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Abstract. In 2021, Germany launched a national emissions trading system (ETS) in its road transport and housing sectors that increases the cost burden of consumers of fossil fuels, the major source of carbon dioxide (CO2) emissions. A promising approach to secure public acceptance for such a carbon pricing would be to entirely reallocate the resulting "carbon" revenues to consumers. This article discusses three alternatives that were discussed in the political arena prior to the introduction of the national carbon pricing: a) a per-capita reallocation to private households, b) the reduction of electricity prices by, e.g., decreasing the electricity tax, as well as c) targeted financial aid for vulnerable consumers, such as increasing housing benefits. To estimate both the revenues originating from carbon pricing and the resulting emission savings, we employ a partial equilibrium approach that is based on price elasticity estimates on individual fossil fuel consumption from the empirical literature. Most effective with respect to alleviating the burden of poor households would be increasing housing benefits. While this measure would not require large monetary resources, we argue that the remaining revenues should be preferably employed to reduce Germany's electricity tax, which becomes more and more obsolete given the steadily increasing amount of electricity generated by renewable energy technologies.

Keywords: Electricity tax, housing benefits, distributional effects.

JEL classification: D12, Q21.

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1. Introduction

Between 1990 and 2018, Germany's greenhouse gas (GHG) emissions shrank by 30.8% (UBA 2019a). Both the energy and the industry sector contributed to this reduction. Being integrated in the European Union's (EU) emissions trading system (ETS), these sectors reduced their emissions by 33.3% and 31.0%, respectively. By contrast, the emissions of the road transport sector, which is not part of the EU ETS, stagnated since 1990: According to Germany's Environmental Protection Agency (UBA 2019a), in 2018, this sector's GHG emissions were still at the level of 1990.

Against this background, Germany launched a national ETS in its road transport and housing sectors in 2021, thereby introducing a "carbon" price on the emission of carbon dioxide (CO2). Yet, contrary to the EU ETS, where prices for emission certificates can vary freely, in this separate ETS, the prices for CO2 allowances will be fixed in the first five years, that is from 2021 to 2025, starting with a carbon price of 25 euros per ton of CO2 that is stipulated to increase to 55 euros in 2025. For the years 2022 to 2024, CO2 prices are fixed to amount to 30, 40 and 45 euros, respectively. Only as of 2026 will emission allowances be auctioned for the first time.

As becomes evident from this carbon price path, the purpose of this climate policy instrument is to raise the cost burden of consumers of fossil fuels, such as natural gas and road fuels, thereby bearing the risk of inciting social unrest and protests when CO2 prices are increased to high levels – see also the protests of the Yellow Vests against increasing the French carbon tax (Douenne, 2020:231). To sustain the currently high acceptance for carbon pricing in Germany, which may easily erode when CO2 prices are skyrocketing, a promising approach would be to entirely reallocate the resulting revenues to consumers.

With a particular focus on measures to reduce the exceptionally high tax and duty burden of German electricity prices[1], which may help to increase the use of "green" electricity from renewable technologies in Non-ETS sectors ("sector coupling"), this article discusses three alternatives to reallocate the "carbon" revenues originating from carbon pricing that were discussed in the political arena prior to the introduction of the national carbon pricing: a) a lump-sum per-capita reallocation of the revenues to private households, b) the reduction of electricity prices by decreasing the electricity tax to the EU minimum tax rates, and c) targeted financial aid for strongly burdened consumers, for example by increasing the housing benefits of poor households.

[1] Note that apart from Danish households, with a price per kilowatt-hour of more than 30 cents, household electricity prices in Germany are the highest within the European Union (Frondel, Kussel, Sommer, 2019), more than half of this price being to due to taxes and surcharges, such as the levy with which the expansion of renewable energy technologies is financed.

Employing a straightforward partial equilibrium approach that is based on price elasticity estimates of individual fossil fuel consumption in the transport and housing sector from the empirical literature (see e. g. Frondel, Vance 2014, 2018), for both private households and the sector Commerce, Trade and Services (CTS), we estimate potential emission savings, as well as the revenues originating from a carbon pricing of three price levels: 25, 45 and 65 euros per ton. 25 euros corresponds to the fixed CO2 price that is stipulated for the starting year 2021 of the national ETS. 45 euros is the fixed carbon price that is stipulated for 2024 and the price of 65 euros per ton reflects the upper limit of the price corridor that is foreseen for 2026 when emission allowances are auctioned for the first time in this separate ETS for Germany. For comparative purposes, note that the CO2 price in the EU ETS currently amounts to around 50 euros per ton.

Carbon pricing burdens poor households more than wealthy households, as poor households generally spend a larger share of their income to cover their energy needs (e.g. Grainger, Kolstad, 2010). To exemplify, rather than comprehensively quantify, the distributional effects of carbon pricing, we illustrate some extreme cases by including three types of households that are particularly threatened by poverty and are very common in German society in terms of their large number (BMAS 2017):

- Poor single-pensioner households that are not eligible for housing benefits, nor any other transfers,
- single-person households that are eligible for social benefits and
- three-person households that are at risk of poverty.

Based on empirical data on the energy consumption of private households originating from the German Residential Energy Consumption Survey (GRECS, http://www.rwi-essen.de/GRECS/), we gauge the fuel cost increases of these three types of households due to carbon pricing. Furthermore, assuming that only the revenues originating from the carbon pricing of the fossil fuel consumption of private households, not those from other sectors, will be reimbursed to private households, we estimate the levels of per-capita reimbursements for these household types. On the basis of both estimates on the fuel cost increases and the per-capita reimbursements, we then calculate the net burden of these three household types due to Germany's carbon pricing.

While we do not present a complete and comprehensive analysis of the distributive impacts of the considered revenue recycling alternatives on German households, our focus is on the growing burden of some types of households that are particularly threatened by poverty (see the Poverty and Wealth Report, BMAS 2017) even without any carbon pricing. In the absence of any revenue reallocation that adequately mitigates the burden of these types of households from carbon pricing, the acceptance of this climate policy instrument may suffer heavily. This is all the more relevant as there are several millions of such types of households in Germany (BMAS 2017). For instance, the number of single-person households that receive social benefits amounted to about 1.63 million in 2019.

In the subsequent section, we present a literature review on the distributional effects of carbon pricing and potential alternatives to reallocate the resulting revenues. In Section 3, we briefly sketch the methodology employed and derive the surcharges on the prices of fossil fuels that result from establishing a national ETS in Germany's transport and housing sectors, as well as the revenues and emissions reductions that may be realized by this kind of carbon pricing. Section 4 exemplifies the distributional effects of carbon pricing on three types of poor households. Section 5 discusses reimbursement mechanisms, while the last section summarizes and draws conclusions.

2. Literature Review

Generally, to reduce greenhouse gas emissions, economists prefer price mechanisms, such as taxes and emissions trading systems (ETS), as the most efficient policy instrument (see e.g. Nordhaus, 1992; Mankiw, 2009; Metcalf, 2009). Actually, many countries have introduced a price on the emissions of carbon dioxide (CO2) and have established a carbon pricing system, either via a carbon tax on the consumption of fossil fuels or an ETS or a combination thereof, with Germany being a late adopter of a national carbon pricing system. However, while being widely accepted as a cost-efficient instrument, carbon pricing has critical distributional effects in that it necessarily increases the cost burden for fossil fuel consumers, which is well-known to have a disproportionately negative effect on low-income households.

In this respect, numerous empirical studies based on consumer expenditure data from both the US and European countries indicate that energy and carbon taxes have a regressive impact, that is, poor households devote a greater share of their income to purchases of fossil fuels than more affluent households – see e.g. Grainger and Kolstad (2010). Particularly those studies that focus on consumption patterns and the short-term direct costs borne by different income groups find a pronounced regressivity of carbon taxes (see e.g. Callan et al., 2009; Grainger and Kolstad, 2010; Mathur and Morris, 2014; Klenert and Mattauch, 2016; Berry, 2019). Grainger and Kolstad (2010), for instance, illustrate for the US that the main drivers behind regressivity are subsistence levels for energy-intensive goods. Using a microsimulation model, Berry (2019) demonstrates for France that a carbon tax for housing and transport is regressive and increases fuel poverty, since households may have limited possibilities to adjust their energy consumption.

Beyond studies that focus on the distinct regressive effects of carbon pricing across income groups and, hence, raise vertical equity concerns, there is a growing literature that stresses the importance of horizontal distributive effects, that is, disproportionate effects of carbon pricing within income groups (see e.g. Rausch et al., 2011; Farrell, 2017; Fischer, Pizer, 2019; Pizer, Sexton, 2019; Cronin et al., 2019; Douenne, 2020). The results of these studies suggest that horizontal distributive effects can be of much higher magnitude than the vertical effects across income groups. Estimating a Quadratic Almost Ideal Demand System, Douenne (2020) analyzes the distributional effects of the French energy tax within income groups, finding that energy used for residential heating, as well as the urban density of the area of a household's residence, are strong drivers for disproportionate horizontal effects.

Given the disproportionate effects of carbon pricing across and within income groups, recent articles frequently tackle the role of the use of "carbon" revenues in making carbon pricing less regressive (see e.g. Callan et al., 2009; Mathur and Morris, 2014; Williams et al., 2015; Goulder et al., 2019; Sallee, 2019). To this end, several alternatives are suggested, such as offsetting regressivity by tax cuts in pre-existing taxes (Metcalf, 2009; Mathur, Morris 2014). In this respect, the microsimulation approach by Callan et al. (2009) for Ireland indicates that even modest changes in income tax rates can offset regressivity and would not require using the whole amount of revenues. However, depending on which pre-existing tax is cut, integrated general equilibrium analyses suggest that tax cuts to make a carbon price distributionally neutral come either at the cost of efficiency (Goulder et al., 2019) or may be efficient, but not sufficient to offset regressivity or even increase it (Rausch et al., 2011; Fullerton and Monti, 2013; Williams et al., 2015).

As alternative, uniform lump-sum transfers are proposed (see e.g. Williams et al., 2015; Klenert and Mattauch, 2016; Cronin et al., 2019) and often found to be progressive, that is, low-income households benefit more from lump-sum transfers relative to their income than wealthy households. The findings by Douenne (2020), however, suggest that equity concerns within income groups persist despite introducing a lump-sum revenue recycling. As a potentially superior alternative to uniform lump-sum transfers, targeted transfers are suggested: Studying the optimal tax design, Sallee (2019) argues that a carbon tax can only be Pareto-optimal when lump-sum transfers are targeted with respect to socio-economic characteristics, such as income. Indeed, analyzing the distributional effects of transfers targeted according to household income, the results of Grainger and Kolstad (2010) indicate that by such a targeted revenue recycling, a carbon price can be made distributionally neutral.

Yet, given numerous studies that point out that losers remain when heterogeneity within income groups is ignored in the revenue recycling scheme (see e.g. Parry et al., 2006; Farrell, 2017; Cronin et al., 2019), targeting recycling with respect to income groups may not be the silver bullet. Even after accounting for heterogeneity in household energy consumption, Sallee (2019), for instance, concludes that targeted transfers are not Pareto improving, as a significant share of households is not sufficiently compensated. Therefore, Sallee (2019) argues that it is impossible to perfectly design targeted transfers. The findings from microsimulations by Douenne (2020) for France are consistent with this conclusion.

In sum, these studies demonstrate the limited benefits from attempting to target transfers, given that household heterogeneity is largely unobservable by the government. In addition, the trade-off between efficiency and equality remains with targeted transfers, as transfers may reduce the carbon price signal for at least some households and thus decrease the efficiency of carbon pricing (Cronin et al., 2019). At least, though, when targeting transfers by returning carbon revenues to low-income households, fuel poverty can substantially decrease (Berry, 2019).

3. Methodology and Revenues from Carbon Pricing and Emission Reductions

Employing a partial equilibrium approach that is based on price elasticity estimates of the fossil fuel consumption of households and automobilists taken from the literature, in this section, for both sectors, Commerce, Trade and Services (CTS) and private households, we estimate the potential emission savings that result from their transport and heating demand, as well as the respective revenues originating from carbon pricing. Note that we only focus on the fossil fuel consumption of private households and firms of the CTS sector, as the majority of firms of the industry sector is ruled by the EU ETS and, thus, is not subject to Germany's carbon pricing. It also bears noting that, compared to general equilibrium analyses, our partial equilibrium approach may provide merely rough estimates on both the emissions savings and the revenues originating from carbon pricing. Nevertheless, these figures suffice to get a good impression on the amounts of revenues that can be reallocated to consumers, an impression that is confirmed by the expectations of the German ministry of finance: The ministry expects the amounts of carbon revenues to range between 7.4 billion euros in 2021 and 12.9 billion euros in 2024 (FMF 2020: 50).

Based on emission factors published by Germany's Environmental Protection Agency (UBA 2019b) for natural gas, heating oil, diesel and petrol reported in Table 1, we first derive the surcharges on the prices of these fossil fuels that are associated with carbon price levels of 25, 45, and 65 euros per ton of CO2. Neglecting the value added tax, which is raised on top of the net price of fuels, the price increase on natural gas would amount to 1.3 cents per kilowatt-hour (kWh) if the CO2 price were to equal 65 euros and 17.2 cents per liter for heating oil (Table 1), corresponding to about 1.7 cents per kWh.[2] For a CO2 price of 25 euros, as is stipulated for 2021 in Germany's separate ETS, the net price increases for road fuels amount to 5.9 cents per liter for petrol and 6.6 cents for diesel, with a value-added tax of 19% coming on top. For a CO2 price

[2] We ignore the value added tax in our calculations, as it seems unlikely that the additional revenues from this tax will be reimbursed to consumers given that the link between these additional tax revenues and carbon pricing remains obscure.

of 65 euros, which is the upper limit of the price corridor for the national ETS in 2026, the net price increase for petrol amounts to 15.4 cents per liter and 17.2 cents for diesel.

These increases are in the range of the daily volatility of gasoline prices, which may easily be larger than 20 cents per liter. Hence, motorists should be familiar with such price changes, leading to the conclusion that, at least in the short run, substantial decreases in driving distances, fuel consumption and corresponding carbon emissions cannot be expected. In fact, estimates on the short-run fuel price elasticities taken from the literature indicate that responses in travel demand are rather moderate. Goodwin (1992), for instance, estimates the short-run fuel price elasticity of petrol consumption at -0.27, but finds a substantially higher long-run elasticity of -0.71 (Litman 2020: 8).

Table 1: Price Increases (net of value-added tax) of Petrol, Diesel, Heating Oil and Natural Gas due to a Carbon Pricing of various CO2 Prices (Sources: UBA 2019b, own calculations)

	Emission factors	€ 25 per ton of CO2	€ 45 per ton of CO2	€ 65 per ton of CO2
Petrol	2.37 kg CO2/liter	5.9 cents/liter	10.7 cents/liter	15.4 cents/liter
Diesel	2.65 kg CO2/liter	6.6 cents/liter	11.9 cents/liter	17.2 cents/liter
Heating oil	2.65 kg CO2/liter	6.6 cents/liter	11.9 cents/liter	17.2 cents/liter
Natural gas	0.20 kg CO2/kWh	0.5 cents/kWh	0.9 cents/kWh	1.3 cents/kWh

In the long run, the permanent rise in fuel prices due to carbon pricing should substantially decrease the diesel and petrol consumption in Germany's transport sector. This conclusion is supported by econometric analysis of Germany's Mobility Panel (MOP), which suggests that the long-run price elasticities for gasoline lie within the range of -0.7 and – 0.4 (Frondel, Peters, Vance 2008; Frondel and Vance 2014, 2018). In other words, making gasoline more expensive through carbon pricing by, say, 10% reduces consumption by approximately 4 to 7%. These price responses are to be expected for both petrol and diesel demand alike, as Frondel and Vance (2014) found similar price elasticity estimates for both fuels.

As a benchmark, by presuming vanishing fuel price responses, that is, price elasticities of zero, in Table 2, we present upper-bound estimates of the revenues emerging from carbon pricing. Given the price increases reported in Table 1 and consumption data for 2017, when Germany's petrol and diesel consumption amounted to 26.58 and 43.23 billion liters (BMVI 2019: 309), the German government can expect substantial "carbon" revenues from the carbon pricing of road fuels. In 2021, for instance, when the price of CO2 will be fixed at 25 euros per ton, these revenues may easily exceed 4 bn euros.

Employing long-run price elasticities of -0.4 for both petrol and diesel cars (Frondel, Vance 2014), rather than neglecting any price response, we find that revenues do not shrink dramatically relative to the benchmark of no behavioral response reported in Table 2. Presuming price levels of 1.3 and 1.5 euros per liter for diesel and petrol, respectively, which roughly reflect the average price levels in Germany in 2019, the price increases reported in Table 1 and a price elasticity of -0.4 imply a reduction in Germany's diesel consumption by 2.0 to 5.3%, depending on the carbon price level (Table 3), and by 1.6 to 4.1% for petrol. These ranges also reflect the relative emission reductions due to the carbon pricing of diesel and petrol.

Comparing Table 3 with Table 2 suggests that in the long term, the desired reduction in gasoline consumption does not dramatically erode the revenues originating from carbon pricing: Despite substantial long-run demand decreases, carbon revenues of billions of euros would still be available to be reimbursed to consumers. Given lower short-run demand responses, the revenues from carbon pricing would even be higher in the short term than those reported in Table 3. In fact, short-term carbon revenues should rather be of the magnitudes displayed in Table 2.

Table 2: Revenues from Carbon Pricing in Germany's Transport Sector if No Demand Response to Carbon Pricing is presumed

	Fuel Consumption	€ 25/ton of CO2	€ 45/ton of CO2	€ 65/ton of CO2
Petrol	26.58 bn liters	1.575 bn euros	2.835 bn euros	4.095 bn euros
Diesel	43.23 bn liters	2.864 bn euros	5.155 bn euros	7.446 bn euros
Carbon revenues	–	4.439 bn euros	7.990 bn euros	11.541 bn euros

Patterns similar to those for petrol and diesel can be expected for the consumption of natural gas and heating oil. With respect to the natural gas consumption of private households, for instance, the difference in the revenues from carbon pricing between the short- and the long-term amounts to just a few 100 million euros if short- and long-run gas price elasticities of -0.1 and -0.4 are presumed (see e.g. Liu 2004). Based on an elasticity of -0.4, the long-run gas demand would shrink by 3.3 to 8.7% given the natural gas consumption of 266.3 bn kWh for private households in 2017 (AGEB 2018) and a price level of 6 Cents per kWh. This reduction in the natural gas consumption of private households, induced by a percentage price increase of 21.6% (= 1,3 Cents/6 Cents) for a CO2 price of 65 euros, may lead to CO2 savings of several million tons per year. Similar calculations were undertaken for the heating oil consumption of private households, as well as the gas and oil demand of the CTS sector, the results of which are not reported.

Taken together, the revenues resulting from the carbon pricing of Germany's road transport, household and CTS sectors are summarized in Table 4, with the corresponding CO_2 savings reported in Table 5. In the long run, a carbon price of 25 euros would generate carbon revenues of about 7.7 bn euros (Table 4). These revenues would exceed the volume generated by Germany's electricity tax, which amounted to 6.86 bn euros in 2018 (BMF 2019). In the short run, revenues may be expected to be even higher due to moderate demand responses.

Table 3: Long-run Reduction of Diesel and Petrol Consumption in Germany's Road Transport Sector and the Revenues from Carbon Pricing if a long-run Price Elasticity Demand of -0,4 is presumed

Carbon prices:	€ 25 per ton of CO2	€ 45 per ton of CO2	€ 65 per ton of CO2
Diesel consumption	42.35 bn liters	41.64 bn liters	40.94 bn liters
Consumption change	-2.0%	-3.7%	-5.3%
CO2 savings	2.335 m tons	4.203 m tons	6.072 m tons
Carbon revenues	2.806 bn euros	4.966 bn euros	7.052 bn euros
Petrol consumption	26.16 bn liters	25.82 bn liters	25.49 bn liters
Consumption change	-1.6%	-2.8%	-4.1%
CO2 savings	0.995 m tons	1.729 m tons	2.588 m tons
Carbon revenues	1.550 bn euros	2.754 bn euros	3.926 bn euros

Table 4: Long-run "Carbon" Revenues from Carbon Pricing

Carbon prices:	€ 25 per ton of CO2	€ 45 per ton of CO2	€ 65 per ton of CO2
Transport	4.356 bn euros	7.720 bn euros	10.978 bn euros
Households (oil, gas)	2.166 bn euros	3.798 bn euros	5.340 bn euros
CTS sector (oil, gas)	1.174 bn euros	2.059 bn euros	2.897 bn euros
Total carbon revenues	7.696 bn euros	13.577 bn euros	19.215 bn euros

With respect to emissions savings, the effects of carbon pricing are not as promising as those for the federal budget. At a carbon price of 65 euros, the long-term CO_2 emissions savings that can be realized in Germany's road transport and housing sectors would be lower than 20 million tons (Table 5). This outcome means that only about a fifth of the emission reductions required for fulfilling Germany's mandatory climate target related to the Non-ETS sectors, such as road Transport, would be achieved. The target for 2030 demands that their emissions are reduced by -38% relative to 2005, when these sectors' GHG emissions amounted to 405.0 million tons (UBA 2019b). In absolute terms, the target necessitates that the GHG emissions of the Non-ETS sectors shrink to 251.1 million tons in 2030. That is, until 2030, these sectors' GHG emissions must be reduced by 107.9 million tons relative to 2018. Apparently, this ambitious target can hardly be reached by carbon pricing alone.

Table 5: Long-run Greenhouse Gas Emissions Savings due to Carbon Pricing

Carbon Prices	€ 25 per ton of CO2	€ 45 per ton of CO2	€ 65per ton of CO2
Road Transport	3.330 m tons	5.995 m tons	8.660 m tons
Households (Oil, Gas)	2.803 m tons	5.045 m tons	7.287 m tons
CTS sector (Oil, Gas)	1.503 m tons	2.705 m tons	3.907 m tons
Total emissions savings	7.636 m tons	13.745 m tons	19.854 m tons

Hence, in addition to any carbon pricing beyond the price levels that are fixed until 2025, Germany must establish further emission abatement measures to ultimately fulfill its climate targets for 2030. However, the government should abstain from employing the revenues accruing from carbon pricing to continue to finance a variety of measures that would not be undertaken under an ideal carbon pricing regime, such as market premia for the support of renewable energy technologies in the heating sector. Instead, to foster the acceptance of the carbon pricing regime, it is critical that the revenues originating from carbon pricing are entirely reallocated to the consumers in a highly transparent way, for instance by substantially reducing taxes and levies on electricity prices for consumers.

4. Impact of Carbon Pricing on Poor Households

Carbon pricing aims at raising the cost burden of those households and firms that consume fossil fuels, such as natural gas and heating oil. This pricing policy particularly affects those consumers who are either unwilling or unable to lower their fossil fuel consumption, for example by substituting fossil fuels through renewable energy sources. Most important from a social policy perspective is that carbon pricing burdens poor households more than wealthy households, as poor households generally spend a larger share of their income to cover their energy needs (e. g. Grainger, Kolstad 2010). Conversely, if the revenues originating from carbon pricing would be reallocated to consumers, this would particularly help to alleviate the cost burden of poor households. Reimbursing these revenues would thus be a promising approach to reduce the potential threat of social distortions and protest waves against this climate policy instrument when CO2 Prices substantially increase.

To exemplify the distributional effects of carbon pricing, as well as the reallocation of the revenues by per-capita transfers, this section presents potential extreme cases, including three household types that are particularly at risk of poverty: a) Poor single-pensioner households that are not eligible for housing benefits, nor any other transfers, b) single-person households that are eligible for social benefits (called Hartz IV in Germany), and c) three-person households threatened by poverty. (By definition, households are at risk of poverty if their net income equals or falls below the threshold of 60% of the median income of households of the same size, see BMAS 2017). Of course, these three types of households are not representative for the population of German households, but nonetheless there are several millions of such households in Germany (BMAS 2017) so that it is highly warranted to focus on these types of households. For instance, the number of single-person households that receive social benefits amounted to about 1.63 million in 2019. Altogether, the number of households with the lowest household net income of € 1,300 at most, to which households of type a) and b) belong to, amounts to some 7.5 million, representing about 17.9% of the total number of households in Germany (Destatis 2020).

Based on data originating from the German Residential Energy Consumption Survey (GRECS) on the energy consumption of private households, we estimate the fuel cost increases of these three types of households due to carbon pricing. Furthermore, assuming that the revenues originating from the carbon pricing of private households, but not those from other sectors, will be entirely reallocated, we estimate the levels of per-capita reimbursements. On the basis of estimates on both the fuel cost increases and the per-capita reimbursements, we then calculate the net burden of these three household types due to Germany's carbon pricing.

To present conservative estimates that are not too optimistic with respect to the households' behavioral response to carbon pricing, we assume that households that are threatened by poverty do not reduce their fossil fuel consumption. This assumption seems plausible given that poor households lack financial opportunities to invest in more energy-efficient and less emissions-intensive technologies and is corroborated by recent research that is also based on GRECS data, concluding that the electricity price elasticities of poor households are not significantly different from zero in statistical terms (Frondel, Kussel Sommer 2019). Moreover, poor households might also have already cut their consumption as much as possible to save money, so that there is little opportunity for them to further reduce energy use in response to carbon pricing.

According to the GRECS data, the average living space of a typical poor single-pensioner household amounts to 55 square meters. The annual heating demand for this area averages about 8,000 kWh if this household heats with natural gas and about 800 liters of heating oil if the heating demand is satisfied with oil. The additional burden of this household type due to the carbon pricing of heating would be as high as 137 euros per year, that is, almost 12 euros per month (Table 8).

If the revenues from the carbon pricing of the private households' consumption of heating oil, natural gas and gasoline would be entirely reallocated to Germany‘s 83 million inhabitants via per-capita premia, each citizen may expect a reimbursement of around 54 to 134 euros per year, depending on the carbon price level (see last row of Table 6).[3] Based on these reimbursement levels, if a poor single-pensioner household does not own a car and heats with gas, this household type may expect a net gain of around 14 to 30 euros per annum. If the household heats with oil, its burden due to carbon pricing would roughly be equalized by the per-capita reimbursement of carbon revenues.

According to the GRECS data, about 40% of the poor single-pensioner households own a car and would experience a further burden due to carbon-price-induced higher gasoline costs. If the car is a diesel, this pensioner would have to bear additional costs between almost 21 to around 54 euros per annum, while owning a petrol car would bring about higher cost between almost 21 to around 49 euros (Table 6). These cost estimates are based on annual average travel distances of this type of household of about 4,500 km, mean specific consumption values of 7.8 liters per 100 kilometers for petrol cars and 7.0 liters for diesel cars, as well as the respective carbon price burden reported in Table 1 for both kinds of gasoline.

Table 6: Annual Burden of a typical Poor Single-Pensioner Household due to Carbon Pricing and potential Per-capita Reimbursement of Revenues

	Consumption	€ 25/ton of CO2	€ 45/ton of CO2	€ 65/ton of CO2
Natural gas	8,030 kWh	40.2 euros	72.3 euros	104.4 euros
Heating oil	792 liters	52.5 euros	94.5 euros	136.5 euros
Diesel	315 liters	20.9 euros	37.6 euros	54.3 euros

[3] The per-capita premia reported in Table 6 are calculated on the basis of, first, the revenues from the carbon pricing of the diesel and petrol consumption of private households, which amounted to 14.64 and 23.19 bn liters, respectively, in 2017 (Destatis 2019). For carbon prices of 25, 45, and 65 euros, these revenues amount to 2.303, 4.085, and 5.814 bn euros and must be added to, second, the revenues reported in Table 4 for the private households, the sum of which must be divided by the number of 83 million German citizens.

Petrol	351 liters	20.8 euros	33.6 euros	48.5 euros
Per-capita reimbursement	—	53.9 euros	95.0 euros	134.3 euros

For a carbon price of 25 euros, for example, the higher heating and gasoline costs of this household type cannot be outweighed by the per-capita reimbursement of 53.9 euros. This also holds true for higher carbon prices of 45 and 65 euros. Therefore, a higher per-capita reimbursement would be required to ensure a positive net balance for this household type. Yet, higher per-capita reimbursements require revenues from areas other than the private household sector, for example from the CTS sector. This, however, would imply that there are no financial resources to alleviate the burden of the firms of the CTS sector.

The second type of household that is scrutinized here refers to single-person households that are eligible for social benefits. Carbon pricing would imply additional costs for heating of about 37 to 95 euros per annum if the household heats with natural gas and almost 48 to 124 euros if heating oil is employed (Table 7). Ultimately, though, this type of households does not have to bear this burden, as the transfers for these households would be increased accordingly.

Table 7: Annual Burden due to Carbon Pricing of a typical Single-Person Household that obtains Social Benefits and potential Per-capita Reimbursement of Revenues

	Consumption	€ 25/ton of CO2	€ 45/ton of CO2	€ 65/ton of CO2
Natural gas	7,300 kWh	36.5 euros	65.7 euros	94.9 euros
Heating oil	720 liters	47.7 euros	85.9 euros	124.0 euros
Diesel	840 liters	55.7 euros	100.2 euros	144.7 euros
Petrol	936 liters	55.5 euros	99.8 euros	144.2 euros
Per-capita reimbursement	—	53.9 euros	95.0 euros	134.3 euros

Like poor single-pensioner households, a large share of about 60% of this second household type does not possess a car. Such households would not have to bear any burden from carbon pricing. Moreover, if carbon revenues would be reimbursed via per-capita transfers, these households would be even better off than without carbon pricing. However, if these single-person households own a car, they would incur carbon costs of

56 to 145 euros for gasoline purchases (Table 7). These figures are based on GRECS data indicating an annual driving distance of this household type of about 12,000 kilometers, on average. Given average consumption values of 7.8 liters per 100 kilometers for petrol cars and 7.0 liters for diesel cars, the annual driving distance of 12,000 kilometers implies a consumption of 936 liters of petrol per year and 840 liters of diesel. The resulting gasoline cost burden of about 54 to 134 euros exceeds the per-capita reimbursements reported in the last row of Table 7. In other words, if households of this type own a car, carbon pricing would burden their budget even if the resulting revenues are reimbursed by lump-sum per-capita transfers.

A third household type that is scrutinized here refers to three-person households at risk of poverty. The heating costs of this household type may increase substantially due to carbon pricing, by up to about 200 euros if heating oil is employed for this purpose (Table 8). If this household type does not own a car and would benefit from per-capita reimbursements, its net balance may nevertheless turn out to be positive, most notably due to the fact that with three household members, this household type enjoys three times the reimbursements of single-person households.

Yet, according to the GRECS data, some 85% of three-person households threatened by poverty own a car and, thus, in addition to heating costs, these households have to bear higher mobility costs: Given average driving distances of around 17,000 and 20,000 kilometers per year for petrol and diesel car drivers, respectively, the additional mobility costs of this household type due to carbon pricing amount to about 80 to 240 euros per annum (Table 8). If the revenues originating from carbon pricing would be reimbursed via per-capita transfers, this household type’s burden could be outweighed. The net balance would turn out to be positive if such households were to heat with the less carbon-intensive natural gas and drive with a petrol car. In contrast, the net balance would be negative for those households that are heating with oil and driving a diesel car.

Table 8: Annual Burden of a typical Three-Person Household Threatened by Poverty due to Carbon Pricing and potential Per-capita Reimbursement of Revenues

	Consumption	€ 25/ton of CO2	€ 45/ton of CO2	€ 65/ton of CO2
Natural gas	11,826 kWh	58.3 euros	105.0 euros	151.6 euros
Heating oil	1,166 liters	77.3 euros	139.1 euros	200.9 euros
Diesel	1,400 liters	92.8 euros	167.0 euros	241.2 euros
Petrol	1,326 liters	78.6 euros	141.4 euros	204.3 euros
Per-capita reimbursement	—	161.5 euros	285.0 euros	403.1 euros

In sum, these examples indicate that, first, households that employ heating oil for heating purposes tend to suffer from a higher burden due to carbon pricing than households that use natural gas. It therefore bears noting that, according to the GRECS data, oil heating is more common among pensioner and poor households than for other household types. Second, larger households tend to benefit more from a per-capita reimbursement than households with less members, given that energy consumption and costs generally do not grow proportionately with the number of household members (Frondel, Kussel, Sommer 2019). Hence, the larger the number of household members, the lower is the net burden under a per-capita reimbursement scheme. In short, this scheme would turn out to be particularly beneficial for families with many children, which are likely to be better off from a carbon pricing with a per-capita reimbursement of the resulting revenues.

Beyond these conclusions, several stylized facts are important to note: First, the energy consumption of wealthy households is generally higher than that of other households, not least due to, on average, a larger number of vehicles and longer driving distances per year. Thus, in perfect accord with the aims of climate policy, under a carbon pricing scheme, wealthy households tend to bear a net burden even if the carbon revenues would be reallocated via per-capita transfers.

Second, while about a quarter of the households in Germany heat with oil and around half with natural gas, a per-capita reimbursement would turn out to be positive for all those households that do not use fossil fuels for heating purposes, but instead employ renewable energy technologies, such as solar thermal collectors. Such households would not suffer at all from carbon pricing if, in addition to regenerative heating technologies, they satisfy their mobility demand by alternative motor technologies, such as electric vehicles.

While such households tend to belong to the higher end of the income distribution, they would be among the winners of any carbon pricing that is accompanied by a per-capita reimbursement. From a social policy perspective, though, such distributional impacts of carbon pricing must not be ignored (see Heindl and Kanschik (2016) for a discussion on environmental policy and distributive justice). This is all the more relevant, as poor households, given their low budget for investments, generally cannot afford more efficient energy technologies, nor any other less carbon-intensive technologies, such as heat pumps. With the ever-increasing cost of Germany's energy transition, the government would be well-advised to pay close attention to the distributional impacts on poor households to avoid jeopardizing the wide acceptance among the German population for this huge societal challenge.

Beyond such adverse distributional effects, another disadvantage of reimbursing carbon revenues via per-capita transfers is that the transaction costs of these transfers are non-negligible: Bureaucracy costs may absorb large shares of the carbon revenues so that per-capita transfers may turn out to be substantially lower than those reported in Table 8, 9, and 10. By contrast, employing carbon revenues to compensate the tax deficits due to the reduction of the electricity tax would not imply any transaction costs. These considerations indicate that it is worthwhile to discuss alternative mechanisms of reallocating the revenues accruing from carbon pricing.

5. Alternative Mechanisms for Reallocating the Revenues from Carbon Pricing

Reducing consumers' electricity costs is among three alternative mechanisms that are discussed in this section. First of all, electricity prices could be reduced by lowering Germany's electricity tax of 2.05 cents per kWh to the EU minimum rates for private households and firms. These minimum rates amount to 0.1 cents per kWh for private households and 0.05 cents for firms.

Abolishing the electricity tax would be warranted for several reasons. First, given that electricity is burdened by the electricity tax irrespective of whether it is produced by fossil-based plants or on the basis of renewable technologies, this tax implies lower incentives for an environmentally benign behavior than a tax with differentiated rates. Moreover, the justification for this tax steadily shrinks with the strongly increasing shares of green electricity in consumption. In 2018, the share of green electricity in consumption amounted to 37.8% (BMWi 2019), whereas this share was lower than 7% in 2000, when the feed-in tariff system for the support of renewable electricity generation technologies was introduced in Germany.

Second, the electricity tax became largely redundant when the EU ETS was introduced in 2005 with the aim to mitigate the environmental impact of both industrial and electricity production. This argument holds particularly true since prices for emissions certificates have increased substantially, from below 10 euros before 2018 to the current level of about 30 euros. The costs for purchasing emission certificates, which are required for the electricity production based on fossil fuels, increase production costs and, hence, tend to increase the electricity prices for consumers. Thus, the EU ETS provides incentives for a less carbon-intensive behavior for both electricity producers and consumers, rendering the electricity tax largely obsolete.

Third, with a share of slightly more than 50% in the end-use price of electricity for private households in 2019 (BDEW 2020), levies and taxes play a much larger role for this type of energy than for other energy carriers, such as natural gas and heating oil. This fact hampers the switch from fossil fuels to green electricity in sectors other than the electricity sector, a switch that is denoted by the notion of sector coupling and regarded as highly relevant for achieving Germany's ultimate climate goal of a carbon-neutral economy in 2050.

Not least, in contrast to per-capita reimbursements, which may lead to increases in the consumption of carbon-emission-intensive products, reducing electricity prices by decreasing taxes and levies does not lead to adverse environmental effects in the form of higher greenhouse gas emissions, as the electricity sector is integrated in the European emissions trading system (ETS), for which annual emissions are limited by a cap. In fact, due to the so-called waterbed effect (see e. g. Perino 2018), the level of CO2 emissions in the EU ETS sectors remains unaffected by any electricity price changes.

All in all, it hardly seems warranted for EU Member countries to still tax electricity beyond the minimum rates that are demanded by the European Commission. Given that the revenues generated by carbon pricing can be employed to replace those originating from the electricity tax, this argument particularly holds true in the context of Germany's ecotax on electricity of 2.05 cents per kWh. The ecotax was introduced in 1999 to also stabilize the monthly contribution rates to pension systems, in addition to the aim of dampening the electricity consumption for environmental reasons ("double dividend"). Our estimates reported in Table 6 indicate that, at a carbon price of 25 euros, the revenues originating from carbon pricing would suffice to replace the annual revenues accruing from the ecotax. In 2018, the ecotax revenues amounted to 6.86 bn euros (BMF 2019).

Were the ecotax to be reduced to the minimum rates, consumers would benefit from electricity cost savings. For instance, for our first type of households, the poor single-pensioner household, whose annual electricity consumption amounts to some 1,860 kWh (Frondel, Sommer 2018), costs savings of around 36 euros would result from reducing the ecotax to the minimum rate of 0.1 cents per kWh, that is, by 1.95 cents. These cost savings, however, cannot outweigh this pensioner's higher heating costs due to carbon pricing (Table 8).

For single-person households that receive unemployment benefits, whose annual electricity consumption amounts to 1,680 kWh according to the GRECS data (Frondel, Sommer 2018), reducing the ecotax would result in annual cost savings of about 33 euros. By comparison, the standard rate of unemployment benefits to cover the needs of everyday life such as food, cloths, and electricity consumption, was raised in 2019 for single-person households by 8 euros, from 416 to 424 euros per month, that is, by around 2%. Annual savings in electricity costs of around 33 euros are thus equivalent to a monthly increase of the standard rate of unemployment benefits of almost 0.7%.

Due to an ecotax cut, a typical three-person household threatened by poverty would save about 72 euros per year, given that its annual electricity consumption amounts to around 3,700 kWh according to the GRECS data. These savings would more than outweigh the higher burden from heating at a carbon price of 25 euros if this household employs natural gas for this task (Table 10). If heating oil is employed, though, this household type would have to bear a net burden, which would be more pronounced if the household owns a car. It deserves noting in this context that, in addition to private households, firms would also benefit from reducing the ecotax, while they may have the opportunity to shift the costs of carbon pricing to the consumers, at least partly.

Although there are numerous reasons that would justify electricity price reductions by lowering the ecotax, from a social policy perspective, there is one disadvantage of this reimbursement mechanism: In absolute terms, poor households would benefit less from reducing electricity prices than wealthy households, given that the electricity consumption of wealthy households is typically higher than that of poor households of the same size (Frondel, Kussel, Sommer 2019).

This disadvantage does not apply to the reimbursement mechanism that is based on lump-sum per-capita transfers, the second alternative that is discussed here. Yet, given that these transfers would be paid to all 83 million citizens of Germany, both children and adults, the per-capita transfers may turn out to be rather low if only those carbon revenues are employed for reimbursement that arise from the fossil fuel consumption of private households, but not those from other sectors. For instance, at a carbon price of 25 euros, this per-capita transfer amounts to about 54 euros (Table 8). However, employing the carbon revenues raised from the fossil fuel consumption of firms in the CTS sector to reimburse households would be ill-advised if the government wants to alleviate the burden of these firms from carbon pricing as well, which might be warranted for competitive reasons.[4]

Arguably, the most effective alternative with respect to mitigating the burden of poor households originating from carbon pricing would be the third alternative that is considered here: targeted measures, such as housing benefits, for strongly affected households. This alternative is in accord with the recommendation of Germany's Council of Economic Experts, who suggest increasing housing benefits as an appropriate instrument against the rising burden of poor households due to growing housing rents (SVR 2018:356).

Housing benefits are exclusively paid to people who do not obtain other transfers, such as unemployment benefits and social assistance, as the latter transfers also cover housing costs. The most recent increase in the housing benefits came into force on January 1, 2020 (Federal Government 2019), with the previous increase dating back to 2016. In 2020, around 660,000 households receive housing benefits, that is, about 1.5% of all households. In 2019, the total amount of housing benefits accounted for around 1.2 bn euros. That is, monthly housing benefits amounted to some 150 euros per household, on average. As of January 2022, housing benefits will be regularly increased every two

[4] In alleviating the net burden of firms accruing from carbon pricing, Germany could adopt the approach of Switzerland, where except for transport fuels, the carbon pricing of fossil fuels was introduced already in 2008. In Switzerland, the reimbursement of the revenues from carbon pricing to firms is proportional to the sum of wages that is paid by a firm. The net burden of labor-intensive firms is therefore lower than that of energy-intensive companies. Energy-intensive companies, though, can be exempted from paying a carbon price if they commit to voluntary carbon mitigation measures (BAFU 2019). In any case, those firms that participate in the Swiss ETS are not additionally burdened by the carbon pricing of fossil fuels.

years. If we assume that these benefits were to be increased by 10%, that is, by 15 euros on average, additional costs of about 120 million euros per annum would have to be borne for the roughly 660,000 recipients of housing benefits.

This amount could be easily covered by the revenues originating from carbon pricing. In addition, the carbon-price-induced growth of the housing costs of transfer recipients should be financed through carbon revenues. If we assume that the average housing costs of transfer recipients were to increase by 50 euros per year due to carbon pricing, another 306 million euros per annum would have to be covered by the revenues from carbon pricing, given that at the end of 2018 there were roughly 7.2 million transfer recipients in Germany (Destatis 2019), among which were 5.6 million beneficiaries of unemployment benefits. Note that 50 euros per year equals roughly the burden due to a carbon price of 25 euros that would have to be paid by our second household type, single-person households that receive unemployment benefits, if these households heat with oil (see Table 9).

With this third alternative, the revenues from carbon pricing have to be distributed to only around 7.9 million recipients of transfers and housing benefits, rather than 83 million German citizens, as with the alternative of a per-capita reimbursement. Thus, a large fraction of the carbon revenues would be left for further targeted social policy measures. Most notably, the government could raise the standard rate of unemployment benefits with which the needs of every-day-life, such as electricity consumption, is covered. During many years, this standard rate was not increased as much as the consumer price index rose (HartzIV.org 2019). An important reason for the temporarily increasing gap between this standard rate and the consumer price index has been the growth in electricity prices since the beginning of the millennium, which is primarily due to increasing taxes and levies (Frondel, Sommer 2018).

6. Conclusion and Policy Implications

In 2021, Germany launched a national emissions trading system (ETS) on carbon dioxide (CO2) allowances in its road transport and housing sectors, two sectors that are not integrated in the ETS of the European Union (EU) so far. Irrespective of its concrete implementation, any carbon pricing regime brings about higher costs for the consumers of fossil fuels. A promising approach to sustain the currently high acceptance for a national carbon pricing in Germany would be to entirely reallocate the resulting revenues to consumers.

This article has discussed three alternative mechanisms to reallocate the revenues originating from carbon pricing that were discussed in the political arena prior to the introduction of the national carbon pricing: a) a lump-sum per-capita reimbursement to private households, b) the reduction of electricity prices by reducing the electricity tax to

EU minimum tax rates, as well as c) financial aid for strongly burdened consumers, for example by increasing the housing benefits of poor households.

While we do not present a complete and comprehensive analysis of the distributive impacts of these revenue recycling alternatives on German households, our focus is on the growing burden of some types of particularly concerned households, such as poor single-pensioner households, that are threatened by poverty even without any carbon pricing. In the absence of any revenue reallocation that adequately mitigates the burden of these types of households from carbon pricing, the acceptance of this climate policy instrument may suffer heavily. This is all the more relevant as there are several millions of such types of households in Germany (BMAS 2017).

Most effective with respect to alleviating the burden of poor households would be the third alternative. While raising housing benefits would not require large amounts of financial resources, the remaining "carbon" revenues should preferably be employed to reduce Germany's electricity tax, as this tax is increasingly losing justification from an ecological perspective. Although there are good reasons for both a per-capita reimbursement of carbon revenues and a reduction of electricity prices, diminishing the electricity tax has several advantages over a per-capita reimbursement, particularly with respect to transaction costs, which would be negligible in case of tax cuts.

Alas, reimbursing "carbon" revenues to consumers in the form of an electricity tax cut or, alternatively, by per-capita transfers is not foreseen by the German government. Rather, carbon revenues are scheduled to support a large spectrum of policy measures, such as increasing the subsidies for the purchase of electric vehicles from 9,000 euros and increasing the commuting allowance of a driving distance to work as of 20 kilometers to outweigh the higher costs of driving due to carbon pricing. Such measures hardly yield any environmental benefits and may even foster counterproductive behavior. Moreover, they tend to favor wealthy, rather than poor, households and are thus questionable from both an ecological and a social policy perspective. Instead, to sustain the currently wide acceptance of carbon pricing in Germany if carbon prices should rise substantially, which is indispensable for reaching the national emission reduction goals, it is critical that the government establishes measures to primarily favor poor households and alleviate their burden originating from carbon pricing.

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