University of Warsaw | Faculty of Economic Sciences

Working Papers
No. 26/2024 (462)

Carbon Taxes in Europe Do Not Hurt the Poor

Michał Brzeziński
Monika Kaczan

Warsaw 2024

ISSN 2957-0506

UNIVERSITY OF WARSAW
FACULTY OF ECONOMIC SCIENCES
WORKING PAPERS

Carbon taxes in Europe do not hurt the poor

Michał Brzeziński [1], Monika Kaczan[2]*

[1] *University of Warsaw, Faculty of Economic Sciences*
[2] *University of Warsaw*
* *Corresponding author: mbrzezinski@wne.uw.edu.pl*

Abstract: This study investigates the distributional impacts of carbon taxes, traditionally examined through simulation studies on the regressivity of hypothetical tax scenarios. However, the dy-namic influence of actually implemented carbon taxes on consumption/income poverty and inequality in a cross-country setting has been less scrutinised. This paper assesses the effect of carbon taxes introduced in the past three decades in 15 European countries on consumption shares of the lowest decile groups, poverty rates and inequality indices. The analysis shows that a $40/ton CO2 tax covering 30% of emissions leads to a consumption share increase of up to 4% for the bottom 20% and 40% of the population, a trend that persisted for five years post-implementation, particularly in nations that efficiently redistribute carbon tax revenues. This resulted in a modest reduction in consumption inequality over three years. In contrast, the impact of carbon taxes on income poverty and inequality is not statistically significant. These findings suggest that concerns about poverty and inequality due to carbon taxes can be miti-gated by implementing a moderate tax combined with a strategically efficient revenue redis-tribution mechanism.

Keywords: climate policy, carbon tax, poverty, inequality, consumption/income distribution, revenue re-cycling

JEL codes: Q54, Q58, Q48, H23, D31

Keywords: We sincerely thank the three anonymous referees whose comments have significantly improved this paper.

1. Introduction

Carbon taxes are considered one of the most cost-effective policy instruments to fight global climate change (Climate Leadership Council, 2019; Peñasco et al., 2021). However, a significant concern related to the imposition of carbon taxes is their potential to affect poorer individuals disproportionately. Carbon taxes, especially without counterbalancing measures, may worsen income distribution, amplify economic poverty and inequality, and put the heaviest cost of fighting climate change on the poorest and the lower middle class (Carattini et al., 2018; Maestre-Andrés et al., 2019). These distributional concerns have become stronger recently when the COVID-19 pandemic pushed an extra 90 million people globally into extreme poverty (Mahler et al., 2022). In addition, income and wealth inequalities, which experienced a historical decline in the 20th century, have risen since the 1980s in most advanced economies (Chancel, 2021). Considering these, assessing the impact of carbon taxes on poverty and inequality seems essential for several reasons. First, a negative perception of the distributional consequences of carbon taxes may fuel public resistance against policies aimed at reducing emissions (Drews and Van den Bergh, 2016). This, in turn, could discourage governments in their efforts to introduce carbon taxes or lead some democracies to roll back already implemented carbon tax schemes. Second, understanding the actual impacts of carbon taxes on observable and policy-relevant indicators such as poverty and inequality indices can help design efficient and, at the same time, more equitable carbon pricing mechanisms. The more informed debate about the poverty impacts of these policies can increase the likelihood of public acceptance and support for such reforms. Third, checking if revenue recycling measures associated with carbon taxes make a difference regarding the overall impact of carbon taxes on poverty and inequality provides additional insights on how to structure policies that are both environmentally effective, distributionally fair, and publicly acceptable.

This paper estimates how income and consumption poverty and inequality indices were affected by introducing carbon taxation in 15 European countries during the last three decades. We follow a time series identification approach of Metcalf and Stock (2023) and Konradt and Weder di Mauro (2023) and employ a local projections methodology of Jordà (2005). We study the dynamic effects over five years after the enactment of carbon taxes. Our sample covers 31 European countries (of which 15 adopted carbon taxes) observed between 1980 and 2018.

The paper contributes to the literature in two ways. First, most studies on the distributional impacts of carbon taxation focus on assessing whether the tax incidence is regressive, i.e. putting a heavier burden on the poorer households than on the richer ones. Although regressivity could imply that inequality is potentially increasing, the effect might be negligible, and no increase in inequality might be observed. Similarly, the impact of carbon taxes on poverty is also unclear. Even if lower-income households are hit harder, their incomes might stay above the poverty line, and they do not slip into poverty. In addition, from a policy perspective, even if regressivity is considered an important social outcome, it seems less relevant as a public statistic. While various key public players, from citizens and policymakers to party officials, labour unions, and business organisations, are well-versed in routinely reported and discussed poverty and inequality metrics like the poverty rate or the Gini index, understanding regressivity information is notably less widespread. It appears plausible that public agents could be more inclined to adjust their beliefs and motivations to act based on the distributional consequences of carbon taxes framed in terms of the poverty rate and mean consumption of the poor rather than regressivity. Despite this, literature concentrating on the effect of carbon taxes on economy-wide inequality measures has received less attention (Markkanen & Anger-Kraavi, 2019). Moreover, even fewer studies examine how carbon taxes influence poverty rates, especially in developed countries (Timilsina, 2022). Thus, our article addresses a critical gap in the literature on distributional consequences of carbon taxation.

Second, most analyses simulate the implications of introducing a hypothetical carbon tax using ex-ante approaches such as microsimulation, input-output, and general equilibrium models (Köppl & Schratzenstaller, 2022). However, a common critique of these models is that they tend to rely on multiple assumptions and do not account for all channels through which carbon taxes may influence inequality and poverty (Rao et al., 2017).[1] In contrast, this paper studies the dynamic effects of actual past European implementation of carbon taxes that capture all various mechanisms through which income and consumption distributions are affected by these taxes. By this, this paper provides more accurate and reliable results than previous literature. To the best of our knowledge, this study is the first to conduct an ex-post dynamic assessment of the distributional effects of existing carbon taxes across multiple countries.

Our findings show that a \$40/ton CO_2 tax covering 30% of emissions increases consumption shares of the bottom 20% and 40% of the population in Europe by around 4% and 2%, respectively. Thus, carbon taxes contributed to the reduction of consumption poverty. This effect has persisted for five years after the carbon tax implementation. Furthermore, we show that this effect was driven by countries that recycle carbon tax revenues. We also found modest improvements in consumption inequality lasting up to three years. On the other hand, our

[1] See section 2 for a fuller exposition of these channels.

analysis revealed that carbon taxes did not exert a statistically significant impact on the income poverty rate and the income poverty gap, nor on income inequality in European countries. These results are consistent among all examined countries, irrespective of whether they allocate carbon tax revenues towards recycling.

The structure of this article is as follows. Section 2 presents existing literature regarding inequality in carbon tax incidence and the impact of carbon taxes on inequality and poverty. Section 3 describes existing carbon taxes and other climate policies in Europe. Section 4 introduces the methodology and data, while Section 5 presents and discusses the results. Finally, Section 6 concludes and delves into the implications for policymakers.

2. The distributional impact of carbon taxes – theoretical and empirical literature

From a theoretical perspective, implementing carbon taxes can affect poverty and inequality through various pathways (Köppl & Schratzenstaller, 2022; Shang, 2023). First, in poorer households, a substantial fraction of income is devoted to essential utilities such as electricity and heating; thus, the imposition of an emissions tax may disproportionately burden these families. Second, carbon taxes potentially elevate the expense of energy-intensive commodities. This impact varies in intensity between socioeconomic groups, with poorer or richer households being more affected, contingent upon their respective consumption patterns of these goods. The third mechanism is the behavioural channel, influenced by household responses to changes in price levels and relative prices. Both consumption level and its composition could be affected due to these price changes. The overall distributional impact hinges on the capacity and willingness of consumers from richer and poorer households to shift away from energy- and emissions-intensive goods rather than reduce their overall consumption in response to price changes. Fourth, enacting carbon taxes may prompt firms to adjust their demand for labour, capital, and resources within specific sectors. These adjustments can also have distributional consequences, such as shifts in demand for workers with different skill levels. In addition, sectors using more carbon, like energy, mining, transport, or manufacturing, might cut down on production and jobs more than sectors like services in response to a carbon tax. In effect, this could increase income inequality or push some groups of workers into poverty. On the other hand, in the longer run, carbon taxes could give rise to job opportunities in sectors like renewable energy, driven by investments in less carbon-intensive energy sources. It is worth noting that these multiple mechanisms could affect consumption and income distribution differently, at least in the short-to medium-run. For this reason, it is crucial to study the effect of carbon taxes on both income and consumption distribution.

Most empirical analyses on the distributional impacts of carbon taxation focus on estimating inequality in carbon tax incidence – that is, the extent to which the burden of carbon taxes falls disproportionately on poorer households. In contrast, assessments of changes in income and consumption inequality measures as a result of carbon taxation are less common (Dissou & Siddiqui, 2014; Markkanen & Anger-Kraavi, 2019), while the topic of how carbon taxes influence poverty has not been yet adequately researched at all (Timilsina, 2022). Furthermore, most studies analyse the consequences of introducing hypothetical carbon taxes. Conversely, very little research examines the distributional implications of carbon taxes, which were actually implemented (Köppl & Schratzenstaller, 2022).

2.1. Inequality in carbon tax incidence

As summarised by Wang et al. (2016), most studies for developed countries demonstrate that carbon tax incidence is regressive, especially if there is no revenue recycling. In particular, such conclusions were obtained for carbon taxes in Denmark (Wier et al., 2005), Sweden (Brännlund & Nordström, 2004), the Netherlands (Kerkhof et al., 2008), Ireland (Callan et al., 2009), France (Bureau 2011), the United Kingdom (Feng et al., 2010) and at the aggregate level in the European Union (Feindt et al., 2021). The meta-analysis of 53 carbon pricing studies by Ohlendorf et al. (2021) found two-thirds of distributional effects were regressive. On the other hand, their results indicate an increased likelihood of progressivity for transport sector policies and studies considering indirect effects, demand-side adjustments or lifetime income proxies. Most of the papers in this area focus on policy simulations that consider the impact of hypothetical carbon taxes. One of the few studies examining the consequences of actually implemented policies is the study by Wier et al. (2005). Using national consumer surveys and input-output tables, they estimated tax progressivity measures such as the Suits index and marginal Gini of existing CO_2 tax in Denmark.[2] Their main conclusion was that in 1996, the Danish carbon tax was regressive. Similar results were obtained in an earlier study focusing on already implemented environmental taxes in Denmark by Jacobsen et al. (2003).[3]

[2] The Suits Index measures the progressivity or regressivity of a tax, ranging from -1 (entirely regressive) to +1 (entirely progressive), with 0 indicating a proportional tax burden.

[3] However, these analyses are static and conducted only for a single year (1996/1997), while this paper estimates the dynamic response of carbon taxes over a time horizon of five years (see Sections 4-5).

2.2. Impact of carbon taxes on inequality

Even though carbon taxes may be regressive, this does not necessarily mean they will increase economy-wide income/consumption inequality. In particular, the observed effect might be practically negligible. For example, the simulation study of Callan et al. (2009) found that although a carbon tax of €20/tCO_2 would be regressive in Ireland, its cost for bottom deciles would be equivalent to at most 2.0% of the total social benefits they receive. Compared to the literature on the regressivity of a carbon tax incidence in developed countries, the question of how carbon taxes influence inequality received less attention in the literature. Among the earliest works are the simulation studies by Symons et al. (1994) for the United Kingdom and by Cornwell and Creedy (1996) for Australia, which combine input-output modelling with data from household expenditure surveys. Both analyses concluded that a hypothetical carbon tax would increase inequality measured by the Gini in those countries by 2.91% and 2.16%, respectively.

Dissou and Siddiqui (2014), in their general equilibrium analysis for Canada, showed that different effects of carbon tax implementation may influence income inequality in opposite ways. They found that while subsequent changes in factor prices contribute to inequality reduction, changes in commodity prices exacerbate it. The overall distributional effect depends on the carbon tax rate in a non-monotonic manner, with the lowest Gini achieved for the rate of $50 per ton of CO_2.

Different implications of various distributional effects of carbon taxes were also investigated in a simulation study by Antosiewicz et al. (2022). Employing a dynamic general equilibrium model for carbon taxation in Poland, they found both direct and indirect price effects and demand changes to be regressive. Their results suggest that only the labour market effect tends to be progressive because mining jobs are relatively more widespread among high-earners. The overall effect of carbon taxes on income inequality was found to be largely dependent on the revenue recycling scheme.

Other recent studies also explore how revenue usage may affect the observed impact of carbon taxes on inequality. Van der Ploeg et al. (2022) estimated an EASI demand system to simulate the implications of a carbon tax in Germany. A carbon tax's effect on income and expenditure Gini coefficients would be negligible on its own. However, recycling the tax revenue via lump-sum transfers would decrease inequality at the cost of lower policy efficiency than in a no-tax scenario. The opposite effect would take place in the case of recycling tax revenue by lowering income taxes.

Fragkos et al. (2021) utilised the GEM-E3-FIT general equilibrium model to estimate the implications of implementing the European Union's emission reduction targets, including universal carbon price consistent with the 2°C Paris Agreement. Their findings suggest that as a result, income inequality measured by Gini and S80/S20 ratio would rise slightly over the years compared to the reference scenario. However, redistributing part of the revenues generated by climate policies via lump-sum transfers and reduced employers' social security contributions can reverse this effect and reduce Gini by up to 0.7 points in 2030 and 1.3 points in 2050.

2.3. Impact of carbon taxes on poverty

Despite the potential disproportionate impacts of carbon taxation on the poorest, the literature focusing directly on the poverty impacts of such taxes is scarce. Existing studies are limited to developing countries, and due to differences in economic systems and consumption patterns, it is hard to extrapolate their results to more affluent nations. Moreover, empirical analyses have not yielded consistent conclusions regarding the relationship between carbon taxes and consumption/income poverty.

Studies by Corong (2008) for the Philippines and Yusuf and Resosudarmo (2014) for Indonesia suggested that enacting carbon taxes would alleviate poverty even without additional revenue recycling schemes. Additionally, Renner (2018) showed that the impact of carbon taxes on poverty in Mexico largely depends on the tax rate and coverage. In contrast, the simulation analyses by Coxhead et al. (2013) for Vietnam and Malerba et al. (2021) for Peru indicated that carbon taxes, when applied without compensation, would intensify poverty. An appropriate redistribution scheme can mitigate this effect and sometimes lead to lower poverty rates than in a no-tax scenario. Similar conclusions regarding the implication of carbon taxes were obtained in a global long-term analysis by Budolfson et al. (2021). On the other hand, Chepeliev et al. (2021) found that the worldwide implementation of carbon pricing measures aligned with achieving the targets of the Paris Agreement can lead to a higher incidence of extreme poverty, yet can also result in a more progressive global distribution of income.

Recently, Malerba et al. (2024) utilised a longitudinal simulation framework to assess the effects of a carbon tax and redistributive schemes on poverty and inequality over time in Peru. They found that the poverty reduction due to revenue recycling accompanying carbon taxes depends significantly on the year within the post-implementation period, suggesting that the design of cash transfer programs must be dynamically adjusted over time to maintain their effectiveness in mitigating poverty.

3. Carbon taxes in Europe

Carbon taxes were introduced in Europe in the early 1990s to reduce greenhouse gas emissions and combat climate change. Scandinavian countries have been leading the movement, with Finland implementing the world's first carbon tax in 1990, followed by Sweden and Norway the next year. As of June 2023, carbon taxes have been adopted by 19 European countries.[4]

Our sample covers 31 European countries (of which 15 adopted carbon taxes as of 2019) observed between 1980 and 2018.[5] Both the tax rate and the share of covered greenhouse gas emissions vary significantly between jurisdictions. The lowest rates of under $1 per ton of CO_2 emissions are set in Poland, and the highest, around $128.9, are set in Sweden[6]. In 2019, the coverage of greenhouse gas emissions ranged from only 3% in Estonia and Spain to 62% in Norway (Konradt & Weder di Mauro, 2023).

Parallel to carbon taxation, in 2005, the European Union introduced the Emissions Trading System (EU ETS). It is a "cap and trade" system limiting emission rights, which can also be traded between companies. As of 2023, all EU members, plus Iceland, Liechtenstein and Norway, participate in EU ETS. Following the approach of Metcalf and Stock (2023), we focus on the so-called EU+ countries (EU member states as well as Norway and Switzerland) that are also part of the EU ETS. By this, we can attribute the variations in distributional measures specifically to differences in carbon tax rates, thereby eliminating the influence of variations in the EU's other major carbon pricing mechanism, the EU ETS.

3.1. Revenue usage

It is estimated that in 2018, carbon taxes in Europe raised over $18 billion in tax revenues (World Bank Group, 2019). These funds can be utilised in three main ways. First, as in most European countries, some or all revenues may be directed to the government's general budget without earmarking. Second, carbon tax revenues may help finance green subsidies and other climate- and environment-related initiatives. Finally, the revenues may be recycled and returned

[4] See Appendix Tables A1-A2 for details of carbon taxation in European countries.
[5] From the group of carbon tax adopters, we exclude Ukraine, as it is not a participant in the EU ETS, and Liechtenstein, due to insufficient data availability.
[6] Carbon tax rates referenced here are the coverage-weighted real carbon tax rates used in our study.

to businesses, households and individuals to compensate for the negative macroeconomic impacts of carbon taxation (EEB, 2021).

Various tax cuts granted to businesses, such as profit or payroll tax cuts, are among Europe's most common forms of revenue recycling. They were implemented in Finland, Norway, Sweden, Denmark and Switzerland. Many economists view tax cuts granted to businesses as the most efficient way of recycling carbon tax revenues to promote overall welfare and economic growth (Carbone et al., 2013; Marron et al., 2015; Jorgenson et al., 2018), which, in turn, could lead to reduced poverty and inequality. However, some researchers argue that these tax cuts may have limited effects on poverty and inequality (Carl & Fedor, 2016).

On the other hand, several studies show that tax cuts granted to individuals and rebates could help offset carbon taxation's potential regressive and poverty-inducing effects (Callan et al. 2009; Goulder et al., 2019). Finland, Sweden, Denmark, and Portugal have implemented income tax cuts for individuals. In France, additional revenues from the 2017 diesel tax rate increase were also directed towards lowering the tax burden on low-income households and the elderly. Lump-sum rebates are found to be the most effective in reducing inequality and supporting the poorest (Klenert & Mattauch, 2016; Jorgenson et al., 2018; Goulder et al., 2019), but so far in Europe, they have been only implemented in Switzerland in the form of flat checks mailed to all individuals.

In our study, we consider the subsample of seven European countries that recycle their carbon tax revenues through tax cuts granted to businesses, tax cuts granted to individuals, and rebates. In some countries, these revenues have not been explicitly earmarked, but the subsequent stages of carbon tax implementation coincided with reductions in income, labour or corporate taxes. Following the literature, we consider them part of the green tax shift and, thus, a form of revenue recycling. A detailed description of carbon tax revenue utilisation in each country can be found in Appendix Table A3.

4. Empirical methodology and data

4.1. Local projections approach

To identify the impact of carbon taxes on income distribution, we follow the literature (Metcalf & Stock, 2023; Konradt & Weder di Mauro, 2023) by using the local projections methodology (LP) of Jordà (2005), adapted to panel data. The LP methodology allows for the estimation of impulse response functions (IRFs), a basic macroeconomic tool to capture the dynamic response of a variable to the shock in another variable (see, e.g., Ramey, 2016). While there are several approaches to estimating the IRFs, the local projections (LP) method of Jordà (2005) estimates the same impulse response as the more complicated Vector Autoregressive (VAR) models, but at the same time, it is simple, robust and provides straightforward inference tools (Montiel Olea & Plagborg-Møller, 2021).[7]

Estimating the causal impact of carbon taxes on income and consumption distribution is complicated by the possible endogeneity. The local projection approach helps in identifying the dynamic response of distributional indices to carbon taxation by allowing for feedback from historical income and consumption distribution and economic conditions to the carbon tax rate. This is obtained by including lagged values of distributional and macroeconomic variables (such as GDP growth) as additional explanatory variables. To identify the causal effect of carbon taxes on distributional indices, we assume that the components of the carbon tax that are not predicted by historical carbon taxes, historical changes in income and consumption distribution and current and past economic shocks are exogenous.[8] Given this assumption, we can use the following LP panel regressions to estimate the dynamic effect of the unexpected component of a carbon tax on income and consumption distributional indices:

$$100\Delta\ln\left(D_{i,t+h}\right) = \beta_h \tau_{i,t} + \sum_{j=1}^{m} \delta_j^h \, \tau_{i,t-j} + \sum_{j=1}^{m} \delta_j^h \, \Delta X_{i,t-j} + \alpha_i^h + \gamma_t^h + \varepsilon_{i,t}^h, \tag{1}$$

where $D_{i,t}$ is a distributional index (i.e. a poverty or inequality measure) for country i in year t, $\tau_{i,t}$ is the coverage-weighted real carbon tax rate in economy i in year t, $\Delta X_{i,t}$ is a set of covariates including (in the baseline specification) GDP growth, change in the unemployment rate, and change in the (log of) distributional index (with m set to 4).[9] The equation (1) is estimated for each horizon (year) $h = 0, \dots, 5$. The lags in the change of the (log of) distributional index are controlled for since future changes in distribution could depend on past changes. We also include country fixed effects, α_i^h, and time fixed effects, γ_t^h, to control for unobserved, respectively, time-invariant and country-invariant heterogeneity (i.e. Europe-wide economic shocks).

[7] However, we employ panel VAR models in robustness tests to validate our results (see Appendix C).

[8] We also tested the hypothesis that the carbon tax rate is strictly exogenous using Granger causality tests. Table C1 in Appendix C shows that we were unable to reject the null hypotheses that changes in the logarithm of distributional indices do not Granger-cause coverage-weighted real carbon tax rates.

[9] To obtain the coverage-weighted carbon tax rate, we interact the carbon tax rate with the 2019 share of its emission coverage.

In our empirical analysis, we estimate separate local projection models (1) for several consumption-based and income-based distributional indices D. The parameter β_h measures the impact of an unexpected change in the carbon tax rate happening at year t on the percentage change in the distributional index D after $t+h$ years. Following Metcalf and Stock (2023) and Konradt and Weder di Mauro (2023), we use the local projection estimates to consider a counterfactual of a one-time permanent increase in the carbon tax rate by \$40 (per ton of carbon emissions) that covers 30% of the country's greenhouse gas emissions.[10] Using Metcalf and Stock's approach (2023), we model the \$40 carbon tax policy by computing a sequence of small adjustments necessary to yield the specified counterfactual. The resulting dynamic responses of distributional indices are displayed on figures as the dynamics of $\{\beta_h\}_{h=0}^{5}$ for the time horizons of up to five years after the tax change. We also present 95% confidence intervals for our estimates calculated with heteroscedasticity robust standard errors clustered at the country level.

4.2. Poverty and inequality indices

As suggested earlier, introducing carbon taxes may affect both households' income and consumption. Taking this into account, we use both distributional measures computed for the distribution of income and the distribution of consumption expenditures. Unfortunately, comparable data on consumption poverty in rich countries is scarce. For instance, popular distributional databases such as the World Bank Poverty and Inequality Platform or Luxembourg Income Study Database (LIS) provide only income distribution statistics for most European countries. On the other hand, consumption poverty data from national statistical agencies are not harmonised and comparable across countries. Given that, we used consumption-based distributional indices from The Global Consumption and Income Project (GCIP) (Lahoti et al., 2016). The GCIP provides comprehensive and comparable data on income and consumption distributions for more than 160 countries between 1960 and 2015. Among others, the GCIP offers consumption-based absolute poverty rates calculated with international poverty lines (such as \$1.25 or \$2.5 per day). However, these indices are not useful in our context due to the relatively high incomes of the poor in European countries. For example, in the case of Finland, the first European country to introduce carbon taxation (1990), the absolute poverty rates based on the above-mentioned international poverty lines were precisely zero in 1990. Hence, we opted to use relative distributional statistics that take into account consumption patterns of the poorer part of

[10] These parameters are very close to our sample means (see Table B1 in Appendix B).

the population – consumption shares of the bottom quantile groups. In particular, we focus on the consumption shares of the bottom 20% and 40% of the population.[11]

Furthermore, while income poverty indices for developed countries are more widely available, they are rarely provided annually. To overcome this difficulty, we follow earlier literature by constructing approximate poverty measures based on the log-normal distribution (Dollar & Kraay, 2002; Marrero & Servén, 2022). For this distribution, poverty measures are a function of the poverty line, the log of mean income, and the standard deviation of the log of income (itself a function of the Gini coefficient). Approximating mean income by the GDP per capita purchasing-power-parity (PPP)-adjusted from the Penn World Table 10.0 (Feenstra et al., 2015) and using income-based Gini indices from Solt (2020), we computed approximate relative annual poverty indices for European countries over 1980-2018 with poverty line equal to 60% of the national median income in a given year. We rely on two relative income-based poverty measures: the poverty rate (percentage of the population with income below the poverty line) and the poverty gap (average shortfall of the population from the poverty line expressed as a percentage of the poverty line). While the poverty rate shows only the share of the population suffering from poverty, the poverty gap measures the intensity of poverty, indicating how far the living standard of the poor is from the poverty line.

We take inequality statistics from two sources. Consumption-based Gini indices come from the GCIP database, while the Gini measures for income distribution are drawn from the Standardized World Income Inequality Database (SWIID) by Solt (2020). The SWIID provides cross-country comparable Gini indices of disposable income inequality for 198 countries from 1960 or later.

To summarise, we focus on poverty measures such as the poverty rate and poverty gap and inequality indicators like the Gini index. The poverty measures capture the impact of carbon taxes at the lower end of income and consumption distributions, while the Gini index provides a summary of overall disparities among individuals in society. However, we acknowledge the limitations of these indices. Poverty measures are sensitive to the choice of poverty thresholds, and the Gini index cannot distinguish whether reductions in inequality are driven by improved incomes for the poorest households or declining incomes for higher-income groups. Additionally, an important consideration is that carbon taxes may lead to income mobility among households, particularly in the short term. For instance, households near the poverty threshold may temporarily fall below or rise above it due to tax-induced changes in wages, energy costs, or

[11] In addition, we also consider mean consumption levels of decile groups expressed in 2005 PPP $.

government compensation mechanisms. These transitions are not fully captured by the static measures we use. Future analyses could benefit from longitudinal data to track household income dynamics and better understand the interplay between policy interventions and economic mobility.

4.3. Carbon tax rates and control variables

The data on carbon tax rates and the share of greenhouse gas emissions covered by the tax come from Metcalf and Stock (2023), who derived it from the World Bank Carbon Pricing Dashboard.[12] Data on the real GDP per capita growth are taken from Penn World Tables 10.0 (Feenstra et al. 2015), while information on unemployment rates comes from the World Bank's World Development Indicators (WDI). In a robustness test, we use additional control variables such as government expenses (as % of the GDP) taken from the WDI and social protection expenditures (as % of the GDP) derived from the Statistics on Public Expenditures for Economic Development (SPEED) database (IFPRI 2019). The descriptive statistics for all variables used in this paper are provided in Table 1.

Table 1. Descriptive statistics for all variables used in the paper

	Mean	SD	Min	Max	*N*
Consumption share (bottom 10% of the population)	3.27	0.34	2.29	5.09	1116
Consumption share (bottom 20% of the population)	7.93	0.64	6.07	11.34	1116
Consumption share (bottom 40% of the population)	20.27	1.20	16.39	26.61	1116
Income share (bottom 10% of the population)	3.29	0.83	0.52	5.78	1116
Income share (bottom 20% of the population)	8.11	1.56	2.42	12.55	1116
Income share (bottom 40% of the population)	21.23	2.73	11.33	28.40	1116
Mean consumption in the first decile group, 2005 PPP $	196.06	91.04	26.83	432.55	1116
Mean consumption in the second decile group, 2005 PPP $	278.71	128.85	41.55	615.16	1116
Mean consumption in the fifth decile group, 2005 PPP $	455.84	206.27	69.61	956.61	1116
Mean consumption in the tenth decile group, 2005 PPP $	1634.4	800.5	255.6	3674.4	1116
Income poverty rate	15.78	3.53	5.85	23.79	1054
Income poverty gap	3.56	1.31	0.73	7.32	1054
Gini index of income inequality	28.35	3.95	18.22	38.75	1054
Gini index of consumption inequality	33.03	2.59	20.53	40.34	1116
Coverage-weighted real carbon tax rate	2.65	8.68	0.00	54.22	1208
Δ GDP per capita, PPP	1.87	3.90	-31.12	14.59	1037
Δ Unemployment rate	4.44	45.76	-50.00	1050.0	1026
Δ Government expenditure / GDP	0.56	8.85	-54.69	134.95	987
Δ Social protection expenditure / GDP	2.85	39.04	-77.09	985.63	1000

Note: See Sections 4.2-4.3 for definitions of variables.
Source: Own computation using data from the GCIP, SWIID, SPEED and the World Bank databases.

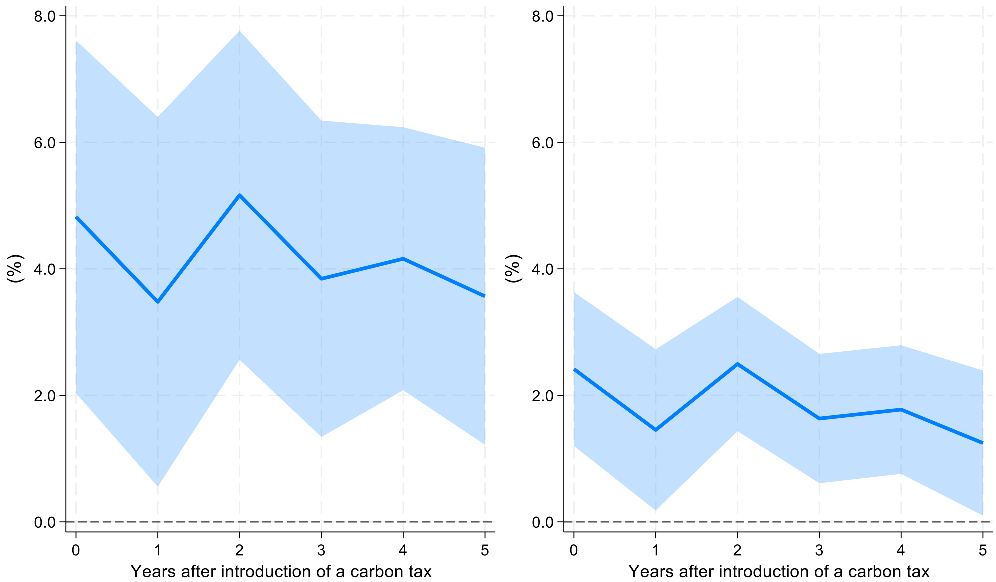
[12] See https://carbonpricingdashboard.worldbank.org/.

5. Results

5.1. The impact of carbon taxes on poverty

Figure 1 presents the dynamic response of the bottom consumption shares to a $40 permanent increase in the carbon tax rate with 30% coverage of emissions, estimated using (1) and the entire sample of 31 European countries from 1980 to 2018. Surprisingly, the effect is positive and statistically significant for both the bottom 20% and bottom 40% consumption share. The magnitude ranges from about 2% in the case of the bottom 40% consumption share to about 4% for the bottom 20% share. The response is positive for both measures five years after the policy reform. The magnitude of the effect seems moderate, but distributional indices are slow-changing variables. Our estimated response to carbon tax changes for both consumption shares is approximately equal to the standard deviation of one-year changes in consumption shares in the sample.

Figure 1. Response of bottom 20% (left panel) and bottom 40% (right panel) consumption shares to a carbon tax in Europe.



Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

To measure the impact of carbon taxes on consumption poverty, we alternatively considered the mean consumption levels of the first and second decile groups. The estimation results have shown that the impact on mean consumption in the lowest decile group is positive (up to 5% in the five-year horizon) but statistically insignificant (Appendix Figure D1). On the other hand, the impact is slightly negative for those in the middle of the consumption distribution (fifth decile group) but also statistically insignificant (Appendix Figure D2). This is consistent with the results from Figure 1, which show the positive and significant impact of carbon taxes on the consumption shares of the poor.

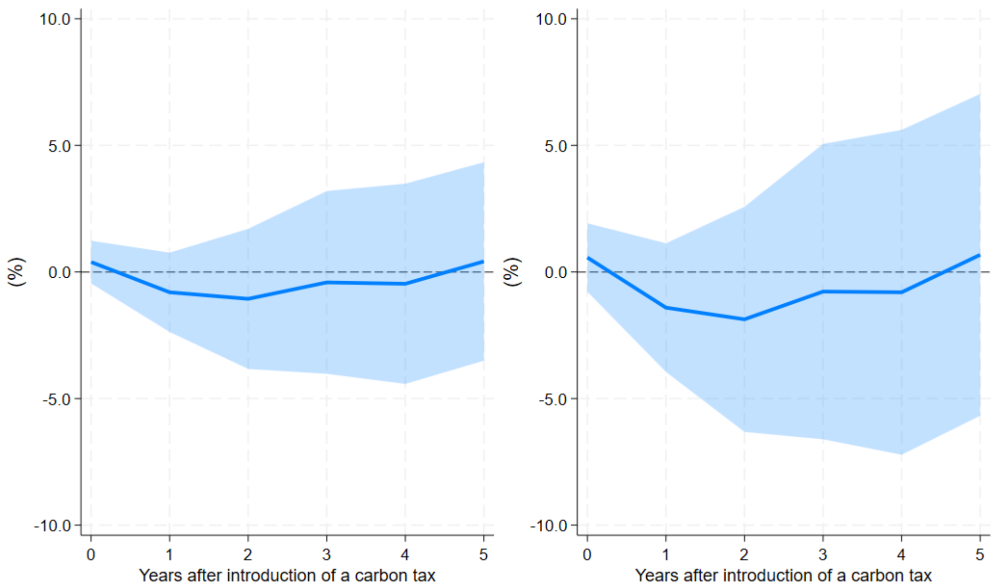
We now turn to the results for income poverty measures (Figure 2). We observe that the effect is small and negative (poverty-reducing) for both the income poverty rate and the income poverty gap over the years 1-4 after the carbon tax change and becomes slightly positive in year 5. However, the effect is not statistically significant throughout the studied time horizon. Figures 1-2 suggest that European carbon taxes did not increase consumption or income poverty. The results presented in Figures 1-2 are consistent – consumption of the bottom population shares increased more than that of the rest of the population, and the population shares with incomes below relative poverty lines did not increase.

Similar results regarding changes of income and consumption across distributions were also found by other studies for European countries. Antosiewicz et al. (2021) reported proportionally higher increases of income for bottom deciles compared to the rest of the population in their lump-sum and price-subsidies scenarios for a Polish carbon tax rate of 30 EUR/ton. Neutrality or slight progressivity of carbon tax within European countries was also found by Feindt et al. (2021) for the tax rate of 25 EUR/ton and by Fragkos et al. (2021) for universal carbon price consistent with the 2°C Paris Agreement in revenue recycling scenario.

These findings, which suggest that carbon taxes do not increase poverty, may be attributed to various mechanisms. One possibility is the relatively minor burden of carbon taxes on the poor, as suggested earlier by Callan et al. (2009) or Bureau (2011). Alternatively, the adverse effects might be offset by revenue recycling mechanisms that compensate for any losses experienced. We further explore this question in section 5.3.

Furthermore, our findings that carbon taxes appear more progressive when evaluated against consumption-based indices, which can also be treated as proxies for lifetime income, than when evaluated against income-based measures are consistent with previous studies (Jacobsen et al., 2003; Wier et al., 2005; Yusuf and Resosudarmo, 2014), as well as the meta-analysis by Ohlendorf et al. (2021). These differences between the indices may be attributed to the permanent income hypothesis (Friedman, 1957). Since consumption expenditures tend to fluctuate less than income over time, households with temporarily low incomes (e.g., students or retirees) may still maintain higher expenditure levels by drawing on savings or accessing credit.

Figure 2. Response of income poverty rate (left panel) and income poverty gap (right panel) to a carbon tax in Europe.

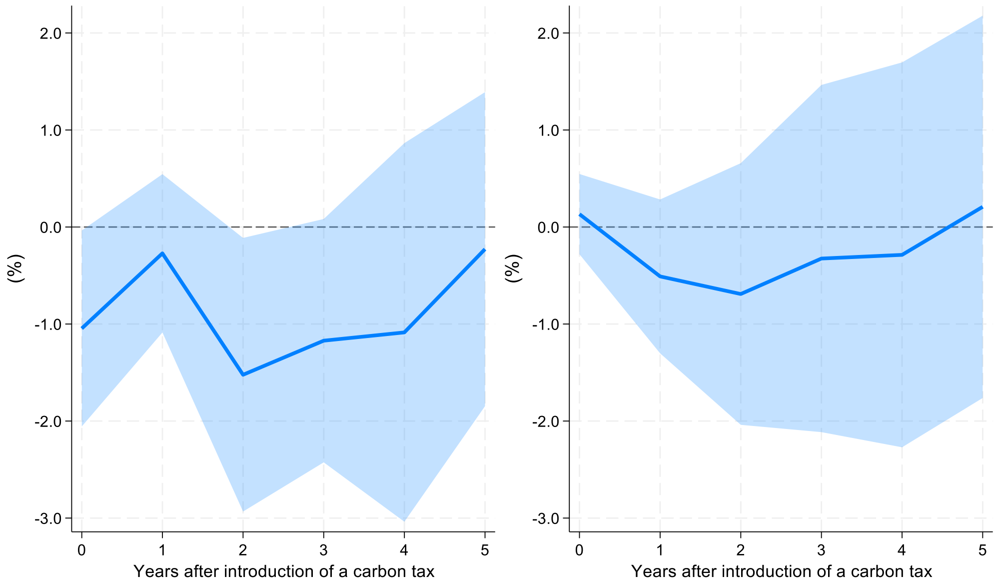


Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

5.2. Consumption and income inequality

Figure 3 illustrates the impact of European carbon taxes on consumption and income inequality. The estimated effects are generally small and tend to reduce inequality, though they are mostly statistically insignificant. For consumption inequality as measured by the Gini index, the negative impact is marginally statistically significant in the year of carbon tax reform implementation and in the second and third after the policy change. This is consistent with the positive (poverty-reducing) effect found in the case of consumption shares of the bottom quintile groups (see Figure 1). However, the magnitude of reduction in consumption inequality is relatively small – about a 1-1.5% reduction in the Gini index. We do not find evidence that implementing carbon taxes in Europe led to higher consumption or income inequality. Moreover, our results are also consistent with earlier studies, including Callan et al. (2009), Dissou and Siddiqui (2014) and Renner (2018), which also reported minimal effects of carbon tax on Gini indices. Our findings imply that the regressivity associated with carbon taxes is either insignificant or that implementing revenue recycling mechanisms effectively neutralised any potential exacerbation of inequality due to these taxes.

Figure 3. Response of Gini index of consumption inequality (left) and Gini index of income inequality (right) to a carbon tax in Europe.



Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

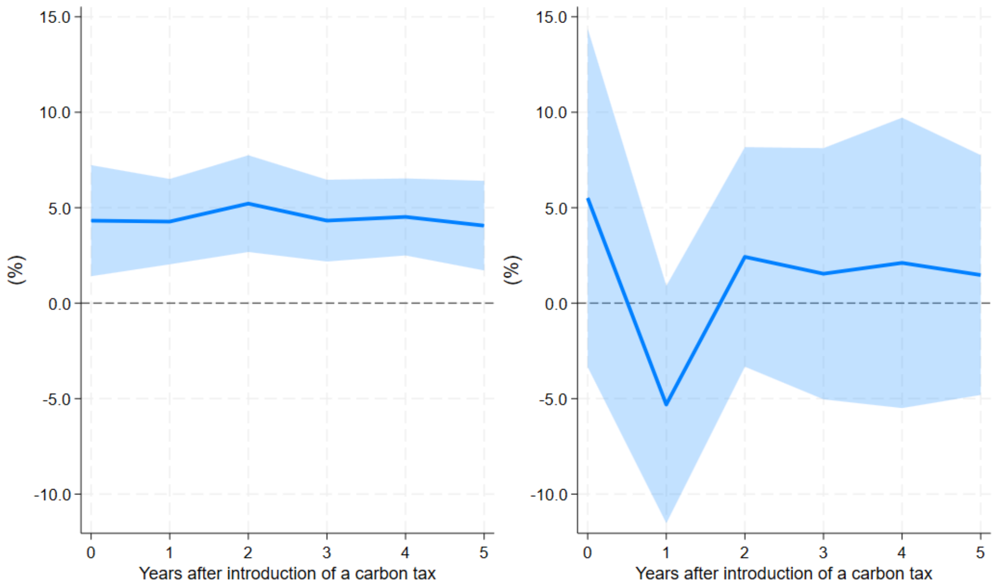
5.3. The role of revenue recycling

Numerous simulation studies have demonstrated that compensation measures within revenue recycling mechanisms are vital in alleviating the adverse distributive effects of carbon taxes (Callan et al., 2009; Bureau, 2011; Budolfson et al., 2021; Antosiewicz et al., 2022). In this section, we study whether revenue recycling plays a role in explaining our results. We estimate equation (1) separately in a subsample of countries recycling revenues from carbon taxation and in a subsample of countries that do not recycle the revenues.[13] Figure 4 presents the results of this exercise for the bottom 20% consumption share.[14] We find that the positive effect of carbon taxes on consumption poverty (as measured by the bottom consumption shares) is driven by countries that recycle carbon tax revenues (Figure 4, left panel). For these countries, the

[13] In both cases, the subsamples include also European countries that do not have carbon taxes.
[14] Results for the bottom 40% consumption share are qualitatively similar (see Appendix Figure D3).

effect is uniformly positive over the studied horizon and larger (up to 5%) than for the full sample of countries (cf. Figure 1, left panel).

Figure 4. Response of bottom 20% consumption shares to a carbon tax in the subsamples of European countries that recycle carbon tax revenues (left panel) and countries that do not (right panel).



Note: The figure shows impulse responses to a \$40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals. Countries that recycle carbon tax revenues include Denmark, Finland, France, Norway, Portugal, Sweden and Switzerland.

On the other hand, in the case of countries that do not recycle revenues, the impact is negative in the first year after the implementation of the tax but marginally statistically insignificant. From the second year onwards, the effect turns slightly positive while remaining insignificant. These results indicate that the revenue recycling schemes in European countries effectively compensate the poor for carbon tax's potential negative distributional consequences. It could even be argued that these schemes overcompensate for the losses incurred by low-income individuals, leading to an increase in their consumption shares following the introduction of carbon taxes.

Our findings indicate that revenue recycling significantly impacts consumption-based poverty measures. As demonstrated in Appendix Figures D5-D9, this effect is not observed in other distributional indices, including all income-based measures, for both countries that recycle tax revenues and those that do not. These results are statistically insignificant. The reason for this disparity is not entirely clear within the scope of our study, but we hypothesise that it may be linked to the characteristics of most revenue recycling schemes in European countries.

Predominantly, these countries implement revenue recycling through reductions in personal taxes (see Appendix Table A3). Such measures may only marginally influence the incomes of the poor, failing to elevate many above the relative poverty line substantially. Conversely, these measures could directly enhance the consumption of low-income households. In summary, our analysis suggests that some revenue recycling strategies used in European countries are effectively aimed at supporting the consumption needs of the poor.

Trust in institutions is another crucial factor influencing the public acceptability and success of carbon pricing policies. Evidence suggests that higher levels of institutional trust, as seen in countries like Finland, Norway, Sweden, and Switzerland, are associated with both more ambitious carbon pricing policies and effective revenue recycling mechanisms. Transparent and equitable use of carbon tax revenues, such as targeted transfers or tax cuts for the poor, enhances trust and increases the policy's political acceptability (Klenert et al. 2018).

5.4. Robustness tests

We conduct extensive sensitivity checks to verify whether the results are robust. First, the estimates are not qualitatively altered when alternative distributional indices are used, such as the consumption share of the bottom 10% of the population or the squared poverty gap index (Appendix Figures D3-D4).

Second, we study whether the distributional impact of carbon taxes depends on whether the rate of carbon taxation is large (exceeding $20). Appendix Figures D10-D12 show that larger taxes have virtually the same effect on income and consumption distribution in Europe as those in our baseline estimations (Figures 1-3).

Third, we use additional control variables in the model (1). They include government expenses (as % of the GDP) and social protection expenditures (as % of the GDP). These controls are added to address the potential concern that carbon taxes, especially those with recycling schemes, may be implemented alongside broader pro-poor policy reforms. The results are not sensitive to including these additional controls (Appendix Table D1**)**.

Fourth, we account for the fact that the simple two-way fixed effects estimator applied to equation (1) can be biased in the presence of heterogeneous group-specific treatment effects (de Chaisemartin & d'Haultfoeuille, 2020). We re-estimate equation (1) using an LP estimator with the "clean control" condition proposed by Dube et al. (2023). This condition restricts the estimation sample so that, for units entering treatment at time t, the control group consists of units that are not yet treated at $t+h$, where $h>0$ is the post-treatment horizon. Using this alternative approach does not affect our results (Appendix Table D1). Finally, Appendix C shows that our results are very close to those obtained from an alternative estimation method – the panel VAR model.

6. Conclusions

The existing literature on the distributional consequences of carbon taxes predominantly focuses on ex-ante simulations or single-country ex-post studies that examine the regressivity of these taxes. This paper, however, represents a novel approach by providing an ex-post dynamic analysis of the impact of carbon taxes on poverty and inequality across fifteen European countries. Our findings indicate that carbon taxes have favourably influenced the distribution of consumption without significantly affecting income distribution. This effect has been sustained for five years following the implementation of carbon taxes. Moreover, our analysis reveals that the positive impact on consumption distribution is predominantly observed in countries that implement revenue recycling mechanisms for carbon taxes.

We acknowledge that our analysis has some limitations. As we model carbon taxes at the aggregate level, it is hard to explore specific mechanisms through which carbon taxes affect poverty and inequality. Thus, we cannot entirely explain, for instance, why the distributional effect of carbon taxation is only observed on consumption poverty measures. Moreover, the potential negative distributional impact of the carbon tax may appear over a longer time horizon than studied in this paper. In addition, other carbon pricing policies, such as emission trading systems, could indirectly affect poverty or inequality. Further research should also examine whether carbon taxes disproportionately impact the poor in other areas of vulnerability, such as reduced savings or increased household debt. In addition, more comprehensive poverty measures capturing both absolute and relative poverty dimensions, such as the indicator introduced by Goedemé et al. (2022) should be studied. Finally, the issue of whether consumption or income distribution will be severely negatively affected by carbon taxes with higher rates is still open. Our analysis focused on moderate carbon tax levels ($40 per ton) and their distributional impacts. However, as carbon pricing increases to levels that more fully internalise the social cost of carbon (e.g., $200 or more per ton), non-linear effects may arise. For instance, higher carbon prices could lead to more pronounced behavioural changes, such as shifts in consumption patterns or energy use, and may disproportionately affect households with limited flexibility to adjust. Future research should explore the implications of significantly higher carbon prices on income and consumption distributions to understand these potential non-linear dynamics better.

Our findings have important implications for climate policy. We demonstrated that concerns about the adverse effects of past carbon taxes on Europe's poorest are unjustified. European carbon taxes, particularly when combined with suitable revenue recycling measures, appear to enhance the consumption share of the bottom quintile groups. These results emphasise the critical role of revenue recycling, primarily targeted at poorer households, in carbon tax design. Our study suggests that well-designed carbon taxes, with focused support for the less affluent, can be an effective and equitable tool in climate policy across various global regions.

References

Antosiewicz, M., Fuentes, J. R., Lewandowski, P., & Witajewski-Baltvilks, J. (2022). Distributional effects of emission pricing in a carbon-intensive economy: The case of Poland. *Energy Policy*, *160*, 112678.

Brännlund, R., & Nordström, J. (2004). Carbon tax simulations using a household demand model. *European Economic Review*, *48*(1), 211–233.

Budolfson, M., Dennig, F., Errickson, F., Feindt, S., Ferranna, M., Fleurbaey, M., Klenert, D., Kornek, U., Kuruc, K., Méjean, A., Peng, W., Scovronick, N., Spears, D., Wagner, F., & Zuber, S. (2021). Climate action with revenue recycling has benefits for poverty, inequality and well-being. *Nature Climate Change*, *11*(12), 1111–1116.

Bureau, B. (2011). Distributional effects of a carbon tax on car fuels in France. *Energy Economics*, *33*(1), 121–130.

Callan, T., Lyons, S., Scott, S., Tol, R. S., & Verde, S. F. (2009). The distributional implications of a carbon tax in Ireland. *Energy Policy*, *37*(2), 407–412.

Carattini, S., Carvalho, M. S., & Fankhauser, S. (2018). Overcoming public resistance to carbon taxes. *Wiley Interdisciplinary Reviews: Climate Change*, *9*(5).

Carbone, J. C., Morgenstern, R. D., Williams III, R. C., & Burtraw, D. (2013). Deficit reduction and carbon taxes: Budgetary, economic, and distributional impacts. Resources for the Future.

Carl, J., & Fedor, D. (2016). Tracking global carbon revenues: A survey of carbon taxes versus cap-and-trade in the real world. *Energy Policy*, *96*, 50–77.

Chancel, L. (2021). Ten facts about inequality in advanced economies. In: O. Blanchard, D. Rodrik (eds.), Combating Inequality: Rethinking Government's Role, The MIT Press.

Chepeliev, M., Osorio-Rodarte, I., & Van Der Mensbrugghe, D. (2021). Distributional impacts of carbon pricing policies under the Paris Agreement: Inter and intra-regional perspectives. *Energy Economics*, *102*, 105530.

Climate Leadership Council (2019) Economists' statement on carbon dividends. https://clcouncil.org/ economists-statement/

Cornwell, A., & Creedy, J. (1996). Carbon taxation, prices and inequality in Australia. *Fiscal Studies*, *17*(3), 21–38.

Corong, E. L. (2008). Tariff reductions, carbon emissions, and poverty: an economy-wide assessment of the Philippines. *ASEAN Economic Bulletin*, 20-31.

Coxhead, I., Wattanakuljarus, A., & Nguyen, C. V. (2013). Are carbon taxes good for the poor? A General equilibrium analysis for Vietnam. *World Development*, *51*, 119–131.

de Chaisemartin, C., & d'Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. American Economic Review, 110(9), 2964-2996.

Dissou, Y., & Siddiqui, M. S. (2014). Can carbon taxes be progressive? *Energy Economics*, *42*, 88–100.

Dollar, D., & Kraay, A. (2002). Growth is good for the poor. Journal of Economic Growth, 7(3), 195–225.

Drews, S., & Van den Bergh, J. C. (2016). What explains public support for climate policies? A review of empirical and experimental studies. Climate Policy, 16(7), 855-876.

Dube, A., Girardi, D., Jordà, Ò., & Taylor, A. M. (2023). *A Local Projections Approach to Difference-in-Differences Event Studies*. Working paper.

EEB (European Environmental Bureau) (2021). A carbon pricing blueprint for the EU. Available at https://eeb.org/library/a-carbon-pricing-blueprint-for-the-eu/.

Eisner, A., Kulmer, V., & Kortschak, D. (2021). Distributional effects of carbon pricing when considering household heterogeneity: An EASI application for Austria. *Energy Policy*, *156*, 112478.

Feenstra, R. C., R. Inklaar & Timmer, M. P. (2015). The Next Generation of the Penn World Table. American Economic Review, 105(10), 3150-3182.

Feindt, S., Kornek, U., Labeaga, J. M., Sterner, T., & Ward, H. (2021). Understanding regressivity: Challenges and opportunities of European carbon pricing. *Energy Economics*, *103*, 105550.

Feng, K., Hubacek, K., Guan, D., Contestabile, M., Minx, J. C., & Barrett, J. (2010). Distributional effects of climate change taxation: the case of the UK. *Environmental Science & Technology*, *44*(10), 3670–3676.

Fragkos, P., Fragkiadakis, K., Sovacool, B. K., Paroussos, L., Vrontisi, Z., & Charalampidis, I. (2021). Equity implications of climate policy: Assessing the social and distributional impacts of emission reduction targets in the European Union. *Energy*, *237*, 121591.

Friedman, M. (1957). Theory of the consumption function. Princeton: Princeton University Press.

Goedemé, T., Decerf, B., & Van den Bosch, K. (2022). A new poverty indicator for Europe: The extended headcount ratio. Journal of European Social Policy, 32(3), 287-301.

Goulder, L. H., Hafstead, M. a. C., Kim, G., & Long, X. (2019). Impacts of a carbon tax across US household income groups: What are the equity-efficiency trade-offs? *Journal of Public Economics*, *175*, 44–64.

IFPRI (International Food Policy Research Institute) (2019). Statistics on Public Expenditures for Economic Development (SPEED).

Jacobsen, H. G., Birr-Pedersen, K., & Wier, M. (2003). Distributional implications of environmental taxation in Denmark. *Fiscal Studies*, *24*(4), 477–499.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *The American Economic Review*, *95*(1), 161–182.

Jorgenson, D. W., Goettle, R. J., Ho, M. S., & Wilcoxen, P. J. (2018). The Welfare Consequences Of Taxing Carbon. *Climate Change Economics*, *09*(01), 1840013.

Kerkhof, A., Moll, H., Drissen, E., & Wilting, H. C. (2008). Taxation of multiple greenhouse gases and the effects on income distribution. *Ecological Economics*, *67*(2), 318–326.

Klenert, D., & Mattauch, L. (2016). How to make a carbon tax reform progressive: The role of subsistence consumption. *Economics Letters*, *138*, 100–103.

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., Stern, N., 2018. Making carbon pricing work for citizens. *Nature Climate Change* 8 (8), 669-677.

Konradt, M., & Weder di Mauro, B. W. (2023). Carbon Taxation and Greenflation: Evidence from Europe and Canada. *Journal of the European Economic Association*, 21(6), 2518-2546.

Köppl, A., & Schratzenstaller, M. (2022). Carbon taxation: A review of the empirical literature. *Journal of Economic Surveys*, 37(4), 1353-1388.

Lahoti, R., Jayadev, A., & Reddy, S. (2016). The global consumption and income project (GCIP): An overview. *Journal of Globalization and Development*, 7(1), 61-108.

Maestre-Andrés, S., Drews, S., & Van Den Bergh, J. C. (2019). Perceived fairness and public acceptability of carbon pricing: a review of the literature. *Climate Policy*, *19*(9), 1186–1204.

Mahler, D. G., Yonzan, N., & Lakner, C. (2022). The Impact of COVID-19 on Global Inequality and Poverty. Policy Research Working Paper No. 10198, The World Bank.

Malerba, D., Gaentzsch, A., & Ward, H. (2021). Mitigating poverty: The patterns of multiple carbon tax and recycling regimes for Peru. *Energy Policy*, *149*, 111961.

Malerba, D., Roscioli, F., Gaentzsch, A., & Ward, H. (2024). Changing carbon footprints and the consequent impacts of carbon taxes and cash transfers on poverty and inequality across years: A Peruvian case study. Energy Policy, 192, 114246.

Markkanen, S., & Anger-Kraavi, A. (2019). Social impacts of climate change mitigation policies and their implications for inequality. *Climate Policy*, *19*(7), 827–844.

Marrero, G. A., & Servén, L. (2021). Growth, inequality and poverty: a robust relationship? *Empirical Economics*, *63*(2), 725–791.

Marron, D. B., Toder, E., & Austin, L. (2015). Taxing carbon: What, why, and how. *Social Science Research Network*.

Metcalf, G. E., & Stock, J. H. (2023). The macroeconomic impact of Europe's carbon taxes. *American Economic Journal: Macroeconomics*, *15*(3), 265–286.

Montiel Olea, J. L. M., & Plagborg-Møller, M. (2021). Local projection inference is simpler and more robust than you think. *Econometrica*, *89*(4), 1789–1823.

Ohlendorf, N., Jakob, M., Minx, J. C., Schröder, C., & Steckel, J. C. (2020). Distributional Impacts of Carbon Pricing: A Meta-Analysis. *Environmental and Resource Economics*, *78*(1), 1–42.

Peñasco, C., Anadón, L. D., & Verdolini, E. (2021). Systematic review of the outcomes and trade-offs of ten types of decarbonisation policy instruments. Nature Climate Change, 11(3), 257–265.

Ramey, V.A. (2016). Macroeconomic Shocks and Their Propagation, in: Handbook of Macroeconomics. Elsevier, pp. 71–162.

Rao, N. D., Van Ruijven, B., Riahi, K., & Bosetti, V. (2017). Improving poverty and inequality modelling in climate research. *Nature Climate Change*, *7*(12), 857–862.

Ravigné, E., Ghersi, F., & Nadaud, F. (2022). Is a fair energy transition possible? Evidence from the French low-carbon strategy. *Ecological Economics*, *196*, 107397.

Renner, S. (2018). Poverty and distributional effects of a carbon tax in Mexico. *Energy Policy*, *112*, 98–110. https://doi.org/10.1016/j.enpol.2017.10.011

Shang, B. (2023). The poverty and Distributional Impacts of Carbon Pricing: Channels and policy implications. *Review of Environmental Economics and Policy*, *17*(1), 64–85.

Solt, F. (2020). Measuring Income Inequality Across Countries and Over Time: The Standardised World Income Inequality Database (SWIID). Social Science Quarterly 101(3):1183-1199.

Symons, E., Proops, J. L. R., & Gay, P. W. (1994). Carbon taxes, consumer demand and carbon dioxide emissions: a simulation analysis for the UK. *Fiscal Studies*, *15*(2), 19–43.

Timilsina, G. R. (2022). Carbon taxes. *Journal of Economic Literature*, *60*(4), 1456–1502.

Van Der Ploeg, F., Rezai, A., & Tovar, M. Á. A. (2022). Gathering support for green tax reform: Evidence from German household surveys. *European Economic Review*, *141*, 103966.

Wang, Q., Hubacek, K., Feng, K., Wei, Y., & Liang, Q. (2016). Distributional effects of carbon taxation. *Applied Energy*, *184*, 1123–1131.

Wier, M., Birr-Pedersen, K., Jacobsen, H. G., & Klok, J. (2005). Are CO_2 taxes regressive? Evidence from the Danish experience. *Ecological Economics*, *52*(2), 239–251.

World Bank Group. 2019. Carbon Pricing Dashboard. https://carbonpricingdashboard.worldbank.org/map_data. Accessed 01.12.2019.

Yusuf, A. A., & Resosudarmo, B. P. (2014). On the distributional impact of a carbon tax in developing countries: the case of Indonesia. *Environmental Economics and Policy Studies*, *17*(1), 131–156.

Supplementary Appendix for
“Carbon taxes in Europe do not hurt the poor.”

Appendix A. Details of carbon taxes in Europe

Table A1. Carbon taxes in Europe.

Country	Enacted	Initial rate (USD per metric ton)	2018 rate (USD per metric ton)	2019 coverage (%)	Carbon Tax revenue in 2018 (USD Million)	Revenue recycling
Finland	January 1990	2.14	70.65	36%	1,458.6	Yes
Poland	January 1990	0.68	0.16	4%	1.2	No
Norway	January 1991	54.81	49.30	62%	1,659.8	Yes
Sweden	January 1991	44.72	128.90	40%	2,572.3	Yes
Denmark	May 1992	22.47	24.92	40%	543.4	Yes
Slovenia	January 1996	15.24	29.74	24%	83.1	No
Estonia	January 2000	1.30	3.65	3%	2.8	No
Latvia	January 2004	1.59	9.01	15%	9.1	No
Switzerland	January 2008	10.01	80.70	33%	1,177.7	Yes
Ireland	January 2010	19.75	24.92	49%	488.8	No
Iceland	January 2010	9.88	25.88	29%	44.0	No
United Kingdom	April 2013	7.66	25.71	23%	1,091.0	No
Spain	January 2014	31.82	30.87	3%	123.6	No
France	April 2014	9.30	57.57	35%	9,263.0	Yes
Portugal	January 2015	8.99	11.54	29%	154.9	Yes

Note: Coverage refers to the percentage of the country’s greenhouse gas emissions covered by the carbon tax. Details on sectoral coverage can be found in Table A2. Details on revenue recycling can be found in Table A3.
Source: World Carbon Pricing Dashboard (https://carbonpricingdashboard.worldbank.org/).

Table A2. Main sectors taxed by carbon taxes in Europe.

Country	Transportation	Industry	Residential & Commercial	Agriculture	Electricity
Finland*	Yes	Yes	Yes	Yes	No
Poland	No	No	No	No	No
Norway*	Yes	Yes	Yes	Yes	No
Sweden*	Yes	Yes	Yes	No	No
Denmark*	Yes	Yes	Yes	Yes	No
Slovenia	Yes	Yes	Yes	No	No
Estonia	No	Yes	No	No	No
Latvia	No	Yes	No	No	No
Switzerland*	No	Yes	Yes	No	No
Ireland	Yes	Yes	Yes	Yes	No
Iceland	Yes	Yes	No	Yes	No
United Kingdom	No	No	No	No	Yes
Spain	No	No	No	No	No
France*	Yes	Yes	Yes	No	No
Portugal*	Yes	Yes	Yes	Yes	No

*Countries that recycle carbon tax revenues.
Source: Konradt and Weder di Mauro (2023).

Table A3. Details on European carbon taxes revenue usage.

Country	Revenue usage
Finland	Over the years, major carbon tax reforms have coincided with reductions in personal income taxes and employer social security contributions. Most sources view it as a green tax shift. Additionally, carbon tax revenues supplement the government's general budget.
Poland	The National Fund for Environmental Protection and Water Management allocates all carbon tax revenues.
Norway	Additional revenues from the increased carbon tax rate in 2013 subsided green technology projects. In the 2015 budget, carbon tax revenue was also roughly attributed to be used for reductions in the corporate capital tax. Besides subsidising green projects and reducing corporate income taxes, most sources view carbon tax revenues as supplementing the government's general budget without specific earmarking.
Sweden	Implementing the carbon tax was part of a broader fiscal reforms which also included reductions in labor and personal income tax. Subsequent stages of carbon tax adoption coincided with reductions in employers' fees (e.g. employer social security contributions reductions) and income taxes (e.g. income-tax-free allowances extensions).
Denmark	The first stage of carbon tax implementation in Denmark was accompanied by significant reductions in income taxes for the household sector. Subsequent stages also came alongside reductions of personal income tax, employer social security contributions, and subsidies for green technologies. Still, most of the revenues are directed toward supplementing the government's general budget.
Slovenia	Part of the revenues used to be directed toward carbon-reduction projects and green subsidies for the industry. Now, all the revenues are transferred to the government's general budget.
Estonia	All carbon tax revenues are allocated to the government's general budget without earmarking.
Latvia	All carbon tax revenues are allocated to the government's general budget without earmarking.
Switzerland	One-third of the revenues are earmarked for green subsidies in the building sector, such as energy efficiency. The remaining two-thirds are redistributed to individuals and businesses in the form of household-level lump sum rebates and employer and payroll rebates.
Ireland	Direct revenue recycling under the Irish carbon tax is limited. Some revenues have been said to fund energy efficiency measures or maintain or reduce payroll taxes. However, without explicit earmarking, most sources still view carbon tax revenues as supplementing the government's general budget.
Iceland	Although some sources suggest that carbon tax prevented other tax increases, tax revenues were not explicitly directed to this cause. Most sources assume that all revenues supplemented the government's general budget without specific earmarking.
UK	All carbon price floor revenues are allocated to the government's general budget without earmarking.
Spain	All carbon tax revenues are allocated to the government's general budget without earmarking.
France	Part of the revenues is set to be spent on green subsidies, including green energy transition plans. The rest is directed to the government's general budget. Following the tax rate increase for diesel use in 2017, additional revenues from the increase are directed to lower the tax burden of low-income households and the elderly. They also support the financial aid given to individuals replacing old diesel vehicles.
Portugal	Most of the revenues are used to reduce households' income taxes, especially those with many children. The rest is directed towards benefits and incentives for sustainable mobility, forestry management and nature conservation.

Source: Own compilation using World Bank Carbon Pricing Dashboard, Sumner et al. (2011), Carl and Fedor (2016), Narassimhan et al. (2017), Marten and van Dender (2019), EEB (2021).

Appendix B. Evidence from Panel-VAR models

As a robustness test, we use panel-VAR models as an alternative estimation approach. Plagborg-Møller and Wolf (2021) show that local projections and VARs estimate the same impulse responses but have different finite-sample properties. Specifically, we estimate bivariate panel VAR regressions with the carbon tax rate and each of our distributional indices as dependent variables, the control variables, each regressor's four latest annual lags, and country and year fixed effects. Similar to the local projection approach, the identification rests on the assumption that the components of the carbon tax that are not predicted by historical carbon taxes, historical changes in income and consumption distribution, and current and past economic shocks are exogenous. Standard errors are estimated using a parametric bootstrap procedure. Similarly to the local projection estimation, we then consider a counterfactual one-time permanent increase in the carbon tax by $40, for a tax covering 30% of the country's emissions.

Table B1 presents the results of this robustness test. We observe that findings from panel-VAR models are very close to those from local projections (Figures 1-3 in the main text). In particular, we obtain small positive impacts of carbon taxes on the bottom 20% and 40% consumption shares, insignificant results for income poverty measures, inequality-reducing effects in case of consumption inequality and insignificant estimates for income inequality.

Table B1. Response of the consumption and income distribution variables to a carbon tax in Europe: estimates from panel VAR models.

	Impact in year		
Model specification	0	1-2	3-5
Panel A. Bottom 20% consumption share			
Fixed effects	0.052***	0.044***	0.034***
	(0.008)	(0.009)	(0.010)
Fixed effects and controls	0.044***	0.040***	0.030***
	(0.007)	(0.007)	(0.008)
Panel B. Bottom 40% consumption share			
Fixed effects	0.026***	0.023***	0.018***
	(0.005)	(0.006)	(0.007)
Fixed effects and controls	0.021***	0.020***	0.016***
	(0.004)	(0.005)	(0.005)
Panel C. Income poverty rate			
Fixed effects	0.001	-0.008	0.010
	(0.004)	(0.008)	(0.011)
Fixed effects and controls	0.005	-0.007	0.017
	(0.004)	(0.008)	(0.011)
Panel D. Income poverty gap			
Fixed effects	0.002	-0.014	0.014
	(0.007)	(0.013)	(0.019)
Fixed effects and controls	0.008	-0.012	0.027
	(0.007)	(0.014)	(0.019)
Panel E. Consumption inequality (Gini index)			
Fixed effects	-0.015*	-0.015	-0.017*
	(0.008)	(0.009)	(0.010)
Fixed effects and controls	-0.007	-0.013**	-0.016**
	(0.005)	(0.006)	(0.007)
Panel F. Income inequality (Gini index)			
Fixed effects	0.000	-0.005	0.003
	(0.002)	(0.005)	(0.006)
Fixed effects and controls	0.002	0.004	0.007
	(0.002)	(0.005)	(0.007)

Note: The table shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using a panel-VAR model. For each dependent variable, two specifications are shown with independent variables being: 1) only country and year fixed effects; 2) country and year fixed effects as the GDP growth and changes in the unemployment rate, government expenses (as % of the GDP) and social protection expenditures. Bootstrapped standard errors appear in parentheses. *, **, *** denote estimates significant at, respectively 10%, 5% and 1%.

References

Plagborg-Møller, M., & Wolf, C. K. (2021). Local projections and VARs estimate the same impulse responses. Econometrica, 89(2), 955-980.

Appendix C. Granger causality tests

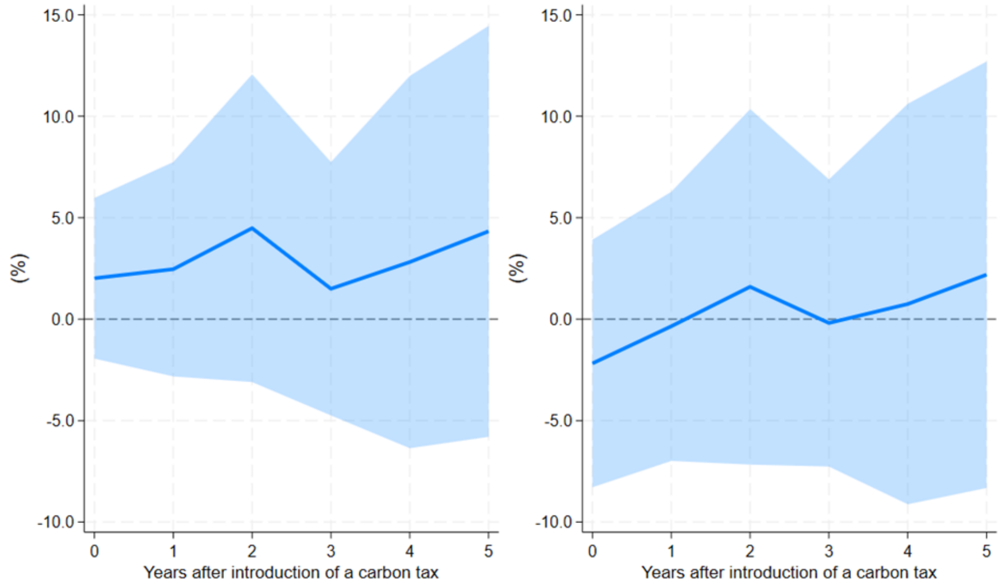
Table C1. Granger causality Wald tests

Distributional index	Wald statistic	P-value
Bottom 20% consumption share	0.1755	0.916
Bottom 40% consumption share	0.0029	0.999
Income poverty rate	1.081	0.582
Income poverty gap	0.8914	0.640
Gini index of consumption	1.9662	0.374
Gini index of income	0.5049	0.777
Mean consumption of the first decile group	0.1721	0.918
Mean consumption of the second decile group	2.5434	0.280

Note: H_0 is that changes in the logarithm of a distributional index do not Granger-cause coverage-weighted real carbon tax rates. The underlying VAR model included two lags of each variable.

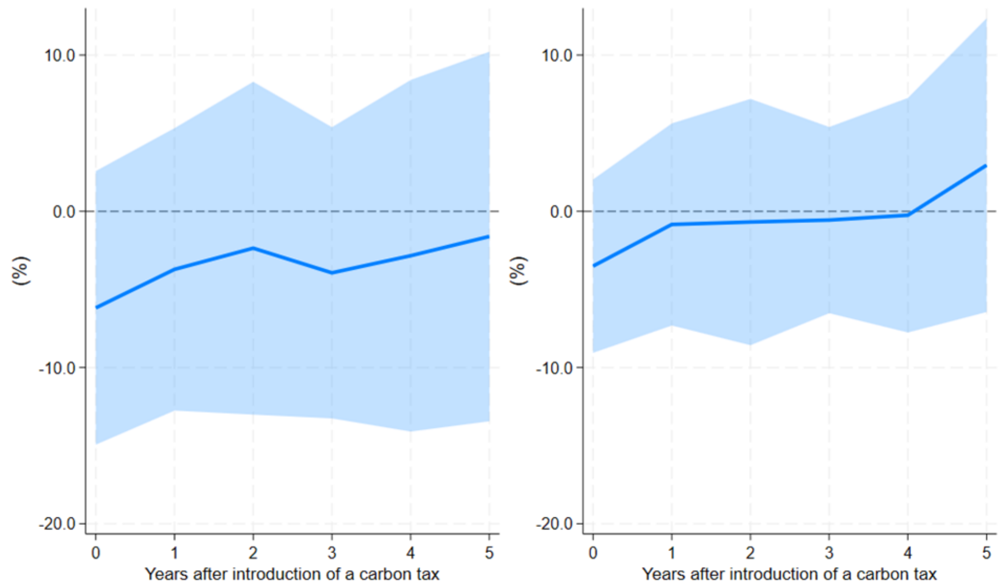
Appendix D. Additional figures and tables

Figure D1. Response of mean consumption of the first decile group (left) and the second decile group (right) to a carbon tax in Europe.



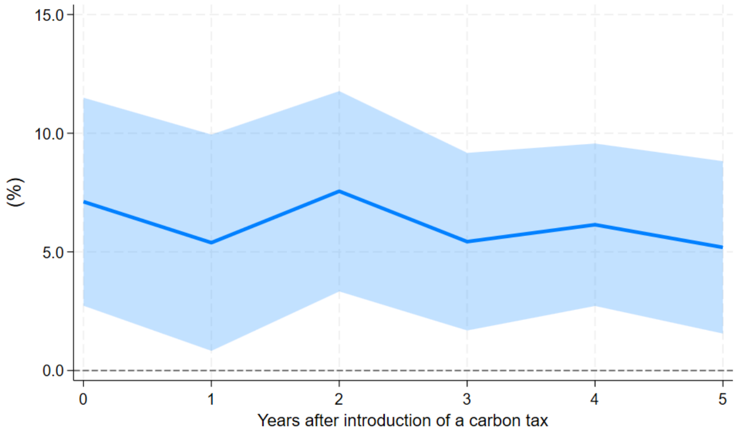
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D2. Response of mean consumption of the fifth decile group (left) and the tenth decile group (right) to a carbon tax in Europe.



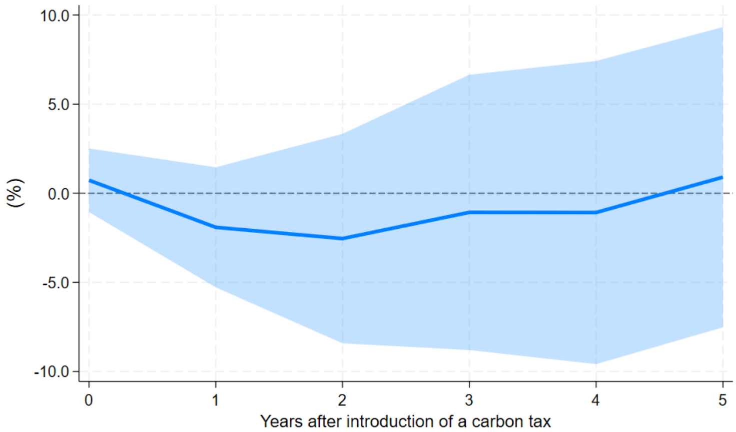
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D3. Response of bottom 10% consumption share to a carbon tax in Europe.



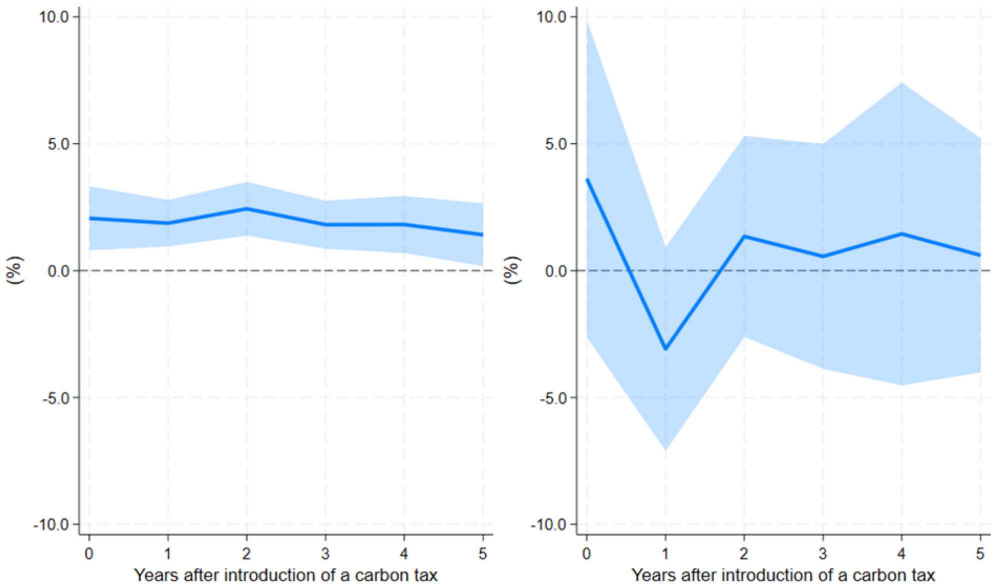
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D4. Response of income squared poverty gap to a carbon tax in Europe.



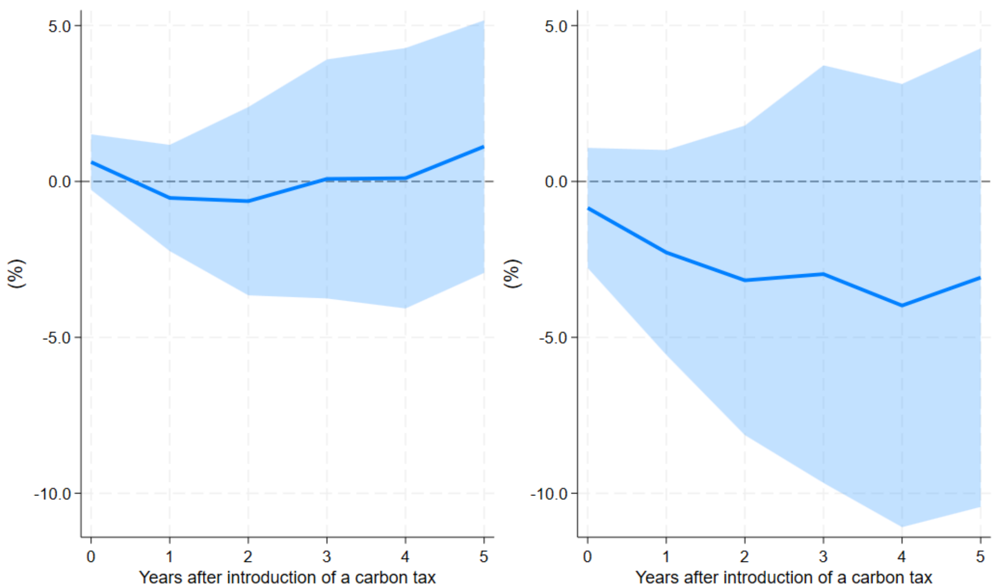
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D5. Response of the bottom 40% consumption shares to a carbon tax in the subsamples of European countries that recycle carbon tax revenues (left panel) and countries that do not (right panel).



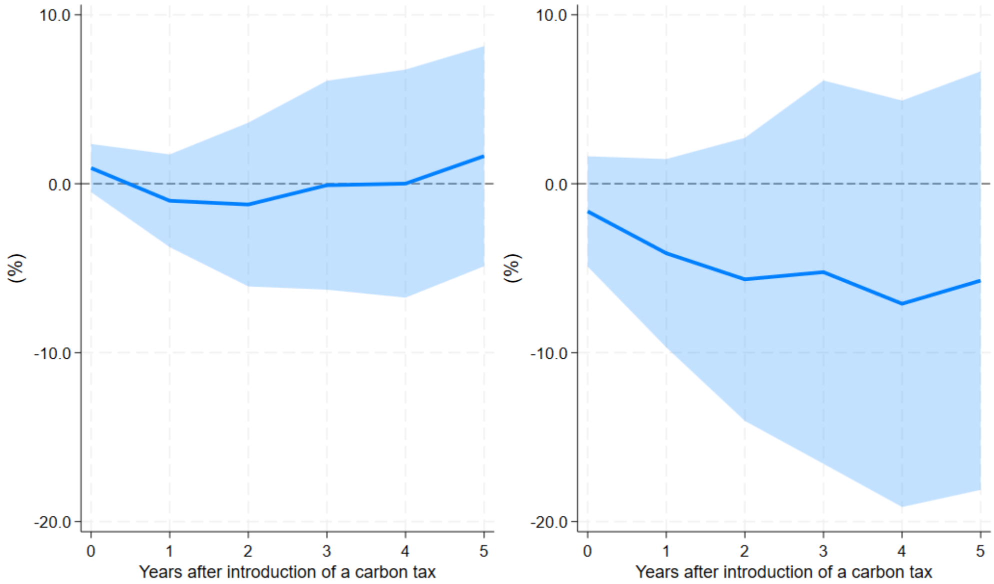
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals. Countries that recycle carbon tax revenues include Denmark, Finland, France, Norway, Portugal, Sweden and Switzerland.

Figure D6. Response of income poverty rate to a carbon tax in the subsamples of European countries that recycle carbon tax revenues (left panel) and countries that do not (right panel).



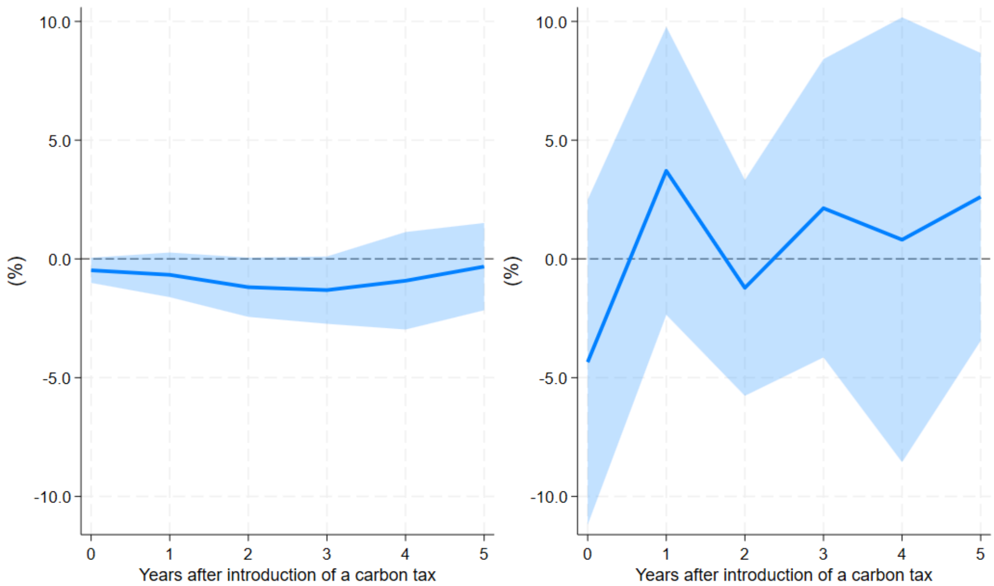
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals. Countries that recycle carbon tax revenues include Denmark, Finland, France, Norway, Portugal, Sweden and Switzerland.

Figure D7. Response of the income poverty gap to a carbon tax in the subsamples of European countries that recycle carbon tax revenues (left panel) and countries that do not (right panel).



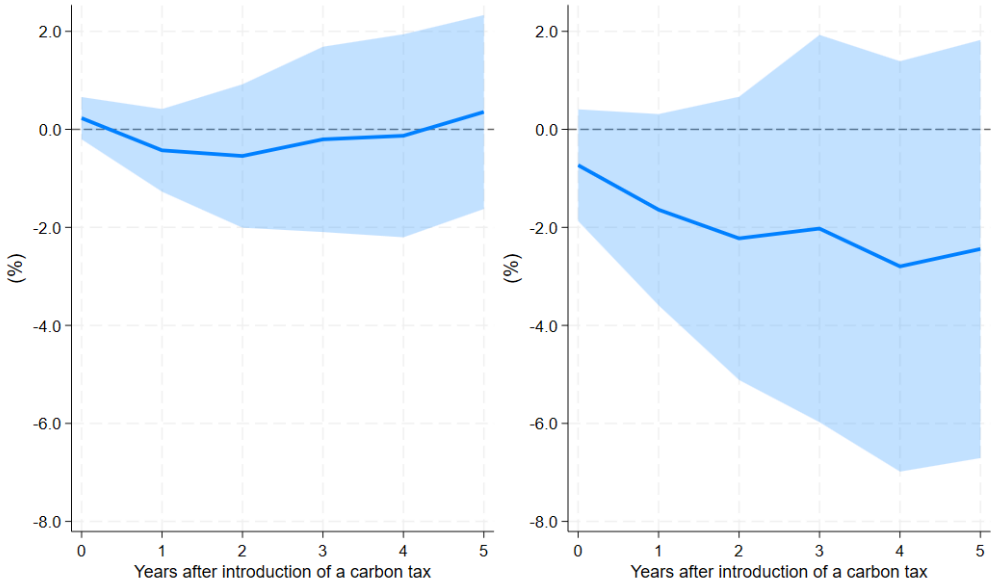
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D8. Response of the consumption Gini indices to a carbon tax in the subsamples of European countries that recycle carbon tax revenues (left panel) and countries that do not (right panel).



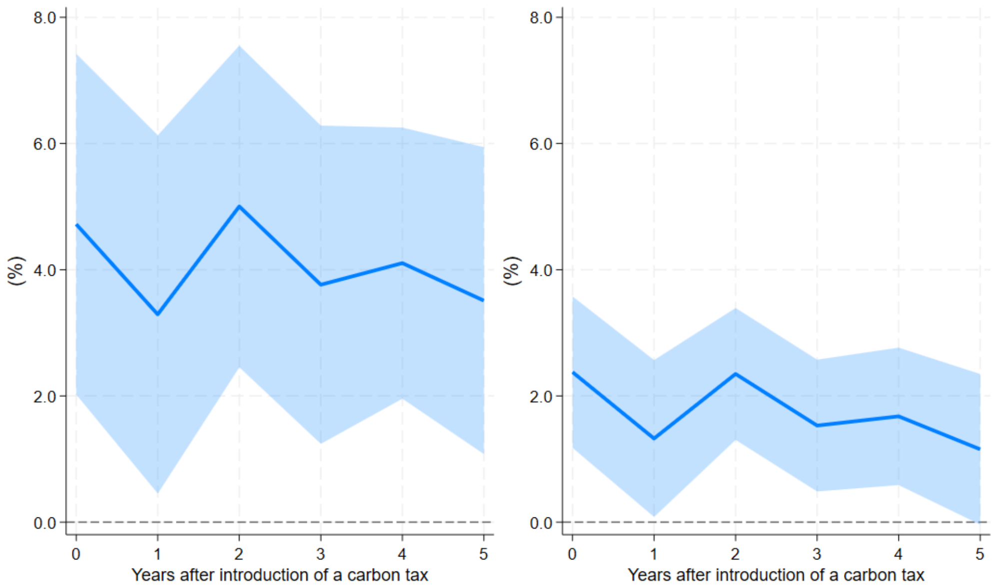
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D9. Response of the income Gini indices to a carbon tax in the subsamples of European countries that recycle carbon tax revenues (left panel) and countries that do not (right panel).



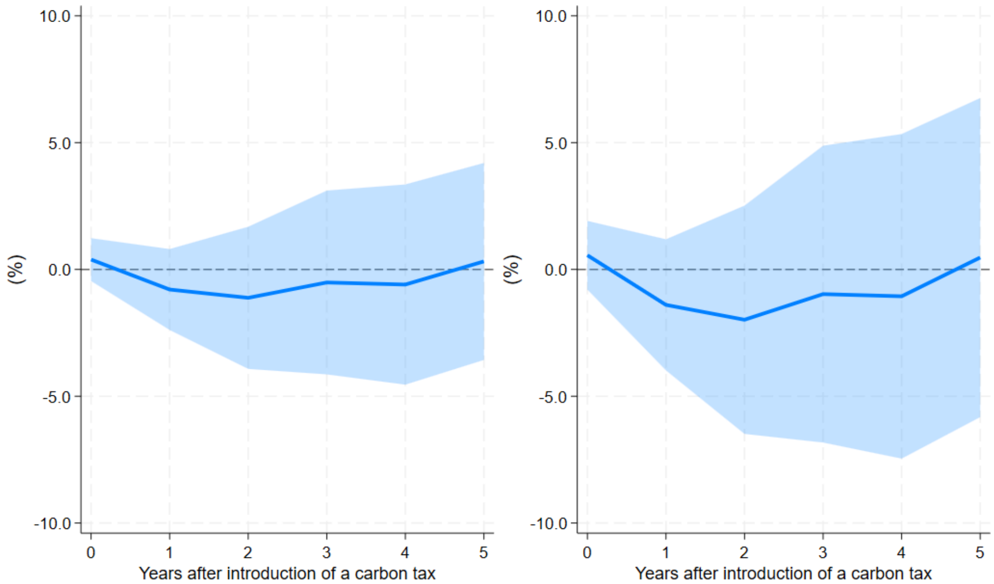
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D10. Response of the bottom 20% (left) and the bottom 40% (right) consumption shares to a carbon tax in the subsample of European countries with large carbon taxes.



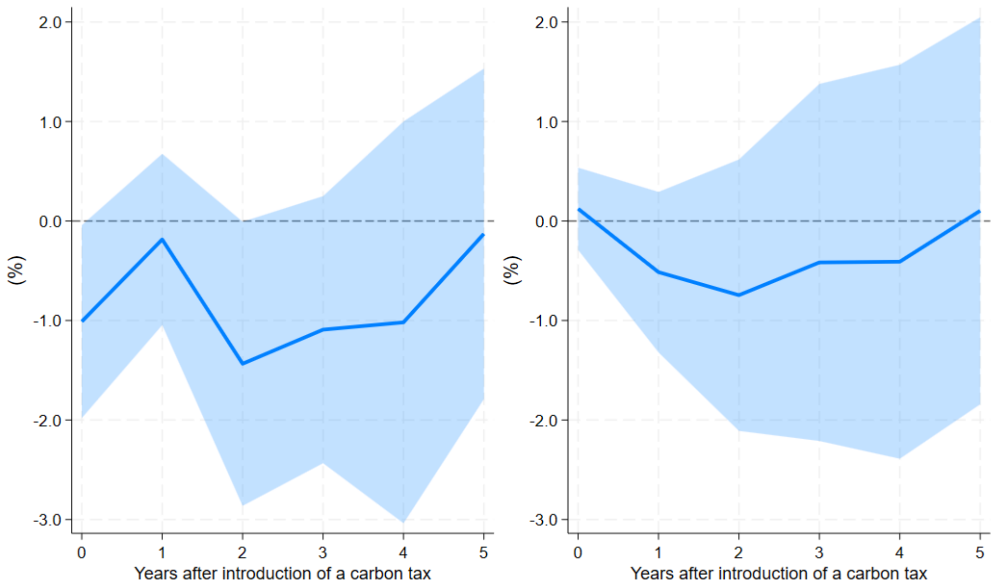
Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D11. Response of the income poverty rate (left) and the income poverty gap (right) to a carbon tax in the subsample of European countries with large carbon taxes.



Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Figure D12. Response of the consumption Gini (left) and the income Gini (right) indices to a carbon tax in the subsample of European countries with large carbon taxes.



Note: The figure shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). Control variables include GDP growth, unemployment rate change, and country and year fixed effects. Shaded areas are 95% confidence intervals.

Table D1. Response of the consumption and income distribution variables to a carbon tax in Europe: estimates from local projections with additional controls and from LP-DiD estimator

Model specification	Impact in year 0	Impact in year 1-2	Impact in year 3-5
Panel A. Bottom 20% consumption share			
LP with additional controls	0.041**	0.049***	0.045***
	(0.017)	(0.015)	(0.012)
LP-DiD with additional controls	0.048***	0.045***	0.045***
	(0.014)	(0.013)	(0.011)
Panel B. Bottom 40% consumption share			
LP with additional controls	0.019**	0.022***	0.017***
	(0.008)	(0.006)	(0.006)
LP-DiD with additional controls	0.024***	0.021***	0.018***
	(0.006)	(0.005)	(0.005)
Panel C. Income poverty rate			
LP with additional controls	0.004	-0.008	0.005
	(0.005)	(0.012)	(0.022)
LP-DiD with additional controls	0.004	-0.009)	0.011
	(0.004)	(0.011)	(0.019)
Panel D. Income poverty gap			
LP with additional controls	0.007	-0.015	0.009
	(0.007)	(0.019)	(0.035)
LP-DiD with additional controls	0.006	-0.015	0.016
	(0.007)	(0.017)	(0.030)
Panel E. Consumption inequality (Gini index)			
LP with additional controls	-0.006**	-0.010**	-0.009
	(0.003)	(0.005)	(0.008)
LP-DiD with additional controls	-0.010**	-0.009**	-0.006
	(0.005)	(0.004)	(0.007)
Panel F. Income inequality (Gini index)			
LP with additional controls	-0.010	-0.009	0.003
	(0.005)	(0.004)	(0.011)
LP-DiD with additional controls	0.001	-0.006	0.004
	(0.002)	(0.005)	(0.009)

Note: The table shows impulse responses to a $40 carbon tax with 30% emission coverage estimated using model (1). For each dependent variable, two sets of results are shown: a) model (1) estimated two-way fixed effects regression with baseline controls (the GDP growth and changes in the unemployment rate) and additional controls (changes in government expenses (as % of the GDP) and social protection expenditures); b) model (1) estimated using the LP approach with a "clean control" condition (LP-DiD) (Dube et al. 2023) with baseline and additional controls. Bootstrapped standard errors appear in parentheses. *, **, *** denote estimates significant at, respectively 10%, 5% and 1%.

University of Warsaw
Faculty of Economic Sciences
44/50 Długa St.
00-241 Warsaw
www.wne.uw.edu.pl
ISSN 2957-0506