I Z A Institute of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 13481

Distributional Effects of Emission Pricing in a Carbon-Intensive Economy: The Case of Poland

Marek Antosiewicz
J. Rodrigo Fuentes
Piotr Lewandowski
Jan Witajewski-Baltvilks

JULY 2020

DISCUSSION PAPER SERIES

IZA DP No. 13481

Distributional Effects of Emission Pricing in a Carbon-Intensive Economy: The Case of Poland

Marek Antosiewicz
IBS and SGH Warsaw School of Economics

J. Rodrigo Fuentes
Pontical Catholic University of Chile

Piotr Lewandowski
IBS and IZA

Jan Witajewski-Baltvilks
IBS and University of Warsaw

JULY 2020

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Distributional Effects of Emission Pricing in a Carbon-Intensive Economy: The Case of Poland*

In this paper, we assess the distributional impact of introducing a carbon tax in Poland. We apply a two-step simulation procedure. First, we evaluate the economy-wide effects with a dynamic general equilibrium model. Second, we use a microsimulation model based on household budget survey data to assess the effects on various income groups and on inequality. We introduce a new adjustment channel related to employment changes, which is qualitatively different from price and behavioural effects, and is quantitatively important. We nd that the overall distributional effect of a carbon tax is largely driven by how the revenue is spent: distributing the revenues from a carbon tax as lump-sum transfers to households reduces income inequality, while spending the revenues on a reduction of labour taxation increases inequality. These results could be relevant for other coal-producing countries, such as South Africa, Germany, or Australia.

JEL Classification: H23, P18, O15

Keywords: climate policy, carbon tax, distributional effect, microsimulation, general equilibrium, employment

Corresponding author:
Marek Antosiewicz
Institute for Structural Research
SGH Warsaw School of Economics
Warsaw
Poland
E-mail: marek.antosiewicz@ibs.org.pl

* We thank the participants of the EcoMod2019 conference for their comments. The research summarised in this paper received funding from the SONATA grant by the National Science Centre, Poland, registration no. 2016/21/D/HS4/02795. This article uses Statistics Poland data. Statistics Poland has no responsibility for the results and conclusions, which are those of the authors. The usual disclaimers apply. All errors are ours.

1 Introduction and motivation

To avoid the potentially catastrophic consequences of climate change, global CO_2 emissions should be substantially reduced. Putting a price on carbon emissions is one of the policy measures seen as essential to mitigating climate change. Carbon pricing has already been implemented in various countries, either through a carbon tax or through a cap-and-trade system. While there are some differences between the two approaches (Goulder and Schein 2013), economists have argued that such market-based measures will be economically efficient, since they incentivise limiting emissions in sectors in which the cost of doing so is lowest. However, despite the presumed efficiency of carbon pricing, governments might be hesitant to implement such measures due to public acceptability issues. Concerns have been raised about the social equity of carbon pricing (Sovacool et al. 2015), and particularly about its aggregate or distributional economic impacts. The literature on the aggregate economic effects of carbon pricing is vast, and shows that the potential net costs of carbon pricing are rather small (see IPCC AR5 WG3, section 6.3.6.2). By contrast, the distributional effects of carbon pricing are still under-researched, even though their relevance for understanding and managing the economic and social challenges related to the transition to a carbon-neutral economy is increasing.

In this paper, we study how labour market adjustments, price responses, and the behavioural reactions of households shape the distributional consequences of emission pricing in a carbon-intensive economy, using the case of Poland. Up to now, three re-distributive channels have been identified in the literature. The first of these channels is the direct price effect. Since low-income households usually spend a larger share of their income on basic goods such as electricity and heating, a tax on emissions might disproportionately affect these families. Evidence that this is indeed the case has been found in Brazil (da Silva Freitas et al. 2016), South Africa (van Heerden 2006), and France (Bureau 2010). The second redistributive channel is the indirect price effect, which in this context means that a price on emissions may increase the price of energy-intensive goods. Previous studies have shown that the indirect effect may have a greater impact either on the poorer households (Jiang and Shao 2014) or the richer households (Goulder et al. 2019) depending on the patterns of consumption of energy-intensive goods. The third redistributive channel is the behavioural channel, which is driven by the consumption response of households to price changes. If low-income households cannot reduce their energy consumption,[1] they might be harder hit by price increases than high-income households. In order to quantify this effect, researchers assume a uniform change in energy goods consumption across various types of households (Buchs et al. 2011), or use more sophisticated methods that account for household heterogeneity by estimating an Almost Ideal Demand System (Labandeira and Labeaga 1999), or by estimating the price elasticity of demand for different subpopulations (Johnstone and Serret 2006). Carbon pricing is usually less regressive if behavioural effects are taken into account, since high-income households are generally less sensitive to changes in the price of energy or energy-intensive goods. However, adopting such a perspective ignores fairness considerations.

Our first contribution to the literature is to introduce an additional, important re-distributive channel related to labour market responses to a carbon tax. The more carbon-intensive sectors, such as energy generation, mining, transport, or manufacturing, are more likely to reduce output and labour demand in response to a carbon tax than less carbon-intensive sectors, such as services. At the same time, these sectors differ in their demand for skills, labour productivity, and wages. As a result, the heterogeneous sectoral responses to a carbon tax can affect the incomes of various groups of workers to varying degrees. To study this

[1] For instance, because they are credit-constrained and cannot invest in a more energy-efficient infrastructure, or because the reduction of energy use would be detrimental for health.

channel, we use a multi-sector Dynamic Stochastic General Equilibrium (DSGE) model that is soft-linked with a microsimulation model. We account for the effects of employment changes – i.e., both reductions and increases in employment – in various sectors. We find that the labour market channel makes a crucial contribution to the overall redistributive effect of a carbon tax. It is qualitatively different from price effects, as workers in carbon-intensive sectors (in which employment tends to decrease after a carbon tax is introduced) are more likely to earn above-median wages. The labour market channel is also quantitatively substantial. Introducing the employment channel is the key contribution of our paper to the literature. Previous research on responses to emission pricing focused primarily on the price and consumption responses, which we also account for.

Our second contribution is to develop a framework to assess the trade-offs between efficiency and equity in climate policy. To this end, we compare the effects of three alternative ways of spending the revenue from the carbon tax under the condition of an identical emission reduction path (linear 95% reduction between 2020 and 2050). First, we consider transferring revenue from a carbon tax to household members in the form of lump-sum benefits. Second, we consider a price subsidy – i.e., compensation for the increase in expenditures on energy resulting from higher energy prices – that would be provided to all households.[2] Third, we consider utilising carbon tax revenue to reduce the taxation of labour, in line with the double dividend hypothesis (Takeda 2007, Faehn et al. 2009, Antosiewicz et al. 2016b). We find that the introduction of a carbon tax is associated with a moderate reduction in GDP, with the largest reduction occurring in the price subsidy scenario (1.5% after 10 years), and the smallest reduction occurring in the double dividend scenario (0.9%). Crucially, we find that these scenarios differ starkly in their distributional consequences. Transferring revenue to households as lump-sum transfers reduces income inequality and increases the incomes of below-median households. This is because lump-sum transfers received by these households more than cover the higher energy costs they face. On the other hand, spending the revenue on reducing labour taxation increases income inequality, as it mainly benefits high-income households. Moreover, spending the revenue on lump-sum transfers appears to be a better option than spending it on subsidising energy prices, as the macroeconomic effects are only slightly worse in the price subsidy scenario, and inequality is greater in the price subsidy scenario than it is in the lump-sum scenario.

Our third contribution is that we quantify the distributional effects of carbon pricing in Poland, which is a particularly interesting case study for several reasons. First, Poland is the largest producer of coal in Europe, and it consumes most of its coal domestically — more than 80% of electricity and heat in Poland are generated from coal. Second, since Poland transitioned from a centrally-planned to a market economy, levels of income inequality in the country have increased substantially. Indeed, according to Eurostat data, Poland has the highest levels of wage inequality in the EU. Moreover, the share of income spent on energy and fuel is substantially higher for the poorest than for the richest households. Third, a large share of the Polish workforce are employed in carbon-intensive sectors. In 2018, about 1% of all workers were employed in coal mining and related industries (Kiewra et al. 2019). Therefore, the introduction of a carbon tax and the move away from coal in Poland may affect households not only through rising energy prices, but through the labour market channel, with households in which some members work in the coal mining industry being the most affected. While we calibrate our model to Poland, our methodology and findings may be relevant for other countries that are dependent on coal and that have high levels of income inequality, such as Australia, South Africa, or Ukraine. Thus, understanding the distributional implications of carbon pricing in such economies may be useful for managing the transition away from coal.

[2] At the time of writing, such a subsidy is being considered by the Polish government in response to energy price hikes introduced in early 2020.

We use two models, a macroeconomic model and microsimulation model, which we soft-link by using the output of the former in the latter. Our macroeconomic model is a multi-sector DSGE model based on an Input-Output structure, which allows for a more nuanced analysis than Computable General Equilibrium models (Hamilton and Cameron 1994, Liang and Wei 2012) or static Input-Output models (Feng et al. 2010) used in previous studies. In particular, our model allows us to study the dynamic effects of carbon tax over time. It also includes more elaborate economic mechanisms, such as endogenous technology adoption by firms, and search and matching mechanism on the labour market. These features enable us to study the labour market channel, which was not taken into account in earlier studies. Our microsimulation model is built on household budget survey data, and it allows us to transmit the macroeconomic impulses to employment outcomes, incomes, and consumption of households, depending on their sector of employment and initial position in the income distribution. A similar hybrid approach was used by Callan et al. (2009) and Alton et al. (2014).

2 The context of climate policy and inequality in Poland

2.1 Carbon intensity and energy mix in Poland

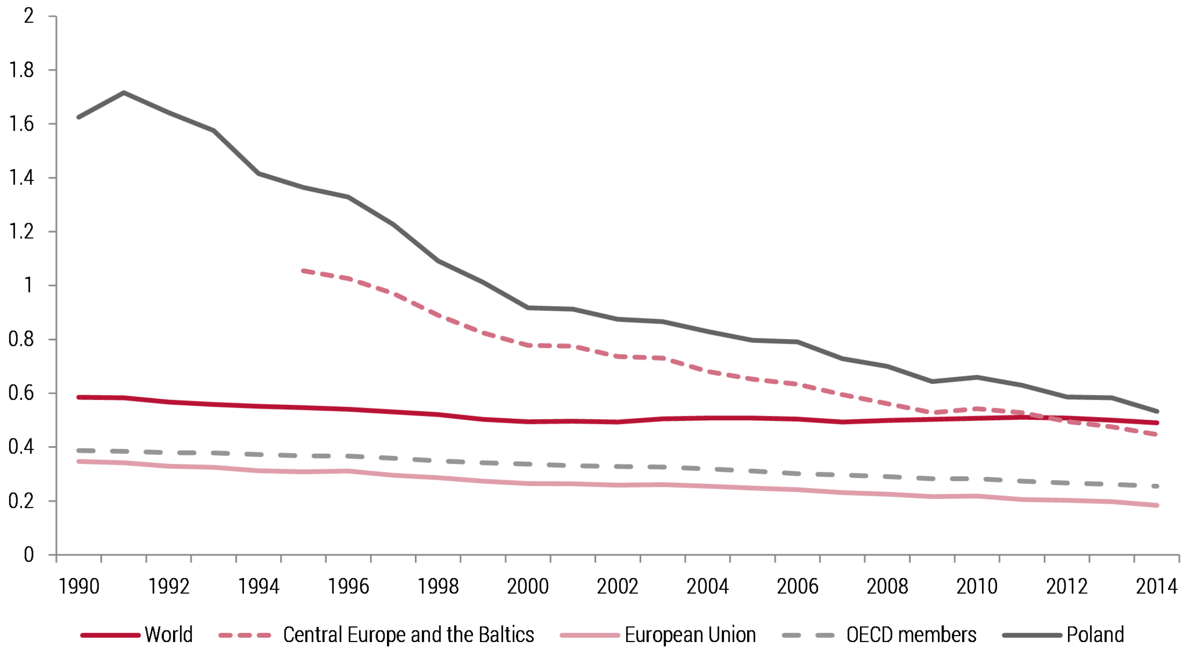
Among the developed economies, the Polish economy is one of the most carbon-intensive. Until the late 1980s, industrialisation in Poland's centrally planned economy was almost entirely fuelled by the extensive use of coal: in 1990, the share of coal in the energy mix was 76%. Since the early 1990s, the relative importance of fossil fuels in the energy mix has changed (with the shares of natural gas and oil increasing), but the share of renewables has remained low (9% of the total primary energy supply in 2017). However, the process of industrial modernisation led to rapid improvements in energy efficiency and a decoupling of emissions from economic growth: between 1990 and 2014, the emission intensity of the Polish economy declined from 1.6 to 0.5 kg CO2 per $US (in 2010 prices; see Figure 1). Nevertheless, the carbon-intensity of Poland remains significantly above the OECD average (0.25 kg CO2 per $US), the EU average (0.18), and the average across Central European and Baltic countries (0.44).

To achieve the targets set by the EU climate policy, the Polish energy mix will have to change quickly, and will most importantly require the complete elimination of coal. Witajewski-Baltvilks et al. (2018) observed that coal consumption in Poland would have to be cut by 20% between 2015 and 2030 to put the country on the path to meeting its target of emitting three tonnes of CO2 per person by 2050. The governmental Energy Policy of Poland (2019) assumes that between 2015 and 2040, the use of coal will decline by 49% (see Figure 2). However, significantly larger changes are necessary to achieve the "2050 net zero" target set by the European Commission.[3]

The decarbonisation of the Polish economy would involve a phase-out of the mining sector and a reallocation of mining workers other sectors. In 2020, Poland is the largest producer of coal in the EU. Most of the coal produced (83% in 2017) is consumed domestically. The amount of coal that is exported is unlikely to increase in the future because the high costs of coal extraction in Poland mean that Polish coal is not competitive outside the domestic market. Thus, a decline in consumption induced by an ambitious climate policy has to involve cuts in production, and corresponding reductions in mining employment. In 2018, coal

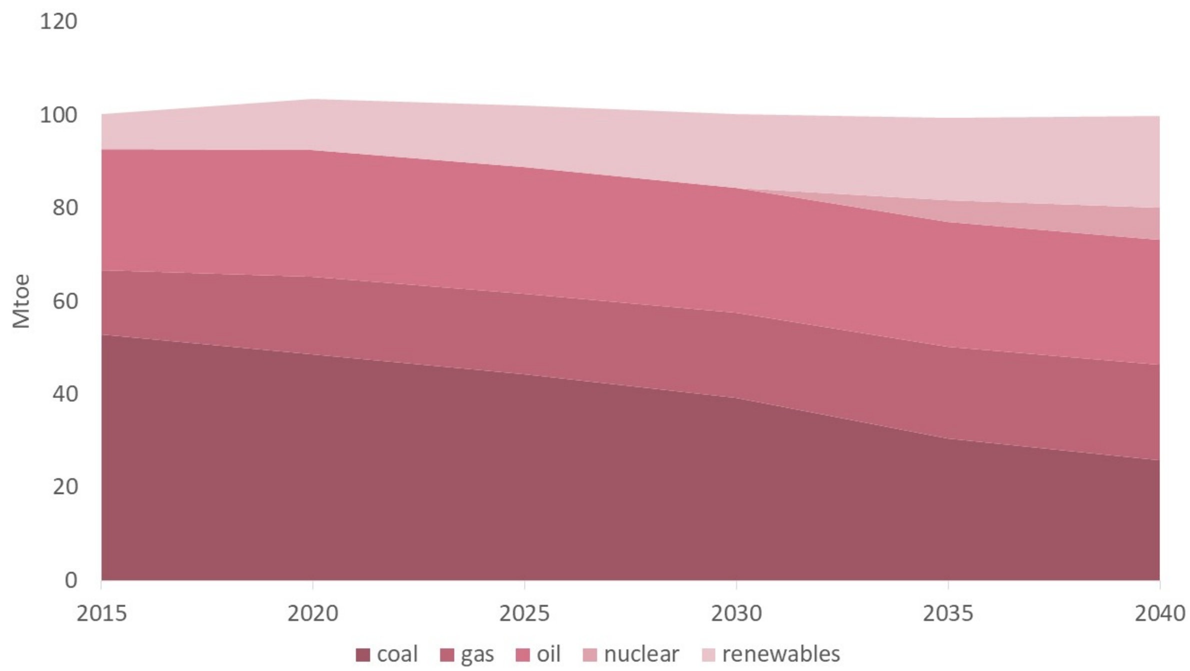
[3]The net zero target is motivated by the commitment to limit the temperature increase to below 1.5 degrees by the end of century. It assumes a complete decarbonisation of the EU economies by 2050. While Poland has not yet committed to this target, it is under pressure to raise its level of ambition in the near future.

Figure 1. Trends in carbon-intensity in Poland against regional averages.



Source: Own elaboration based on World Bank data.

Figure 2. Projections of the energy mix according to the Energy Policy of Poland.



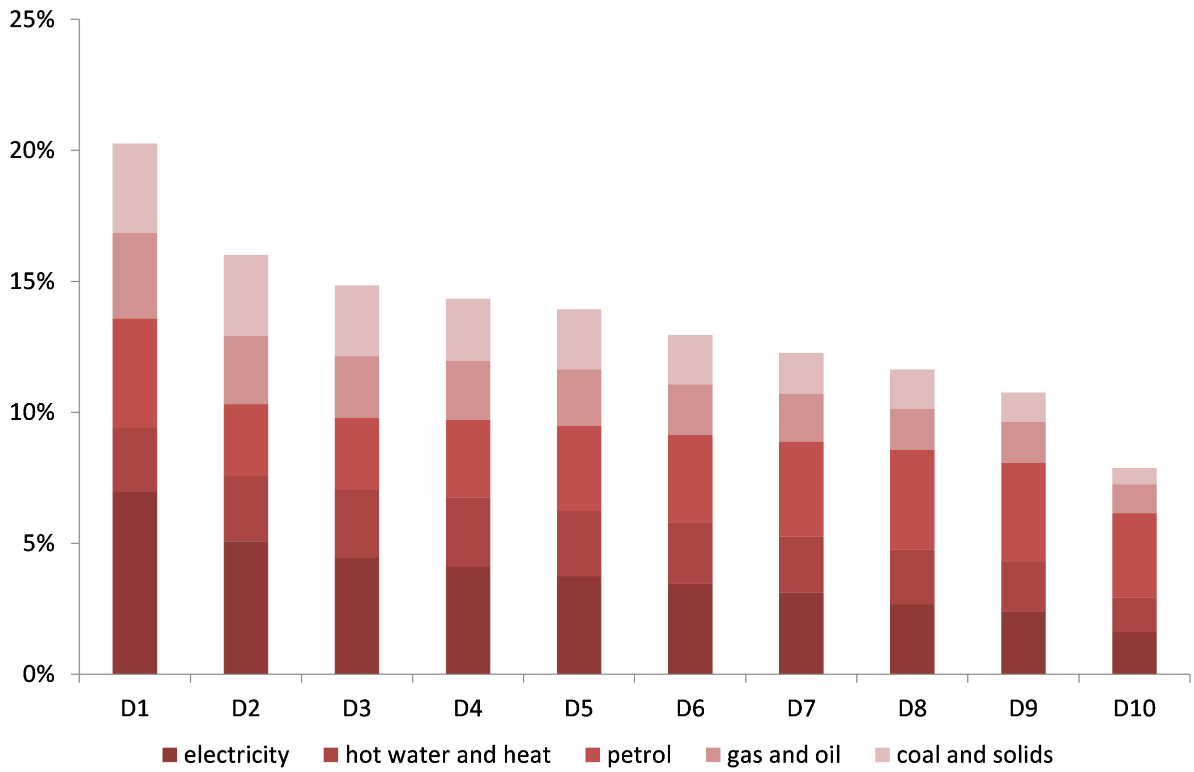
Source: Own elaboration based on the Energy Policy of Poland (2019).

mining employed 82,000 workers, and it is estimated (Kiewra et al. 2019) that an additional 60,000 workers were employed in sectors dependent on coal mining, which jointly constituted 1% of total employment.[4] Moreover, in Poland, large shares of employment are in energy/carbon-intensive sectors, such as manufacturing (21.2% in 2018) or transportation and storage (6.3%), relative to the EU average shares (15.5% and 5.3%, respectively). Therefore, the expected employment effects of decarbonisation are likely to be more far-reaching in Poland than they are in the majority of EU countries.

2.2 Inequality and living standards in Poland

In Poland, income inequality increased substantially between 1989 and 2007. Although it has remained at a stable level since 2007, Poland became one of the countries with the highest levels of income inequality in the EU (Brzeziński, 2017). The increases in the top income shares and above-median inequality have been particularly pronounced in Poland (Bukowski and Novokmet, 2017). Earnings inequality has also been greater in Poland than it is in most EU countries, with the top 10% of workers earning 4.6 times more than the bottom 10% in 2014, the most recent year for which data on this issue are available (Lewandowski and Magda, 2018). Considerable wage dispersion is a key factor in this high level of income inequality, especially given that the Polish tax and benefit system does little to reduce income inequality (Goraus and Inchauste, 2016, Myck and Najsztub, 2016). As a consequence, shocks that affect the employment level and the wage distribution have a relatively strong effect on income inequality in Poland (Brzeziński, 2017).

Figure 3. Share of expenditures on energy and fuel in household income in Poland, by equivalised income deciles (2018).



Source: Own calculations based on Household Budget Survey data.

[4]Hard coal mining in Poland is concentrated in the Silesia region, where it provides a larger share of jobs (5% overall, and up to 8% among males, in 2018).

The share of spending on electricity, gas, and other fuels in the total consumption expenditures of Polish households is relatively high. According to the Eurostat data, in 2015 (the most recent data available), this share was 11.7%, and was considerably higher than the EU average of 7.3%. Moreover, lower-income households in Poland spend a much larger share of their income on energy and fuel than higher-income households (Figure 3). In 2018, this share was twice as large among the bottom 20% of the population as it was among the top 20% of the population. Almost $3/4$ of the differences in the share of income spent on energy and fuels across different income groups can be attributed to differences in the share of income spent on electricity, coal, and solid fuels (used mainly for heating). As a consequence, 10% of households in Poland suffer from multidimensional energy poverty resulting from objective (monetary) energy deprivation and subjective deprivation (Sokołowski et al., 2020). The combination of high levels of wage and income inequality and the vulnerability of low-income households to high energy costs means that the distributional effects of climate policy in Poland are of particular importance (Żuk and Szulecki 2020).

3 Methods and data

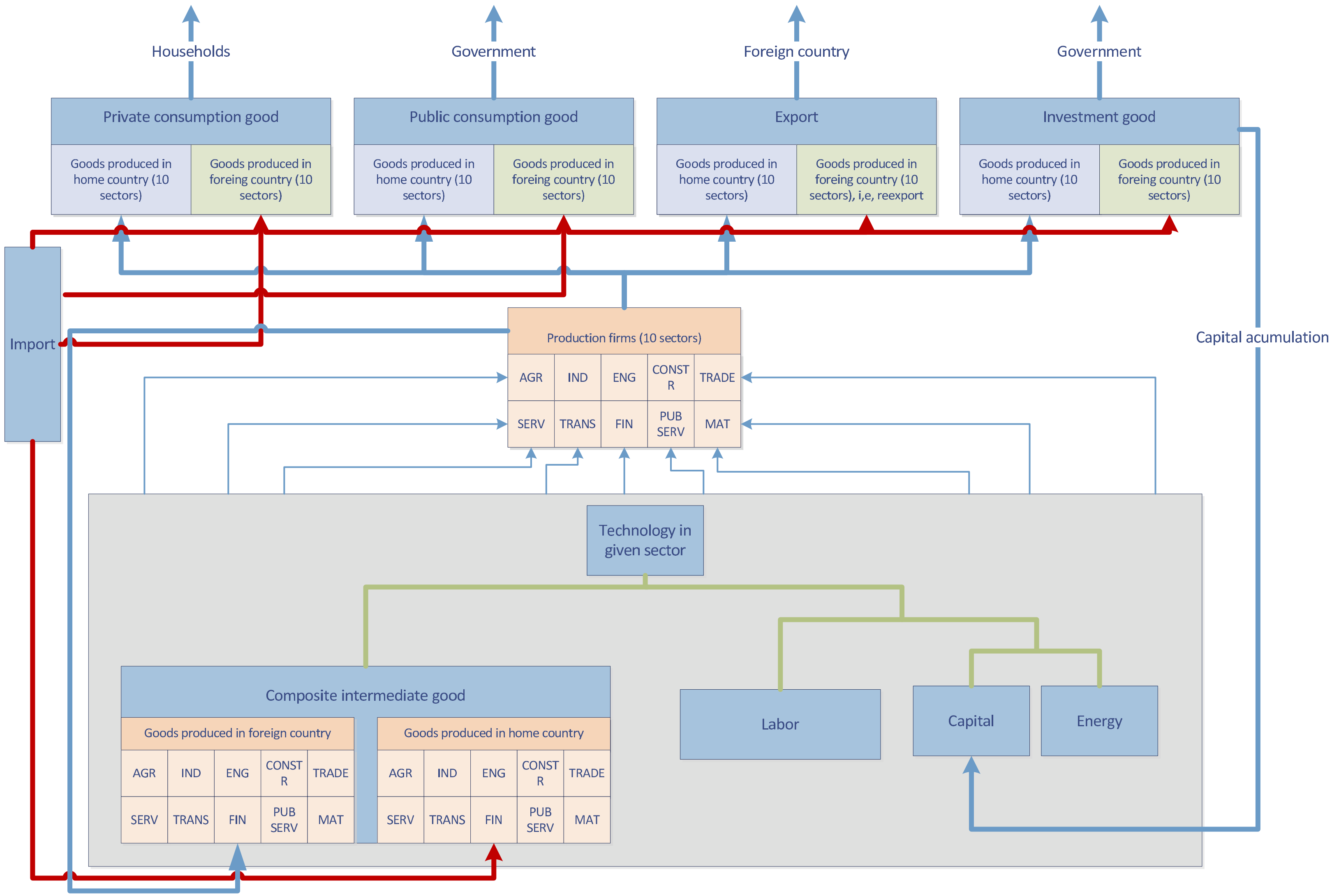
To assess the distributional effect of the carbon tax, we use a two-stage simulation approach. In the first step, we apply a macroeconomic multi-sector dynamic stochastic general equilibrium (DSGE) model of the Polish economy named MEMO (MacroEconomic Mitigations Options). We use this model to simulate the changes in employment, wages, and prices of goods at a sector level in response to the introduction of a carbon tax. In the second step, we map the results of the macroeconomic model to a microsimulation model based on household budget data to evaluate the effects of the carbon tax on household incomes and inequality. In this section, we present the two models, our data sources, and the scenarios that we simulate.

3.1 MEMO - Macroeconomic DSGE model

MEMO combines two strands of economic modelling: it is an Input-Output (IO) model embedded in a dynamic stochastic general equilibrium framework. The advantages of using such a framework over a static IO model are that it enables us to account for a variety of dynamic economic adjustment mechanisms. In the context of our study, the most important features of MEMO are that it has an open economy search and matching mechanism on the labour market and endogenous technical adaptation of energy-efficiency in response to changes in the price of carbon emissions.

The main agents of the model are: a) households, which maximise utility from consumption; b) firms, which maximise profits; c) the government, which collects taxes and spends the revenue on public consumption; and d) the foreign trade sector. The firm's production side of the model is shown in Fig. 4, and is divided into several sectors and calibrated to the NACE Rev. 2 symmetric Input-Output table for Poland in 2015 (provided by Statistics Poland). In each sector, a representative firm operates a nested constant elasticity of substitution (CES) production function. In the first stage, the firm combines capital and energy, which is then combined with labour, and, finally, with materials (intermediate use). Materials are composed of the products of all sectors, which are further disaggregated into imported and domestically produced materials. The output of each sector can be used by the household and government for consumption, invested or put to intermediate use by firms, or exported. The parameters controlling the shares of each flow in the production and use structure are set according to the data in the IO matrix.

Figure 4. Firm production structure.



Source: Own elaboration.

Table 1. Sector aggregation from NACE and input for microsimulation model for reference scenario for 2025 (in %).

	NACE	employment	wage	price	volume
AGR	A	0.0	-1.5	0.0	-0.7
MIN	B	-7.1	-2.1	-	-
MIN-coal	B05	-	-	25.4	-3.5
MIN-oil	B06	-	-	-0.4	0.0
MIN-gas	B06	-	-	32.0	-4.4
LIND	C10-16	0.0	-1.5	-0.2	-0.7
EIIND	C17-18,20-24	-0.5	-1.5	0.3	-0.7
AIND	C25-C33	0.0	-1.5	-0.3	-0.7
RPP	C19	-0.5	-2.1	4.4	0.0
ENE	D-E	0.0	-0.2	6.7	-0.7
CON	F	-0.9	-1.6	-0.5	-0.7
TRA	H	-0.1	-1.5	0.4	-0.7
PRV	G,I-N,R-U	0.0	-1.5	-0.4	-0.7
PBL	O-Q	0.6	-1.4	-0.7	-0.7

Note: Sectors are as follows: AGR - agriculture, MIN: mining, LIND: light industry, EIIND: energy intensive industry, AIND: advanced industry, RPP: refined petroleum product industry, ENE: electricity generation, CON: construction, TRA: transport, PRV: market services, PBL: public services.

When defining the aggregation of NACE Rev. 2 sectors into those used in MEMO, we pay particular attention to distinguishing between sectors related to the energy system. We identify 11 sectors, as well as three types of fossil fuel products. The sectors are agriculture, mining (which distinguishes between specific fossil fuel products), light industry, energy-intensive industry, advanced industry, coke and refined petroleum products, electricity generation (separated into renewable and fossil fuel generation), construction, transport, market services, and non-market services. Emissions are modelled as linear functions of the intermediate use of fossil fuel products: coal, oil, gas, and refined petroleum products. The specifications of the sector aggregation are shown in Table 1 under the column *NACE*. Further details of MEMO, such as equations and calibration procedures, can be found in the technical research report by Antosiewicz and Kowal (2016a).

The following results of the MEMO model, expressed as percent deviations from the no-intervention scenario, are used as inputs in the microsimulation model:

- employment in sectors
- wages in sectors
- price of sector goods / products
- volume of household purchases of sector goods / products

The output for MEMO for one of the simulations (reference lump sum simulation for the year 2025) considered in our study is shown in Table 1.

3.2 Microsimulation model

The microsimulation model is responsible for translating the sector output of the macroeconomic model into changes in the distribution of household income. It is based on the household budget survey data (HBS) described in section 3.4.

The microsimulation consists of calculating the change in the equivalised income of households resulting from changes in the labour income, and in expenditures on energy and other goods and services. In particular, a single run of the microsimulation model consists of the following steps:

1. Start with the pre-processed household and individual database.
2. Update the labour income of individuals according to the output of the macroeconomic model. We assume that the labour income of all individuals employed in a given sector changes by the same percentage deviation implied by the macroeconomic model.
3. Simulate shifts from employment to unemployment. In sectors for which the macroeconomic model predicts an employment decline, we randomly sample individuals who lose their jobs, change their status to unemployed, and assign them a labour income equal to zero.
4. Simulate shifts from unemployment to employment. In sectors for which the macroeconomic model predicts an employment increase, we sample individuals whose status is unemployed, and assign them to work in these sectors. We sample unemployed individuals in a directed way, using their position in the income distribution calculated on the basis of the HBS data. We randomly sample an equal number of job seekers from each income decile and assign them wages in the respective decile of wages in a given sector. This mechanism prohibits individuals from the bottom of the income distribution from obtaining a wage from the top of the wage distribution, which ensures consistency with the matching patterns commonly observed in labour markets (Postel-Vinay, Robin 2002). We refer to changes in labour income as the employment effect.
5. Simulate changes in the expenditures on energy goods resulting from price changes. We refer to these changes as the direct price effect.
6. Simulate changes in the expenditures on energy goods resulting from changes in the amount of goods purchased. We refer to these changes as the direct behavioural effect.
7. Simulate changes in the expenditures on goods and services from other sectors resulting from price changes. We refer to these changes as the indirect price effect.
8. Simulate changes in the expenditures on goods and services from other sectors resulting from changes in the amount of goods purchased. We refer to these changes as the indirect behavioural effect.
9. Each individual receives an equal lump-sum transfer from the carbon tax revenue.
10. Repeat the above steps $N = 100$ times.

We repeat the above steps N times. The simulation procedure is stochastic because of the sampling of new wages and of individuals who change their labour market status. For each of $N = 100$ simulations, we calculate the changes in equivalised household income by decile, and the contributions of each particular channel. Finally, we take the averages of the results across simulations and present them.[5] All results are scaled using the weights of households provided in the survey data.

3.3 Policy scenarios

Here, we describe the macro- and microeconomic assumptions that underlie the three alternative scenarios of carbon taxation and recycling of revenue that we consider. In all of the scenarios, we assume that by 2050 emissions will be 95% lower than in 2020, with the target reduction increasing linearly over time. This process results in emissions reductions of 13% in 2025 and 28% in 2030. For each scenario, we use the results from MEMO for 2025 and 2030. Thus, we simulate the distributional effects of the carbon tax 5 and 10 years after its introduction.

Table 2. CO2 emissions reduction and the required carbon tax level.

	2025			2030		
	lump-sum	price subsidy	double div.	lump-sum	price subsidy	double div.
CO2 reduction in %	13.2	13.2	13.2	28.2	28.2	28.2
CO2 tax	29.0	29.0	29.6	80.3	80.3	82.5
CO2 tax	124	124	128	345	345	353

Source: Own calculations based on the DSGE model.

We consider three scenarios that differ with respect to how the carbon tax revenue is being spent. In each scenario, the carbon tax rate is calculated endogenously to meet the emissions target (Table 2). The scenarios are as follows:

- The lump-sum (reference) scenario. The revenue from the carbon tax is distributed as a lump-sum transfer to each individual. The tax is at the level of 124 PLN (29 EUR) in 2025 and 345 PLN (80 EUR) in 2030. The transfer amount is 31.4 PLN and 53.9 PLN per person in 2025 and 2030, respectively.
- The price subsidy scenario. The revenue from the carbon tax is used to subsidise the increases in the prices of energy and fuels for households. The carbon tax rate is the same as it is in the lump-sum scenario. The remaining part of revenue, equal to 10.6 PLN for both 2025 and 2030, is distributed as an equal lump-sum transfer to household members. Because of the price subsidy, the prices of energy and fuels faced by households in this scenario are essentially the same as they are in the baseline scenario with no carbon tax.
- The double dividend scenario. The revenue from the carbon tax is used to reduce the labour tax. As a lower labour tax increases the supply of labour, which is endogenous in our model, it increases GDP. As a result, the level of carbon tax required to achieve the same reduction in emissions is higher (by 4-8 PLN). As in the price subsidy scenario, the revenues that are not spent on the reduction of labour taxation are distributed as a lump-sum transfer.

[5] The average across simulations is equivalent to the median because the distribution of simulation results is symmetric. Complete distributions of the simulation results are available upon request.

Table 3. Basic household statistics by income decile.

decile	1	2	3	4	5	6	7	8	9	10
mean size	2.69	2.71	2.81	2.83	2.82	2.89	2.91	2.84	2.76	2.75
labour income PLN	233	400	561	699	901	1076	1311	1642	2202	3907
all income PLN	781	1240	1520	1735	1944	2170	2438	2774	3340	5454
labour income share %	30	32	37	40	46	50	54	59	66	72
employed %	27	26	30	33	37	40	44	49	55	59
unemployed %	14	8	5	5	3	2	2	1	1	1
pensioners %	19	26	26	26	25	25	24	22	17	10
students %	11	10	9	9	9	7	6	6	5	5
employed in mining %	0.5	0.9	1.0	1.7	1.5	1.8	1.6	1.7	1.9	1.6

Note: Unemployment share counted as share of total population of given decile, not as share of active on the labour market. Pensioners include those who are retired and those who receive some form of disability benefits. Employed in mining is the share of those employed in this sector out of all persons employed. Source: Own calculations based on household budget survey data.

3.4 Household budget survey data

Here we describe the household budget survey (HBS) data, collected by Statistics Poland, which form the basis of our microsimulation model. We use the 2016 HBS data, which contain information on a sample of 36,886 households. Each household is surveyed for a full month, and discloses detailed information on the incomes, expenditures, and various socio-economic characteristics of its members. The HBS is composed of the following datasets: a) general household statistics, b) household expenditures by type of goods in the given month (2.6 million observations), c) individual household member statistics (99,230 observations), and d) individual incomes by type in the given month (131,947 observations).

Defining individual labour income, labour market status, and household income are key operations we perform on the HBS data in order to build the microsimulation model. For each person, we aggregate their labour income, defined as the sum of income from all forms of dependent employment and self-employment. For each household, we aggregate the labour income of its members, and its expenditures on categories of goods consistent with the sector classification used in the macroeconomic model.

To define household income, we use the variable prepared by the Statistics Poland (*DOCH*), which encompasses all types of household income, including labour, pensions, benefits, financial, capital, and transfers. We equivalise household income using the current OECD scales.[6] Next, we define the position of each household in the income distribution by assigning its decile of the equivalised income distribution. For the employed household members, we additionally define the sector they work in and calculate their position (decile) in the sector-specific wage distribution.

Next, we outline the key differences between households positioned across the equivalised household distribution in Poland. The share of labour income in total household income is larger for households with higher total income: it ranges from 30% among the poorest households to 72% among the households in the top income decile (Table 3). The share of labour income among the poorer households is smaller because a larger share of the people in these households are unemployed, students, or individuals whose main sources of income are pensions or benefits. Importantly, the share of people who are employed in mining is noticeably larger among households with equivalised income above the median, and especially in the top 30%, than it is among households with below-median income.

[6] We assign a weight equal to one to the first household member, 0.5 to each additional member aged 14 or older, and 0.3 to each additional member aged 13 or younger.

Table 4. Wages in microsimulation model based on household budget survey data and rescaled wages for macroeconomic MEMO model.

	AGR	MIN	LIND	EIIND	AIND	RPP	ENE	CON	TRA	PRV	PBL	mean
HBS	247	3347	1935	2414	2416	4203	3282	2117	2611	2477	2649	2169
MEMO	542	2669	1846	2393	2307	5216	3605	2390	2603	2423	2330	2169

Note: Sectors are as follows: AGR - agriculture, MIN: mining, LIND: light industry, EIIND: energy intensive industry, AIND: advanced industry, RPP: refined petroleum product industry, ENE: electricity generation, CON: construction, TRA: transport, PRV: market services, PBL: public services.
Source: Own calculations based on household budget survey data for microsimulation model and on Eurostat data for macroecconomic MEMO model.

Finally, we provide evidence that the sectoral wage levels in the macroeconomic and microsimulation models are consistent with each other, which is critical for the soft-linking of models.[7] The sectors with above-mean wages are the same for both models, with the exception of the construction sector, and the mean income in the mining sector is one of the highest in both models (Table 4).

4 Results and discussion

In the first subsection, we discuss the macroeconomic effects of introducing a carbon tax in Poland; and in the second subsection, we present the distributional effects.

4.1 The aggregate effects of carbon tax

The macroeconomic effects of introducing a carbon tax differ depending on how the revenue is used, because the economic incentives created by different revenue recycling schemes.[8] In each scenario, GDP, investment, and consumption are lower than they are in the baseline scenario of no carbon tax (Table 5). However, the decline is smaller in the double dividend scenario (0.4% in 2025 and 0.9% in 2030) than in the lump-sum and price subsidy scenario (0.6% in 2025 and 1.4-1.5% in 2030). In the double dividend scenario, the reduction in the labour tax raises the supply of labour, which, in turn, increases the marginal productivity of capital and leads to higher levels of employment and investment than in the other two scenarios. As a consequence, labour income (after tax) is noticeably higher in the double dividend scenario than it is in the lump-sum and price subsidy scenarios (see Table 2). Moreover, employment and labour income in the double dividend scenario are even slightly higher than they are in the baseline scenario of no carbon tax. At the same time, the carbon tax rate necessary to achieve the targeted GHG reduction is higher in the double dividend scenario than it is in the lump-sum and price subsidy scenarios, because levels of economic activity and private benefits from GHG emissions are higher in the double dividend scenario.

If the carbon tax revenue is used to subsidise the energy consumption of households (compensating for the increase in energy prices due to the carbon tax), its distortionary effects on firms are the strongest. Thus, the declines in GDP, investment, and employment are largest in this scenario (Table 5). In comparison to the lump-sum scenario, the price subsidy scenario increases the consumption of fuels and decreases the consumption of other goods. Moreover, higher demand for energy and fuels increases the market (pre-subsidised) prices of those goods, and thus increases the costs of production for firms (which do not

[7] We rescale the labour income from the macroeconomic model to the mean obtained from the HBS.
[8] In each scenario, we assume the same path of GHG emission reductions – i.e., a 13% reduction by 2025 and a 28% reduction by 2030 – which is consistent with a 95% reduction in GHG emissions by 2050 (relative to 2020).

Table 5. Effects of carbon tax on selected macroeconomic variables in 2025 and 2030 for three recycling scenarios - deviations from the baseline (no carbon tax), in %.

	2025			2030		
	lump-sum	price subsidy	double div.	lump-sum	price subsidy	double div.
GDP	-0.6	-0.6	-0.4	-1.4	-1.5	-0.9
Investment	-2.0	-2.3	-1.4	-3.7	-4.2	-2.5
Employment	-0.2	-0.2	0.3	-0.4	-0.4	0.5
Consumption	-0.8	-0.7	-0.5	-2.1	-2.0	-1.3
Labour income after tax	-1.6	-1.7	2.4	-3.7	-3.9	4.6
Price of energy	7.52	7.54	7.70	15.70	15.72	16.10

Source: Own calculations based on the DSGE model.

receive any subsidies). As a result, demand, investment, and output decline more in the price subsidy than they do in the lump-sum scenario. However, the differences with respect to the lump-sum scenario are minuscule, at least in the 10-year horizon that we study (1.5% vs. 1.4% decline in GDP by 2030).

4.2 The effects of carbon tax on various income groups and inequality

Next, we discuss the effects of a carbon tax on household incomes, distinguishing between 10 groups based on the deciles of equivalised household income, and on overall income inequality, as measured by the Gini coefficient and the ratio between the ninth and the first decile of the income distribution (D9/D1 ratio).

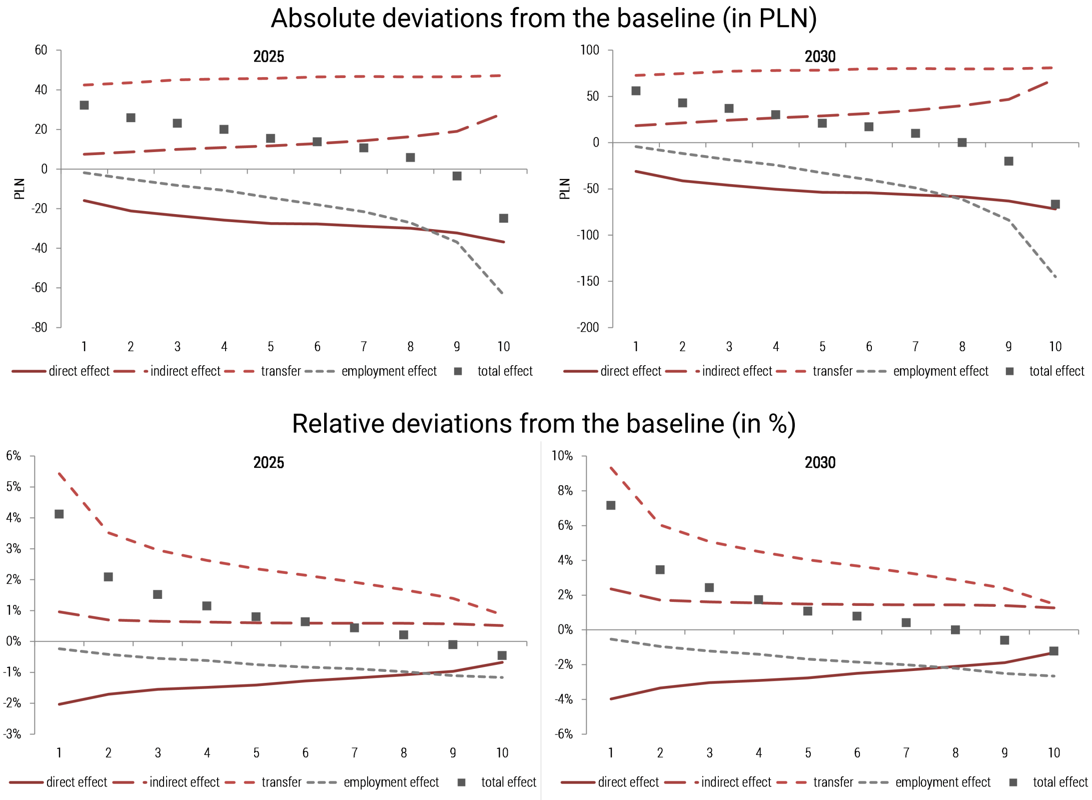
Table 6. Results for selected inequality statistics for scenarios.

		2025			2030		
	data	lump-sum	price subsidy	double div.	lump-sum	price subsidy	double div.
Gini coeff.	27.92	27.51	27.62	28.18	27.24	27.44	28.60
D9/D1 ratio	3.36	3.29	3.31	3.43	3.25	3.28	3.50

Source: Own calculations based on the DSGE model and the Polish HBS data.

We find that the overall distributional effect of a carbon tax is largely driven by how the revenue is spent: distributing the revenues from the carbon tax as lump-sum transfers to households reduces income inequality, while spending the revenues on a reduction of labour taxation increases inequality. In the lump-sum transfer scenario, the total income of households with (initially) below-median incomes increases in comparison to the baseline, because the gains from the lump-sum transfer more than compensate for the losses resulting from the higher prices of energy and other goods (Figure 5). In the double dividend scenario, the income gains from higher employment and lower labour taxation are larger for higher decile groups, which means that inequality widens. In the price subsidy scenario, inequality shrinks, but to a much lesser extent than in it does in the lump-sum scenario (Table 6).

Figure 5. The effects of the lump-sum transfer scenario of carbon tax introduction on income by decile income groups in Poland, in absolute (top panel) and relative (bottom panel) terms.



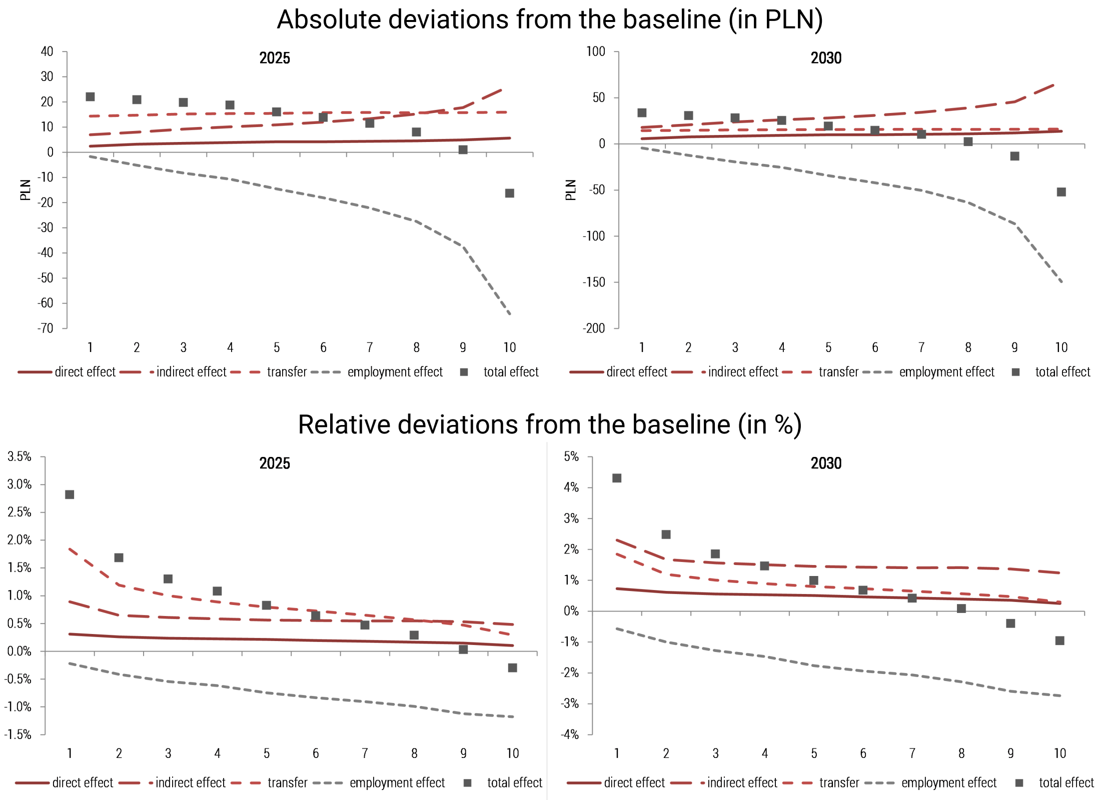
Source: Own simulations based on the DSGE model and the Polish HBS data.

In the lump-sum scenario, the direct effects of a carbon tax are clearly regressive in relative terms. Among the poorest 20% of households, the direct effect amounts to a 1.9% income loss in 2025 and a 3.7% income loss in 2030. Among the richest 20% of households, the effects are about half as large. In absolute terms, the higher-income households are affected to a greater extent because their energy consumption is higher. At the same time, the indirect effects are positive. This means, however, that households reduce consumption of goods other than energy in order to compensate for the higher costs of energy goods. Although in absolute terms the size of this effect increases with income, in relative terms it decreases with income. Importantly, the total effect related to price changes is clearly regressive: among the poorest 20% of households, these effects amount to an income loss of about 1.0% in 2025 and of 1.6% in 2030; while among the richest 10% of households, the direct and indirect effects almost cancel each other out (Figure 5).

In the lump-sum scenario, the employment effect reduces incomes across the income distribution. However, it affects the richer households to a greater extent in both absolute and relative terms. This outcome is attributable to two labour market features. First, carbon-intensive sectors, such as energy, mining, and manufacturing, in which labour demand tends to decrease after the introduction of a carbon tax, offer higher wages than sectors that are more resilient to the introduction of a carbon tax, such as public services, hospitality, and retail. Second, the poorest households are more likely to be jobless and to live off of pensions and other benefits (which we assume are unaffected by the carbon tax). As a result, among the bottom 20% of households, the income decline driven by the employment effect is only 0.3% in 2025 and 0.7% in 2030. The respective figures for the top 20% of households are 1.1% in 2025 and 2.5% in 2030. Overall, the market mechanisms (direct and indirect consumption effects and the employment effect) reduce the disposable income of all of the household income groups, but to the greatest extent among households that have above-median incomes, but that do not belong to the top 10%.

Importantly, if the revenue is distributed as a lump-sum transfer, 80% of households benefit from higher incomes, and only the households in the top 20% record an income decline. The overall impact of the carbon tax is to reduce inequality: the Gini coefficient, as well as the D9/D1 ratio, are lower than they are in the baseline scenario of no carbon tax (Table 6).

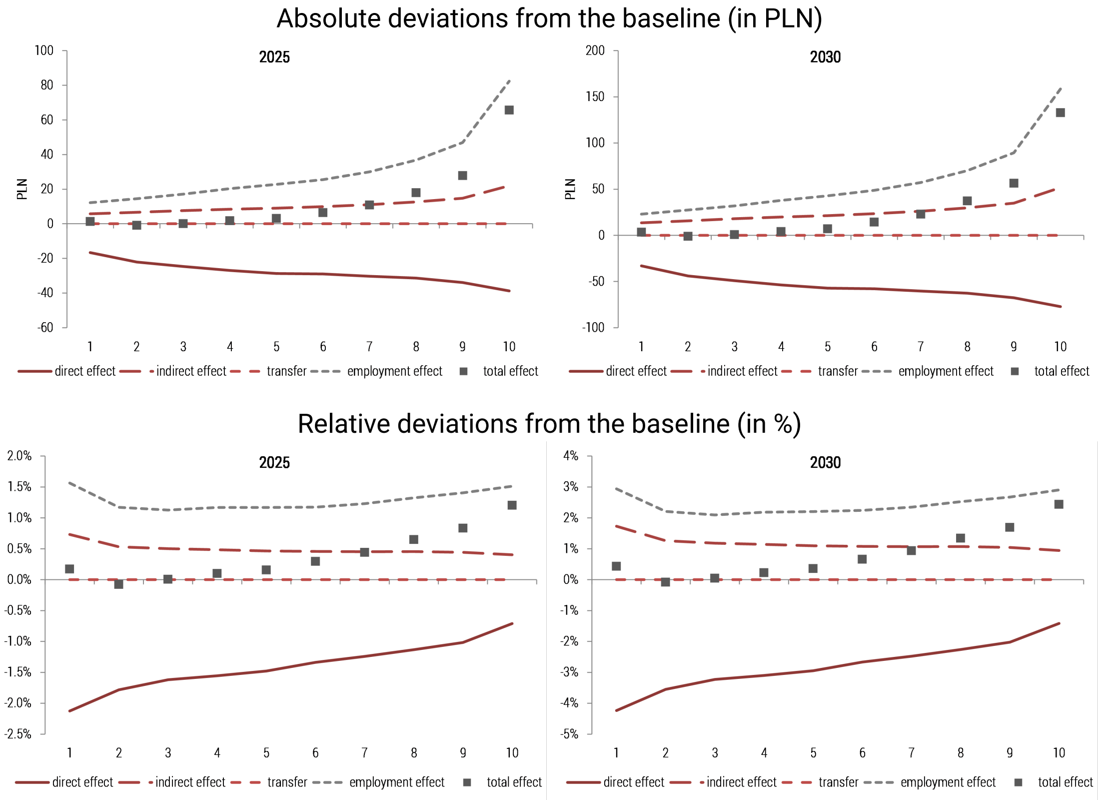
Figure 6. The effects of the price subsidy scenario of carbon tax introduction on income by decile income groups in Poland, in absolute (top panel) and relative (bottom panel) terms.



Source: Own simulations based on the DSGE model and the Polish HBS data.

In the price subsidy scenario, the revenue from the carbon tax is first distributed according to the household spending on energy goods, and the remaining funds are distributed as a lump-sum transfer. Thus, the direct price effect is close to zero (Figure 6). The direct effect comes only from the reduction in consumption of energy and fuels, and is small (from 0.1% among the top 10% of households to 0.3% among the bottom 10% of households). As the energy and fuel prices paid by firms are not subsidised, the changes in the prices of other goods and the indirect effect are virtually the same in this scenario as they are in the lump-sum scenario. The lump-sum transfers are positive, but are substantially lower than they are in the lump-sum scenario because 66% and 80% of the carbon tax revenues are spent on price subsidies in 2025 and 2030, respectively. As a consequence, the lump-sum transfers play a much smaller role in the final outcome. The incomes of the below-median households increase more than in the reference scenario, but less than in the lump-sum scenario. The difference is the most pronounced for the first decile. At the same time, the incomes of the above-median households are higher in this scenario than they are in the lump-sum scenario, as these households benefit more from energy price subsidies than the below-median households. The overall level of income inequality is lower in this scenario than it is in the baseline scenario (no carbon tax), but is higher than it is in the lump-sum scenario (Table 6).

Figure 7. The effects of the double-dividend scenario of carbon tax introduction on income by decile income groups in Poland, in absolute (top panel) and relative (bottom panel) terms.



Source: Own simulations based on the DSGE model and the Polish HBS data.

In the double dividend scenario, the revenue from the carbon tax is used to finance a reduction of the labour (payroll) tax. As there is no price subsidy in this scenario, the direct and indirect effects are virtually identical to those in the lump-sum scenario. They are marginally lower (by 0.2 pp. on average) because using the revenue from the carbon tax on an equivalent reduction in the labour (payroll) tax leads to higher GDP, and, in turn, to higher disposable incomes than in the lump-sum scenario. However, the main difference between these scenarios is in the employment effect (Figure 7). A lower payroll tax tends to increase employment, and the resulting gain in labour income rises in line with the household's position in the income distribution (especially in absolute terms). As a result, the incomes of households that had below-median incomes before the introduction of the carbon tax remain virtually the same as in the baseline scenario of no carbon tax. However, the incomes of households that had above-median incomes increase in comparison to the baseline scenario. Moreover, the size of this income gain increases with income in both absolute and relative terms. Thus, compared to the other scenarios, the double dividend scenario is characterised by the highest GDP and employment levels, but also by the highest income inequality levels (Table 6).

5 Conclusions

In this paper, we have studied the macroeconomic and distributional effects of the introduction of a carbon tax in a carbon-intensive economy, using the example of Poland. In our analysis, we used a macroeconomic model soft-linked with a microsimulation model. We gauged the roles of three key channels: price, behavioural, and employment effects. Our key contribution was the development of a framework to quantify the employment effects. We have shown that the employment channel is qualitatively different from the price and behavioural channels, and that it is quantitatively relevant.

Specifically, we found that the distributional effect of a carbon tax is largely dependent on the how the revenue is spent. Transferring revenue to households as lump-sum transfers reduces income inequality and increases the incomes of households that initially had incomes below the median. This is because the lump-sum transfers received by these households more than compensate for the higher energy costs they face. However, spending the revenue on reducing labour taxation (double dividend) increases income inequality; i.e., it increases employment, which, in turn, mainly benefits households that initially had relatively high incomes. At the same time, we found that GDP and employment levels are higher if the carbon tax revenue is used to reduce labour taxation than if it used to finance lump-sum transfers or energy price subsidies. Therefore, our framework allowed us to assess the equity vs. efficiency trade-offs in climate policy, which was the second key contribution we intended to make. Our models have been calibrated for Poland, but our results could be relevant for other coal-producing countries, such as South Africa, Germany, or Australia.

Our findings have important policy implications. First, they suggest that lump-sum transfers should be preferred over energy price subsidies, as the former lead to superior outcomes: i.e., to higher levels of GDP and employment and to lower levels of inequality. Second, our results indicate that the reduction of labour taxation cushions the negative macroeconomic consequences of a carbon tax, but leads to notable increases income inequality. Hence, a reduction of labour taxation should be combined with tax and benefit policies aimed at helping the losers of such a measure.

Our study has limitations. We did not study social transfers targeted to specific sub-populations, which may be considered by governments with a high institutional capacity to identify groups in need and to target social policies to them. Moreover, we did not account for regional disparities. It is possible that the job and income losses resulting from the introduction of a carbon tax would be geographically concentrated in different regions than employment and income gains. Finally, we did not study how externalities from carbon tax, such as lower congestion or pollution levels, would benefit different income groups, and whether these outcomes would magnify or attenuate the distributional effects pertaining to income. Studying these more nuanced distributional effects could be an avenue for further research.

References

[1] Alton, T., Arndt, C., Davies, R., Hartley, F., Makrelov, K., Thurlow, J., and Ubogu, D. (2014). Introducing carbon taxes in South Africa. *Applied Energy, 116*, 344-354.

[2] Antosiewicz, M., and Kowal, P. (2016a). MEMO III - A large scale multi-sector DSGE model. IBS Research Report 02/2016. Available online: http://ibs.org.pl/en/publications/memo-iii-a-large-scale-dsge-model/

[3] Antosiewicz, Marek, Piotr Lewandowski and Jan Witajewski-Baltvilks (2016b). "Input vs. Output Taxation—A DSGE Approach to Modelling Resource Decoupling," Sustainability, MDPI, Open Access Journal, vol. 8(4), pages 1-17, April.

[4] Brzezinski, M. (2017) Is High Inequality an Issue in Poland? IBS Policy Paper No. 01/2017.

[5] Bukowski P., Novokmet F. (2017) Top Incomes during Wars, Communism and Capitalism: Poland 1892-2015, SE International Inequalities Institute Working Paper 17

[6] Buchs, M., Bardsley, N., and Duwe, S. (2011). Who bears the brunt? Distributional effects of climate change mitigation policies. *Critical Social Policy, 31*(2), 285-307.

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

[8] Callan, T., Lyons, S., Scott, S., Tol, R. S., and Verde, S. (2009). The distributional implications of a carbon tax in Ireland. *Energy Policy, 37*(2), 407-412.

[9] Energy Policy of Poland. 2019. Ministry of Energy. Available online at https://www.gov.pl/web/aktywa-panstwowe/polityka-energetyczna-polski-do-2040-r-zapraszamy-do-konsultacji1 (accessed on 7th March 2020)

[10] Fæhn, Taran, Gómez-Plana, Antonio G. and Kverndokk, Snorre, 2009. "Can a carbon permit system reduce Spanish unemployment?," Energy Economics, Elsevier, vol. 31(4), pages 595-604, July.

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

[12] da Silva Freitas, L. F., de Santana Ribeiro, L. C., de Souza, K. B., and Hewings, G. J. D. (2016). The distributional effects of emissions taxation in Brazil and their implications for climate policy. *Energy Economics, 59*, 37-44.

[13] Goraus, K.M., Inchauste, M.G. (2016). The Distributional Impact of Taxes and Transfers in Poland. Policy Research working paper; no. WPS 7787. Washington, D.C.: World Bank Group.

[14] IPCC. (2018). Global Warming of 1.5C. An IPCC Special Report on the Impacts of Global Warming of 1.5C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Edited by V. Masson-Delmotte, P. Zhai, H. Portner, D. Roberts, J. Skea, P. Shukla, A. Pirani, et al. in press.

[15] Jiang, Z., and Shao, S. (2014). Distributional effects of a carbon tax on Chinese households: A case of Shanghai. *Energy Policy, 73*, 269-277.

[16] Johnstone, N., and Serret, Y. (2006). 1. Distributional effects of environmental policy: introduction. *The distributional effects of environmental policy, 614*, 1.

[17] Goulder, L. H., and Schein, A. R. (2013). Carbon taxes versus cap and trade: a critical review. *Climate Change Economics, 4*(03), 1350010.

[18] Goulder, L. H., Hafstead, M. A., Kim, G., and 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.

[19] Hamilton, K., and Cameron, G. (1994). Simulating the distributional effects of a Canadian carbon tax. *Canadian Public Policy / Analyse de Politiques*, 385-399.

[20] Kiewra, D., Szpor A., Witajewski-Baltvilks J. (2019) Sprawiedliwa transformacja węglowa w regionie śląskim. Implikacje dla rynku pracy, IBS Research Report 02/2019, May 2019.

[21] Labandeira, X., and Labeaga, J. (1999). Combining input-output analysis and micro-simulation to assess the effects of carbon taxation on Spanish households. *Fiscal studies, 20*(3), 305-320.

[22] Lewandowski P., Magda I., 2018, The labor market in Poland, 2000-2016. IZA World of Labor 2018: 426 doi: 10.15185/izawol.426

[23] Liang, Q. M., and Wei, Y. M. (2012). Distributional impacts of taxing carbon in China: results from the CEEPA model. *Applied Energy, 92*, 545-551.

[24] Myck M., Najsztub, M. (2016). Distributional Consequences of Tax and Benefit Policies in Poland: 2005–2014. CenEA Working Paper Series WP02/16.

[25] Sokołowski J., Lewandowski P., Kiełczewska A., Bouzarovski S.,(2020), A multidimensional index to measure energy poverty: the Polish case, Energy Sources, Part B: Economics, Planning, and Policy, 1-21

[26] Sovacool, B. K., Ryan, S. E., Stern, P. C., Janda, K., Rochlin, G., Spreng, D., ... and Lutzenhiser, L. (2015). Integrating social science in energy research. *Energy research & social science*, 6, 95-99.

[27] Takeda, S. (2007), The double dividend from carbon regulations in Japan, The Japanese and International Economies, 21, 336–364

[28] Van Heerden, J., Gerlagh, R., Blignaut, J., Horridge, M., Hess, S., Mabugu, R., and Mabugu, M. (2006). Searching for Triple Dividends in South Africa: Fighting CO2 pollution and poverty while promoting growth. The Energy Journal, 113-141.

[29] Witajewski-Baltvilks, J.I., Lewandowski, P., Szpor, A., Baran, J., Antosiewicz, M. 2018. Managing coal sector transition under the ambitious emission reduction scenario in Poland. Focus on labour, IBS Research Reports 04/2018, Instytut Badan Strukturalnych.

[30] Żuk, P., and Szulecki, K. (2020). Unpacking the right-populist threat to climate action: Poland's pro-governmental media on energy transition and climate change. *Energy research & social science*, 66, 101485.