leads to a slight increase in value-added (0.08% and 1.22%), whereas in Bulgaria (-0.9%), Poland (-1.2%) and Romania (-1.4%), value-added falls slightly by 2032.

However, breaking down the results by sector, it becomes apparent that the effects vary significantly. Most strikingly, introducing a carbon price would actually raise the value-added in the energy sector for all countries. The reason is that the tax would incentivize energy companies to switch from unprofitable but heavily subsidized fossil fuel power plants to renewable energy, which generally have much lower marginal costs. Services would experience slightly negative deviations from a no-tax scenario across all countries ranging from -0.3% in Germany to -2.1% in Poland. Given the expected growth of these sectors on the back of the restructuring of Central European economies, the negative economic impact is likely to be manageable. Moreover, the abundant EU funds available from the Just Transition Mechanism and the comprehensive regional strategies under the Territorial Just Transition Plans would further support a smooth low-carbon transition (Primova, Vladimirov and Trifonova, 2022).

In the industrial sector, there is more variation of the regional performance the region, with Germany and Hungary showing positive impact from the carbon price, and negative in Bulgaria, Poland and Romania. The latter could be explained by the carbon intensity of the industry in those countries, as well as the inability of many companies to implement a swift transformation of their production processes, once a carbon price is introduced leading to higher production costs. However, these negative deviations could be tackled by decisive government action which facilitates investments in energy efficiency, the replacement of fossil fuel use with renewables and a general optimization of business processes. The energy crisis in 2022 has shown how many manufacturing companies have been able to quickly and meaningfully reduce natural gas consumption in response to much higher prices (McWilliams and Zachmann, 2022). Targeted government support to mitigate the immediate impact of skyrocketing costs, conditioned by plans for energy intensive businesses to implement technology changes, could help restore competitiveness and reduce carbon emissions.

In terms of the labor market, the carbon price barely affects employment rates as the model points to only small losses of employment growth by 2032 (see Figure 45). The expansion of low-carbon sectors would offset to a large extent the losses in employment in carbon-intensive sectors such as heavy industry and fossil fuel-powered energy production. This is also reflected in the expansion of employment in the service sector across all countries; a sector that is traditionally considered to be less carbon intensive.

Figure 45: Differences in employment (% deviation from the no-carbon price scenario)



Source: own calculations.

As many energy companies are still mulling whether to double down on fossil fuel investments (e.g. new LNG import infrastructure) or to focus on renewables, a carbon price could be the push they need to encourage this transformational shift. Indeed, the results show that, compared to a no-tax scenario, fossil fuel imports would fall in all countries except foreign oil purchases in Germany. Natural gas imports will drop most sharply between 10% in Romania and 35% in Hungary. Hence, by reducing Europe's dependence on fossil fuel imports, especially from Russia, the positive impact of a carbon price would go beyond the acceleration of the decarbonization process and will also include the strengthening of energy and climate security.

Comparative household impact

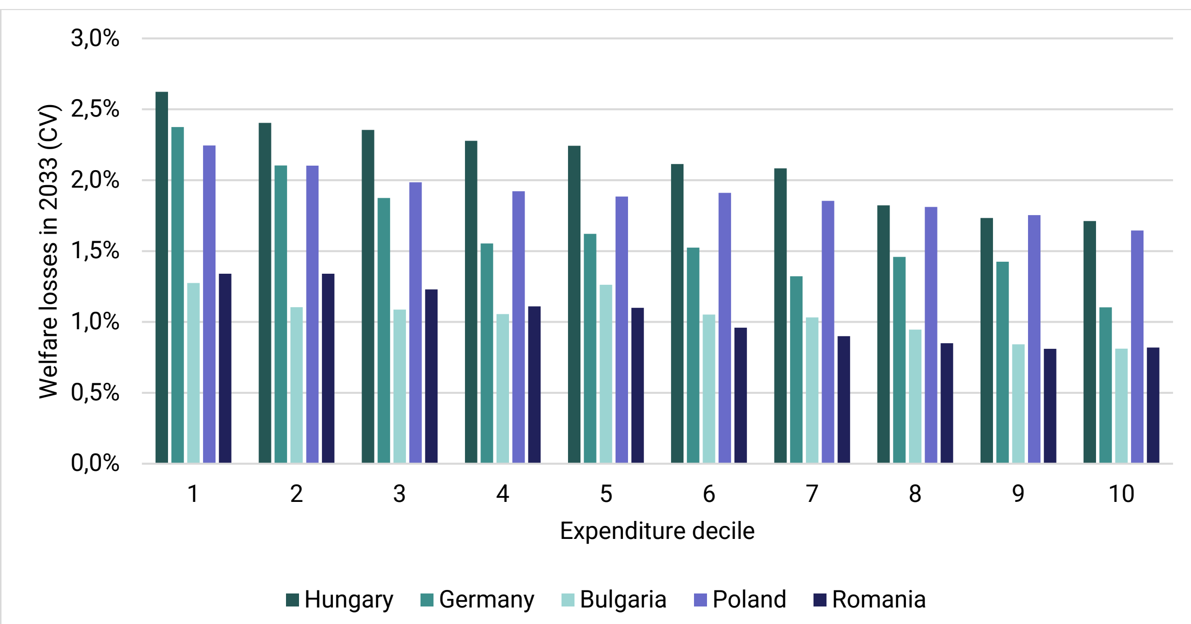
The comparative welfare analysis developed in this section describes the losses of each household after the introduction of a national carbon pricing regime.

The introduction of this carbon tax alters the relative prices of different goods and services, which in turn shifts the consumption pattern for these categories, which is precisely what QUAIDS models. Accordingly, the micro-model numerically characterizes how these shifts alter the welfare of households across the income distribution. The results can be split into two main categories: welfare effects before and after any of the three redistribution strategies discussed above are implemented. The micro-results take into account the different expenditure patterns from the five countries in our sample, providing estimates tailored to the microeconomic reality revealed by citizens' consumption behavior in the past five years.

Results before redistribution

Figure 46 shows how welfare losses are distributed across the ten expenditure deciles in all five countries in our sample. The results refer to losses in 2032, as computed iteratively starting from 2022 using the QUAIDS model previously described. Welfare losses are measured using the compensating variation (CV) computed at the average point of each decile identified in the five national sets of HBSs.

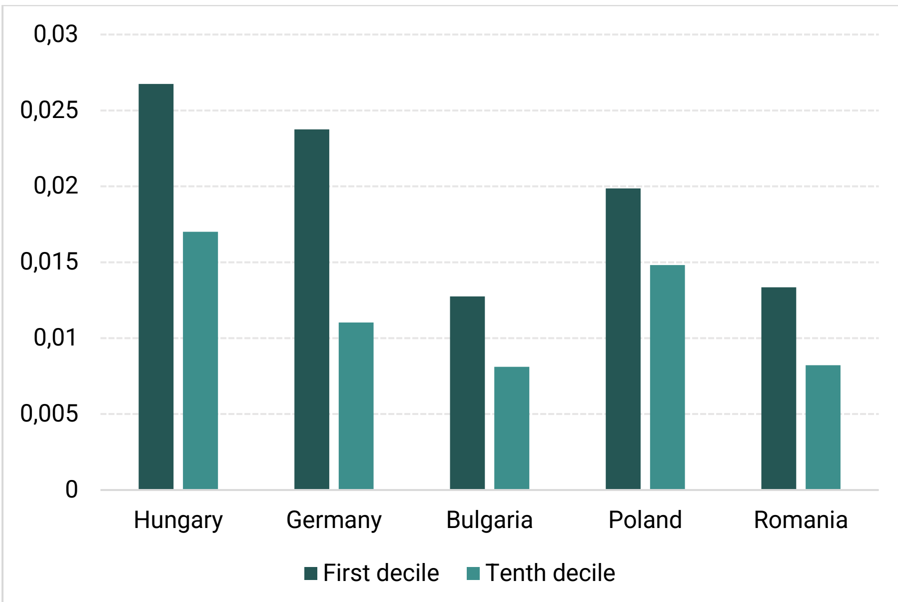
Figure 46: Welfare losses in 2032 prior to redistribution in the five countries



Source: own calculations.

Even before the revenues collected by the five governments are redistributed, in one form or another, to the consumers, the carbon taxes only seem to display minor regressive tendencies. This means that the relative burden imposed by the tax on households belonging to lower income deciles, in all the five countries, is only weakly higher than the burden for more affluent households. Hungary has the highest welfare losses in 2032, as households would have to earn on average 2.2% more following the introduction of a carbon price to maintain their initial consumption levels, while Bulgarian consumers are the least vulnerable with welfare losses at around 1.1%. If we look at the top 10% and the bottom 10% in terms of expenditure as indicators for this discrepancy, we see that Germany is the country with the most pronounced adverse distributional effects, followed by Hungary, while Bulgaria exhibits the smallest differences between deciles. These results are shown in Figure 47.

Figure 47: Welfare losses in 2032 prior to redistribution in the five countries: bottom and top decile

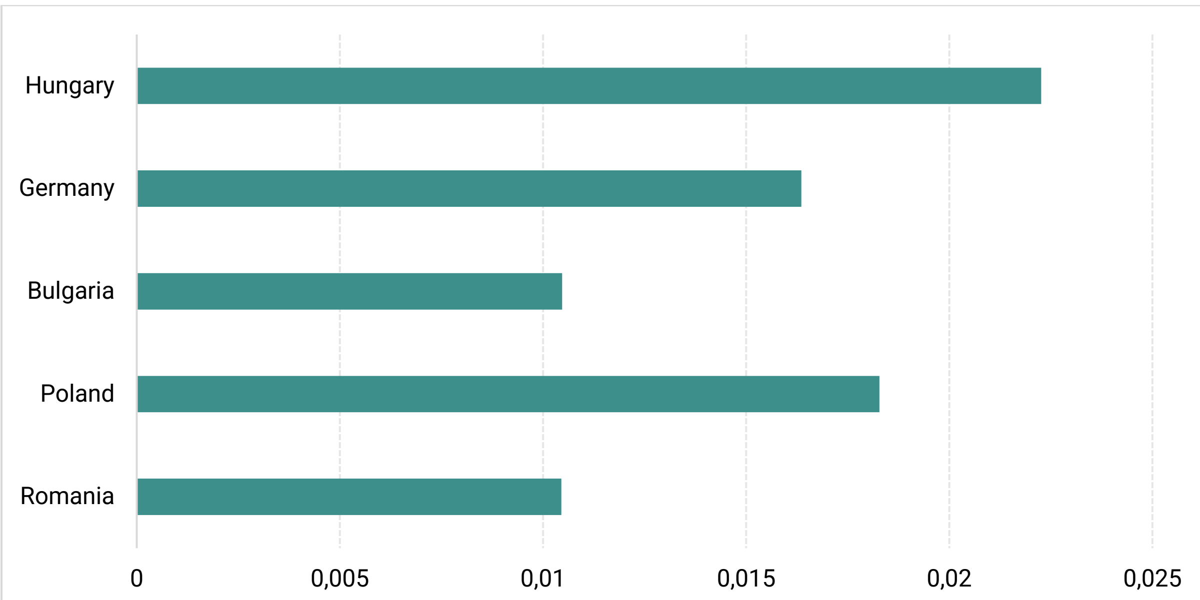


Source: own calculations.

The main reason the carbon tax does not induce a strong positive relationship between the level of income and the level of welfare losses is that it is applied nationwide, cross-sectoral, covering categories of consumption with vastly different patterns of welfare losses. The average losses of a carbon tax that applies to different sectors with different carbon-intensities and for which we have different expenditure patterns aggregates multiple types of losses, associated with each sector. If the tax were restricted to non-transport energy goods, it would display strong regressive tendencies based on our modelling results. Additionally, if the tax was restricted to the transport sector, it would be strongly progressive in the sample. When the carbon tax is applied on a broad category, the between-decile average losses are determined additively from the within-sector variations. This pattern, where the distributional effects of a carbon tax depend on its scope of application, has been thoroughly confirmed in the literature, including cross-country analyses that discuss such impacts across the European Union. Therefore, our model corroborates previous findings (Feindt *et al.*, 2021; Landis, Fredriksson and Rausch, 2021; Vandyck *et al.*, 2021; Ilyas *et al.*, 2022; Khabbazan, 2022; Tovar Reaños and Lynch, 2023).

While minor differences between average losses between deciles are typical and expected given the complexity and heterogeneity of national demand patterns, strictly from a distributional perspective, the deviation seem to be addressable through governmental policy. This is corroborated by the results produced through the MEMO macro-model, which, together with these results, indicate that socially optimal climate policymaking that follows the European targets is tenable in the five countries, even in the presence of minor distributional discrepancies. However, the same analysis of the micro and macro modelling results implies that while affordable in all five countries, the introduction of carbon pricing mechanisms will lead to particular challenges across various economic sectors and energy consumers. Figure 48 displays the average loss for the entire population. Hungary and Poland are the most affected countries.

Figure 48: Average welfare losses in 2032 per household in the five countries



Source: own calculations.

On the extreme sides of the distribution of welfare losses, we find Hungary and Bulgaria. Hungary has the highest average welfare losses in 2032, calculated as the mean loss of the population (followed by Poland), while Bulgaria has the smallest (followed by Romania). Germany stands in the middle of the distribution of average losses in 2032. A significant portion of the variation between states is attributed to variation in the trajectory of the optimal carbon pricing level until 2032. Nevertheless, the five countries are comparable, with their losses mainly ranging between 0.009 and 0.026, translating to 0.9% and 2.6% of total expenditure, a relatively small interval given the scope of the analysis (more than a decade of simulated behavioral changes). Based on existing studies, welfare losses induced in the short-term by a carbon tax should not be higher than a couple of percentage points (Steckel et al., 2021; Ohlendorf et al., 2021). There are two main implications of this finding.

Thus, the distributional effects of carbon pricing in Central and Eastern Europe, even before revenue redistribution, are rather mild. However, the negligible regressivity masks welfare losses, which could be detrimental, especially for poor households. While the average losses are not extreme, given the levels of energy poverty in the five countries in past years (as well as the extra number of people at risk of energy poverty), even small losses could have powerful repercussions, such as inducing social backlash against carbon pricing and climate policies at large (Baranzini and Carattini, 2017; Carattini *et al.*, 2017; Maestre-Andrés, Drews and van den Bergh, 2019; Douenne and Fabre, 2020; Sommer, Mattauch and Pahle, 2020).

Results after redistribution

As energy taxes and carbon taxes, in particular, generate significant revenues for the government, recycling the new funding sources could improve the distributional aspects of the energy transition pursued through carbon pricing (Beiser-McGrath and Bernauer, 2019; Savin *et al.*, 2020; Levi, 2021). The precise estimates for the welfare gains and losses depend on the particularities of each country. Three general conclusions can be drawn:

First, carbon pricing can improve the welfare of the least affluent when coupled with the right redistribution strategy. This is the case for all five countries, as long as either the price subsidy or the lump-sum strategies are followed. In particular, this is relevant for countries with relatively high welfare losses, such as Hungary or Germany. Furthermore, relatively poor countries in the region, such as Romania and Bulgaria, also see the average losses of the least affluent reduce dramatically; in some cases, these households gain after redistribution.

Second, regardless of the type of revenue redistribution approach that the government pursues, any welfare losses generated by carbon pricing are mitigated across the populations of the five countries. This flexibility trait of carbon pricing is essential for policymakers, as some redistribution options might be politically infeasible due to internal policy conflicts. For example, price subsidies could be more easily implemented in countries that already have robust welfare states able to collect data on the requirements of less affluent households. Nevertheless, even in the scenario where authorities do not employ the optimal redistribution strategy (optimal based on their social welfare and distributional objectives), second-best approaches are sufficiently good at alleviating the adverse consequences of carbon taxes.

Third, some revenue redistribution approaches produce macro effects while reducing the distributional effects induced by the carbon tax (e.g., increase inequality). For example, reducing other distortionary taxes with the revenues obtained from the carbon tax is likely, for all the five countries in the sample, to primarily benefit the more affluent households, increasing nationwide wealth inequality. This is especially true for highly unequal countries in CEE, such as Romania. However, in cases such as Germany, seeking a double dividend could be particularly beneficial for the middle class in a country which emphasizes the essential role of this stratum. If governments seek to maximize the welfare of this particular section of the population while using other income sources to cushion the losses of the poor, reducing other taxes might be the most suited solution. As a general rule, when governments select their optimal revenue recycling mechanism from a set of feasible alternatives, they must balance considerations regarding multiple interconnected elements of the economy.

Energy poverty

To enable a comparative cross-country analysis, we rely on a definition of energy poverty constructed by the EU Energy Poverty Observatory which also relies on HBSs data (Vondung and Thema, 2020). Therefore, we use an expenditure-based indicator that defines energy poor households as the ones whose total energy expenditure falls below M/2, with M taken to be the median energy consumption of the entire population. Our results provide, for each of the five countries, this indicator for multiple scenarios: before carbon tax (baseline), with carbon tax but without redistribution, and with carbon tax and redistribution (three different scenarios separately accounted for. As per the guidelines of the EU Energy Poverty Observatory, the indicators are based on electricity and heating related energy expenditure and do not consider mobility related expenses.

Table 13 shows the values of the energy poverty indicator, as computed for all the countries and different scenarios. The baseline values of energy poverty are computed for the year 2022, while all the other indicators are computed for the last year analyzed, 2032. The trajectory between 2022 and 2032 is determined, by assumption, only by the demand-driven shifts in consumption due to the carbon tax. The values for both 2022 and 2032 are well within the reasonable expectations resulting from the previous calculations conducted by the EU Energy Poverty Observatory (Drescher and Janzen, 2021; Karpinska and Śmiech, 2021; Tundys, Bretyn and Urbaniak, 2021).

The level of energy poverty across the entire region is non-negligible, with only Germany currently having less than 10% of the population at risk of energy poverty. The within-region variation is significant, with variations of almost 10 percentage points between the countries displaying extreme values in all scenarios (i.e., Germany and Romania).

Table 13: Energy poverty levels

	Baseline scenario (2022)	Post-tax scenario (2032)	Post-redistribution scenarios (2032)		
Country			**Lump-sum**	**Double dividend**	**Price subsidy**
Bulgaria	17,46%	18,22%	16,85%	18,01%	14,05%
Germany	8,25%	10,93%	8,34%	9,15%	6,02%
Hungary	13,29%	18,94%	14,65%	18,54%	13,55%
Poland	14,82%	19,55%	13,34%	15,35%	13,02%
Romania	18,81%	21,64%	16,75%	18,85%	14,85%

Source: own calculations.

The most significant reductions in energy poverty after redistribution can be seen with the price subsidy. With the exception of Hungary, where rates would be similar, all countries would see reductions between 1 and 4 percentage points. Slightly smaller energy poverty cuts are implied in the lump-sum scenario in Romania, Poland and Bulgaria, while Germany and Hungary would see a slight increase. This is explained by the fact that the poorest households receive the same monetary amount as the richest households, although relative to their budget they still receive greater support. In a double-dividend scenario, energy poverty rates would increase in all countries, the most in Hungary and the least in Romania. Given that the double-dividend scenario is comparable to an income tax cut, it is expected that affluent households will benefit disproportionally more, while poorer households would barely see any welfare gains.

A price subsidy is most effective at reducing energy poverty, as it will primarily benefit poorer households. However, such a policy might potentially generate a backlash from middle and high-income households, who would have to swallow higher welfare losses. In addition, the price subsidy distorts market signals to households that could otherwise invest in improving energy efficiency or be incentivized to save energy. Regulated prices have been the main strategy for reducing energy poverty[17] in the CEE region, which has

[17] Due to data availability constraints, the present study uses an expenditure-based definition for energy poverty that takes into account households with expenditures that are below 50% of the national median. While this captures better energy poverty in the lower income deciles, it might miss energy poverty among the middle class living in energy inefficient dwellings and thus having relatively high energy expenditures. Tackling energy poverty requires a strategic, integrated approach that goes beyond the scope of this study, which focuses on carbon pricing mechanism that does not exacerbate but rather alleviates energy poverty.

undermined the financial stability of state-owned utilities, public energy suppliers, and has, at the same time, contributed to wasteful consumption patterns.

In comparison, a simpler redistribution system like the lump-sum rebate comes with fewer administrative risks attached and will be more likely to gain the support of different societal groups. Lump-sum cash transfers do not distort market signals and allow all households to directly support housing investments that improve their comfort and reduce energy demand. Cash transfers must, however, be attached to strict spending requirements so that the financial support is used for energy efficiency investments and replacement of appliances rather than for supporting general spending.

Three general conclusions can be drawn from these results.

First, carbon pricing can improve the welfare of less affluent households with an appropriate redistribution mechanism. As the CEE region is characterized by structural income and wealth inequalities, the findings from the modelling assessment would improve public backing for a carbon price, which in turn would facilitate its political implementation. Moreover, while households largely maintain the same level of spending due to the redistribution payments they receive, the emissions related to their consumption patterns will decrease as their spending behavior is elastic to price changes between different expenditure categories.

Second, carbon price-induced welfare losses will be mitigated, in all three types of revenue redistribution approach considered in this study.

Third, some revenue redistribution approaches produce second-order effects while reducing the distributional effects induced by the carbon price. Using the carbon price revenues to allow for other tax cuts, for example, will primarily benefit wealthier households, but still poorer households would receive welfare gains especially if the tax cuts are specifically tailored to changing their energy behavior.

Implications of the Russian Invasion in Ukraine

In the present study, the effect of carbon pricing on prices and consequently on households is isolated from other critical factors, such as commodity prices and overall inflation. This distinction has become critical for a fact-based public debate considering the current energy crisis, to counter widespread misinformation narratives blaming the crisis on the European Green Deal and higher carbon prices.

The worsening of affordability risks across Europe since 2021 has largely been driven by the link between natural gas and electricity prices. Gas supply shortages, coupled with a strong economic recovery after the end of the COVID lockdowns, led to skyrocketing gas prices. Meanwhile, the reliance on gas power plants to meet peak demand makes them the market price-setter and their higher operational costs have pushed up electricity prices dramatically in the fall and winter of 2021, and they have remained very volatile ever since. The situation was exacerbated by the increase in crude oil, coal, and ETS prices that raised the overall energy import bill of European countries and the electricity production cost for all fossil-fuel-based plants.

This crisis has revealed how the overreliance on fossil fuels can significantly increase energy and climate security risks and could undermine the viability of the energy transition. It has also bolstered voices urging for the revision or even the halting of the European Green Deal. This would be the wrong response. The European Green Deal is not the cause of the energy crisis, but the solution. It is also potentially the strongest instrument for reversing climate change and increasing the energy security of the EU and its members.

The Russian policy of squeezing European gas markets to worsen the stability of power markets has forced European governments to take drastic action to blunt the Russian attack and shield their energy markets and economies from the fallout. The total financial support in the form of direct subsidies and tax deductions across EU countries for households and businesses has reached EUR 350 billion, an amount deemed necessary to mitigate the impact of high prices.

Higher energy prices are, in theory, necessary to justify the economic viability of energy efficiency investments and more rapid deployment of cutting-edge renewable energy technologies. However, their short-term detrimental impact on industrial competitiveness and living standards have pushed governments to adopt market-distorting measures such as fuel subsidies and price caps, that could undermine long-term energy and climate policy.

Energy poverty undermines the acceptability and feasibility of the deep decarbonization of the energy sector. The increase in CO_2 prices will raise energy poverty risks and could cause a social backlash against renewable investments. However, carbon pricing is necessary for the decarbonization of the energy system as it disincentivizes fossil fuel-based power production. A critical policy conclusion is that sending the right market signals for the acceleration of decarbonization policies is not the only prerequisite for a successful transition. Unless affordability is guaranteed, or basic support mechanisms are planned to avoid extreme outcomes, energy poverty will remain the primary barrier to structural changes.

National expenditures and the share of the household income taken up by energy costs are the key components of an energy affordability assessment. They are strongly affected not only by the price level of different energy sources, but also by the fuel mix, consumer choices, and energy efficiency. In this sense, high energy consumption and the use of more expensive fuels strongly influence affordability risks. This also significantly limits short-term solutions and measures that policymakers may take to reduce the effect of extreme prices on households and businesses. Improvements that structurally change the population's response to price shocks require a long-term commitment that five-year political cycles are insufficient to guarantee.

Related to this, the EU should show leadership by mandating that member states redirect the additional tax revenues from the rising ETS, and various windfall taxes towards strategic investments aimed at ensuring long-term supply security and diversification, the uptake of cutting edge low-carbon technologies, and the radical transformation of energy demand in transportation, industry, and buildings.

Distilling the modelling results through the Energy and Climate Security Risk Index, carbon pricing has the potential to significantly reduce energy and climate security risks on several fronts. The expected reduction of fossil energy intensity levels across Central Europe would significantly reduce the exposure of national economies to energy price fluctuations, while more of the value added will increasingly come from non-energy intensive sectors. Higher carbon costs would have a slight negative impact on overall affordability risks, but as the most recent experience from the energy crisis has demonstrated, the impact of carbon prices on energy costs pales in comparison to the volatility of natural gas and oil prices, which were the main factor driving up affordability risks ahead of the war in Ukraine.

The expected reduction of fossil fuel imports due to carbon pricing will also have a significant positive impact on geopolitical risks. With gas imports falling by between 10% (Romania) and 35% (Hungary) over the next decade, this could directly translate into lower reliance on Russian gas without the need to invest in new gas import infrastructure. Finally, a significant reduction of carbon emissions will bring down sustainability risks through lower CO_2 emissions per capita and per GDP produced, as well as increasing the share of low CO_2 electricity generation.

Introducing a carbon price signal that can meaningfully accelerate the low carbon transition is of critical importance for reducing energy and climate security risks. This can be accomplished not only without hurting vulnerable households – it can be part of the solution to reduce energy poverty and inequality more generally. EU and national policymakers need well-designed carbon pricing and redistribution policies. These policies also need to be well communicated to the general public to counter disinformation narratives that seek to undermine and delay the low-carbon transition and to perpetuate the region's dependence on imported fossil fuels.

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