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Distributional Effects of Carbon Pricing by Transport Fuel Taxation

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Abstract

We introduce a new microsimulation model built on household transport data to study the distributional effects of carbon-based fuel taxation of private road transport in Germany. Our data includes annual mileage at the car-level, the distinction between fuel types, as well as car-specific fuel consumption, allowing for a very detailed analysis. The model allows focusing on different types of households as well as identifying effect heterogeneity across the income distribution. We compare the recent fuel tax scheme with three policy reform scenarios to empirically test several hypotheses regarding distributional effects of carbon pricing. We find that the legal status quo of the fuel tax has overall regressive effects, with the tax on petrol acting regressive and the tax on diesel acting progressive. A transformation of the current tax into a revenue-neutral carbon-harmonised fuel tax yields a progressive distributional effect, while an introduction of a new carbon tax on transport fuels is neither clearly regressive nor progressive. Combining both tax schemes also has non-regressive effects. Our results suggest that policy makers face various options for pricing road transport greenhouse gas emissions without causing an overall disproportionate tax burden on low-income households.

Keywords: carbon pricing, fuel tax, distributional effects, road transport, microsimulation, ex-ante impact assessment
JEL: H22 H23 Q48 Q58 R48.

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1 Introduction

Reducing greenhouse gas (GHG) emissions is a major goal of most countries' governments in their attempts to facing the challenges of climate change. The transport sector has been identified as one of the relevant mitigation options (German Advisory Council on the Environment, 2017). The United Nations Intergovernmental Panel on Climate Change (IPCC) estimates in its Fifth Assessment Report that a 10% increase of transport fuel prices could yield a 7% reduction in fuel consumption and GHG emissions in the long run (IPCC, 2014, 1160f). Policy measures like carbon taxes or emission trading systems aim at incentivising customers to lower their consumption levels of carbon fuels, as carbon dioxide (CO_2) is the predominating GHG emitted by human activities (IPCC, 2014, 358).[1] While carbon pricing potentially internalises external costs and yields economic efficiency, it might cause adverse distributional effects. Protests like the yellow vests movement in France are closely related to increases of fuel prices (Douenne, 2020). This suggests that the distributional effects of policy measures implemented to fight climate change might be of utter importance for the overall acceptance of these measures. Understanding the distributional effects of measures that affect fuel prices is, thus, a prerequisite for an informed debate on how to solve the challenges of global warming – both from an academic and a policy perspective.

In this paper, we introduce a new microsimulation model to study the distributional effects of the current transport fuel taxation in Germany which depends on volume and does not relate to GHG emissions. We then apply it to three alternative tax schemes based on the frequently discussed idea of carbon pricing (e.g. Dertinger and Schill, 2019; Edenhofer et al., 2019; Feld et al., 2019; Ismer et al., 2019; Lange et al., 2019; Preuss et al., 2019). These reform scenarios take up various approaches currently under discussion and range from a revenue-neutral system change to the introduction of a new tax. Specifically, we analyse (i) a transformation of the current tax into a revenue-neutral carbon-harmonised fuel tax, (ii) an introduction of a new carbon tax on transport fuels, and (iii) a combination of both tax schemes.

Our paper contributes to the literature on the distributional effects of carbon pricing by energy taxation in general (e.g. Berry, 2019; Labandeira et al., 2009; Pizer and Sexton, 2019; Speck,

[1] For this reason, GHG emissions are often measured in CO_2 equivalents. In the remainder of this article, we use the term CO_2 emissions synonymously.

1999; Wang et al., 2016) and transport fuel taxation in specific (e.g. Bento et al., 2009; Bureau, 2011; Filippini and Heimsch, 2016; Flues and Thomas, 2015; OECD/Korea Institute of Public Finance, 2014; Poterba, 1991; Sterner, 2012). Despite the recent flood of policy reports on the expected distributional effects of carbon pricing in Germany (e.g. Agora Verkehrswende and Agora Energiewende, 2019; Bach et al., 2019, 2020; Blanck et al., 2020; Edenhofer et al., 2019; Feld et al., 2019; Frondel, 2020; Gechert et al., 2019; Lange et al., 2019; Leprich et al., 2019; Preuss et al., 2019; Stiftung Arbeit und Umwelt der IG BCE, 2019; Zerzawy and Fiedler, 2019), scientifically valid empirical evidence on taxing the GHG emissions of transport fuels is scarce. We contribute to the literature by augmenting the existing studies in the following aspects. First, to consider household-specific mobility behaviour, we set up a new microsimulation model based on household transport data to study the first-round effects of alternative tax regimes. With that model, we can account for heterogeneity across households which allows a detailed analysis of household-specific tax burdens. Second, and in contrast to the previous empirical literature for Germany, our data encompasses car-specific fuel consumption, annual mileage at the car-level as well as the distinction between fuel types. Our model combines the advantages of three major data sources: Mobility in Germany (MiD) 2017, the German Mobility Panel (MOP) 2017/2018, and the Sample Survey of Income and Expenditure (EVS) 2018. This rich and unparalleled data allows a very detailed analysis of the distributional effects of fuel taxation. Most existing studies on Germany (e.g. Agora Verkehrswende and Agora Energiewende, 2019; Bach et al., 2019; Feld et al., 2019; Gechert et al., 2019; Leprich et al., 2019) solely base on data such as the Socio-Economic Panel (SOEP) or the EVS, which hardly cover household-specific mobility aspects. The information provided in these datasets refers only to the car fuel expenditures estimated by the survey participants. It disregards car-specific fuel consumption and the respective annual mileage. However, these factors are decisive for the individual tax burden resulting from a carbon tax and the analysis of distributional effects. This is particularly true given the important role of diesel cars in Germany.[2] Our extensive database ensures that the tax burden is calculated at the vehicle-level. To the best of our knowledge, such a detailed database has not yet been used to analyse the distributional effects of transport fuel taxation. Third, our ex-ante evaluation provides new scientific evidence on a highly policy relevant

[2] The share of diesel cars in annual mileage is around 45% (Federal Statistical Office, 2020) and the average annual mileage of diesel cars nearly doubles that of petrol cars (Federal Motor Transport Authority, 2020b). Despite the higher GHG emissions of one litre of diesel, it is taxed less than petrol in Germany.

question by comparing and combining two frequently discussed alternative policy measures. To this end, we systematically distinguish the distributional effects of taxing petrol and diesel fuel, about which little is known so far (Harding, 2014)

We focus on Germany for three reasons. First, Germany is one of the seven largest issuers of GHG in the world (Crippa et al., 2020). It is, therefore, an important international player in the debate on GHG emissions as the Federal Climate Change Act requires it to reduce GHG emissions by at least 55% in 2030 compared to the year 1990 (German Bundestag, 2019b). Second, for reducing GHG emissions, the German parliament agreed on the Fuel Emissions Trading Act (Brennstoffemissionshandelsgesetz – BEHG) in December 2019, which includes a pricing of GHG emissions in the transport and heating sectors (German Bundestag, 2020). As there has been a controversy on the potentially small effects of the BEHG on GHG emissions (e.g. German Bundestag, 2019a; Harthan et al., 2020) and climatologists aim at higher emission prices (e.g. Edenhofer et al., 2019; German Environment Agency, 2019), our reform scenarios are designed to reflect the ongoing policy debate.[3] Third, we can exploit the above-mentioned rich database.

With respect to the status quo fuel taxation regime in Germany, we find that the ratio of tax burden to net income declines with income. This is in line with the overwhelming majority of the literature which shows that fuel taxes tend to place a greater burden on poor households in relation to net income than on rich households (e.g. Bento et al., 2009; Gianessi et al., 1979; Poterba, 1991; Spiller et al., 2017; Steinsland et al., 2018; Sterner, 2012; Teixidó and Verde, 2017; Tiezzi and Verde, 2019), weakening its social acceptance in society (Kallbekken and Sælen, 2011). Yet, we are the first to explicitly show that the effect of the German fuel tax on petrol is regressive, while taxing diesel acts progressive. Our first reform scenario analyses the transformation of the current tax into a revenue-neutral carbon-harmonised fuel tax. The simulation results show that this reform has a progressive distributional effect. While the average tax burden decreases for the lowest six deciles of the income distribution, it increases for the upper four deciles. The second reform scenario introduces a new carbon tax of 100 euro/tCO_2 on transport fuels. Overall, its distributional effects are less clear-cut. While aggregated measures suggest a weakly progressive shift, there is a considerable amount of heterogeneity between households. Finally, the third scenario combines the

[3]The original carbon prices implemented by the BEHG in December 2019 were substantially lower than the ones currently in force that have been readjusted within less than a year.

introduction of a carbon-harmonised fuel tax with an additive 65 euro carbon tax. We conclude that the reform causes a progressive shift in tax progression and that its redistributive effect at least does not prove regressive. Overall, the changes in households' individual tax burden due to the tax reforms are economically significant. The effects of the revenue-neutral carbon-harmonised fuel tax are, on aggregate, relatively small (ranging from an annual relief of 20 euro in the 1st decile of the income distribution to a burden of 70 euro in the 10th decile). These aggregate effects, however, cloud a considerable degree of heterogeneity. Our microsimulation approach allows us to identify winners and losers within income deciles. Focusing on those households only whose tax burden increases due to the reform, the additional tax burden ranges between 220 euro (1st decile) and 310 euro (10th decile) per year. The absolute additional tax burden is highest for the carbon tax, amounting to 290 euro (2.0% of net household income) for reform losers in the 1st decile and 560 euro (0.8%) in the 10th decile. These changes in tax burdens could well play a role for the political feasibility of these or similar reforms. Our rich data base allows us to further analyse different subgroups that are relevant in this context. These subsample analyses focus on commuters, families, and rural households.

The paper is structured as follows: Section 2 places the paper in the literature. Section 3 describes the alternative policy scenarios, defines the outcome measures, and derives the hypotheses. Section 4 introduces the microsimulation approach and describes the study population. The results are reported in Section 5. Section 6 provides a discussion and finally concludes on policy implications.

2 Related Literature

This section reviews the literature on the distributional effects of carbon pricing (Subsection 2.1) and transport fuel taxes (Subsection 2.2). Subsequently, we describe the research gap and the starting points for our analysis (Subsection 2.3).

2.1 Carbon Pricing

Taxes on externalities to align private and social marginal costs of activities have long been discussed in economics since the seminal work by Pigou (1920). Carbon pricing is widely seen as the most cost-effective instrument to decarbonise energy consumption and mitigate GHG emissions (e.g. Meckling et al., 2017; Tietenberg, 2013). While determining the actual size of externalities and, subsequently, efficient emission levels is beyond the scope of the present paper[4], we focus on the distributional effects of different carbon tax regimes which are part of the ongoing public debate.

Environmental taxes in general are often suspected to put a higher burden on poorer households than on richer ones (Bento, 2013; Baranzini et al., 2017; Combet et al., 2010), as the former usually spend a higher share of their disposable income on necessities like transport fuels (Kaus, 2013). A considerable branch of the literature on the distributional effects of carbon taxes does not distinguish between transportation fuels, heating fuels, and electricity (e.g. Combet et al., 2010; Douenne and Adrien, 2020; Feindt et al., 2021; Hassett et al., 2009; Labandeira et al., 2009; Landis et al., 2021; Metcalf, 2009; Parry, 2015; Rausch et al., 2011). In a meta study based on 53 empirical studies, Ohlendorf et al. (2018) find a significantly higher occurrence of progressive effects if only the transport sector is analysed. Barker and Köhler (1998) identify a slightly regressive effect of carbon taxes for most of the eleven examined EU countries, including Germany, but also a slightly progressive effect when only taking transport fuels into account. Similar patterns are found by Vandyck et al. (2021) in a more recent study of eleven EU countries. Focusing on Austria, Eisner et al. (2021) find a regressive effect for electricity and heating, but an disproportionate tax burden on middle-income households for transport fuels. Elkins and Baker (2001) explain these patterns by the different expenditure distributions of transport fuels and domestic fuels, i.e. heating fuels and electricity. Support for this finding is provided by Callan et al. (2009)'s study on tax equity and Büchs and Schnepf (2013), who analyse the relation between household characteristics and sources of CO_2 emissions. Nevertheless, some empirical studies on the distributional effects of carbon taxes report conflicting results (e.g. Berry, 2019; Martini, 2009).[5] A broader picture of the distributional effects of carbon taxes on transport fuels is provided by literature surveys (Elkins and Baker, 2001;

[4] Tscharaktschiew (2014) estimates the marginal social costs of road transport and indicates externalities of around 0.30 euro/l for gasoline, yielding an optimal fuel tax on gasoline in Germany of 0.96 euro/l. For diesel, estimates suggest an even higher level of marginal social costs (Santos, 2017; Tscharaktschiew, 2014). This does not only hold for diesel passenger cars but, in particular, for diesel powered heavy duty vehicles (Santos, 2017). These findings, which are in line with previous research on optimal taxation of petrol and diesel (e.g. de Borger and Mayeres, 2007; Mayeres and Proost, 2013), refer to different sources of transport externalities such as GHG, particulate pollution, noise, congestion and accidents.

[5] Berry (2019) examines the recently introduced carbon tax in France and finds similar distributional effects for transport and domestic energy, explained by "increasing car dependency among low-income households". Martini (2009) rejects regressive effects for domestic fuels in Italy but confirms them for transport fuels.

Pizer and Sexton, 2019; Speck, 1999; Wang et al., 2016; Zhang and Baranzini, 2004) and meta analyses (Alvarez, 2019; Ohlendorf et al., 2018). By identifying several drivers for the direction of the distributional effect, their findings question the universal validity of a "regressivity assumption".

In addition to the international evidence presented above, several studies conduct ex-ante-analyses of the distributional effects of a carbon price introduction on transport and domestic fuels in Germany (e.g. Agora Verkehrswende and Agora Energiewende, 2019; Bach et al., 2019, 2020; Blanck et al., 2020; Edenhofer et al., 2019; Eisenmann et al., 2020; Feld et al., 2019; Frondel, 2020; Gechert et al., 2019; Lange et al., 2019; Leprich et al., 2019; Preuss et al., 2019; Stiftung Arbeit und Umwelt der IG BCE, 2019; Zerzawy and Fiedler, 2019).[6] All of these studies are based on household survey data and most of them use either the SOEP 2015 or the EVS 2013. Only a few studies rely on other data like the German Residential Energy Consumption Surveys (GRECS) of the years 2006 to 2013 (Frondel, 2020), the MOP of the years 2017 to 2019 (Blanck et al., 2020) or the MiD 2017 (Eisenmann et al., 2020). Yet, the majority of studies (i) do not distinguish transport and domestic fuels (Agora Verkehrswende and Agora Energiewende, 2019; Edenhofer et al., 2019; Feld et al., 2019; Leprich et al., 2019; Preuss et al., 2019), (ii) do not explicitly provide the tax burden in relation to income (Blanck et al., 2020; Eisenmann et al., 2020; Frondel, 2020; Lange et al., 2019; Leprich et al., 2019; Zerzawy and Fiedler, 2019) or (iii) do not report the pure tax effect but only its combination with a revenue recycling scheme (Eisenmann et al., 2020). There are four studies that do not suffer from these shortcomings. Three of them, however, report the identical analysis (Bach et al., 2019, 2020; Stiftung Arbeit und Umwelt der IG BCE, 2019). Based on SOEP data, their microsimulation model yields a slightly regressive effect for a carbon tax on petrol and diesel, as the tax share of the net income decreases between the 7th and the 10th decile. The results of the fourth study (Gechert et al., 2019), which is also based on SOEP data, indicate an even more regressive effect.

2.2 Transport Fuel Taxes

Economists have investigated the distributional effects of transport fuel taxes for several decades (e.g. Bento et al., 2009; Eliasson et al., 2018; Poterba, 1991; Stucker, 1977). While most early

[6] Nearly all of these studies can be classified as technical reports without a clear-cut scientific focus, as only the study of Eisenmann et al. (2020) has been published in a peer-reviewed scientific journal.

studies found evidence for regressive effects (e.g. Gianessi et al., 1979; Stucker, 1977), more recent contributions suggest that the GDP and income-dependent heterogeneity of car-ownership are important drivers for the distributional effect of a transport fuel tax. Johnson et al. (1990) find progressive effects for the UK, which they explain with less car-ownership in low-income groups, since their data reveal an around eleven times higher probability for car-ownership in the highest compared to the lowest income decile. Blow and Crawford (1997) and Santos and Catchesides (2005) show that fuel taxes in the UK are strongly regressive when focusing on car-owning households only, but progressive when considering all households.

Consistent with the results presented above, in an analysis of transport fuel taxes in 23 OECD countries, including Germany, Flues and Thomas (2015) finds that the distributional effects are more regressive the higher the GDP per capita. Sterner (2012) analyses the fuel taxes of seven European countries and finds a slightly regressive effect in the UK, but the most progressive effect in the poorest country, Serbia. Likewise, progressive fuel tax incidence in low-income countries has been reported for Chile (Agostini and Jiménez, 2015) and Costa Rica (Blackman et al., 2010). While empirical evidence clearly stresses a regressive effect of fuel taxation in the US (e.g. Bento et al., 2009; Chernick and Reschovsky, 1997; Gianessi et al., 1979; Poterba, 1991; Spiller et al., 2017; Stucker, 1977; Teixidó and Verde, 2017; Tiezzi and Verde, 2019; West, 2004; West and Williams, 2004), the distributional effects are more ambiguous within other high-income countries (Flues and Thomas, 2015; Sterner, 2012). In Spain, for instance, Asensio et al. (2003) identify a progressive effect for the lower half of income deciles and a regressive effect for the upper half, characterised by Sterner (2012) as rather proportional on average. In Sweden, the fuel tax acts progressive from the 2nd to the 9th decile (Eliasson et al., 2018), but barely regressive in total (Eliasson et al., 2018; Sterner, 2012). Yet, for the majority of countries, such as for Austria (Bernhofer and Brait, 2011), France (Bureau, 2011; Berry, 2019; Sterner, 2012), Ireland (Callan et al., 2009), Italy (Sterner, 2012), and Norway (Steinsland et al., 2018), the existing empirical evidence suggests regressive effects. Given the literature presented so far, in line with Pizer and Sexton (2019), we conclude that the direct effects of transportation fuel taxes tend to be rather progressive in poorer countries and quite heterogeneous in richer countries, attributing the latter to income-specific heterogeneity in car-ownership and commuting patterns.

Studies on the German transport fuel tax usually find that middle-income households bear the largest tax burden in relation to income (e.g. Bork, 2000; Flues and Thomas, 2015; Sterner, 2012). Sterner (2012) concludes that the tax is marginally regressive, but rather proportional. Nikodinoska and Schröder (2016) find that abolishing the transport fuel tax would lower inequality in the distribution of post-tax income moderately, while doubling it would increase inequality slightly. The last amendments of the taxes on transport fuels in Germany date back to the so-called Eco Tax Reforms between 1999 and 2003, which raised the fuel tax on petrol and diesel by around 0.15 euro/l. Both, ex-ante (Bach et al., 2002; Grub, 2000) and ex-post (Bach et al., 2019) studies on the fuel tax rise identify a regressive distributional effect. Bach et al. (2018) examine a hypothetical 0.15 euro/l increase of transport fuel prices and find a slightly regressive effect, which is much more regressive when considering only households with cars.

Only a few German studies differentiate between petrol and diesel or analyse tax schemes which might allow for deductions to be made about each fuel's distinct distributional effect.[7] Bach et al. (2016) simulate a fuel tax of 0.703 euro/l, which implies a much stronger increase for diesel than for petrol, and find a slightly regressive joint effect. Jacobs and Quack (2018) find a progressive effect for a revenue-neutral introduction of a fuel tax based on CO_2 emissions, which leads to an increase of the fuel tax on diesel by 0.19 euro/l and a decrease of the fuel tax on petrol by 0.12 euro/l. Although Bach et al. (2019) do not explicitly address the topic, their results strongly indicate that the German diesel tax is progressive, while the petrol tax is regressive.

2.3 Research Gap

Even given the studies described above, considerable uncertainty remains regarding the concrete effects of carbon pricing in the German tax system: Sterner (2012) focuses on petrol solely. Flues and Thomas (2015), Bach et al. (2016) and Nikodinoska and Schröder (2016) do not distinguish between petrol and diesel due to data restrictions. Bork (2000), Grub (2000) and Bach et al. (2002) use data that dates back to 1993. The database utilised by Jacobs and Quack (2018) is rather small

[7] International evidence is rather ambiguous. Flues and Thomas (2015) conclude for the average of all analysed 21 OECD countries (Austria, Belgium, Chile, the Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Poland, the Slovak Republic, Slovenia, Spain, Switzerland, Turkey, and the UK) that "taxing diesel higher would hit the rich harder than the poor". On the other hand, the meta-analysis of Pizer and Sexton (2019) concludes that the "gasoline tax is progressive whereas a diesel tax disproportionately harms the poor by raising the costs of the public transportation upon which they rely". Yet, similar evidence from Costa Rica (Blackman et al., 2010) raises the question whether the latter is attributable primarily to the relevance of bus diesel in countries with a lower income level than in Germany.

and does not adequately reflect the German population. Only the studies of Bach et al. (2018) and Bach et al. (2019) adequately account for the income heterogeneity of households owning diesel and petrol cars. Their data, however, lacks sophisticated information on real car use. Except from the work of Eisenmann et al. (2020)[8], none of the reported German studies appropriately considers the extensive structural developments of the German car fleet in terms of diesel use, which is of utter importance: On the one hand, the fuel tax per litre of petrol is around 39% higher than of diesel. On the other hand, the average annual mileage for both petrol and diesel rises significantly with income, but much faster for diesel than for petrol (Jacobs and Quack, 2018). Overall, diesel accounts for around 45% of the annual mileage of private households (Federal Statistical Office, 2020). Additionally, the diesel share of the German passenger car fleet has more than doubled since the year 2000 (Federal Motor Transport Authority, 2020a). All this has non-negligible implications for the analysis of the distributional effects of fuel type specific tax amendments which will be caused by carbon pricing.

Our study contributes to the literature by, first, its sophisticated microsimulation model that has significant advantages over less disaggregated methods and utilises a more recent and more suitable database able to accurately model real car use. Second, we simulate the distributional effects of three hypothetical reform scenarios, two of which take a so far unexamined approach to the introduction of carbon pricing and put it in reference to the status quo and the extensively studied concept of a pure carbon tax on transport fuels.[9] Third, we focus on road transport and systematically examine the contribution of diesel taxation to distributional impacts, which, to the best of our knowledge, has not been done before. Fourth, despite the specific characteristics of the German transport sector and its corresponding tax system, we address questions that are of high relevance for comparable countries such as France or Austria. By relating the simulated tax burdens to individual household incomes and aggregating them to standardised distributional measures, one may assume that the external validity of our results should be higher than that of less detailed studies.

[8]Eisenmann et al. (2020), however, do not simulate individual households, but similar household groups. They neither provide the resulting tax burden in relation to household income nor do they investigate the tax effect without revenue recycling.

[9]See (e.g. Bach et al., 2019, 2020; Blanck et al., 2020; Gechert et al., 2019; Lange et al., 2019; Leprich et al., 2019; Stiftung Arbeit und Umwelt der IG BCE, 2019; Zerzawy and Fiedler, 2019).

3 Study Design

In Subsection 3.1, we introduce the four policy scenarios for transport fuel taxation in Germany that we will analyse with our microsimulation model. The status quo of the tax regime serves as reference scenario, while the three reform scenarios include a revenue-neutral carbon-harmonised fuel tax, a carbon tax and, finally, a combination of the latter two. Subsection 3.2 discusses general methodological aspects regarding the measurement of the distributional effects of fuel taxes. It also presents the indicators used to identify the distributional effects of the reform scenarios. Finally, Subsection 3.3 derives testable hypotheses regarding the reforms' distributional effects based on the literature summarised in Section 2.

3.1 Policy Scenarios

As of 2020, the fuel tax defined in the German Energy Tax Act amounts to 0.6545 euro/l for petrol and 0.4704 euro/l for diesel (see Table 1).[10] The difference in taxation levels of petrol and diesel and the implications caused by the variance of annual mileage, fuel consumption, and car ownership across income deciles are of particular interest to us. We will not only study the overall distributional effect of the transport fuel tax, but also the fuel type specific effects for petrol and diesel in the status quo tax regime (Scenario SQ). According to our simulation, the total transport fuel tax revenue raised from private households in the year 2017 amounts to 29,900 million euro, of which 19,500 million euro stems from the taxation of petrol and 10,300 million euro from diesel. The reported figures include that share of the 19% value-added tax (VAT) that is levied on the fuel tax burden, but not on the net fuel price.[11]

Starting from the status quo, we set up and examine three reform scenarios based on the idea of carbon pricing. As fuel taxes have been the most powerful policy instrument against climate change so far (Sterner, 2007), we examine this type of tax in the first reform scenario. Although fuel taxes are ad quantum taxes determined by the volume, weight or energy content of the fuel, they can be considered as implicit carbon taxes (see Baranzini et al., 2000).[12] Since different fuels

[10] We only report information on petrol and diesel as other taxed fuels have negligible market shares. They will, however, be considered in our analysis (see also Subsection 4.2).

[11] Unless indicated otherwise, the tax-related VAT share is included in all results provided below.

[12] Carbon taxes are either based on the carbon content of the combusted fossil fuel or on the amount of CO_2 that is emitted by combusting fossil fuels (Baranzini et al., 2000). The ratio between carbon content and CO_2 emissions

Table 1: Taxes on Transport Fuels by Policy Scenario

		Scenario			
		Reference	Reform		
Instrument	Unit	SQ	CH	CT	CHCT
Fuel Tax					
Petrol	euro/l	0.6545	0.5381	0.6545	0.5381
Diesel	euro/l	0.4704	0.6146	0.4704	0.6146
LPG	euro/l	0.0974	0.4152	0.0974	0.4152
CNG	euro/kg	0.1946	0.3781	0.1946	0.3781
Carbon Tax					
Petrol	euro/l	-	-	0.2320	0.1508
Diesel	euro/l	-	-	0.2650	0.1723
LPG	euro/l	-	-	0.1790	0.1164
CNG	euro/kg	-	-	0.1630	0.1060
Total Tax					
Petrol	euro/l	0.6545	0.5381	0.8865	0.6889
Diesel	euro/l	0.4704	0.6146	0.7354	0.7869
LPG	euro/l	0.0974	0.4152	0.2764	0.5316
CNG	euro/kg	0.1946	0.3781	0.3576	0.4841

Sources: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

SQ: Status quo fuel tax.

CH: Revenue-neutral carbon-harmonised fuel tax.

CT: Status quo fuel tax + 100 euro/tCO_2 carbon tax.

CHCT: Revenue-neutral carbon-harmonised fuel tax + 65 euro/tCO_2 carbon tax.

have different CO_2 emission factors, the fuel tax per CO_2 emission unit can vary widely across fuel types.[13] The status quo of the German fuel tax implies that one gram of CO_2 emissions is taxed about 60% higher for petrol than for diesel. Due to lower consumption costs of diesel compared to petrol, consumers might opt to buy more polluting, larger cars and drive more with a less fuel-efficient driving style (Schipper et al., 2002).[14] Consequently, several studies (e.g. Harding, 2014; Montag, 2015; Söllner, 2018) recommend to harmonise fuel and energy taxes based on the fuels' CO_2 emission factors in order to economically incentivise consumers towards reducing GHG emissions via fuel consumption. Even at the European level, a corresponding amendment to the Energy Taxation Directive has already been proposed and discussed, but has not yet been implemented (European Commission, 2011).

Revenue-neutral carbon-harmonised fuel tax (Scenario CH): Our first reform scenario, therefore, harmonises the German transport fuel tax with the CO_2 emission factors of each fuel. We adjust the tax level of each fuel type such that, assuming identical consumer behaviour, the current total tax revenue is maintained. This allows for a straightforward comparison with the status quo while, at the same time, taking into account the differences in CO_2 emission factors across fuel types. Considering that the combustion of one litre of diesel emits around 14% more CO_2 than the combustion of one litre of petrol, the carbon-harmonised fuel tax is 14% higher for one litre of diesel than for one litre of petrol.[15] Given the status quo tax revenue reported above, the revenue-neutral carbon-harmonised fuel tax equals 0.6146 euro/l for diesel and 0.5381 euro/l for petrol (see Table 1).[16]

is defined by physics: each tonne of combusted carbon emits a fixed amount of 3.67 tonnes of CO_2 (Baranzini et al., 2000). This interdependency makes both terms often used synonymously. For the sake of clarity we will refer to CO_2 emissions in the remainder of the article.

[13]A CO_2 emission factor indicates the amount of CO_2 emitted in relation to a suitable measurement unit of the source material. In reality, the CO_2 emission factors of fuels are not constant. Several different petrol grades and biofuels are commercially available, the diesel composition differs in summer and winter, and the composition of fuels varies by refinery and time (Juhrich, 2016). Our study applies the simplifying assumption of one unified value of CO_2 emission factor per fuel type, based on official data for Germany: One litre of petrol emits 2.32 kg and one litre of diesel emits 2.65 kg CO_2 when combusted (Federal Motor Transport Authority, 2011).

[14]As the complexity of diesel engines increases their initial costs compared to petrol engines (Reinhart, 2016), diesel cars gain in advantage the heavier and more powerful they are, which has been fostered by the rapid improvement of the diesel technology (Schipper and Fulton, 2013).

[15]Yet, the tax amount levied per kilometre would still be lower for diesel cars than for petrol cars if diesel engines were more efficient than petrol engines (Harding, 2014).

[16]To derive revenue-neutral tax levels, we calculate the implicit average fuel tax per unit of CO_2 emission of private households in the status quo. To this aim, we aggregate the transport fuel consumption of private households by fuel type, determine the corresponding CO_2 emissions, and relate them to the aggregated fuel tax payments by private households. The new fuel tax levels for the individual fuel types are obtained by multiplying this average fuel tax per CO_2 by the amount of CO_2 emissions of the respective fuel types.

Carbon tax (Scenario CT): Referring to current policy developments, we simulate the introduction of a carbon tax based on a fixed price for GHG emissions and levied on top of the current fuel tax (see Table 1). The German parliament has recently introduced carbon pricing by adopting a national cap-and-trade system for GHG emissions from the transport and heating sectors (German Federal Government, 2019). Until 2025, the BEHG defines fixed prices for GHG emission certificates between 25 euro/tCO_2 (in 2021) and 55 euro/tCO_2 (in 2025). In 2026, the certificates will be traded within a price range of 55 and 65 euro. This fixed price works like a carbon tax. From 2027 onwards, a capped number of emission certificates is supposed to be traded freely. As scientific evidence suggests that a higher price will be necessary to reach the GHG emission reduction goals (e.g. Edenhofer et al., 2019; German Environment Agency, 2019)[17], we analyse the distributional effects of a carbon price of 100 euro/tCO_2.[18] In line with the relation of the CO_2 emission factors of fuels described in CH, a carbon tax of 100 euro/tCO_2 implies an additional 0.2320 euro/l for petrol and 0.2650 euro/l for diesel. This results in a total tax burden of 0.8865 euro/l for petrol and 0.7354 euro/l for diesel. Without behavioural adjustments, its introduction would, according to our simulations, lead to a total tax revenue of transport-related taxes on fuels and CO_2 emissions of 42,900 million euro.

Combined Tax Scheme (Scenario CHCT): Finally, we combine the elements of the two tax regimes in Scenario CH and Scenario CT. The resulting reform CHCT, therefore, comprises the carbon-harmonised fuel tax described above and an additional carbon tax of 65 euro/tCO_2. 65 euro/tCO_2 corresponds to the upper boundary of the German carbon price in 2026 under current law.[19] At the same time, the scenario represents a combination of the two instruments that appears justifiable in terms of environmental policy as it, unlike CH, does not lead to potentially unintended incentives through tax reduction. As can be seen in Table 1, the joint tax per litre of petrol is 0.6889 euro in this scenario. It is composed of the carbon-harmonised fuel tax of 0.5381 euro/l and the carbon tax of 0.1508 euro/l. For diesel, the joint tax is 0.7869 euro/l, comprising a fuel tax of

[17] Proposed price scenarios range from 70 euro/tCO_2 to 350 euro/tCO_2 depending on assumptions, e.g. on price elasticities.

[18] A major advantage of choosing 100 euro is the easy proportional conversion of most results into alternative CO_2 emission prices. Additional variants with a carbon tax of 25 euro/tCO_2 and 100 euro/tCO_2 complement the analysis as a robustness check.

[19] Note that the additional carbon tax in CHCT differs from CT as we do not interpret CHCT as an "interaction" of the two first-mentioned scenarios, but rather as a scenario that adds the already decided carbon tax to households' status quo tax burden. As a robustness, check we also simulate variants of this scenario with a carbon tax of 25 euro/tCO_2 and 100 euro/tCO_2.

0.6146 euro/l and a carbon tax of 0.1723 euro/l. Overall, this is equivalent to a unified carbon price of 297 euro/tCO_2, including 232 euro from the carbon-harmonised fuel tax and 65 euro from the carbon tax. If private households do not adapt their mobility patterns, the expected tax revenue will amount to 38,300 million euro, which is an increase of 28% compared to the status quo.

3.2 Measurement Concept

First, we need to define a proxy of the households' financial ability to pay taxes on transport fuels. As Sterner (2012) points out, the approach taken can have an impact on the results of the tax incidence analysis. There are two main approaches in the literature, which differ in the time dimension over which the ability to pay is assessed. One takes a lifetime ability-to-pay approach and relies on total household consumption expenditures as an indicator. The other follows a short-term financial capacity approach and focuses on annual income. Poterba (1991) argues for a long-term approach and finds that annual expenditures are a more reliable indicator of households' ability to pay taxes over an entire lifetime because they are less prone to intertemporal fluctuations. In line with further studies (e.g. Agostini and Jiménez, 2015; Chernick and Reschovsky, 1997; Hassett et al., 2009), he shows that a short-term approach leads to overestimation of regressivity. Chernick and Reschovsky (1997) and Teixidó and Verde (2017) question Poterba's (1991) long-term approach and the studies that follow his approach. Chernick and Reschovsky (1997) criticise that the lifetime-ability-to-pay approach relies on several assumptions. This includes high income mobility, households basing their gasoline consumption on lifetime income rather than current income and that total consumption needs to be a constant fraction of lifetime income if total consumption expenditure in a given year is the core variable for the analysis. Teixidó and Verde (2017) argue that these assumptions influence the reliability and accuracy of the results obtained by the tax incidence analysis. They reason that households' consumption choices depend on their actual financial situations rather than hypothetical lifetime incomes. Furthermore, they argue that the lack of reliable income data and computational simplicity can explain the frequent use of Poterba's (1991) approach. Based on the above reasoning, our study relies on the short-term ability-to-pay approach. Fuel taxes need to be paid out of current household income in a given year, which makes the tax burden over current income ratio highly relevant for the perceived burden. Our database contains high-quality income data, rendering the arguments in favour of the lifetime approach less relevant.

Second, to address possible heterogeneity between income groups when analysing absolute and relative monetary burden, we order the population according to their financial situation. We focus on income deciles and assign households to ten equally sized groups ordered by their net equivalent income.[20]

Table 2: Interpretation of Progressivity and Redistribution Indices

		Distributional effect		
Index	Measure	Regressive	Proportional	Progressive
Suits (S)	Tax progression	-1 $\leq S < 0$	$S = 0$	$0 < S \leq 1$
Kakwani (K)	Tax progression	-1 $\leq K < 0$	$K = 0$	$0 < K \leq 1$
Musgrave/Thin (M)	Redistribution	$0 \leq M < 1$	$M = 1$	$1 < M < +\infty$
Reynolds/Smolensky (R)	Redistribution	-$\infty < R < 0$	$R = 0$	$0 < R < +\infty$

Third, we need to find adequate statistical summary measures to evaluate the distributional effects of taxes on transport fuels. There exist numerous potential approaches (for a more detailed discussion, see Lambert (2001)). Our analysis relies on the Suits index as a measure that reflects the *progression of the tax* (Suits, 1977) and the Musgrave/Thin index to quantify the *redistribution of the tax* (Musgrave and Thin, 1948).[21]. Since previous studies (e.g. Sterner, 2012; Agostini and Jiménez, 2015) used the Suits index for the analysis of tax incidence, we also resort to this measure. The Suits index captures the degree of deviation of a tax system from proportionality. It directly measures the concentration of the tax burden in relation to the concentration of income. As Table 2 summarises, the Suits index ranges from -1 (maximum regressivity) to 1 (maximum progression). 0 indicates proportionality. In addition, we use the concentration curves underlying the Suits index to identify possible non-monotonic trends that would not be visible in the summary index. Here, the cumulative share of total tax burden on the horizontal axis is set against the cumulative share of total income on the vertical axis. The diagonal represents a proportional tax. The concentration

[20]The concept of net equivalent income relies on the assumption of economies of scale in the cost of living of multi-person households and on the assumption of an equal distribution of wealth within a given household. The net equivalent income is calculated by attributing weights to all household members. We take the weighting factors from the OECD scale which places a value of 1.0 on the head of the household, 0.5 on each additional adult member, and 0.3 on each child. The household's total income is then divided by the corresponding total weight of the household's members, yielding the net equivalent income (Becker et al., 2003).

[21]The calculation of the indices is performed with the STATA module PROGRES, adopting the assumptions for cases with no or with negative income (Peichl and van Kerm, 2007)

curve lies above this diagonal for a regressive tax and below for a progressive tax. As robustness check, we rely on the Kakwani index (Kakwani, 1977), which determines tax progression as the difference between the concentration coefficient of the tax and the Gini coefficient of income. It is greater than 0 for progressive taxation and less than 0 for regressive taxation.

Scenario CHCT combines the revenue-neutral carbon-harmonisation of the fuel tax (as in CH) with the introduction of an additional carbon tax (as in CT) of 65 euro/tCO_2. Since the CH component essentially serves as a carbon tax, the additional carbon tax of the CT component just increases its tax burden by a fixed percentage. The ratio between the tax levels of all fuel types is identical in CH and CHCT, as it is based solely on the CO_2 emission factors of the individual fuel types in both scenarios. As a consequence, the relative tax distribution among households (i.e. tax progression) as depicted by a concentration curve is identical for CH and CHCT. This is not the case for the *absolute amount* of money redistributed by the tax reform. As the Suits and Kakwani indices do not account for the latter, but only for tax progression, they will suggest no differences between both reform scenarios. Consequently, CHCT will yield to the same tax progression effect than CH. We will therefore focus our analysis regarding CHCT on the redistribution effects and rely on the commonly used index of Musgrave and Thin (1948). It focuses on the distribution of income towards equality and relates the inequality of pre-tax and post-tax income to each other. As a robustness check, we additionally refer to the index proposed by Reynolds and Smolensky (1977). The Musgrave/Thin index is larger (smaller) than 1 for progressivity (regressivity), while the Reynolds/Smolensky index is larger (smaller) than 0 (see Table 2). These indices do not only consider the progression of a tax, but also its amount (Lambert, 2001, p. 207f). The latter aspect constitutes an important difference to the Suits and Kakwani indices. A change in tax rates by a fixed percentage with the same tax structure is reflected in the values of the redistribution indices, whereas there is no change in the tax progression indices.

3.3 Hypotheses

As described in Section 2, the average annual mileage of petrol and diesel cars increases with household income. This increase is much stronger for diesel than for petrol. Car-ownership rises with household income (Nobis and Kuhnimhof, 2018) and fuel efficiency is comparatively unaffected by income (Jacobs and Quack, 2018). With rising income, households therefore consume more petrol and diesel on average. Fuel taxation will yield a regressive effect if average fuel consumption increases less than proportionally with household income. Based on the above reasoning and in line with Bach et al. (2019), we expect fuel taxes on petrol (diesel) to have a regressive (progressive) effect in the German status quo tax scheme (Scenario SQ). In addition to these fuel-dependent distribution effects, when studying the overall effect of the fuel tax, one must consider that, in total, private households consume around 40% more petrol than diesel (Federal Statistical Office, 2020). Accordingly, the tax on petrol contributes more to the aggregate effect of the entire fuel tax than the tax on diesel. Similar effect sizes for both individual taxes would, on aggregate, imply an overall regressive effect. Additionally, the proportion of petrol to diesel consumption decreases with income, and, therefore, the average tax paid per litre of fuel also decreases with income. Summing up the above arguments and the literature discussed in Section 2, we end up with the following hypotheses:

Hypothesis 1a: *The transport fuel tax on petrol (Scenario SQ) has a regressive effect.*
Hypothesis 1b: *The transport fuel tax on diesel (Scenario SQ) has a progressive effect.*
Hypothesis 1c: *On aggregate, the transport fuel tax (Scenario SQ) has a regressive effect.*

The revenue-neutral carbon-based harmonisation of the fuel tax (Scenario CH) implies an increase of the progressive diesel tax and a decrease of the regressive petrol tax. We expect the joint effect of these tax changes to be clearly progressive. Also, the results of our preceding analysis strongly point into this direction (Jacobs and Quack, 2018). These considerations yield:

Hypothesis 2: *The amendment of the transport fuel tax to a revenue-neutral carbon-harmonised fuel tax (Scenario CH) has a progressive effect.*

Just like the carbon-harmonised transport fuel tax, the additional carbon tax (Scenario CT) would be around 14% higher for one litre of diesel than for one litre of petrol. As the proportion of petrol to diesel consumption decreases with income, the average carbon tax per litre of fuel would increase with income, yielding a progressive partial effect. It remains theoretically unclear whether the total effect of this partial effect and the above-mentioned effects of car ownership, annual mileage, and fuel efficiency increase the average carbon tax expenditures more than proportionally to the household income. Only in this case we would observe a joint progressive distributional effect.

Compared to the existing fuel tax, the carbon tax on transport fuels should be less regressive or even more progressive, as petrol taxes are substantially lower than diesel taxes. The evidence from the international studies mentioned above does not provide an unambiguous picture. However, the studies on this subject in Germany indicate slight regressivity (Bach et al., 2019, 2020; Gechert et al., 2019; Stiftung Arbeit und Umwelt der IG BCE, 2019). Since overall the arguments for regressivity prevail, Hypothesis 3 reads:

Hypothesis 3: *A carbon tax on transport fuels (Scenario CT) has a regressive effect.*

According to our considerations above, we expect a progressive effect of the fuel tax reform (Scenario CH) and a regressive effect of the carbon tax (Scenario CT). Our last reform CHCT combines the core elements of CH (revenue-neutral carbon-harmonisation of the fuel tax) and CT (introduction of an additional carbon tax of 65 euro/tCO_2). The tax burden of the carbon-harmonised fuel tax is equivalent to a 232 euro carbon tax. Introducing the additional carbon tax, therefore, increases the tax burden relative to CH by a fixed percentage. As argued in Subsection 3.2, this leaves tax progression in CHCT unaltered compared to CH. We therefore focus on the *absolute amount* of money redistributed by the tax reform when analysing the effects of CHCT. To derive a hypothesis regarding the redistributional effects of this reform scenario, it appears to be helpful to compare the effects of petrol (Hypothesis 1a) and diesel (Hypothesis 1b) taxation. Compared to the status quo, on the one hand, the petrol tax would increase by 0.0344 euro/l, which we expect to have a regressive redistributional effect. On the other hand, the diesel tax would increase by 0.3165 euro/l and thus nine times as much, for which we expect a progressive effect of a corresponding magnitude. The relation of the tax increases suggests that we will observe a regressive total effect only if the regressive effect of petrol (Hypothesis 1a) is much stronger than the progressive effect of diesel (Hypothesis 1b). Our last hypothesis summarises these considerations:

Hypothesis 4: *Amending the transport fuel tax to a revenue-neutral carbon-harmonised fuel tax in combination with the introduction of a* 65 *euro carbon tax on transport fuels (Scenario CHCT) does not yield a regressive redistribution effect.*

4 Data

In Subsection 4.1, we describe the microsimulation model and the data we use to analyse the tax incidence of the policy regimes described above. Subsection 4.2 presents descriptive statistics of key variables.

4.1 Microsimulation Approach

This study represents the first application of the Car Tax Model (CARMOD), a static partial microsimulation model based on an integrated mobility dataset.[22] CARMOD simulates the tax incidence of the year 2017 for passenger cars of private households under the German institutional framework. We focus on the first-round effects ("morning-after effects") of the variations in the tax regimes. Indirect effects which can arise due to behavioural responses and changes of consumption prices other than taxes (Pizer and Sexton, 2019) are not taken into account. In a similar, yet less detailed approach for seven European countries, Sterner (2012) finds that the distributional effects of fuel taxes do not differ much regardless of whether indirect effects are taken into account or not, especially in high-income countries. Our approach, thus, allows deriving clear-cut first-round effects without relying on additional assumptions related to the estimation of behavioural responses.[23]

For the present paper, CARMOD incorporates the new fiscal instruments as well as all existing excise duties on transport fuels, which are the fuel tax and the value added tax.[24] The microsimulation model computes each household's individual tax burden by applying the tax scheme to the corresponding household and car characteristics.

Since no existing dataset contains all variables needed for our investigations, the integrated database of CARMOD is composed of four national German household surveys: The data of MiD 2017 serves as the fundament, which is supplemented by additional information of the MOP 2017, the EVS 2018, and the German vehicle mileage survey (FLE) 2014.[25] This provides us with an ex-

[22]The model has been developed to conduct the analyses presented in this paper. A more technical description of the model and data can be found in Quack and Jacobs (2021).

[23]When running a robustness check with a simplified behavioural response assuming a universal fuel price elasticity of 0.5, we basically find less pronounced effects. Yet the main results provided in the remainder of the paper remain qualitatively stable. A discussion on the potential differences between direct and indirect effects is provided in Section 6.

[24]Taxes on electricity – but also on the fuels that produced this electricity – used by plug-in electric cars are not taken into account, as their impact is negligible to date.

[25]The information of the FLE is not used in our analysis, therefore no description is provided.

ceptionally rich database on which we build our microsimulations.

At the time of data collection – between May 2016 and September 2017 – the MiD was the world's largest household survey on private mobility. With nationwide representative data on 316,361 individuals in 156,420 households owning 216,844 passenger cars, it provides unparalleled information (Eggs et al., 2018). The MiD contains the usual demographic aspects as well as sophisticated data on mobility patterns of the household members, complemented by relevant economic indicators such as net household income. It covers information on up to three passenger cars that exist in each household. The car data includes annual mileage and fuel type, which largely determine the analysed tax burden. Auxiliary attributes like a car's year of construction, vehicle segment[26], and engine power[27], which are used for data imputation, supplement the car data.

The MOP, collected as an annual panel since 1994, includes detailed information on the mobility behaviour and car use of households. The wave used in our study comprises 1,850 households representative of Germany in the reporting period 2017, for which 1,602 car-specific fuel logbooks were collected in spring 2018 (Ecke et al., 2019). The fuel logbooks provide data on fuel consumption measured in real operation, on mileage, and on individual vehicle specifications like the fuel type and the vehicle type. As the MiD lacks information on actual fuel consumption, the database is supplemented by corresponding variables of the MOP.

The EVS data provides representative statistics on the living conditions of German households. Since 1962/63 it has been conducted every five years by the Federal Statistical Office and the statistical offices of the German states. Due to its comprehensive data quality, it acts as official source for the Federal Government and other national institutions. With about 60,000 households, it is the largest official dataset on income and expenditures within the European Union. For the purpose of this study, the EVS 2018 (Research Data Centres of the Statistical Offices of the Federation and the Federal States, 2018) provides income information for households with a monthly net income of 9,000 euro and more, as these incomes are censored within the MiD.

Around 4% of the cars in the MiD data contain missing information on the attributes relevant

[26] Although the questionnaire also asked for cars of the vehicle segment camper vans, the data does not comprise information about this segment. Instead, the data handles camper vans as if they belonged to other vehicle segments, primarily utilities or large vans. Due to the small share of camper vans in the vehicle fleet, we consider this inaccuracy as insignificant for our results.

[27] Engine power, as some other variables, has been collected only within a base sample, which comprises 33,389 households.

for the tax incidence analysis.[28] Additionally, the fuel consumption of cars is not included in the survey. In the following paragraph, we briefly describe how we deal with missing data and unobserved attributes in our analysis.[29]

98.5% of missing information on engine power is missing due to the survey design, as the corresponding households were not asked to report the engine power of their car. They can thus be considered as missing completely at random (MCAR). We, however, also observe item non-response in some cases. We assume that the missing observations of the car's fuel type, annual mileage, and year of construction, but also those missing observations of engine power that are not MCAR, are missing at random (MAR).[30] According to Allison (2009), listwise deletion of observations with missing data that are MAR is legitimate only in specific situations.[31] Deleting observations that are MAR imposes the risk of biased results in a microsimulation setting, as the remaining data does not represent the exact distributions and interrelations of the original population. Instead of deleting these observations, we follow Rubin (1987) and apply multiple random imputation (MI). The idea of MI resembles a Monte Carlo approach for the application of missing data (Schafer, 1997). For each of the n copies of the data set, the missing values are estimated by regressing the missing variables on a set of suitable explanatory variables. Compared to single imputation approaches, the amount of uncertainty introduced by the randomness of the imputation method is represented in the standard errors of the imputed variables over all n datasets (Allison, 2009). Missing data techniques like MI are also applied when attributes are not only partially missing but missing completely. In that case a donor dataset is required to add the missing attribute to the recipient dataset. Both datasets need to contain the same attributes, matching in scale and levels, which provide sufficient explanation for the missing attribute.[32]

[28]The car's fuel type (0.4% missing) and annual mileage (3.9% missing) determine the energy tax and the CO_2 tax directly. The attributes year of construction (2.5% missing), vehicle segment (4.9% missing), and engine power (94.1% missing) are not needed to determine the tax directly but are used as explanatory variables for the imputation attributes of the missing data of fuel type and annual mileage.

[29]A detailed description of the imputation techniques applied in our model is provided in Quack and Jacobs (2021).

[30]Missing data is said to be MCAR if neither other attributes nor the missing attribute itself influence the probability of the attribute to be missing. It is said to be MAR if the value of the missing data does not influence the probability that the data is missing after controlling for other attributes. As long as the data is MCAR or MAR it is not necessary to model the missing data mechanism within the imputation process (Allison, 2009).

[31]Regression analysis for example produces unbiased estimates if the dependent variable does not influence the probability of any missing data of independent variables (Allison, 2009).

[32]This application is referred to as statistical matching (e.g. Alpman, 2016; Cohen, 1991; D'Orazio et al., 2006; Leulescu and Agafitei, 2013). Statistical matching implies higher statistical uncertainty than imputing missing values for only a fraction of the observations based on the same dataset.

CARMOD therefore applies the concept of MI to the handling of missing data and the integration of unobserved attributes within a computationally intensive procedure.[33] In the first step, any missing observations of fuel type and annual mileage of the MiD cars are imputed. Furthermore, the fuel consumption of all cars is predicted based on MOP data and monthly net incomes of 9,000 euro and above are predicted based on EVS data. This is repeated 150 times, as this number of iterations tends to be a sufficient compromise between computational requirements and statistical accuracy.[34] This procedure generates 150 copies of the original dataset that only differ in the imputed values and the matched attributes. In the second step, each individual household's tax burden is simulated for each dataset yielding 150 slightly different results. In the third step, CARMOD pools these results by calculating their mean and their accompanying standard deviation. This allows to quantify the statistical uncertainty caused by the randomness of the data integration process. As a robustness check, we additionally simulate a model with 500 imputation iterations. The results and their standard deviations differ only marginally from each other without compromising their message.[35]

4.2 Descriptive Statistics

The study population of the CARMOD database consists of 156,420 households, which extrapolates to 41.0 million private households in Germany with a total of 43.7 million passenger cars.[36] Since this paper focuses on the analysis of distributional effects, we present descriptive statistics across all households and separately by deciles according to their net equivalent income. As reported in Table 3, households' average net income is around 1,120 euro in the 1st decile and rises to 6,120 euro in the 10th decile. 22.5% of all households reported that no car existed in their household. 53.3% have one car, 24.2% have more than one car.[37] The share of households without cars varies across

[33]Both imputation steps are conducted with Stata 16 using the *MI* command (StataCorp, 2019).

[34]White et al. (2011) suggest to use at least as many imputation iterations as the share of incomplete observations multiplied by 100. Since we not only impute missing values for a fraction, but for all observations, we therefore need at least 100 iterations of imputation.

[35]Detailed results are available on request.

[36]This includes privately and commercially registered cars, and thus also privately used company cars, as long as they are at a private household's disposal. Taxis, for example, may be considered depending on the judgement of the corresponding households. Vehicles used to transport goods, such as light commercial vehicles used by craftsmen, are not part of the data.

[37]0.6% of the observed households report having more than three cars. As the data only provides detailed information on up to three cars per household, it lacks information on 1.7% of all households' cars. Our analysis, thus, tends to underestimate households' average tax burden. However, given the small number of households with truncated information, we argue that the effects on our results are negligible.

Table 3: Description of the Study Population

Variable	Unit	Households by net equivalent income decile										
		All	1	2	3	4	5	6	7	8	9	10
Data on households												
Mean of household net income	euro	3,000	1,120	1,610	2,070	2,450	2,890	2,830	3,410	3,590	3,870	6,120
Households without a car	%	22.5	53.4	35.1	21.0	18.2	20.1	18.9	17.8	15.1	14.4	11.4
Households with one car	%	53.3	40.4	53.9	63.8	64.1	58.3	59.1	50.1	47.2	47.6	49.0
Households with more than one car	%	24.2	6.3	11.0	15.2	17.6	21.6	22.0	32.1	37.7	37.9	39.6
Subgroup: commuters	%	33.8	12.0	21.5	25.7	27.5	31.1	31.2	41.2	46.5	52.7	48.6
Subgroup: rural households	%	34.4	39.3	38.3	38.1	36.2	34.1	34.4	34.6	32.4	30.3	25.9
Subgroup: families	%	19.4	13.1	22.3	17.8	19.8	26.3	11.4	29.4	22.2	17.8	14.3
Mean of annual mileage: households*	km/year	19,800	15,000	15,200	15,500	16,700	18,600	18,800	21,900	22,900	23,600	26,000
Mean of CO_2 emissions: households*	kg/100km	17.7	17.1	17.3	17.4	17.6	17.6	17.7	17.7	17.9	17.8	18.6
Mean of fuel tax by CO_2 emissions*	euro/tCO_2	290	310	310	300	300	300	300	290	290	280	270
Mean of fuel tax by mileage*	euro/100km	5.20	5.30	5.30	5.30	5.30	5.20	5.20	5.10	5.10	5.00	5.10
Data on cars												
Petrol cars	%	66.7	77.9	76.2	75.1	72.0	68.6	68.7	64.5	63.4	60.5	54.8
Diesel cars	%	31.6	20.9	22.5	23.0	26.3	29.8	29.5	34.1	34.9	37.4	43.3
LPG/CNG cars	%	1.0	0.7	1.0	1.2	1.0	1.0	0.9	0.8	1.0	1.1	1.0
Hybrid cars	%	0.6	0.4	0.3	0.7	0.6	0.5	0.9	0.5	0.5	0.7	0.6
Electric cars	%	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Mean of car age	years	8.9	11.9	10.7	9.6	9.3	8.8	8.9	8.5	8.4	7.9	7.6
Mean of annual mileage: cars	km/year	14,600	13,000	12,800	12,800	13,500	14,100	14,300	15,000	15,300	15,900	17,200
Mean of annual mileage: petrol cars	km/year	11,800	11,300	11,300	11,100	11,600	11,600	11,900	12,000	11,900	12,000	12,500
Mean of annual mileage: diesel cars	km/year	20,600	19,600	17,600	17,800	18,300	19,600	19,700	20,900	21,300	21,900	23,000
Mean of fuel consumption: petrol cars	litre/100km	7.6	7.4	7.4	7.5	7.6	7.5	7.6	7.6	7.7	7.6	8.1
Mean of fuel consumption: diesel cars	litre/100km	6.8	6.5	6.7	6.7	6.7	6.7	6.8	6.8	6.9	6.8	7.1

Sources: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

*Evaluations refer to households with at least one car.

deciles: it is highest in the 1st decile (53.4%) and drops to 11.4% in the 10th decile. Around 40% of households in the 10th decile own more than one car, whereas this share only amounts to 6% in the 1st decile. Most cars (66.7%) of private households are petrol cars, followed by diesel cars (31.6%). A subordinate role is taken by liquified petroleum gas (LPG) or compressed natural gas (CNG) fuelled cars (1.0%), hybrid cars (0.6%), and all-electric cars (0.1%).[38] The share of diesel cars increases with household income: it is more than twice as high among households in the 10th decile (43.3%) than in the 1st decile (20.9%).

The average annual mileage *per car-owning household* amounts to around 19,800 km. Households in the upper deciles drive more on average than households in the lower deciles, with the average annual mileage increasing successively from around 15,000 km (1st decile) to 26,000 km (10th decile). The average annual mileage *per car* amounts to around 14,600 km, with petrol cars being driven 11,800 km on average and diesel cars almost twice as much (20,600 km). The annual mileage of both increases (with some fluctuations) with income. This increase is more pronounced for diesel cars.

Cars owned by households from the 1st decile are on average 11.9 years old, which is 4.3 years older than in the 10th decile. Despite being older, the cars of households in the 1st decile have the lowest fuel consumption compared to the other deciles, with an average of 6.8 litres of diesel and 7.6 litres of petrol per 100 km. Households in the 1st decile therefore have the lowest average CO_2 emissions per 100 km. These amount to 17.1 kg/100 km and rise with slight fluctuations to 18.6 kg/100 km in the 10th decile.

A household's average fuel tax burden per tonne of CO_2 depends on fuel consumption and fuel type. Due to the fuel-specific carbon prices of the fuel tax, the tax burden per tonne differs among households. For example, households in the 1st decile pay 310 euro/tCO_2, whereas households in the 10th decile pay only 270 euro/tCO_2. A similar, albeit less pronounced, picture emerges when the average tax burden is set in relation to kilometres. Households from the 1st decile pay an average fuel tax of 5.30 euro/100 km, whereas households in the 10th decile pay only 5.10 euro/100 km.

[38] As the data provides no distinction between LPG and CNG, which accounted for 0.2% of the car fleet in 2017, we assume for the simulation that all gas-powered cars are fuelled by LPG due to its dominant share in the German car fleet (Federal Motor Transport Authority, 2017). For similar reasons, we assume that all hybrid cars run on petrol. Hybrid cars also comprise plug-in hybrid electric cars, which accounted for about 6% of hybrid cars registered by private households in 2017 (Federal Motor Transport Authority, 2017). Similar to all-electric cars, electricity charging of plug-in hybrid electric cars is not subject to fuel taxation and is therefore not considered.

In the later analysis, we will not only focus on the distributional effects of the total population, but consider population subgroups that, in addition to their economic situation, are likely to be particularly affected by a change in fuel taxes due to their occupational, geographical, or social situation. Their special requirements as well as dependencies on mobility motivate these subgroup analyses. As a first subgroup, we consider households with commuting mobility patterns (*commuters*) who might particularly depend on driving due to their occupational situation and thus might be strongly affected by changes in fuel taxation.[39] The share of commuters increases across income deciles. In the 1st decile, commuters make up just over 10% of all households, in the middle of the income distribution already about 30%, and in the 10th decile this share is almost 50%. Due to their geographical location and thus possible longer distances and a higher reliance on cars, households living in rural areas comprise the second subgroup (*rural households*). According to the summarised regional statistical spatial type of the MiD 2017, we divide the sample into rural and urban households.[40] The proportion of households living in rural regions decreases from the 1st to the 9th decile from almost 40% to around 30%. In the 10th decile, only a quarter of households live in rural areas. As a third subgroup dimension, we differentiate between households with and without children. The subgroup *families* includes households with at least one person younger than 18 years of age. The share of families is about 19% and varies considerably between income deciles.

5 Simulation Results

This section describes the simulation results. We start with the distributional effects of fuel taxes in the status quo in Subsection 5.1 and present the results for the three reform scenarios in Subsections 5.2, 5.3, and 5.4.

Table 4: Results of Progressivity and Redistribution Indices

	Scenario								
	SQ			CH		CT		CHCT	
Index	Tax effect (1)	Petrol only (2)	Diesel only (3)	Tax effect (4)	Reform effect (5)	Tax effect (6)	Reform effect (7)	Tax effect (8)	Reform effect (9)
Suits	-0.0309	-0.1209	0.1393	-0.0022	0.0288	-0.0222	0.0087	-0.0022	0.0288
Kakwani	-0.0194	-0.1053	0.1428	0.0081	0.0275	-0.0111	0.0083	0.0081	0.0275
Musgrave/Thin	0.9989	0.9975	1.0012	0.9997	0.0008	0.9985	-0.0003	0.9995	0.0006
Reynolds/Smolensky	-0.0008	-0.0017	0.0008	-0.0002	0.0006	-0.0010	-0.0002	-0.0004	0.0004

Sources: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

Notes: Columns (5), (7), and (9) display the differences between the reform scenarios' tax effects (Columns 4, 6, and 8) and SQ (Column 1).

5.1 Status Quo of the Fuel Tax (Scenario SQ)

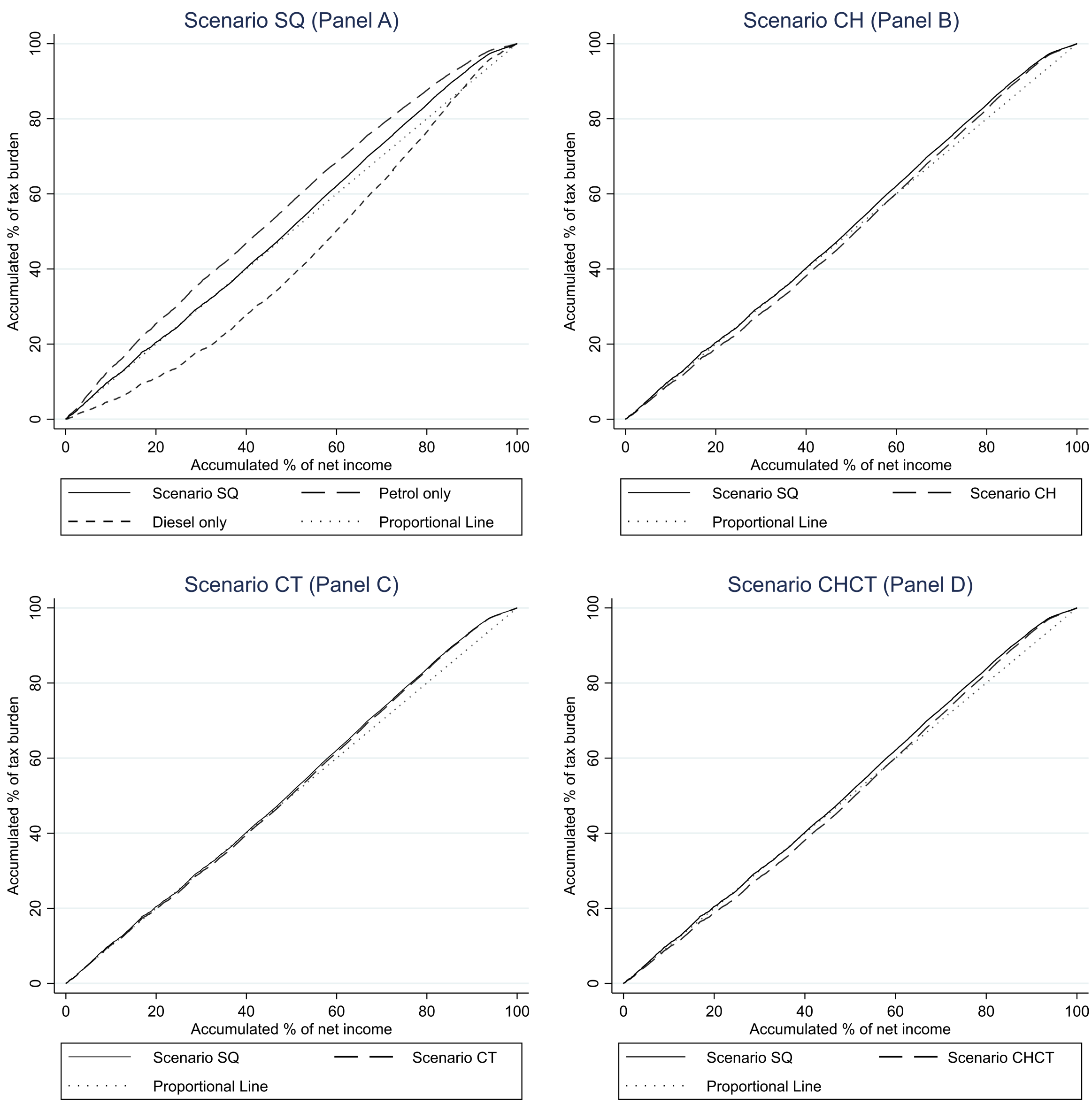
Columns (1) to (3) of Table 4 report the aggregated distributional effects of the fuel tax in the status quo (Scenario SQ). All reported index values in the results section significantly ($p < 0.001$) larger (progressive) or smaller (regressive) from 0 (Suits, Kakwani, and Reynolds/Smolensky indices) or 1 (Musgrave/Thin index).[41] For the sake of brevity, we, therefore, do not report the *p*-values when referring to these coefficients. We, however, report *p*-values when comparing index values between reform scenarios. Consistent with Hypotheses 1a and 1b, the Suits index for the fuel tax on petrol (-0.1209) indicates a regressive tax progression, while the progression of the fuel tax on diesel (0.1393) is progressive. The Suits index of the overall fuel tax (-0.0309) is negative, indicating a regressive effect. It is, however, substantially closer to proportionality (0) than to extreme regressivity (-1). If anything, this result tends to speak in favour of Hypothesis 1c, though the economic significance remains questionable. The redistribution effects measured by the Musgrave/Thin index are in line with the findings on tax progression measured by the Suits index. They indicate a regressive redistribution for the overall fuel tax (0.9989) and the fuel tax on petrol (0.9975), and a progressive redistribution for the fuel tax on diesel (1.0012). Both the Kakwani index and the Reynolds/Smolensky index support our conclusions for all three hypotheses.

[39] As the data does not contain a direct classification of a household as "commuter", we define this subgroup as follows: To capture those who work at least in a half-day job and, thus, potentially commute regularly, we consider persons who are employed with more than 18 hours of working time or who are trainees. Persons who do not report daily or almost daily car use, persons without car driving license ownership, persons without car availability, and persons living in households that report not having a car are not considered commuters.

[40] Further information on the typology of the German regions is provided by the Federal Ministry of Transport and Digital Infrastructure (2020).

[41] The statistical tests provided in this analysis refer to the uncertainty due to the imputations of missing data. All *p*-values correspond to one-sided t-tests.

Figure 1: Concentration Curves for Scenarios



Source: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

Panel (A) of Figure 1 depicts concentration curves, relating the cumulative share of the total tax revenue (vertical axis) to the cumulative share of total household income (horizontal axis). Although they are conceptually closely related to the Suits index, they provide additional insights into the distributional effects of fuel taxation as they map the tax progression across the entire income distribution. The concentration curve of petrol taxation (wide dashed line) runs in a smooth arc constantly above the proportionality line, reflecting its regressivity. It shows that 80% of the tax revenues of petrol are paid by only a little more than 70% of households. The fine dashed line depicts the concentration curve for the taxation of diesel. It is below the proportionality line for most of the income distribution, indicating progressivity. Especially in the lower half of the income distribution, its distance from the proportionality line is larger than for the fuel tax on petrol. Interestingly, the concentration curve intersects the proportionality line just ahead of the top income decile and runs above it. Finally, the solid line shows the combination of the effects of petrol and diesel. On aggregate, the progressive petrol tax and the regressive diesel tax yield a concentration curve of the overall fuel tax which runs almost exactly on the proportionality line up to the middle of the income distribution, implying that below this income level, the ratio of income and tax burden is rather balanced. In the upper half of the income distribution, the concentration curve leaves the proportionality line and runs above it, which, in total, indicates a regressive tax effect.

We, next, consider the distribution of the average tax burden across income deciles. The fuel tax levied on private households' annual transport fuel consumption increases from an average of 330 euro in the 1st decile to 1,090 euro in the 10th decile (Column 1 of Panel A in Table 5). The share of net income spent on fuel tax also tends to decrease with increasing income, albeit quite slightly (Column 2).

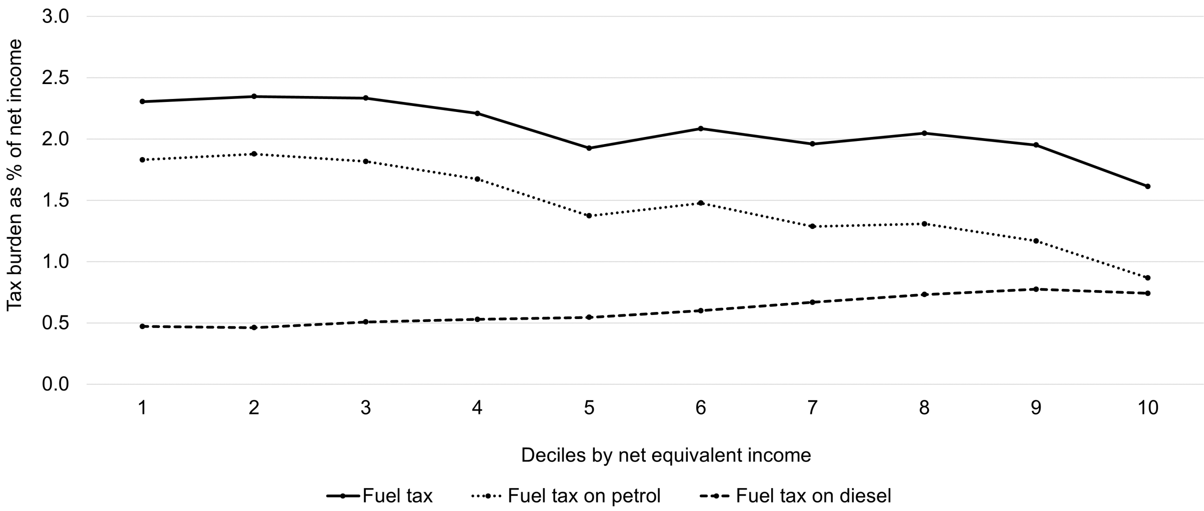
Figure 2 depicts the relative tax burden by income deciles graphically. The solid line illustrates that this share does not fall monotonously, but has small fluctuations in the middle of the income distribution. Given the rather small differences across deciles, we cautiously interpret the results in favour of a weakly regressive tax burden. Figure 2 also confirms the regressive trend for the taxation of petrol fuel and the progressive trend for the taxation of diesel fuel as indicated by the aggregated measures. For diesel, the tax burden relative to income nearly doubles between the lowest and the highest decile, while it is halved for petrol.

Table 5: Average Absolute and Relative Tax Burden by Net Equivalent Income Decile

		Scenario							
		SQ		CH		CT		CHCT	
		Tax effect		Reform effect		Reform effect		Reform effect	
		abs.	rel.	abs.	rel.	abs.	rel.	abs.	rel.
		euro	%	euro	%	euro	%	euro	%
	Decile	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All households (Panel A)	1	330	2.3	-20	-0.2	140	0.9	70	0.4
	2	480	2.3	-30	-0.2	200	0.9	100	0.4
	3	600	2.3	-30	-0.1	250	0.9	130	0.5
	4	660	2.2	-20	-0.1	280	0.9	150	0.5
	5	710	1.9	-10	-0.1	300	0.8	190	0.5
	6	730	2.1	-10	-0.1	310	0.9	190	0.5
	7	850	2.0	10	0.0	370	0.8	250	0.5
	8	920	2.0	20	0.0	400	0.9	280	0.6
	9	930	2.0	30	0.1	420	0.9	300	0.6
	10	1,090	1.6	70	0.1	500	0.7	390	0.6
Winner (Panel B)	1	-	-	-120	-0.9	-	-	-	-
	2	-	-	-120	-0.6	-	-	-	-
	3	-	-	-130	-0.5	-	-	-	-
	4	-	-	-130	-0.5	-	-	-	-
	5	-	-	-140	-0.4	-	-	-	-
	6	-	-	-140	-0.4	-	-	-	-
	7	-	-	-160	-0.4	-	-	-	-
	8	-	-	-160	-0.4	-	-	-	-
	9	-	-	-170	-0.4	-	-	-	-
	10	-	-	-180	-0.3	-	-	-	-
Loser (Panel C)	1	-	-	220	1.4	290	2.0	150	0.9
	2	-	-	220	1.0	300	1.4	160	0.7
	3	-	-	230	0.8	310	1.2	170	0.6
	4	-	-	230	0.7	340	1.1	190	0.6
	5	-	-	240	0.6	380	1.0	230	0.6
	6	-	-	240	0.7	380	1.1	230	0.6
	7	-	-	260	0.6	450	1.0	300	0.7
	8	-	-	270	0.6	480	1.0	330	0.7
	9	-	-	280	0.6	490	1.0	350	0.7
	10	-	-	310	0.5	560	0.8	440	0.6

Sources: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

Figure 2: Distribution of Relative Tax Burden in Scenario SQ

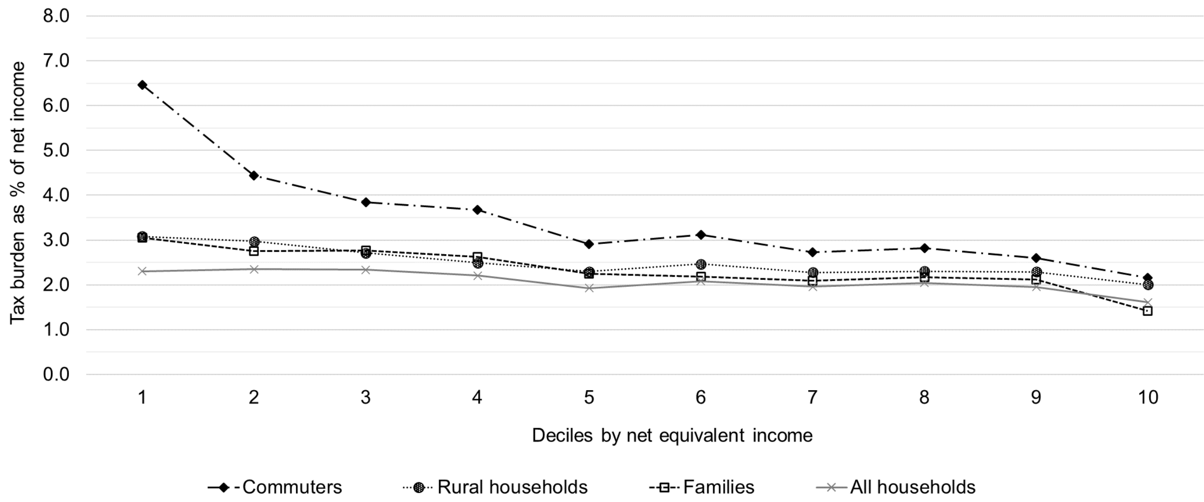


Source: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

Result 1: *The findings presented in this subsection are consistent with Hypotheses 1a (regressivity of the tax on petrol) and 1b (progressivity of the tax on diesel). In sum, the results for the tax on transport fuel yield weak support of Hypothesis 1c (i.e. a regressive effect of the status quo fuel tax scheme).*

While this paper focuses on the vertical distributional effects of alternative policy scenarios, our data additionally allow us to analyse horizontal heterogeneity between subgroups of the population. We, therefore, compare the average fuel tax burden in relation to income for commuters, families, and households living in rural areas as defined in Subsection 4.2. Figure 3 depicts the change in relative tax burden per income decile for the different subgroups. With the exception of families in the 10th decile, the three groups face a higher tax burden compared to the total of all households. The tax particularly burdens commuters in the lower four deciles, with almost a threefold higher tax share (compared to all households) in the 1st decile. Although their tax burden decreases with increasing income, it is well above the tax burden of families and rural households. Only in the 10th decile, the tax burdens of commuters and rural households nearly match. In the lower half of the income distribution, the tax burdens of families and rural households are at a similar level. In the upper income half, the tax burden on families tends to converge with the slightly decreasing level of the total population, whereas that of rural households remains constantly higher.

Figure 3: Distribution of Change in Relative Tax Burden for Subgroups in Scenario SQ



Source: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

5.2 Carbon-Harmonised Fuel Tax (Scenario CH)

The revenue-neutral harmonisation of the fuel tax described in Subsection 3.1 yields changes in the ratio between the taxes on petrol and diesel due to their different CO_2 emission factors. While in the status quo, the tax per litre of petrol is 0.1841 euro higher than that of diesel, the tax per litre of petrol will be 0.0766 euro lower than that of diesel after the harmonisation (see Table 1). Households with only diesel passenger cars will, thus, face a price increase and households with only petrol passenger cars will face a decrease. For households owning both diesel and petrol vehicles, the identification of reform “winners” and “losers” depends on the composition of the emissions actually caused: If the share of a household’s emissions caused by petrol cars is sufficiently high, the higher costs due to the increased taxation of diesel will be overcompensated and the household will benefit from the reform.

As can be seen in Column (4) of Table 4, the four summary measures describing the reformed fuel tax in Scenario CH hardly indicate an overall deviation from proportionality. The indices of Suits (−0.0022), Musgrave/Thin (0.9997), and Reynolds/Smolensky (−0.0002) denote a regressive tax, while the Kakwani index (0.0081) denotes a progressive tax. All indices increase unambiguously and significantly ($p < 0.001$) compared to the status quo (Column 5). Both tax progression indices increase by almost the same amount (Suits index +0.0288, Kakwani index +0.0275), indicating a progressive shift. The increase of the redistribution indices of Musgrave/Thin (+0.0008) and Reynolds/Smolensky (+0.0006) supports the interpretation of a progressive distributional effect due to the tax reform (Hypothesis 2), although it is very small in magnitude.

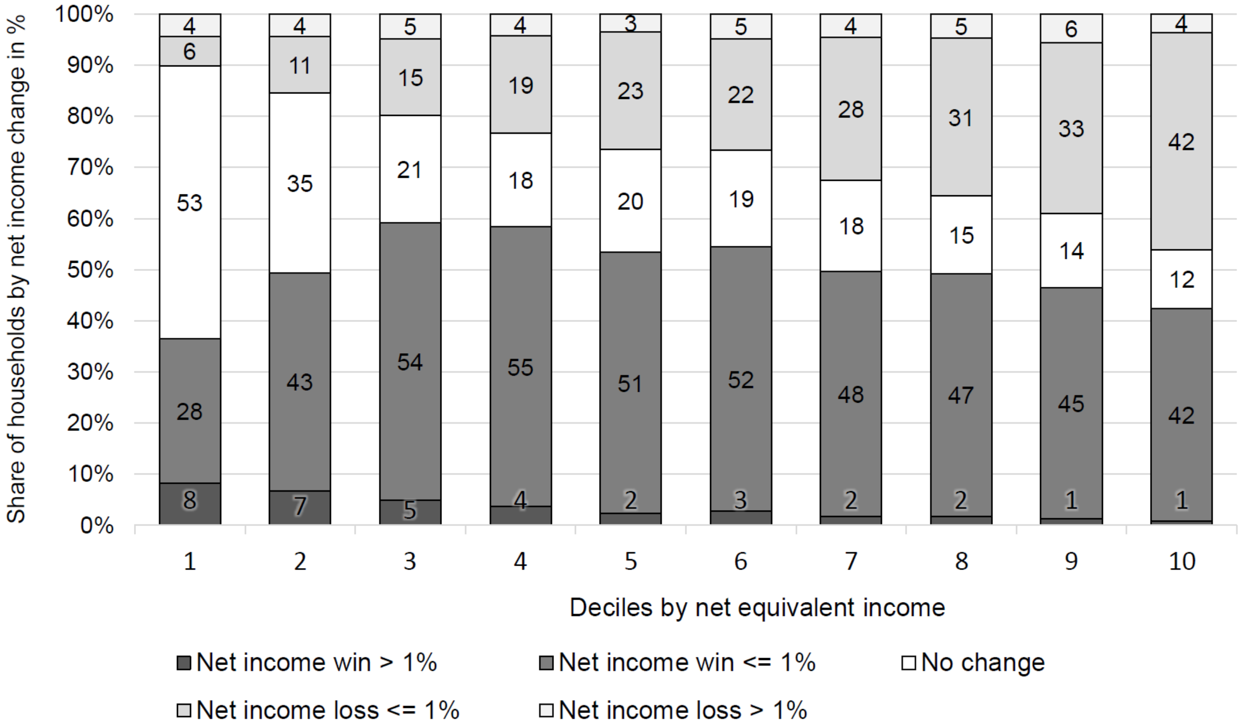
The positive shift in the Suits index is reflected by the CH concentration curve (dashed line) running below the SQ curve (solid line) in Panel (B) of Figure 1. In the upper half of the income distribution, the regressive course is weakened, while in the lower half of the distribution even a slightly progressive course is discernible.

Table 5 reveals a considerable amount of heterogeneity in the changes in average tax burdens across income deciles. Taking all households into account (Panel A), the lower 60% of the income distribution are, on average, relieved (Columns 3 and 4), while the households in deciles 7 to 10, on average, pay more taxes than in the status quo. Overall, the monetary effects of the reform tend to be relatively small. The average reliefs in the yearly tax burden range from 10 to 30 euro, which amounts to 0.2% of the relative burden at maximum. The households in the highest four deciles have to pay additional taxes of between 10 (7th decile) and 70 euro (10th decile). This corresponds to a relative additional burden of a maximum of 0.1%.

The average effects per decile, however, hide heterogeneity *within* deciles. One of the strengths of our microsimulation approach is that we can identify winners and losers within income deciles. Figure 4 depicts the shares of households per decile that win or lose from fuel tax harmonisation. This figure does not only focus on the extensive margin (winning or losing due to the reform), but also on the intensive margin (extent of winning or losing as measured by the change in the ratio of tax burden to income). The share of losers tends to be considerably smaller among households in the lower income groups: Only 10% of the households in the 1st decile experience a monetary loss, whereas 36% benefit from the reform. The 53% of the households who are unaffected in this decile are those who do not own a car. The share of winner households rises with income from decile 1 to 4. Subsequently, it tends to fall slightly in the second half of the income distribution. Since the share of households without a car decreases with income, the share of losers also increases. The proportion of households with losses of more than 1% of income is rather small and ranges between 3% and 6% without a clear trend, while the share of households that are mildly negative affected (loss between 1% and 0%) rises with income and quadruples from the 1st to the 10th decile (42%).

Complementary, Table 5 splits the sample into winner (Panel B) and loser (Panel C) households and reports their average additional tax relief and burden. Both the additional tax relief and burden increase with income. While the absolute tax relief ranges from 120 euro (1st decile) to 180 euro (10th decile), the average additional burden amounts to 220 euro and 310 euro, respectively (Column 3 in Panels B and C). In relative terms, lower incomes benefit on average more than upper incomes among the winners (Column 4 in Panel B). The additional tax burden for low-income households that lose on average amounts to 1.4% of their income, which is the highest relative burden (Column 4 in Panel C). Even though the monetary effects of the tax reform do not seem to be overly large on aggregate, the results of this more detailed analysis show that the introduction of the carbon-harmonised fuel tax has non-negligible monetary effects for both the winning and the losing households – with the share of losers increasing drastically with income.

Figure 4: Distribution of Winners and Losers in Scenario CH

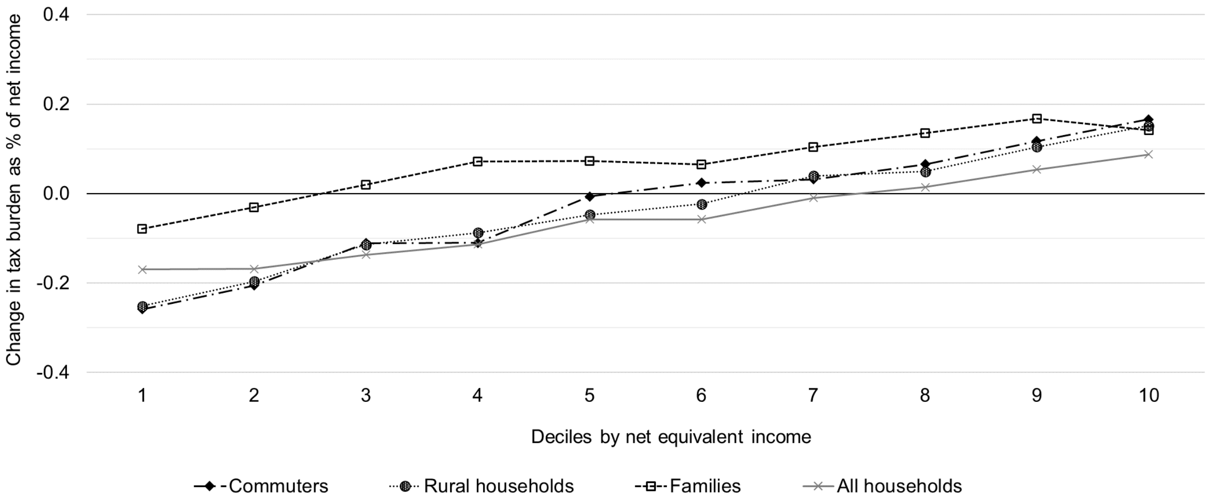


Source: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

Result 2: *The overall progressive effect measured by a positive shift in the Suits index and the course of the corresponding concentration curve as well as the analysis of winning and losing households point to support for Hypothesis 2.*

A revenue-neutral harmonisation of the fuel tax can lead to heterogeneous effects not only vertically, but also horizontally. Figure 5 depicts the changes in the average relative tax burden across the income distribution for the subgroups defined in Subsection 4.2. As for the total of all households, lower income groups are relieved, upper income groups are burdened. However, compared to the aggregate over all households, even lower deciles are burdened by the tax reform in the subgroup analyses. Families in particular are only relieved in the 1st and 2nd deciles. In comparison to all households, families are more heavily burdened, regardless of their income situation. Differences across deciles are most strongly pronounced for commuters and rural households. In the two lower deciles, the relief is greater than for all households. For higher incomes, the relief is lower and the burden higher.

Figure 5: Distribution of Change in Relative Tax Burden for Subgroups in Scenario CH



Source: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

5.3 Carbon Tax (Scenario CT)

We now analyse the distributional effects of an additional carbon tax of 100 euro/tCO_2 as described in Subsection 3.1 (Scenario CT).

The resulting Suits index is −0.0222 (Column 6 of Table 4). Its increase compared to the status quo is statistically significant ($p < 0.001$) and equals 0.0087 (Column 7 of Table 4), which suggests a (weakly) progressive shift in tax progression caused by the carbon tax. This result is supported by the almost equally large change of the Kakwani index (0.0083, $p < 0.001$). Our two measures of redistribution, the Musgrave/Thin index (−0.0003) and the Reynolds/Smolensky index (−0.0002), however, decrease slightly, but statistically significantly ($p < 0.001$). In contrast to the (weakly) progressive shift in tax progression, they suggest that the carbon tax implies a (weakly) regressive redistribution. Overall, these results point to a tendency towards a proportional reform effect rather than a regressive effect, as proposed in Hypothesis 3.

Panel (C) of Figure 1 depicts the concentration curves for the status quo (solid line) and the carbon tax (dashed line). The introduction of the carbon tax increases progressivity at the bottom of the income distribution and reduces regressivity at the top. The shift is more visible in the middle of the income distribution.

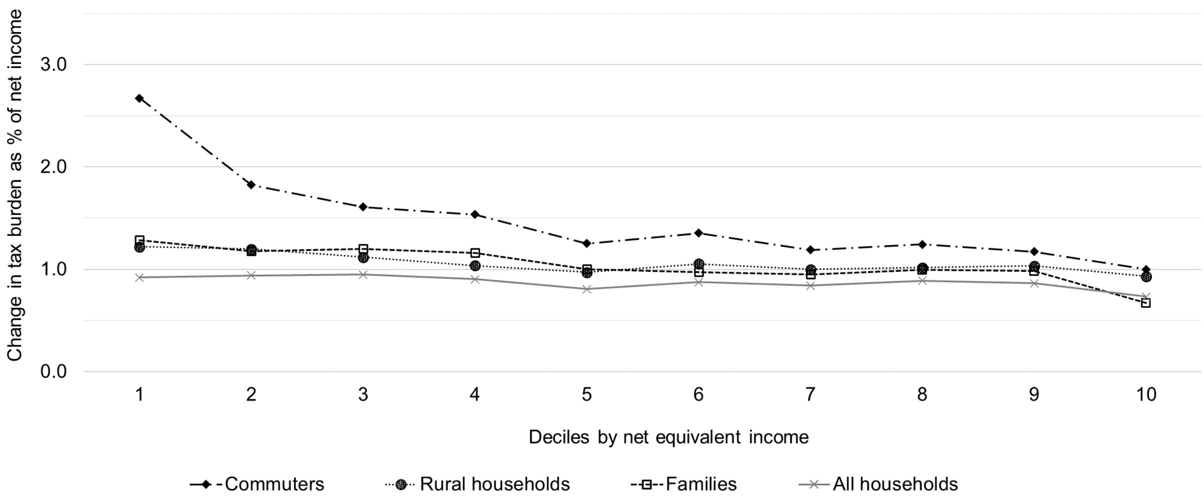
Column (5) in Panel (A) of Table 5 reports the increases in average tax burdens by income deciles. In absolute terms, the monetary burden caused by the carbon tax increases with income. On average, the additional annual burden amounts to 140 euro in the 1st decile and equals 500 euro in the 10th decile. Considering the burden measured in relation to household income yields a less clear pattern. It amounts to between 0.7 and 0.9% (Column 6 in Panel A of Table 5).

The analysis so far included those households that do not own a car and are, thus, not directly affected by the carbon tax. Focusing only on households who own a car, Column (5) of Panel (C) of Table 5 reveals that their annual additional burden is inevitably higher than for the whole population. On average, it amounts to 290 euro in the 1st decile and increases to 560 euro in the 10th decile. This translates into a higher relative burden in all deciles. Its increase is stronger among those households with lower incomes, reflecting the heterogeneity in the share of households without cars. Column (6) of Panel (C) shows that the relative burden decreases with income, which suggests regressivity of a carbon tax if we only examine households affected by the tax: On average, affected households in the 1st decile additionally pay 2.0% of their net income due to the reform, while the 10th decile only pays 0.8%.

Result 3: *Hypothesis 3 led us expect a regressive effect of the carbon tax on transport fuels. Considered together, the aggregated measures and the detailed consideration of the relative tax burden between the income deciles lead to a rejection of Hypothesis 3. Focusing the analysis on the subgroup of car owners only, however, yields a pattern which is consistent with the hypothesis.*

The subgroup results resemble those of the status quo. The carbon tax particularly affects low-income households that commute. Figure 6 shows that, for the 1st decile, their average additional tax burden is almost three times higher than for the total of all households. Not only commuting households in lower deciles are comparatively more affected. Although commuters' additional relative tax burden decreases with rising income, it is considerably higher than the relative tax burden of all households, families, and rural households. Likewise, the additional relative tax burden of families and rural households is higher than that of all households, except for families in the 10th decile.

Figure 6: Distribution of Change in Relative Tax Burden for Subgroups in Scenario CT



Source: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

5.4 Combined Tax Scheme (Scenario CHCT)

The last policy scenario combines the basic features of Scenario CH and Scenario CT: We replace the fuel tax by a revenue-neutral carbon-harmonised fuel tax combined with the introduction of a 65 euro carbon tax (see Subsection 3.1).

As reported in Subsection 5.2, overall, CH leads to a progressive effect as measured by the Suits and Kakwani indices. Both indices only take into account the tax level ratio between fuel types, which remains unchanged in CHCT (see Subsection 3.2). Their values will, thus, not differ between CH and CHCT (Columns 5 and 9 of Table 4): Regardless of the CT value, they indicate a progressive shift in tax progression. Accordingly, the shifts of the concentration curves are identical in Panels (B) and (D) of Figure 1. As described above, we therefore focus on the redistribution effect of the tax in this subsection. In SQ, the Musgrave/Thin index equals 0.9989, which, consistent with the Suits index, implies weakly regressive redistribution. With the carbon-harmonised tax (CH), the Musgrave/Thin index slightly increases to 0.9997, indicating a shift towards a more equal (and almost proportional) redistribution. While the tax rate structure remains the same in CHCT (as argued in Subsection 3.2), households' tax burden increases compared to CH due to the carbon tax. Compared to SQ, this higher tax burden in CHCT yields a slight increase of the Musgrave/Thin index. This increase by 0.0006 ($p < 0.001$) to 0.9995 is marginally smaller than for CH. However, it still indicates a (small) progressive effect on the income distribution, which is supported by the Reynolds/Smolensky index (+0.0004, $p < 0.001$). The (weakly) regressive redistribution effect of the carbon tax as identified in Subsection 5.3 does, therefore, not lead to an overall regressive redistribution by the reform analysed in CHCT, supporting Hypothesis 4.

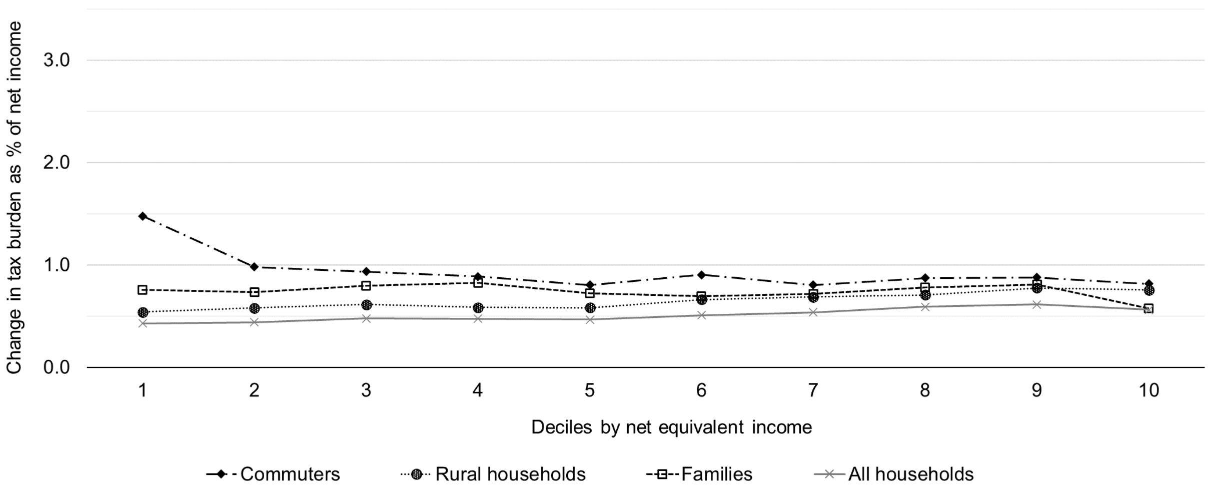
Columns (7) and (8) in Panel (A) of Table 5 report the increases in average absolute and relative tax burdens per income decile compared to the status quo. The additional absolute tax burden rises substantially from an average of 70 euro in the 1st decile to an average of 390 euro in the 10th decile. In relation to income, the difference between the deciles is smaller, but the relative burden still increases with income.

Focusing the analysis on households with cars only (Panel C of Table 5) also reveals an increase of the absolute burden with income compared to the status quo. The relative burden, however, does not increase with income in this subsample. Households in the 1st decile now bear the highest average additional burden (0.9%) relative to their income. For all remaining deciles, the additional relative burden equals 0.6 or 0.7%.

Result 4: *Overall, our results support Hypothesis 4. We conclude that CHCT does not yield a regressive redistribution effect. It furthermore leads to the same progressive shift in tax progressivity as CH.*

The impact of replacing the fuel tax by a revenue-neutral carbon harmonised fuel tax in combination with the introduction of a 65 euro carbon tax on the relative tax burden of certain household types is similar to the results reported in the previous subsections. As shown in Figure 7, commuters comparatively bear the largest burden, but families and households in rural areas also pay a higher relative share of their income than the total of all households. The additional relative tax burden for commuters falls from an average of 1.5% to below 1.0% across the deciles. For the other two groups, the additional relative tax burden remains similar across deciles, varying slightly between 0.5 and 0.8%. Only families in the 10th decile have an additional relative tax burden similar to that of all households.

Figure 7: Distribution of Change in Relative Tax Burden for Subgroups in Scenario CHCT



Source: Microsimulation based on MID 2017, MOP 2017/2018 and EVS 2018.

6 Discussion and Conclusion

The reduction of greenhouse gas emissions became a major topic in political debates within the last years. While the efficiency gains caused by measures such as carbon pricing are clear-cut, the distributional effects of such policy reforms are important not only from a politico-economic perspective. In this paper, we derive six hypotheses regarding the distributional effects of different policy measures and test these hypotheses empirically. Based on a unique dataset for Germany (including information on car-specific fuel consumption, annual mileage at the car-level as well as the distinction between fuel types) and a new microsimulation model, we analyse three distinct policy reform scenarios in the domain of fuel taxation. The microsimulation approach allows not only to analyse aggregate effects of different policy regimes, but also to study differences in the reforms' impact across the income distribution and between specific subgroups of the population.

Our results show that the German legal status quo of transport fuel taxation has regressive effects: While the absolute tax burden increases with income, the relative share of tax burden over household income decreases with income. Based on detailed data on fuel consumption, car types, and mobility, we are the first to explicitly show that the fuel tax on petrol is regressive, while taxing diesel acts progressive in the status quo.

Replacing the current fuel tax by a revenue-neutral carbon-harmonised fuel tax (Scenario CH) yields a progressive distributional effect according to our simulation results. Households in the first six deciles of the income distribution, on average, benefit from the tax reform, while the tax burden increases for the upper four deciles. Splitting the sample into reform winners and losers reveals a considerable additional burden that ranges between 220 euro (1st decile) and 310 euro (10th decile) per year. In contrast, households who benefit from the reform, on average, pay between 120 euro (1st decile) and 180 euro (10th decile) less taxes.

The distributional effects of a new carbon tax of 100 euro/tCO_2 on transport fuels (Scenario CT) are less clear-cut than expected. Aggregated measures on tax progression suggest a weakly progressive effect, while measures on redistribution suggest a weakly regressive effect.

In contrast to CH, the group of reform losers in CT consists of all households that own cars. For them, the reform has a regressive distributional effect. While the absolute annual burden is lowest in the 1st decile (290 euro) and highest in the 10th decile (560 euro), the burden relative to a household's income amounts to 2.0% in the 1st decile, but only 0.8% in the 10th decile. Taken together, for the overall population, our results suggest the carbon tax to be neither clearly regressive nor progressive, which is not in line with our hypothesis.

When we focus on aggregate measures, a combination of the elements of the first two tax reforms (Scenario CHCT) yields a weakly progressive redistribution effect. Among all households, the average share of tax burden over household income increases modestly between the 1st (0.4%) and 10th decile (0.6%). Focusing on reform losers only, however, does not yield a clear trend in terms of relative burden, which is rather constant across deciles (0.6% and 0.7% for the upper nine deciles). The absolute burden triples from 150 euro (1st decile) to 440 euro (10th decile). Overall, we conclude that the introduction of a harmonised fuel tax in combination with an additive carbon tax does at least not yield a regressive redistribution effect, whereas the shift in tax progression corresponds to the clearly progressive effect of CH.

Although the aggregated distributional measures reveal differences between the reform scenarios, one might at first glance conclude that these differences are quantitatively not very large. A particular advantage of our microsimulation approach is that it allows shedding additional light on the heterogeneity behind these aggregate measures. Our analysis based on income deciles shows that households' additional tax burden differs substantially across the income distribution and between reform scenarios. The reform-induced changes in both the absolute and relative tax burden are economically significant. An additional burden of several hundred euro (or up to 2.0% of a household's disposable income) could well play a role for the political feasibility of these or similar reforms. Interestingly, and contrary to earlier studies on the German transport fuel tax (Bork, 2000; Flues and Thomas, 2015; Sterner, 2012), we do not find evidence that middle income groups are particularly hit. In addition, our study does not confirm earlier findings on the regressivity of a carbon tax (Bach et al., 2019, 2020; Gechert et al., 2019; Stiftung Arbeit und Umwelt der IG BCE, 2019). This finding might be due to the facts that we can distinguish between petrol and diesel cars in our analysis and that our data includes information on yearly mileage.

Our approach has the following limitations. First, our simulations analyse three distinct reform scenarios. These scenarios reflect recent debates about policy instruments capable to reduce GHG emissions. While it appears worthwhile starting with a revenue-neutral reform and expanding the analysis to higher taxes subsequently, the actual tax rates are, however, debatable. Furthermore, one might argue that CHCT could focus on the "interaction" of CH and CT, replicating the tax rates chosen in CH and CT. We have explicitly motivated the choice of the specific tax rates in 3.1. However, it is interesting to test whether the main results are robust to variations in these tax rates. In a series of robustness checks, we, therefore, simulate CT and CHCT with alternating carbon taxes of 25, 65, and 100 euro/tCO_2.[42] Tax burdens vary proportionally to the variation in the carbon tax for CT. An increase of the carbon tax, therefore, yields a slightly progressive shift in tax progression, but a slightly regressive shift in redistribution. However, we consider the resulting differences in the results to be economically insignificant overall. For CHCT, we only find a slight rise in redistribution as the carbon tax increases. This is in line with our interpretation of redistribution when the tax rate structure remains constant, as argued in Subsection 5.4.

Second, our simulation model focuses on first-round effects, i.e. it does not take into account behavioural responses. A fuel tax increase might induce households to drive less or to buy more fuel-efficient cars. For future research, it might thus be worthwhile to augment our analyses, for example based on estimates of the price elasticities of fuel consumption. Bach et al. (2019), however, argue that welfare effects as calculated based on a model that takes into account second-round effects will not necessarily differ tremendously from those derived from a "morning-after model". According to

[42] Detailed results are available on request.

their reasoning, adjustments to an increase in the level of taxation either yield direct costs or utility decreases for the households. Their mobility costs increase if they do not adjust their consumption; their capital costs increase if they buy new cars. If they decide for less mobility or longer travel times by public transport, this will most likely cause direct utility losses. Furthermore, analyses which take into account second-round effects will need to rely on critical assumptions regarding the variation in the vehicle population caused by the reforms. While incorporating these effects might make the analysis more realistic, it also introduces a higher degree of uncertainty. As a first robustness check in that dimension, we simulate the dynamic effects of the policy scenarios assuming a general fuel price elasticity of demand of 0.5.[43] While the overall average tax burden decreases compared to the first-round effects for all scenarios, we observe a stronger adaption in relation to income with larger income for CH and CHCT. For all reform scenarios, this results in smaller shifts in tax progression and redistribution once the household response to the tax increase is simulated.

Third, our model does not feature regional differences. In particular, fuel tourism at the national borders is not taken into account due to restricted data availability and complex interdependencies of international fuel policies and consumer behaviour. While differences in fuel tax policies between countries tend to induce cross-border fuelling, it remains unclear whether this phenomenon might be quantitatively important for our analysis. Data from the German Federal Statistical Office (2011) reveal that as of 2006, German residents bought 10% of diesel and 16% of petrol for their passenger cars in other countries.[44] Newer data suggest that these shares decreased until 2017 (Federal Statistical Office, 2019). Even if we considered fuel tourism a quantitatively important topic on aggregate, the lack of detailed data would leave it unclear whether there are relevant differences across income deciles. Future research might, conditional on data availability, address this issue.

Fourth, we have discussed alternative ways of measuring a household's financial ability to pay taxes in Subsection 3.2. Poterba (1991) argues that a short-term approach focusing on current

[43]For the mere purpose of testing the sensitivity of our results, we neither distinguish between the potentially heterogeneous behavioural adjustments of different population subgroups over different time horizons, nor do we apply the results of different methods of measurement and different countries. The used price elasticity of 0.5 bases on a result for Germany (−0.45) from (Frondel and Vance, 2014, 458) and the result of the international literature review for static models (−0.48) from (Goodwin et al., 2004, 283).

[44]This includes fuel bought for both domestic travel and travel abroad.

income might overestimate regressive effects. While a lifetime-ability-to-pay approach tends to be less prone to intertemporal fluctuations, it relies on other critical assumptions regarding households' consumption choices. The lack of reliable income data has been argued to be the reason for the application of the lifetime-approach (Teixidó and Verde, 2017). Given that our database contains high-quality income data, we conclude that the arguments in favour of the lifetime approach are less relevant in our setting. We indeed find regressive effects for the German legal status quo. However, as our analyses focus on the comparison of the status quo with the three reform scenarios, we would not expect a scenario-specific overestimation effect. Moreover, our results show that the three reform scenarios do not yield additional regressive effects.

Our results have several implications for policy makers. First, pricing the externalities of GHG emissions is a key objective of climate policy. The revenue-neutral carbon-harmonisation of the fuel tax creates an additional carbon price lever of almost 300 euro/tCO_2 while yielding a progressive effect (Result 2). Contrary to the status quo fuel tax, it directly taxes the GHG emissions independently of the fuel type – offering better potential to internalise the externalities caused from driving and, therefore, mitigate GHG emissions (Meckling et al., 2017; Tietenberg, 2013). One might, in general, expect negative distributional effects if a carbon price of this magnitude is introduced. Moreover, a tax cut on certain fuels, as with petrol in CH, appears unrealistic in practice given the climate policy challenges. Yet, combining the implementation of the German carbon price with a revenue-neutral carbon-harmonisation of the transport fuel tax as in CHCT addresses these aspects: If policy makers aim at increasing the carbon price without causing regressive distributional effects, the proposed combination of measures appears to be worth considering. Not only is the carbon price lever significantly higher than in the status quo (without sending adverse signals by tax cuts), but the progressive distributional reform effect (Result 4) is so large that it almost completely neutralises the regressivity of the status quo fuel tax (Result 1). Our analyses reveal that CHCT, apart from the presumed GHG mitigation potential, offers more progressive and thus, possibly, more favourable distributional effects than CT or the status quo.

Second, we find that in the status quo the progressive tax on diesel has a lower tax level than the regressive tax on petrol (Result 1). We can, therefore, deduce from our results that raising the fuel tax on diesel, e.g. to the level of petrol, has a progressive effect. Compared to the full carbon-harmonisation of CH and CHCT, an alignment of the tax levels of petrol and diesel might be politically more feasible in the short-term. From an environmental perspective, it does at least shift the fuel tax considerably closer to carbon pricing.

Third, we find no evidence that a carbon price on transport fuels does, on average, disproportionately burden low-income households (Result 3). If the goal is to avoid an increase in inequality, then our results for a 100 euro carbon tax provide little argument against a further increase in the German carbon price on transport fuels. If one also wants to ensure social acceptance among the reform losers, then the additional tax revenues can be redistributed through targeted social benefits and subsidies that enable low-emission mobility.

Fourth, it will be misleading to focus only on the average additional tax burden in the different policy scenarios. These average values tend to hide the partially very large effects for individual groups – which might also be the case for other policy measures not explicitly investigated in this paper. While it appears to be less important whether the average household wins 20 euro (1st decile in CH) or loses 70 euro (10th decile) per year, the additional tax burden varies considerably with income and household characteristics. As a consequence, the winners' tax burden will on average decrease by 110 euro in the 1st decile, but it will also increase by 210 euro for those among the poorest households who belong to the group of losers because they use their car frequently. Although, from an environmental perspective, it appears reasonable that heavy users (which belong to the group of "reform losers" in our analyses) are penalised by these reforms, it might be worthwhile to address cases of hardship especially during a transition period. Specific groups of households might neither be able to adjust to a less carbon intense mobility behaviour in the short run nor to bear the additional tax burden. This could apply to households with lower incomes, but also commuters, families, and households located in rural areas. Our analyses show that the additional tax burden for these groups is above average.

References

Agora Verkehrswende and Agora Energiewende (2019). Klimaschutz auf Kurs bringen: Wie eine CO2-Bepreisung sozial ausgewogen wirkt.

Agostini, C. A. and J. Jiménez (2015). The distributional incidence of the gasoline tax in Chile. *Energy Policy 85*, 243–252.

Allison, P. D. (2009). *Missing data* ([Nachdr.] ed.), Volume 136 of *Sage university papers Quantitative applications in the social sciences.* Thousand Oaks, Calif: Sage Publ.

Alpman, A. (2016). Implementing Rubin's alternative multiple-imputation method for statistical matching in Stata. *The Stata Journal 16*(3), 717–739.

Alvarez, M. (2019). Distributional effects of environmental taxation: An approximation with a meta-regression analysis. *Economic Analysis and Policy 62*, 382–401.

Asensio, J., A. Matas, and J.-L. Raymond (2003). Petrol expenditure and redistributive effects of its taxation in Spain. *Transportation Research Part A: Policy and Practice 37*(1), 49–69.

Bach, S., M. Beznoska, and V. Steiner (2016). *Wer trägt die Steuerlast in Deutschland? Verteilungswirkungen des deutschen Steuer- und Transfersystems*, Volume 114 of *DIW Berlin*. Berlin: DIW Berlin Deutsches Institut für Wirtschaftsforschung.

Bach, S., H. Buslei, M. Harnisch, and N. Isaak (2019). Ökosteuer-Einnahmen sorgen noch heute für niedrigere Rentenbeiträge und höhere Renten.

Bach, S., M. Harnisch, and N. Isaak (2018). Verteilungswirkungen der Energiepolitik - Personelle Einkommensverteilung: Forschungsprojekt im Auftrag des Bundesministeriums für Wirtschaft und Energie.

Bach, S., N. Isaak, L. Kampfmann, C. Kemfert, and N. Wägner (2020). Nachbesserungen beim Klimapaket richtig, aber immer noch unzureichend – CO2-Preise stärker erhöhen und Klimaprämie einführen.

Bach, S., N. Isaak, C. Kemfert, U. Kunert, W.-P. Schill, S. Schmalz, N. Wägner, and A. Zaklan (2019). CO2-Bepreisung im Wärme- und Verkehrssektor: Diskussionen von Wirkungen und alternativen Entlastungsoptionen.

Bach, S., M. Kohlhaas, B. Meyer, B. Praetorius, and H. Welsch (2002). The effects of environmental fiscal reform in Germany: A simulation study. *Energy Policy 30*(9), 803–811.

Baranzini, A., J. Goldemberg, and S. Speck (2000). A future for carbon taxes. *Ecological Economics 32*(3), 395–412.

Baranzini, A., J. C. J. M. van den Bergh, S. Carattini, R. B. Howarth, E. Padilla, and J. Roca (2017). Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations. *Wiley Interdisciplinary Reviews: Climate Change 8*(4), e462.

Barker, T. and J. Köhler (1998). Equity and Ecotax Reform in the EU: Achieving a 10 per cent Reduction in CO2 Emissions Using Excise Duties. *Fiscal Studies 19*(4), 375–402.

Becker, I., R. Hauser, and Hans-Böckler-Stiftung. (2003). *Anatomie der Einkommensverteilung : Ergebnisse der Einkommens-und Verbrauchsstichproben 1969-1998*. Berlin: Edition Sigma.

Bento, A. M. (2013). Equity Impacts of Environmental Policy. *Annual Review of Resource Economics 5*(1), 181–196.

Bento, A. M., L. H. Goulder, M. R. Jacobsen, and R. H. von Haefen (2009). Distributional and Efficiency Impacts of Increased US Gasoline Taxes. *The American Economic Review 99*(3), 667–699.

Bernhofer, D. and R. Brait (2011). Die Verteilungswirkungen der Mineralölsteuer in Österreich. *Wirtschaft und Gesellschaft - WuG 37*(1), 69–93.

Berry, A. (2019). The distributional effects of a carbon tax and its impact on fuel poverty: A microsimulation study in the French context. *Energy Policy 124*, 81–94.

Blackman, A., R. Osakwe, and F. Alpizar (2010). Fuel tax incidence in developing countries: The case of Costa Rica. *Energy Policy 38*(5), 2208–2215.

Blanck, R., K. Kreye, and W. Zimmer (2020). Impulse für mehr Klimaschutz und soziale Gerechtigkeit in der Verkehrspolitik.

Blow, L. and I. Crawford (1997). *The distributional effects of taxes on private motoring*, Volume 65 of *Commentary (Institute for Fiscal Studies)*. London: Institute for Fiscal Studies.

Bork, C. (2000). *Steuern, Transfers und private Haushalte: Eine mikroanalytische Simulationsstudie der Aufkommens- und Verteilungswirkungen*, Volume 99 of *Finanzwissenschaftliche Schriften*. Frankfurt am Main: Peter Lang Verlag.

Büchs, M. and S. V. Schnepf (2013). Who emits most? Associations between socio-economic factors and UK households' home energy, transport, indirect and total CO2 emissions. *Ecological Economics 90*, 114–123.

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

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

Chernick, H. A. and A. Reschovsky (1997). Who pays the gasoline tax? *National tax journal 50*(2), 233–259.

Cohen, M. L. (1991). Statistical Matching and Microsimulation Models. In C. F. Citro and E. A. Hanushek (Eds.), *Improving information for social policy decisions*. Washington, D.C: National Academy Press.

Combet, E., F. Ghersi, J.-C. Hourcade, and D. Théry (2010). Carbon Tax and Equity: The Importance of Policy Design. In C. D. Soares, J. Milne, and H. Ashiabor (Eds.), *Critical Issues in Environmental Taxation, volume VIII*, pp. 277–295. Oxford: OUP Oxford.

Crippa, M., Guizzardi Diego, Muntean Marilena, Schaaf Edwin, Solazzo Efisio, Monforti-Ferrario Fabio, Olivier Jos, and Vignati Elisabetta (2020). Fossil CO2 emissions of all world countries - 2020 report.

de Borger, B. and I. Mayeres (2007). Optimal taxation of car ownership, car use and public transport: Insights derived from a discrete choice numerical optimization model. *European Economic Review 51*(5), 1177–1204.

Dertinger, A. and W.-P. Schill (2019). Ansätze zur Umgestaltung von Abgaben und Umlagen auf Strom sowie Heiz- und Kraftstoffe.

D'Orazio, M., M. Di Zio, and M. Scanu (2006). *Statistical matching: Theory and practice*. Wiley series in survey methodology. Chichester: John Wiley.

Douenne, T. (2020). The Vertical and Horizontal Distributive Effects of Energy Taxes: A Case Study of a French Policy. *The energy journal 41*(3).

Douenne, T. and F. Adrien (2020). Yellow Vests, Carbon Tax Aversion, and Biased Beliefs.

Ecke, L., B. Chlond, M. Magdolen, C. Eisenmann, T. Hilgert, and P. Vortisch (2019). Deutsches Mobilitätspanel (MOP) - Wissenschaftliche Begleitung und Auswertungen: Bericht 2017/2018: Alltagsmobilität und Fahrleistung.

Edenhofer, O., C. Flachsland, M. Kalkuhl, B. Knopf, and M. Pahle (2019). Optionen für eine CO2-Preisreform: MCC-PIK-Expertise für den Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung.

Eggs, J., R. Follmer, D. Gruschwitz, C. Nobis, M. Bäumer, and M. Pfeifer (2018). Mobilität in Deutschland – MiD Methodenbericht. Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministeriums für Verkehr und digitale Infrastruktur.

Eisenmann, C., F. Steck, L. Hedemann, B. Lenz, and F. Koller (2020). Distributional effects of carbon taxation in passenger transport with lump-sum offset: low income households, retirees and families would benefit in Germany. *European Transport Research Review 12*(1), 51.

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

Eliasson, J., R. Pyddoke, and J.-E. Swärdh (2018). Distributional effects of taxes on car fuel, use, ownership and purchases. *Economics of Transportation 15*, 1–15.

Elkins, P. and T. Baker (2001). Carbon Taxes and Carbon Emissions Trading. *Journal of Economic Surveys 15*(3), 325–376.

European Commission (2011). Proposal for a Council Directive amending Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity. COM(2011) 169 final.

Federal Ministry of Transport and Digital Infrastructure (2020). RegioStaR - Regional Statistical Spatial Typology for Mobility and Transport Research.

Federal Motor Transport Authority (2011). Fachartikel: Emissionen und Kraftstoffe.

Federal Motor Transport Authority (2017). Fahrzeugzulassungen (FZ) - Bestand an Kraftfahrzeugen nach Umwelt-Merkmalen: Statistische Mitteilungen des Kraftfahrt-Bundesamtes FZ 13. 1. Januar 2017.

Federal Motor Transport Authority (2020a). Fahrzeugzulassungen (FZ) - Bestand an Kraftfahrzeugen nach Umwelt-Merkmalen: Statistische Mitteilungen des Kraftfahrt-Bundesamtes FZ 13. 1. Januar 2020.

Federal Motor Transport Authority (2020b). Verkehr in Kilometern - Inländerfahrleistung (VK): Entwicklung der Fahrleistungen nach Fahrzeugarten seit 2015.

Federal Statistical Office (2011). Weiterentwicklung der Berechnungen zum Energieverbrauch und zu den CO2-Emissionen des Straßenverkehrs im Rahmen des NAMEA-Rechenansatzes: Methodenbericht.

Federal Statistical Office (2019). Transportleistungen und Energieverbrauch im Straßenverkehr 2007 – 2017: Umweltökonomische Gesamtrechnungen.

Federal Statistical Office (2020). Mileage and fuel consumption of private household's cars.

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

Feld, L., C. Schmidt, I. Schnabel, A. Truger, and V. Wieland (2019). *Sondergutachten des Sachverständigenrats: Aufbruch zu einer neuen Klimapolitik* (1., Auflage ed.). Wiesbaden: Statistisches Bundesamt.

Filippini, M. and F. Heimsch (2016). The regional impact of a CO2 tax on gasoline demand: A spatial econometric approach. *Resource and Energy Economics 46*, 85–100.

Flues, F. and A. Thomas (2015). The distributional effects of energy taxes. *OECD Taxation Working Papers* (23).

Frondel, M. (2020). CO2-Bepreisung in den Sektoren Verkehr und Wärme: Optionen für eine sozial ausgewogene Ausgestaltung. *Zeitschrift für Energiewirtschaft 44* (1), 1–14.

Frondel, M. and C. Vance (2014). More pain at the Diesel pump? An econometric comparison of Diesel and Petrol Price Elasticities. *Journal of transport economics and policy 48* (3), 449–463.

Gechert, S., K. Rietzler, S. Schreiber, and U. Stein (2019). Wirtschaftliche Instrumente für eine klima- und sozialverträgliche CO2-Bepreisung.

German Advisory Council on the Environment (2017). Time to take a turn: climate action in the transport sector.

German Bundestag (2019a). Experten: Geplanter CO2-Preis zu niedrig: Parlamentarischer Beirat für nachhaltige Entwicklung/Ausschuss.

German Bundestag (2019b). *Gesetz zur Einführung eines Bundes-Klimaschutzgesetzes und zur Änderung weiterer Vorschriften: KSG.*

German Bundestag (2020). *Gesetz über einen nationalen Zertifikatehandel für Brennstoffemissionen (Brennstoffemissionshandelsgesetz): BEHG.*

German Environment Agency (2019). CO2-Bepreisung in Deutschland: Ein Überblick über die Handlungsoptionen und ihre Vor- und Nachteile.

German Federal Government (2019). Klimaschutzprogramm 2030 der Bundesregierung zur Umsetzung des Klimaschutzplans 2050.

Gianessi, L. P., H. M. Peskin, and E. Wolff (1979). The Distributional Effects of Uniform Air Pollution Policy in the United States. *The Quarterly Journal of Economics 93* (2), 281.

Goodwin, P., J. Dagay, and M. Hanly (2004). Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review. *Transport Reviews 24* (3), 275–292.

Grub, M. (2000). Verteilungswirkungen der ökologischen Steuerreform auf private Haushalte: Eine empirische Analyse. *Vierteljahrshefte zur Wirtschaftsforschung 69* (1), 17–37.

Harding, M. (2014). *Personal Tax Treatment of Company Cars and Commuting Expenses: Estimating the Fiscal and Environmental Costs*, Volume 20 of *OECD Taxation Working Papers.*

Harthan, R. O., J. Repenning, R. Blanck, H. Böttcher, V. Bürger, V. Cook, L. Emele, W. K. Görz, K. Hennenberg, W. Jörß, S. Ludig, F. C. Matthes, R. Mendelevitch, L. Moosmann, M. Scheffler, K. Wiegmann, H. Brugger, T. Fleiter, T. Mandel, M. Rehfeldt, and J. Steinbach (2020). Abschätzung der Treibhausgasminderungswirkung des Klimaschutzprogramms 2030 der Bundesregierung: Teilbericht des Projektes „THG-Projektion: Weiterentwicklung der Methoden und Umsetzung der EU-Effort Sharing Decision im Projektionsbericht 2019 („Politikszenarien IX")".

Hassett, K. A., A. Mathur, and G. E. Metcalf (2009). The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis. *The energy journal 30*(2).

IPCC (2014). *Fifth Assessment Report (AR5): Climate Change 2013/2014: Climate change 2014*. New York, NY, USA: Cambridge University Press.

Ismer, R., M. Haußner, K. Meßerschmidt, and K. Neuhoff (2019). Sozialverträglicher CO2-Preis: Vorschlag für einen Pro-Kopf-Bonus durch Krankenversicherungen. *DIW Berlin Discussion Paper 1819*.

Jacobs, L. and L. Quack (2018). Das Ende der Dieselsubvention: Verteilungseffekte einer CO2-basierten Energiesteuerreform. *Wirtschaftsdienst 98*(8), 578–586.

Johnson, P., S. McKay, and S. Smith (1990). The distributional consequences of environmental taxes.

Juhrich, K. (2016). CO2 Emission Factors for Fossil Fuels: Emissions Situation (Section I 2.6).

Kakwani, N. C. (1977). Measurement of tax progressivity: An international comparison. *The economic journal : the journal of the Royal Economic Society 87 (1977)*, 71–80.

Kallbekken, S. and H. Sælen (2011). Public acceptance for environmental taxes: Self-interest, environmental and distributional concerns. *Energy Policy 39*(5), 2966–2973.

Kaus, W. (2013). Beyond Engel's law - A cross-country analysis. *The Journal of Socio-Economics 47*, 118–134.

Labandeira, X., J. Labeaga, and M. Rodriguez (2009). An integrated economic and distributional analysis of energy policies. *Energy Policy 37*(12), 5776–5786.

Lambert, P. J. (2001). *The distribution and redistribution of income* (3. ed. ed.). Manchester: Manchester Univ. Press.

Landis, F., G. Fredriksson, and S. Rausch (2021). Between- and within-country distributional impacts from harmonizing carbon prices in the EU. *Energy Economics 103*, 105585.

Lange, J., J. Nitsch, U. Siebert, S. Lessenich, and R. Freitag (2019). Energiesteuern klima- & sozialverträglich gestalten: Wirkungen und Verteilungseffekte des CO2-Abgabekonzeptes auf Haushalte und Pendelnde.

Leprich, U., F. Zerzawy, S. Fiedler, and P. Butchbacher (2019). Umsetzung einer wirtschaftsverträglichen CO2-Bepreisung in Deutschland für den ETS- und den Nicht-ETS-Bereich.

Leulescu, A. and M. Agafitei (2013). *Statistical matching: A model based approach for data integration : 2013 edition* (2013 edition ed.), Volume 2013 EDIT_L of *Methodologies and working papers*. Luxembourg: Publications Office.

Martini, C. (2009). The distributive effects of carbon taxation in Italy. *Departmental Working Papers of Economics - University 'Roma Tre'* (103).

Mayeres, I. and S. Proost (2013). The taxation of diesel cars in Belgium – revisited. *Energy Policy 54*, 33–41.

Meckling, J., T. Sterner, and G. Wagner (2017). Policy sequencing toward decarbonization. *Nature Energy 2*(12), 918–922.

Metcalf, G. E. (2009). Designing a Carbon Tax to Reduce U.S. Greenhouse Gas Emissions. *Review of Environmental Economics and Policy 3*(1), 63–83.

Montag, J. (2015). The simple economics of motor vehicle pollution: A case for fuel tax. *Energy Policy 85*, 138–149.

Musgrave, R. A. and T. Thin (1948). Income Tax Progression, 1929-48. *Journal of Political Economy 56*, 498–514.

Nikodinoska, D. and C. Schröder (2016). On the emissions–inequality and emissions–welfare trade-offs in energy taxation: Evidence on the German car fuels tax. *Resource and Energy Economics 44*, 206–233.

Nobis, C. and T. Kuhnimhof (2018). Mobilität in Deutschland – MiD Ergebnisbericht: Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministers für Verkehr und digitale Infrastruktur (FE-Nr. 70.904/15).

OECD/Korea Institute of Public Finance (2014). *The Distributional Effects of Consumption Taxes in OECD Countries* (22 ed.). OECD Publishing.

Ohlendorf, N., M. Jakob, J. C. Minx, C. Schröder, and J. Steckel (2018). Distributional Impacts of Climate Mitigation Policies - A Meta-Analysis. *DIW Berlin Discussion Paper* (1776).

Parry, I. W. H. (2015). Carbon tax burdens on low-income households: A reason for delaying climate policy? In B. Clements, R. Mooij, S. Gupta, and M. Keen (Eds.), *Inequality and fiscal policy*, pp. 233–252. Washington, DC: International Monetary Fund.

Peichl, A. and P. van Kerm (2007). PROGRES: Stata module to measure distributive effects of an income tax.

Pigou, A. C. (1920). *The economics of welfare*. London: Macmillan.

Pizer, W. A. and S. Sexton (2019). The Distributional Impacts of Energy Taxes. *Review of Environmental Economics and Policy 13*(1), 104–123.

Poterba, J. M. (1991). Is the Gasoline Tax Regressive? *Tax Policy and the Economy 5*, 145–164.

Preuss, M., W. H. Reuter, and C. M. Schmidt (2019). Verteilungswirkung einer CO2-Bepreisung in Deutschland.

Quack, L. and L. Jacobs (2021). The Car Tax Microsimulation Model CARMOD [Unpublished manuscript].

Rausch, S., G. E. Metcalf, and J. M. Reilly (2011). Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households. *Energy Economics 33*, S20–S33.

Reinhart, T. E. (2016). Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #2: Report No. DOT HS 812 194.

Research Data Centres of the Statistical Offices of the Federation and the Federal States (2018). Einkommens- und Verbrauchsstichprobe 2018 - Grundfile 3 (AAGSHB), SUF, Version 0.

Reynolds, M. and E. Smolensky (1977). *Public Expenditures, Taxes, and the Distribution of Income: The United States, 1950, 1961, 1970.* Burlington: Elsevier Science.

Rubin, D. B. (1987). *Multiple imputation for nonresponse in surveys.* Wiley series in probability and mathematical statistics Applied probability and statistics. New York, NY: Wiley.

Santos, G. (2017). Road fuel taxes in Europe: Do they internalize road transport externalities? *Transport Policy 53*, 120–134.

Santos, G. and T. Catchesides (2005). Distributional Consequences of Gasoline Taxation in the United Kingdom. *Transportation Research Record: Journal of the Transportation Research Board 1924*, 103–111.

Schafer, J. L. (1997). *Analysis of incomplete multivariate data* (1. ed. ed.), Volume 72 of *Monographs on statistics and applied probability.* Boca Raton: Chapman & Hall.

Schipper, L. and L. Fulton (2013). Dazzled by diesel? The impact on carbon dioxide emissions of the shift to diesels in Europe through 2009. *Energy Policy 54*, 3–10.

Schipper, L. J., C. Marie-Lilliu, and L. Fulton (2002). Diesels in Europe: Analysis of Characteristics, Usage Patterns, Energy Savings and Co_2 Emission Implications. *Journal of transport economics and policy 36*(2), 305–340.

Söllner, F. (2018). Road traffic taxation in Germany: the present system, its problems and a proposal for reform. *Journal of Tax Reform 4*(1), 57–72.

Speck, S. (1999). Energy and carbon taxes and their distributional implications. *Energy Policy 27*(11), 659–667.

Spiller, E., H. M. Stephens, and Y. Chen (2017). Understanding the heterogeneous effects of gasoline taxes across income and location. *Resource and Energy Economics 50*, 74–90.

StataCorp (2019). Stata: Release 16: Statistical Software.

Steinsland, C., L. Fridstrøm, A. Madslien, and H. Minken (2018). The climate, economic and equity effects of fuel tax, road toll and commuter tax credit. *Transport Policy 72*, 225–241.

Sterner, T. (2007). Fuel taxes: An important instrument for climate policy. *Energy Policy 35*(6), 3194–3202.

Sterner, T. (2012). Distributional effects of taxing transport fuel. *Energy Policy 41*, 75–83.

Stiftung Arbeit und Umwelt der IG BCE (2019). CO2-Bepreisung für den Verkehrssektor? Bedeutung und Entwicklung der Kosten räumlicher Mobilität der privaten Haushalte bei ausgewählten verkehrspolitischen Instrumenten.

Stucker, J. P. (1977). The distributional implications of a tax on gasoline. *Policy Analysis 3*(2), 171–186.

Suits, D. B. (1977). Measurement of tax progressivity. *The American Economic Review 67*(4), 747–752.

Teixidó, J. J. and S. F. Verde (2017). Is the Gasoline Tax Regressive in the Twenty-First Century? Taking Wealth into Account. *Ecological Economics 138*, 109–125.

Tietenberg, T. H. (2013). Reflections - Carbon Pricing in Practice. *Ecological Economics 7*(2), 313–329.

Tiezzi, S. and S. F. Verde (2019). The signaling effect of gasoline taxes and its distributional implications. *The Journal of Economic Inequality 17*(2), 145–169.

Tscharaktschiew, S. (2014). Shedding light on the appropriateness of the (high) gasoline tax level in Germany. *Economics of Transportation 3*(3), 189–210.

Vandyck, T., M. Weitzel, K. Wojtowicz, L. R. L. Santos, A. Maftei, and S. Riscado (2021). Climate policy design, competitiveness and income distribution: A macro-micro assessment for 11 EU countries. *Energy Economics 103*, 105538.

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

West, S. E. (2004). Distributional effects of alternative vehicle pollution control policies. *Journal of Public Economics 88*(3-4), 735–757.

West, S. E. and R. C. Williams (2004). Estimates from a consumer demand system: implications for the incidence of environmental taxes. *Journal of Environmental Economics and Management 47*(3), 535–558.

White, I. R., P. Royston, and A. M. Wood (2011). Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in medicine 30*(4), 377–399.

Zerzawy, F. and S. Fiedler (2019). Lenkungs- und Verteilungswirkungen einer klimaschutzorientierten Reform der Energiesteuern.

Zhang, Z. and A. Baranzini (2004). What do we know about carbon taxes? An inquiry into their impacts on competitiveness and distribution of income. *Energy Policy 32*(4), 507–518.

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