Vertical and Horizontal Distribution of Fuel Tax Burdens: Evidence from Odometer Records in Finland

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Abstract

Using detailed administrative data on all cars and residents in Finland, we analyze the distributional implications of Finnish motor fuel taxes both across and within income deciles. We measure fuel tax burdens as the share of household income spent on fuel taxes, and estimate household-level burdens using car-level data on odometer readings, fuel economy and car ownership. Finland has some of the highest fuel taxes in the world, allowing us to observe fuel consumption choices made in an environment with significant fuel costs. Contrary to common belief, we find that fuel taxes are not regressive among all households; instead, upper-middle income households bear the highest tax burdens. Fuel taxes are regressive only among the 67 percent of households that own a car, as car ownership is much less common in the lowest income deciles. Most of the variation in tax burdens, however, is found within rather than across income deciles. Differences across income deciles explain only 1.5 percent of the variation in fuel tax burdens. We find that households that are located outside city centers, have children, or include employed people face higher tax burdens within income deciles. While average fuel tax burdens across income deciles could easily be equalized by redistributing the tax revenue, the within-decile differences are nearly impossible to eliminate even with targeted transfers. This is because less than 50 percent of the overall variation in fuel taxes paid is explained by observable household characteristics.

1 Introduction

Transportation is one of the main sources of global CO_2 emissions, accounting for about 20 percent of total emissions worldwide.[1] Cutting emissions to meet international climate targets will most likely require adopting policies that increase fuel prices. However, such policies remain highly contested, often on the grounds that the burdens they place on consumers are unequally distributed. Policy instruments aiming to address these distributional concerns are increasingly gaining in popularity. As a major example, carbon pricing in the European Union is poised to expand to the transportation sector in 2027 with the introduction of the EU ETS2[2], which will be accompanied by a Social Climate Fund (SCF) that provides member states with funding to support households in transportation poverty, among other vulnerable groups.[3]

Identifying vulnerable households will thus be key in making the SCF and similar instruments effective and efficient. Crucially, transportation poverty is not necessarily a function of income alone, making it important to understand not only the distribution of burdens between income groups (the "vertical" dimension of equity), but also within them (the "horizontal" dimension). In addition to concern for the most vulnerable households, addressing horizontal inequity may be necessary for political reasons: voters with burdens larger than they are willing to bear may mobilize to block proposed increases in carbon prices, as we saw with the rise of the Yellow Vests movement in France in 2018 (Douenne and Fabre 2022). Research suggests that the perceived fairness of carbon pricing is indeed important for its public acceptability (Carattini, Carvalho, and Fankhauser 2018; Maestre-Andrés, Drews, and Bergh 2019). Moreover, the relevance of horizontal equity is supported by research showing that people perceive inequalities within a similarly situated reference group as particularly unfair (Hvidberg, Kreiner, and Stantcheva 2023).

We provide new evidence on the distributional consequences of carbon pricing in the road transportation sector by using detailed administrative data from Finland, a country with some of the highest fuel taxes in the world. The individual-level data allow us to analyze the distribution of fuel tax burdens along both the vertical and horizontal dimension. We also identify households at the intersection of multiple characteristics that make them potentially vulnerable to increasing fuel prices. In addition, we investigate how redistributing the tax revenue affects the distribution of tax burdens. We measure fuel tax burdens as the share of household income spent on paying fuel taxes. To estimate these burdens, we combine vehicle-level data on odometer readings and fuel economy with individual-level data on income. The data cover the full population of Finnish residents

1. https://ourworldindata.org/co2-emissions-from-transport

2. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets2-buildings-road-transport-and-additional-sectors_en

3. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/social-climate-fund_en

and cars registered in the country. We also observe a host of other household characteristics that allow us to decompose the variation in fuel tax burdens on an exceptionally granular level.

We find that fuel taxes are not regressive among all Finnish households. Instead, the share of income spent on fuel taxes roughly follows an inverse U-shaped pattern, with the heaviest tax burdens faced by upper-middle income households around the seventh income decile. However, if we restrict our attention only to the 67 percent of households that have a car, fuel taxes appear regressive, as the average tax burden falls monotonically with income. Surprisingly, we do not find much of a difference in the average fuel economy of cars between income deciles, but observe that the median households in the two highest income deciles drive twice as much as the median households in the lowest two. The strong income dependence of both car ownership and mileage contributes to making tax burdens more even across income deciles.

Most of the variation in tax burdens, however, arises from within-decile rather than across-decile differences. Differences across income deciles explain only 1.5 percent of the variation in fuel tax burdens. We show that ignoring horizontal inequity can yield slightly overoptimistic estimates of the welfare impacts of a tax change even when using a standard social welfare function in which the value of money only depends on income. However, such measures do not account for households with similar incomes potentially having different needs and abilities to adapt. We find that households that are located outside city centers, have children, or include employed people face higher fuel tax burdens within nearly every income decile. Despite finding some regularities, we are only able to explain less than half of the overall variation in fuel taxes paid even with the rich information on households available in the data.

We demonstrate how redistributing the tax revenue can easily remedy concerns over inequity across income groups. For example, redistributing less than 13 percent of the tax revenue using progressive lump-sum transfers can make the regressivity of fuel taxes disappear among car-owning households. In contrast, horizontal inequity seems practically impossible to eliminate: due to the challenges in explaining the variation in taxes paid, even the most granularly targeted redistribution schemes can leave a large share of households with high tax burdens in all income deciles. Furthermore, lump-sum transfers actually increase horizontal variation by substantially overcompensating some households. Instead of trying to minimize horizontal variation, we show that policymakers could compensate a more narrowly defined group of vulnerable households using only around 10 percent of total fuel tax revenue.

Our paper contributes to the literature on the distributional effects of carbon pricing and fuel taxation in four ways. First, we use administrative data that cover the entire population of cars and individuals in Finland and contain exceptionally rich information on both. Most previous studies rely on consumer expenditure survey data with smaller sample sizes and less detailed observations compared to our data (e.g. West and Williams 2004; Hassett, Mathur, and Metcalf 2009; Burtraw, Sweeney, and Walls 2009; Beck et al. 2015; Cronin, Fullerton, and Sexton 2019; Douenne 2020). An exception is the study by Eliasson, Pyddoke, and Swärdh (2018), who use similar data from Sweden.

Second, we provide new evidence on the vertical distribution of fuel tax burdens in a high-cost context. Although there is a long tradition of estimating the vertical distribution of carbon tax burdens, most studies focus on countries with substantially lower fuel taxes, such as the United States. In a meta-analysis of the literature analyzing the vertical distribution of carbon and fuel taxes, Ohlendorf et al. (2021) find that conclusions on the regressivity of the taxes are very country-dependent. Given this variation, it is important to study the issue in a wider range of countries. Existing estimates of the vertical distribution of fuel taxes in Europe are fairly small in number but still range from regressive to proportional and progressive (e.g. Santos and Catchesides 2005; Sterner 2012; Eliasson, Pyddoke, and Swärdh 2018).

Third, we add to the relatively small literature on the horizontal inequity arising from fuel and other carbon taxes. While some recent studies highlight the horizontal dimension (e.g. Eliasson, Pyddoke, and Swärdh 2018; Cronin, Fullerton, and Sexton 2019; Fischer and Pizer 2019; Douenne 2020), most of the literature has traditionally focused on the vertical dimension. This is likely at least in part because the normative implications of horizontal inequity are less clear (for a discussion, see Fischer and Pizer 2019), and because a comprehensive analysis places heavier demands on data than in the case of vertical inequity. In line with the limited number of existing studies, we document substantial horizontal variation in tax burdens. Understanding the horizontal dimension is becoming increasingly valuable in practical policy making, with concerns over energy poverty and political backlash from excessive tax burdens. With our novel data set, we are able to decompose the variation in fuel tax burdens within income deciles in great detail.

Finally, our combined analysis of the vertical and horizontal distribution of fuel tax burdens also allows us to evaluate the distributional implications of redistributing the fuel tax revenue back to households. A consistent finding in the literature, which is corroborated by this study, is that redistributing carbon tax revenues equally to all households would turn even regressive vertical distributions progressive, due to high-income households spending much more on these taxes in absolute terms (West 2004; Burtraw, Sweeney, and Walls 2009; Beck et al. 2015; Cronin, Fullerton, and Sexton 2019). However, similar to Cronin, Fullerton, and Sexton (2019) and Sallee (2019), we find that large variation in fuel tax burdens remain within income deciles after redistributing the tax revenue. Moreover, a large share of households are not even close to fully compensated.

The remainder of this paper is organized as follows. Section 2 presents the data and explains how we estimate fuel tax burdens. Section 3 presents the main results on the distributional effects of the Finnish fuel tax. Section 4 then analyzes the observed variation in fuel tax burdens in more detail, while section 5 discusses how fuel taxes burdens could be compensated by redistributing the tax revenue. Finally, section 6 concludes the study.

2 Estimating Fuel Tax Burdens

In this paper, we assess the distributional impacts of fuel taxes by comparing estimates of fuel taxes paid as a share of disposable household income across Finnish households. To achieve this, we use car-level data on mileage and fuel economy together with individual-level data on car ownership, income and a host of other background characteristics. These administrative data cover the entire population of cars and individuals in Finland. Our estimates of fuel taxes paid are based on estimating annual fuel consumption in liters at the household level and multiplying the estimated liters by the Finnish per-liter fuel tax rates. We calculate the share of annual disposable income devoted to paying fuel taxes and compare these shares across households.

The data used in this paper are provided by Statistics Finland. The original source of the car-level data is the official vehicle registry maintained by Traficom, the Finnish Transport and Communications Agency. The car data consist of two parts. One has odometer readings recorded during mandatory vehicle inspections, covering readings from all inspections done to any vehicle since January 1, 2013. The other includes detailed vehicle-level technical information—e.g. fuel economy, fuel type, and make and model—in quarter-yearly cross-sections covering the entire stock of vehicles in Finland on the last of March, June, September and December for each year starting from 2013. The following sections provide a more detailed explanation on how we construct the tax burden estimates.

2.1 Vehicle Kilometers Traveled

The odometer readings allow us to calculate vehicle kilometers traveled (VKT) during the time between any two inspections for any vehicle. We restrict our attention to passenger cars[4] because larger vehicles such as vans, trucks and buses are more likely used in business even if their owners can be traced back to households. Smaller vehicles such

4. According to Finnish law, passenger cars are motor vehicles that are primarily used for transporting people and have at least four tires, a maximum speed exceeding 25 kilometers per hour and no more than eight seats in addition to the driver's seat.

as mopeds and motorcycles, on the other hand, do not have their odometer readings regularly recorded.

All cars are mandated by law to be inspected at regular intervals, the lengths of which depend on the age of the car, as shown in Figure 1. Prior to May 2018, cars had to be inspected for the first time three years after their initial registration. The next inspection had to be done at five years old, after which inspections were required every year. Starting May 2018, mandatory inspections are more infrequent during the first ten years, while yearly inspections are still required after that. The first inspection is not required until four years after initial registration, and subsequent inspections must be done every two years until the vehicle is ten years old.

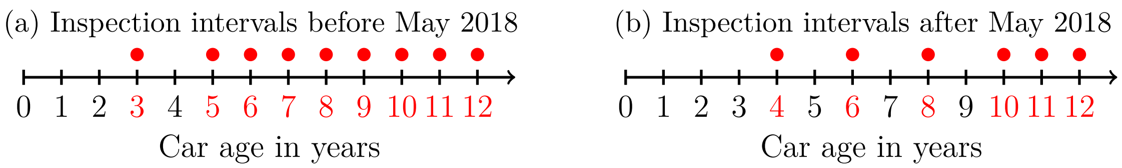

Figure 1: Mandatory inspection intervals by car age

To estimate the VKT for a given calendar year, we use odometer readings from all inspection intervals that overlap the year. Specifically, we first calculate for each inspection interval the average VKT per day. We then check the number of days each inspection interval overlaps with the calendar year. Finally, we multiply the daily average VKT by the number of overlapping days and sum up across all inspection intervals of the car. This gives us an estimate of the total VKT during the calendar year.

Because new cars are inspected more infrequently, the sample of cars for which we can estimate VKT for a given year gets smaller, and more selected towards older cars, as we approach the current year. This is why we base our distributional analyses on the year 2016, for which we are able to estimate VKT for nearly all cars. However, the longer inspection intervals for new cars may still lead to some bias in our results. Because the intervals overlap with multiple years, our estimates of VKT for 2016 reflect responses to fuel taxes, fuel prices and other shocks not only in 2016 but in years around 2016 as well. Fortunately for our study, the Finnish car fleet is relatively old, with the average car being around 12 years old, suggesting that any such bias should ultimately be minor.

2.2 Fuel Economy

To translate the annual VKT estimates into estimates of annual fuel liters consumed, we use car-level information on fuel consumption per 100 kilometers driven found in the vehicle data. These fuel economy values come from car manufacturers and are based on the New European Driving Cycle test (NEDC), a procedure that was used in assessing the fuel economy of new cars in Europe until the year 2018.[5]

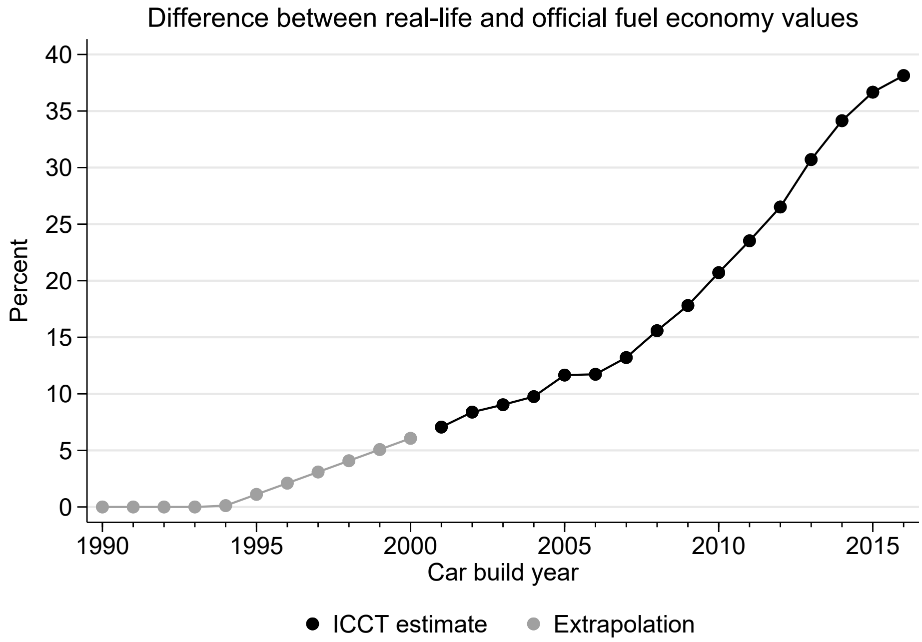

Figure 2: Estimated difference between real-life and official fuel economy values

A problem with the NEDC fuel economy values is that they systematically overestimate fuel efficiency when compared to data on real-life fuel consumption, an observation widely documented for example by the International Council on Clean Transportation (ICCT) (Tietge et al. 2019) as well as Reynaert and Sallee (2021). We take this problem into account by inflating the fuel economy values in our data using estimates of the difference between real-life and official fuel economy values.[6] These estimates are plotted in Figure 2. The black dots are estimates provided by Tietge et al. (2019) and represent the average gap between real-life and official values by car build year[7] based on German data. As these estimates only extend back to the year 2001, we predict the values for years before that by extrapolating the linear trend between 2001 and 2007 backwards until the gap reaches zero. We argue that our extrapolation is reasonable based on a

5. The NEDC produces estimates separately for urban and extra-urban driving, as well as a combined estimate. Since we do not know which kilometers have been driven where, we opt for the combined number. Ultimately, the differences between the estimates are negligible in light of our finding in section 4.2 that most variation in fuel consumption is due to VKT rather than fuel economy.

6. Our conclusions on the distributional effects of fuel taxes in section 3 are not greatly affected by our choice to inflate the official fuel economy readings. Instead, the inflated readings give a more realistic picture of the overall scale of the fuel tax burdens.

7. In the vehicle data, we only observe the year each car was first registered, which should correspond very closely to the year the car was built.

very similar trend observed by Tietge et al. (2019) in a smaller sample from Switzerland between 1996 and 2001.

Another challenge with the fuel economy values is that they are not available for all cars. In the 2016 data, a missing fuel economy value is reported for 26.6 percent of cars, most of them being cars first registered before the year 2000. We combat this problem by forming fuel economy predictions for the cars with missing values using data on cars with non-missing values. Specifically, we regress fuel economy on dummies for fuel type[8], make and model, and cars registered after the year 2007, when the European Union started regulating the fuel economy of new cars, as well as linear controls for cylinder volume, car weight and the registration year of the car. We also include various interactions between these variables. We then form a linear prediction of fuel economy for the cars with missing values. Although we cannot know for certain how reliable our predictions are, a correlation of 0.94 between the official and predicted fuel economy values among cars with non-missing values makes us confident in our predictions.

2.3 Tax Burdens

In Finland, motor fuels are subject to an excise tax defined in euro cents per liter.[9] It consists of three components: a CO_2 tax, an energy content tax, and a small strategic stockpile fee. The size of the CO_2 component depends directly on the CO_2 emissions of burning the fuel, whereas the other two components are historically more fiscal in nature. From the consumers' point of view, however, the components are all equal in their effect on fuel prices. Gas stations in Finland report tax-inclusive fuel prices, which means that the contribution of each component is not directly observable at the pump.

The Finnish excise taxes on motor fuels are among the highest in the world. In January 2022, the retail blends of gasoline and diesel sold at gas stations were taxed approximately at 72 and 49 euro cents per liter respectively.[10] In comparison, the average fuel taxes on gasoline and diesel were about 55 and 43 euro cents per liter in the European Union, the member states of which tend to tax fuels at the highest levels globally. The Finnish tax rates are particularly high compared to those in the United States, where the sum

8. Gasoline, diesel, hybrid, electric etc.

9. Fuels are also subject to a value added tax (VAT), which was 24 percent of the excise tax-inclusive price in 2016. However, because the VAT is not specific to fuels and also depends on their market price, we do not include it in our calculations of the tax burden in this paper.

10. The tax rates on pure gasoline and diesel were higher at nearly 76 and 60 euro cents per liter. The fuels sold in the retail market are mixes of pure gasoline or diesel blended with biofuels and other additives, which have lower tax rates. Estimates of the tax rates on retail fuel blends are provided by the Finnish Ministry of Finance and reported by the European Commission at https://ec.europa.eu/taxation_customs/tedb/advSearchForm.html?taxType=EDU_ENERGY. The database includes fuel taxes rates in all European Union member states.

of federal and state fuel taxes was on average 11 euro cents per liter for gasoline and 13 euro cents per liter for diesel in January 2022.[11].

In 2016, the year which we analyze in this paper, the excise taxes in Finland amounted to 68.13 euro cents per liter on gasoline and 50.61 euro cents per liter on diesel. To obtain an estimate of annual fuel taxes paid per vehicle, we multiply our estimates of total liters of fuel consumed by these numbers. We then sum over all the cars used by a given household to arrive at our household-level estimates. Measuring the burden of fuel taxes, or carbon taxes more generally, as a share of income spent on the tax is the most common approach in the literature (e.g. Poterba 1991; West 2004; Hassett, Mathur, and Metcalf 2009; Grainger and Kolstad 2010; Sterner 2012; Cronin, Fullerton, and Sexton 2019). However, an estimate of taxes paid is ultimately only a first-order approximation of the total burden imposed on households, as we do not observe how much more fuel they would consume in the absence of the tax, or the utility they would gain from the additional consumption.

In line with most previous studies on the distributional consequences of fuel taxes and carbon pricing, we also opt to not make assumptions on demand responses. Studies that do incorporate heterogeneity in demand responses tend to find that low-income households adjust their fuel consumption more in response to a tax increase than high-income households, making the distributional impacts more progressive than a comparison without demand responses would suggest (e.g. West and Williams 2004; Bureau 2011; Douenne 2020). We also do not consider indirect costs operating through the prices of other goods or general equilibrium effects on income and employment. Hassett, Mathur, and Metcalf (2009) find that, in the United States between 1987 and 2003, the indirect burden from a hypothetical carbon tax would have been smaller and less regressive than the direct burden. On the other hand, studying unexpected changes in the supply of allowances in the EU ETS, Känzig (2023) finds relatively large and regressive general equilibrium impacts on household incomes and employment. Thus, while outside the scope of our analysis, we acknowledge that indirect effects might also play a role in the distributional effects of fuel taxation.

Finally, when using the same tax rate for all Finnish households in our calculations, we make the implicit assumption that the pass-through of the tax is 100 percent everywhere in the country. While standard in the literature (see e.g. West and Williams 2004; Hassett, Mathur, and Metcalf 2009; Cronin, Fullerton, and Sexton 2019), this may somewhat understate the true variation in burdens between and within income groups. Using gas station-level fuel price data from Finland, Harju et al. (2022) find substantial geographical variation in the pass-through rates of a large diesel tax increase of around 10 euro cents per

11. According to information provided by the U.S. Energy Information Administration, the average taxes on gasoline and diesel were about 49 and 57 cents per gallon, which correspond to about 11 and 13 euro cents per liter using the January 1, 2022 exchange rate.

liter implemented in 2012. Specifically, they estimate that pass-through rates were up to 15 percentage points lower in high-income and urban areas compared to low-income and rural areas. However, even though we do know the residential locations of individuals, we do not know where they refuel their cars, so we opt for assuming uniform pass-through.

2.4 Household Characteristics

The vehicle data include pseudonymized identifiers for the owners of each car.[12] We observe how many days a year each person owned each car and use this information to assign the car-level estimates of fuel liters consumed to all the different owners of each car. Using the identifier for the owner of each car, we merge the vehicle data with administrative individual-level population data provided by Statistics Finland. The population data contain information on e.g. the age, gender, annual income, employment, and residential location all individuals living in Finland on the last day of each calendar year. In the data, we also observe all the household members of each car owner, which allows us to aggregate the estimates of fuel taxes paid from the individual level to the household level. Households in the data are defined as household-dwelling units, which are comprised of all individuals permanently living in the same dwelling.

To compare fuel tax burdens at different income levels, we divide households into income deciles based on equivalized disposable household income in 2016. Disposable household income is the total sum of salary income, entrepreneurial income, property income, and transfers received net of income taxes paid across all household members. Equivalized disposable household income is defined as disposable household income divided by a weighted number of household members. The weights are based on the modified OECD equivalence scale, the purpose of which is to make households of different sizes and compositions comparable. The first adult in the household receives a weight of 1, all other members aged 14 and over a weight of 0.5, and members aged under 14 a weight of 0.3.

A number of studies have demonstrated how measuring income at the annual level results in fuel taxes and carbon pricing appearing more regressive than if one were to measure income over the whole lifetime of an individual, usually proxied with annual expenditure (e.g. Poterba 1991; Hassett, Mathur, and Metcalf 2009; Cronin, Fullerton, and Sexton 2019). We move forward with annual income, as information on it is readily available for all Finnish households. However, we also assess the distribution of fuel tax burdens using multi-year averages of income.

12. Each car may have up to two different owners: the legal owner and the registered owner. The first legally owns the car but the second is, from the legal point of view, intended to be the primary user of the car. In line with this legal purpose, we assign the registered owner as the user of a car if one has been reported.

Table 1: Summary statistics for households in 2016

	Mean	Median	SD
Vehicle kilometers traveled	12,302	8,834	13,979
Fuel taxes paid	€598	€443	€672
Disposable income	€39,247	€31,691	€69,925
Fuel taxes paid, % of disposable income	1.5%	1.1%	1.8%

The values in the table are calculated from a sample of 2,498,800 households, covering 94.1 percent of all Finnish households in 2016. This sample includes all households that have 1) information on VKT for all cars, 2) total annual VKT below 100,000, 3) non-zero income, and 4) fuel expenditure not exceeding 50 percent of income. All euro amounts are reported in 2016 euros.

Table 1 presents summary statistics of vehicle kilometers traveled, fuel taxes paid, and income among Finnish households in 2016. The data contain a total of 2,654,579 households, out of which 2,498,800, or 94.1 percent, are included in our sample. We drop 145,323 households for which we do not have information on VKT for all cars, as well as 6,404 households that have zero disposable income. To exclude outliers resulting from potential errors in the odometer readings data, we further drop 2,001 households that have annual VKT exceeding 100,000, and 3,260 households with fuel expenditure exceeding 50 percent of disposable income.[13] The average of household vehicle kilometers traveled in 2016 is around 12,300. This translates to household fuel taxes totaling 598 euros on average, or a relatively modest 1.5 percent of disposable household income. However, the standard deviation exceeds the mean both in vehicle kilometers traveled and taxes paid, indicating that a lot of variation is masked by these averages.

3 Distribution of Fuel Tax Burdens

3.1 Vertical Dimension

Figure 3 plots mean and median fuel tax burdens across income deciles, along with interquartile ranges within income deciles. The left panel of Figure 3 shows that the fuel tax does not appear to be regressive among all Finnish households. Instead, the average share of income devoted to paying fuel taxes varies between 1 and 2 percent and roughly follows an inverse U-shaped pattern with households in the seventh decile

13. We use annual average prices of €1.37 per liter for gasoline and €1.187 per liter for diesel reported by Statistics Finland to estimate annual fuel expenditure for each household.

facing the highest burdens. Not only are average tax burdens smaller among low-income households than among middle-income households, the median households in the three lowest deciles pay no fuel taxes at all.

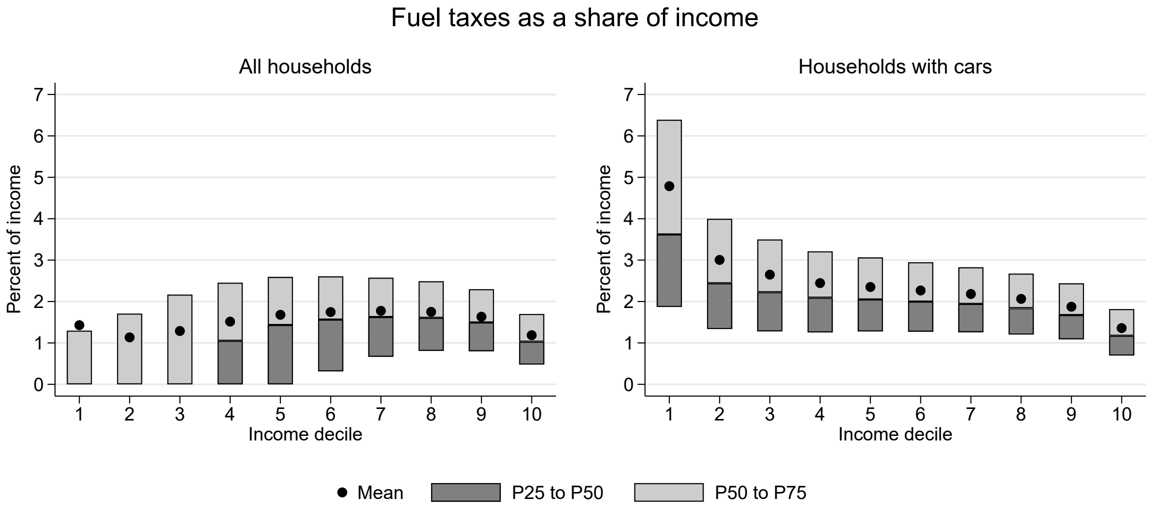

Figure 3: Fuel tax burdens across income deciles

In contrast, if we only consider the group of households that owned a car during the year 2016, the fuel tax seems clearly regressive. In the right panel of Figure 3 we can see that average fuel tax burdens are the highest in the lowest income decile and decrease monotonically with income. The mean of fuel taxes as a share of income is 4.8 percent in the first income decile but only 1.4 percent in the tenth decile. The stark difference in the regressivity of fuel taxation between car-owning households and the entire population of Finnish households is due to a clear selection into car ownership with respect to income, as illustrated in Figure 4. The share of households with a car increases strongly with income. In the first income decile, only 30 percent of household had a car during 2016, whereas in the highest three deciles the share is over 85 percent. In total, only about 67 percent of the households in our sample had a car in 2016, meaning that 33 percent of households would not have faced any direct monetary burden from a fuel tax increase.

Few studies directly evaluate the regressivity of fuel taxes separately for all households and the group of households that have a car. One example is Santos and Catchesides (2005) who report a very similar finding in the UK: fuel tax burdens follow an inverse U-shaped pattern across income deciles among all households but fall starkly with income among car-owning households. Sterner et al. (2011) argue more generally that the regressivity of fuel taxation in a given country depends on the country's overall income level through its effect on car ownership. They demonstrate how fuel taxes are often progressive in developing countries, where cars are luxury goods owned mostly by high-income households. In contrast, studies from the United States, where the car ownership

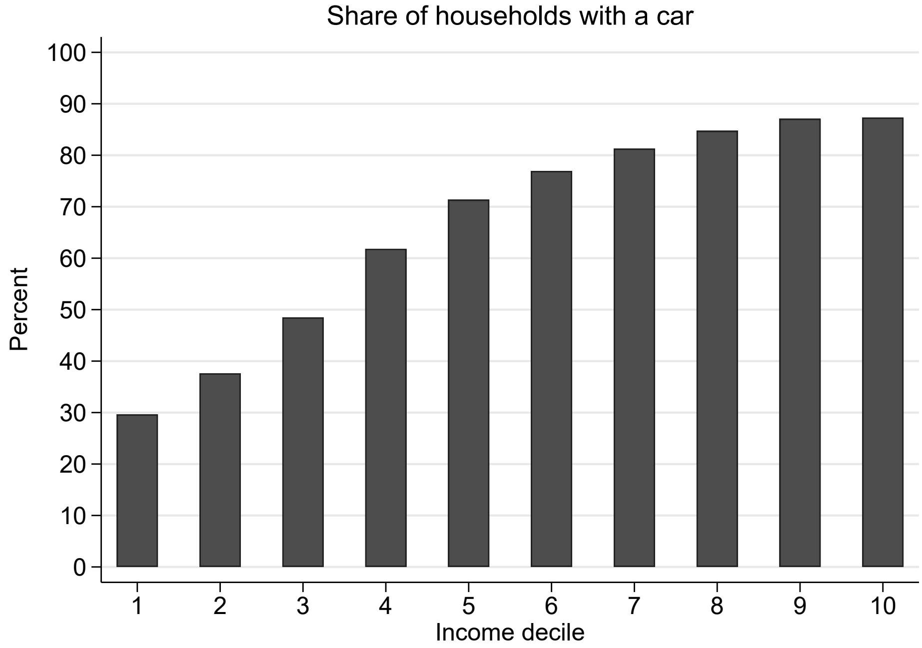

Figure 4: Car ownership rates across income deciles

rate is very high, are more likely to find that fuel taxes are regressive. (e.g. Poterba 1991; Hassett, Mathur, and Metcalf 2009; Burtraw, Sweeney, and Walls 2009) In Europe, where incomes are high but on average lower than in the United States, car ownership is also less common and fuel taxes are closer to being proportional (Sterner 2012).

Pizer and Sexton (2019) argue that differences in the regressivity of fuel taxes across wealthy countries could also be explained by commuting behavior and public transportation infrastructure. Specifically, they note that commuting distances are shorter and public transportation infrastructure is better in Europe compared to the United States, where many low-income individuals have to rely on cars and travel long distances to work.

Conclusions on the regressivity of fuel taxes also depend on the choice of income measure. Poterba (1991) argues that using annual income exaggerates the regressivity of fuel taxes, since it does not account for over-time variation in income, especially in the lowest income deciles. He shows that regressivity diminishes if annual income is replaced with annual expenditures, which is a proxy for lifetime income if consumers are engaging in consumption smoothing. This finding has been corroborated by other studies since (e.g. Hassett, Mathur, and Metcalf 2009; Cronin, Fullerton, and Sexton 2019).

While we do not observe annual expenditures, we do observe incomes for multiple years. Figure 5 shows how the vertical distribution of fuel tax burdens changes if income is measured as a multi-year average instead of only in 2016. Including just one year before and after 2016 into the income average clearly reduces the mean fuel tax burden in the first income decile relative to all the other deciles. Adding another year on either side makes the burden even smaller. This suggests that temporary income shocks may indeed exaggerate fuel tax burdens in the lower end of the income distribution. In contrast, tax burdens do not appear to flatten in other parts of the distribution. That being said, a five-year time window obviously captures only a small part of life-time income and might not make as large of a difference at higher incomes.

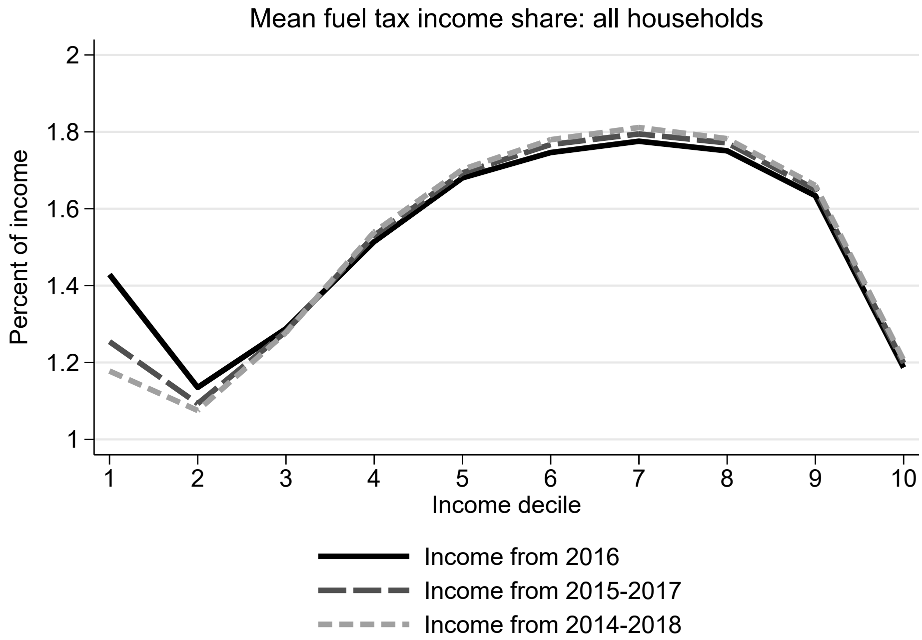

Figure 5: Vertical distribution of fuel tax burdens with multi-year average incomes

Notes: The sample of households used in calculating the average fuel tax burdens changes between the three income definitions based on availability of income information. The deciles are also calculated separately for each income definition.

3.2 Horizontal Dimension

Returning to Figure 3, we see that fuel tax burdens vary considerably within income deciles. Among all households, for instance, all of the within-decile interquartile ranges of fuel tax burdens are wider than the difference between the largest and smallest averagetax burden across income deciles. Overall, the variation in fuel tax burdens across income deciles is dwarfed by the variation within income deciles. We find that only about 1.5 percent of the variation in fuel tax burdens is explained by variation across income deciles, while 98.5 percent of the variation is found within income deciles.

The welfare implications of this type of horizontal inequity have been the subject of some debate among economists. Even if one agrees that "treating equals equally" is a desirable goal, analyzing the welfare losses from failing to do so is not a straightforward task in the standard welfare theory framework. Fischer and Pizer (2019) provide a thorough discussion, arguing that at the heart of the controversy is the inherent need for a reference point, something that is not required when analyzing vertical equity. In the case of fuel taxation, a reference point for assessing welfare losses at the household level could be e.g. the welfare loss faced by the average household with the same income. However, determining equals in terms of income still requires first defining the state of the world in which incomes are measured. We could compare either 1) welfare losses between individuals with the same pre-tax income if a tax is imposed or 2) welfare gains between individuals with the same post-tax income if the tax is removed. Ultimately, the practical importance of this distinction depends on the size of the tax relative to income.

We assess how relevant horizontal inequity is in standard welfare analysis by asking how the results differ when outcomes are measured at the level of individual households versus at the level of a representative household in each income group. The former approach incorporates horizontal variation, while the latter only accounts for vertical differences between income groups. In particular, consider the constant relative inequality aversion utility function presented by Atkinson (1970):

$$U(y) = a + bu(y),\ u(y) = \begin{cases} \frac{y^{1-\gamma}}{1-\gamma} & \text{if } \gamma \neq 1 \\ \ln y & \text{if } \gamma = 1 \end{cases} \tag{1}$$

where a and b are some constants capturing the scale of the utility, y is income, and $\gamma \geq 0$ is the income elasticity of utility. Suppose then that a household i in income group k has a pre-tax income of y_k^0, but households with the same pre-tax income face different taxes such that their post-tax incomes y_{ki}^1 differ. An individual household's welfare loss from the tax is then

$$L(y_{ki}^1) \coloneqq U(y_k^0) - U(y_{ki}^1) = b(u(y_k^0) - u(y_{ki}^1)) \tag{2}$$

A representative household in income group k has a post-tax income level of $E[y_{ki}^1]$ and faces a welfare loss of $L(E[y_{ki}^1])$. The ratio of the expectation of (2) to $L(E[y_{ki}^1])$ then tells us how much larger the average welfare loss is at a given income level under horizontal inequity compared to no horizontal inequity:

$$\frac{E[L(y_{ki}^1)]}{L(E[y_{ki}^1])} = \frac{u(y_k^0) - E[u(y_{ki}^1)]}{u(y_k^0) - u(E[y_{ki}^1])} \tag{3}$$

If we were to define equals in the post-tax world, instead, we could write an analogous welfare gain ratio for removing the tax as

$$\frac{E[G(y_{ki}^0)]}{G(E[y_{ki}^0])} = \frac{E[u(y_{ki}^0)] - u(y_k^1)}{u(E[y_{ki}^0]) - u(y_k^1)} \tag{4}$$

where outcomes are now heterogeneous in the pre-tax state 0, and equals have the same post-tax income y_k^1. Since $u(y)$ is concave, Jensen's inequality tells us that $E[u(y_{ki})] \leq$

$u(E[y_{ki}])$, meaning that (3) is always at least, and (4) at most one. In other words, welfare losses from imposing a tax are potentially underestimated, and welfare gains from removing it overestimated, if horizontal variation is ignored.

Importantly, (3) and (4) are invariant to a and b but depend on the degree of inequality aversion captured by the parameter γ. In a recent meta-analysis, Acland and Greenberg (2023) find a mean value of 1.6 for γ, while also recommending sensitivity analysis with values of 1.2 and 2.0. Using these values, Figure 6 illustrates how horizontal inequity affects the welfare effects of fuel taxation. Specifically, Figure 6 plots the welfare loss ratio in (3) and the inverse of the welfare gain ratio in (4) across both the pre- and post-tax income distributions, with income groups k measured at the precision of 1000 euros per year. We see that the ratios are close to one across most of the income distribution but relatively large at the very lowest incomes. Both ratios suggest a fairly similar impact of horizontal inequity but differ somewhat at the lowest incomes. This is because the lowest income levels exhibit the highest degree of heterogeneity in tax burdens, which results in the composition of pre- and post-equals also differing the most at these incomes.

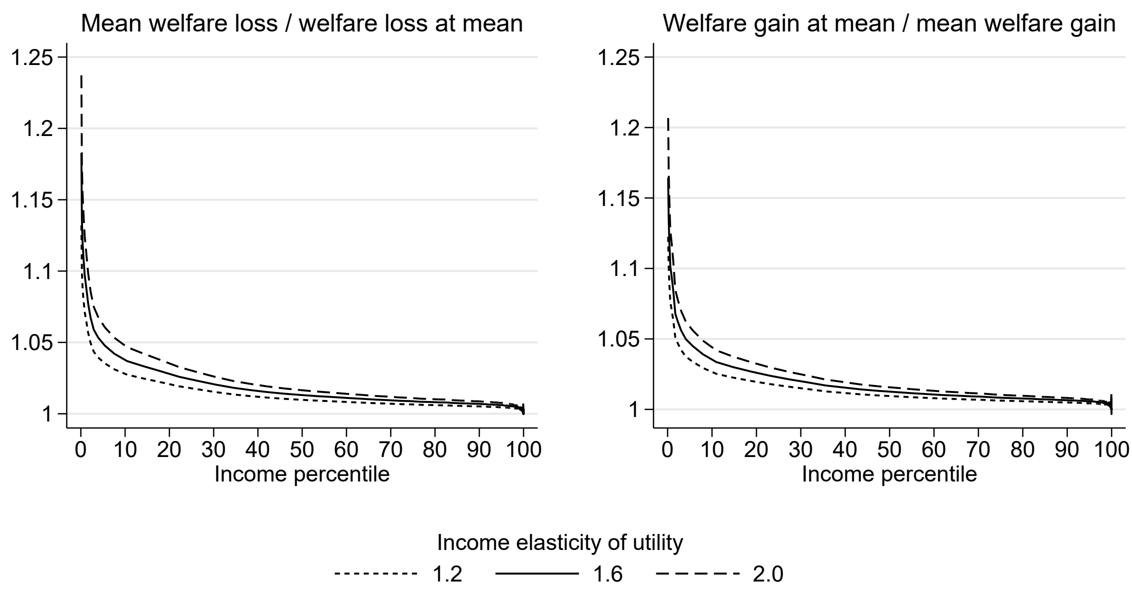

Figure 6: Impact of horizontal inequity on social welfare measures

Notes: Means are taken over households with the same pre- (left panel) or post- (right panel) tax disposable income at the precision of 1000 euros per year.

However, one should be vary of concluding, based on these results, that horizontal inequity leads to very large welfare effects for the worst-off households. As discussed in section 3.1, annual income may not be the best measure of economic status at low incomes. Moreover, observations with an annual income of just a few hundred or even a few thousand euros are somewhat questionable. The welfare loss and gain ratios increase sharply only in the first income percentile, where annual incomes are below 5000 euros. In contrast, Finnish residents were entitled to annual income support of more than 5000 euros in 2016 if they were not able to afford necessities with their other income or wealth.

The ratios in Figure 6 being so close to one suggests that, for the scale of taxes we consider, horizontal equity does not appear to be much of an issue from a standard welfare perspective. This is perhaps surprising in light of the fact that most of the variation in fuel tax burdens falls within rather than across income deciles. To define a measure that responds more to horizontal inequity, it thus seems beneficial to impose separate preferences on global and local inequality aversion, such as in the model by Auerbach and Hassett (2002). However, whereas estimates readily available for the former (see e.g. Acland and Greenberg 2023), there is little empirical guidance for calibrating the latter. Thus, in line with the recommendation by Fischer and Pizer (2019), we prefer to present the information on horizontal inequity by calculating decile-specific interquartile ranges for the tax burdens as in Figure 3. Determining the degree of inequality aversion is then up to the society.

While the welfare impacts of horizontal variation appear small when measured with standard tools, there are at least two reasons why horizontal inequity can matter in practice. First, households with high burdens may be, to some extent, locked into those burdens. For example, a households may not be able to change their location from more car-dependent areas to a less car-dependent ones without significant welfare losses, even if their current income would be enough to live elsewhere. Moving very far can also require changing jobs or schools, both of which can carry considerable costs and risks. Another form of lock-in can be imposed by time and health constraints. For example, parents of young children may be burdened not only by their own transportation needs, but also those of their children, and elderly people's alternatives may be limited by health issues that prevent the choice of active transportation. Ultimately, whether such concerns matter is a value judgement that we leave up to policymakers. Our aim here is to just describe the scale of potential issues from different perspectives.

The second motivation for addressing horizontal inequity is a political one. Irrespective of whether people agree on the role of horizontal inequity in assessing the fairness of fuel taxation, the case remains that the people who consume a lot of fuel stand to lose more from increases in fuel taxes. If these people are numerous, they may end up blocking policies that would benefit the society at large. Understanding the sources and extent of horizontal inequity can thus be important even if one does not deem it unfair. With these motivations in mind, the next section asks which household characteristics explain differences in tax burdens within income deciles, and to what extent the variation may be idiosyncratic.

4 Explaining the Variation in Tax Burdens

4.1 Home Location, Household Composition and Employment

To understand the horizontal variation in fuel tax burdens, we first focus on three household characteristics that are likely of particular interest for policymakers. Regional differences are perhaps the most often highlighted source of horizontal variation in fuel tax burdens. Residential location might matter a great deal, given the shorter distances and usually better public transit service in urban compared to rural areas. Household composition, and especially having children in the household, is another dimension that tends to come up in public discussion. Finally, the burden of fuel taxes might depend on labor market status, as many workers rely mostly on cars to commute to work.

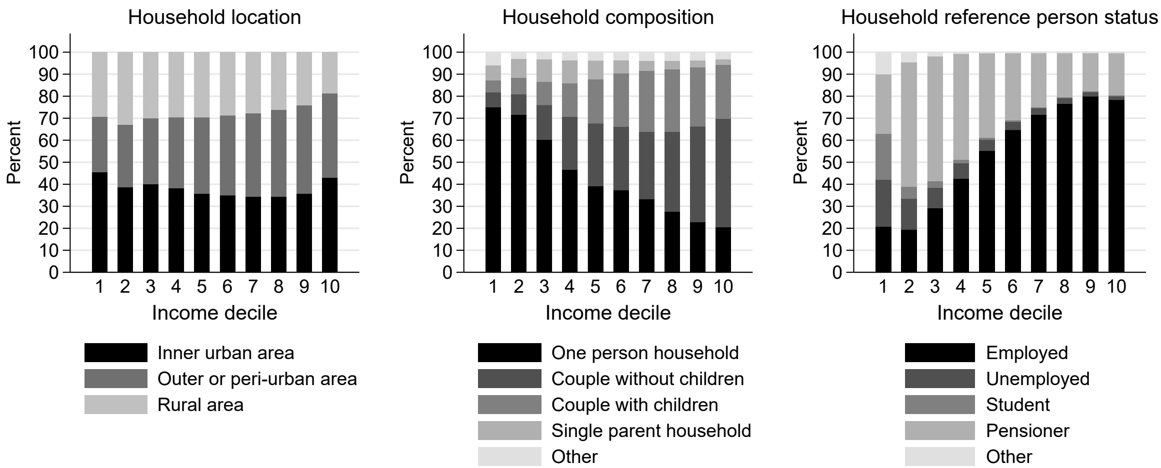

Figure 7: Distribution of household types within income deciles

Figure 7 shows how households within each income decile differ with respect to these characteristics. In the left panel, we see that households in the lower income deciles are slightly more likely to reside in rural areas or inner urban areas, which correspond to city centers.[14] On the other hand, living in outer or peri-urban areas, essentially suburbs, is more common in higher income deciles. While the differences in household location are fairly small, household composition exhibits substantial variation across income deciles, as seen in the middle panel. In the lowest two income deciles, more than 70 percent of households are one-person households and few households have children. In contrast, couples with children comprise nearly 50 percent of households in the highest two deciles and the share of one-person households is only around 20 percent.

14. The location of each household is based on a urban-rural classification created by the Finnish Environment Institute.

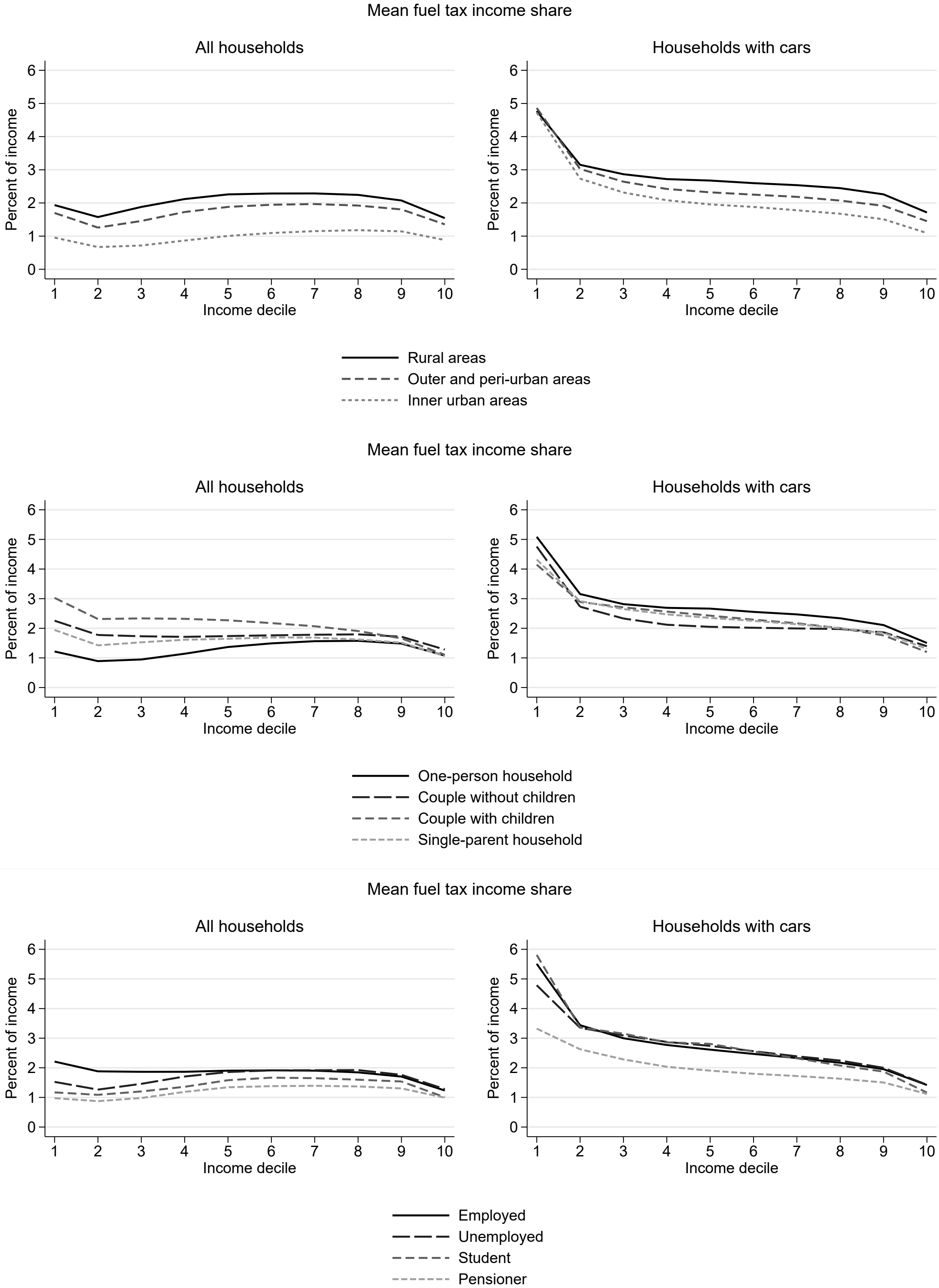

Figure 8: Variation in average fuel tax burdens within income deciles

Finally, the right panel of Figure 7 shows how households in different income deciles also differ systematically with respect to the labor market status of the household reference person. Following the definition used by Statistics Finland, we define the reference person as the person with the highest gross income in the household, unless the highest earning person is a child under 25 living with their parents. If everyone in the household has zero income, the oldest person in the household is chosen as the reference person. Using this definition, the share of households with an employed reference person increases strongly with income, from around 20 percent in the lowest income deciles to around 80 percent in the highest deciles. Conversely, the share of households with an unemployed reference person decreases from around 20 percent in the first income decile to almost zero in the tenth decile. The share of pensioners also drops significantly from 55 percent in the second income decile to 20 in the tenth decile. The first income decile, however, clearly stands out from the other deciles: the share of student households is 20 percent, whereas they are almost non-existent in the other deciles. In addition, the share of pensioner households is only 25 percent, less than half of the share in the next two deciles.

Figure 8 shows how the average fuel tax burden varies within income deciles in the three dimensions presented in Figure 7. In the top panel, we see that fuel tax burdens are on average highest in rural areas, second highest in outer and peri-urban areas and lowest in inner urban areas in every income decile. Among all households, the difference in average burdens between rural areas and inner urban areas is fairly constant at 1 percent of income across the income deciles. This is a sizable difference, considering that the average decile-specific fuel tax burdens vary between 1 and 2 percent, as shown in Figure 3. Among car-owning households, the difference between rural and inner urban areas increases slightly with income, from almost no differences in the first income decile to almost 1 percent of income in the highest income deciles.

The middle panel of Figure 8 plots average fuel tax burdens within income deciles for different household compositions. Here, it is worth reminding that the burdens and deciles are defined with respect to equivalized income in order to make households of different sizes more comparable (see section 2.4 for details). Among all households, fuel tax burdens are on average lowest in one-person households in every decile, while couples with children have the highest burdens in every decile but the highest deciles. The differences in average burdens between households of different compositions in the highest deciles are, however, very small. In fact, the within-decile variation with respect to household composition is the largest in the first decile and decreases with income. In the first decile, the difference in average fuel tax burdens between couples with children and one-person households is around 2 percent of income. Differences as large as this are not present in any income decile among car-owning households. Although one-person households appear to have the highest tax burdens among car-owners, the average burdens for other household compositions are smaller by no more than about 0.5 percent of income.

Finally, the bottom panel of Figure 8 shows how average fuel tax burdens vary with respect to the labor market status of the household reference person. Looking at all households in the lower half of the income distribution, average fuel tax burdens are highest in households with an employed reference person, followed by unemployed households, student households and pensioner households. In the upper half of the income distribution, the order is the same with the exception that households with an unemployed reference person appear to have the highest average burdens by a very small margin. The within-decile differences in the sizes of the tax burdens between unemployed, student and pensioner households are nearly constant across income deciles. Among car-owning households, average fuel tax burdens do not appear to depend on the status of the reference person, with the exception that pensioner households have systematically lower average burdens in every decile.

Overall, the variation in average fuel tax burdens across household types within income deciles is smaller among car-owning households than among all households. In other words, the differences in average burdens across household types appear to be more strongly related to differences in car-ownership probabilities rather than differences in how intensively cars are used. Car ownership choices are thus an important determinant of the distributional implications of fuel taxation not only across income deciles but also between different types of households within income deciles.

The average fuel tax burdens plotted in Figure 8 help us to identify vulnerable households that might be disproportionately affected by fuel tax increases at least in the short run, when behavioral responses are more limited. First, households living outside inner urban areas might be considered vulnerable not only because of the higher average fuel tax burdens in these areas but also because of more limited possibilities to switch from cars to public transit. Second, although couples with children have on average the highest fuel tax burdens, all households with underage children might more broadly be deemed vulnerable, as changes in the number of parents in the household are possible also in the short run. Third, households with employed adults could also fall into the category of vulnerable households because the average fuel tax burdens are highest among households with an employed reference person. Furthermore, employment often necessitates commuting to a workplace, meaning that using some form of transportation is required on a regular basis.

The group of vulnerable households should probably only include lower-income households, as high-income households can more easily afford cleaner technologies or changes in consumption. For the purpose of this illustration, we define lower-income households broadly as those in the lower half of the income distribution. Using the three criteria for vulnerable households defined above, 38.7 percent of households satisfy at least one criterion in addition to the income requirement, 13.9 percent satisfy at least two in addition to the income requirement, and 5.5 percent satisfy all three in addition to the income requirement. Figure 9 demonstrates how the average fuel tax burden increases with the number of vulnerability categories satisfied in every income decile below the median. The figure also shows that the fuel tax is regressive among the group of households that meet all three criteria, even without restricting the sample to car owners. One reason for the regressivity is that in this group the within-decile car ownership rates are around 80–90 percent even in the lowest income deciles.

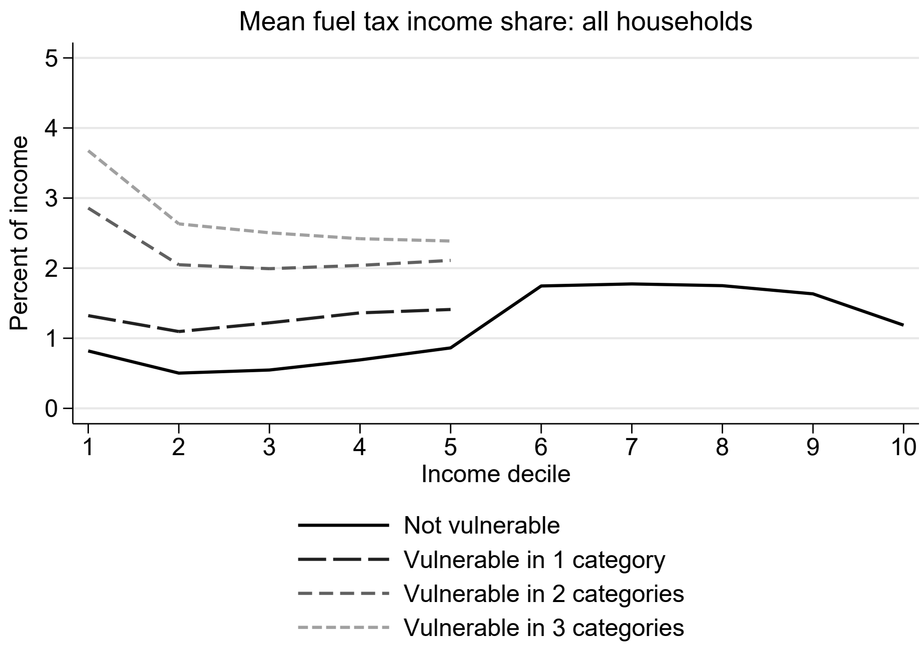

Figure 9: Average fuel tax burdens across income deciles for vulnerable households

Notes: Vulnerable household are defined as having below median income and falling into at least one of the following categories: 1) living outside inner urban areas, 2) having children, or 3) including employed household members.

4.2 Fuel Economy and Kilometers Traveled

The variation in fuel taxes paid across households is a direct consequence of variation in fuel consumption. In addition to car ownership, the two factors that determine fuel consumption are vehicle kilometers traveled and fuel economy. Figure 10 shows how the latter two factors vary both across and within income deciles among car-owning households. Surprisingly, fuel economy exhibits on average almost no variation with respect to income.[15] Cars with better fuel economy are generally newer, and thus more expensive and have more higher-end features. If high-income households demand more of these features, average fuel economy could potentially be better in higher income deciles. While we do observe in the data that cars in the higher income deciles are on average clearly newer, they are also heavier and have a larger cylinder volume, both of which factors are correlated with lower fuel economy. With electric vehicles becoming increasingly popular, however, fuel economy may play a more important role in determining the regressivity of fuel taxes in the future if these zero-emissions vehicles are acquired more frequently by high-income households.

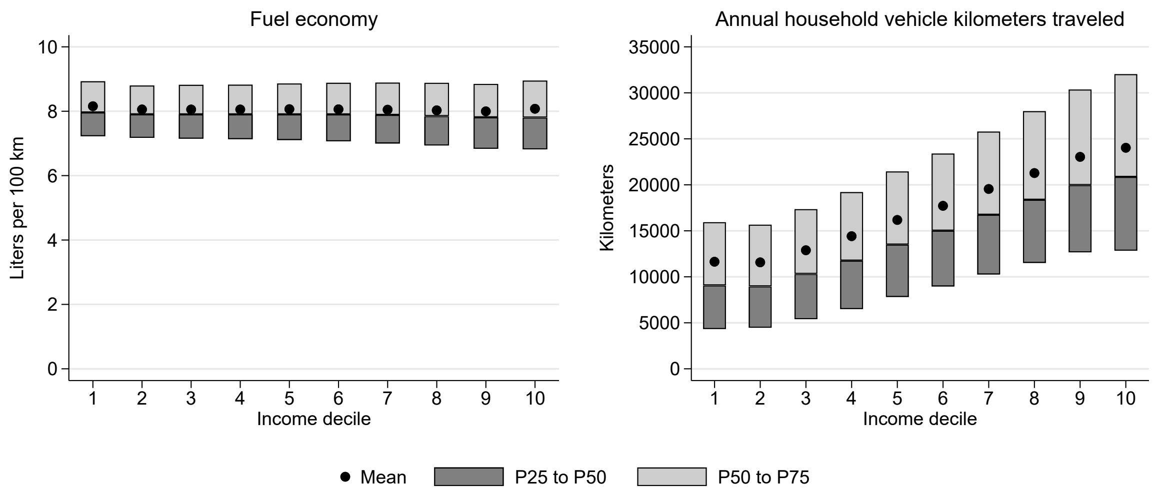

Figure 10: Sources of variation in fuel consumption among car-owning households

As there is very little variation in fuel economy both across and within income deciles, the vast majority of the variation in fuel taxes paid among car owners comes from heterogeneity in vehicle kilometers driven. Figure 10 demonstrates how average vehicle kilometers driven increase monotonically with income. In the highest decile, car-owning households drive on average a total of 24,000 kilometers per year, while car owners in the first decile drive on average a total of 11,600 kilometers. The variation within income deciles is, however, even greater than the difference in averages between deciles. Among car-owning households, the standard deviation of vehicle kilometers traveled ranges from 10,400 kilometers in the first decile to 15,400 in the tenth decile. The within-decile variation in tax burdens among car-owning households seen in Figure 3 is thus primarily a consequence of the large within-decile variation in vehicle kilometers traveled.

15. The within-decile statistics on fuel economy in Figure 10 are based on the fuel economy values of all cars used by any household in the decile.

4.3 Predicting Fuel Taxes Paid with Detailed Data

As demonstrated in section 4.1, the distribution of fuel tax burdens exhibits meaningful variation with respect to some key household characteristics. However, this section shows that most of the variation in fuel taxes paid at the household level remains unexplained despite our attempts to capture it with very detailed data on household characteristics.

Table 2: Predicting fuel taxes paid by households

	(1)	(2)	(3)	(4)
Average fuel tax	€598.6	€598.6	€598.6	€598.6
Average absolute prediction error	€411.2	€379.2	€350.1	€254.2
R^2	0.307	0.394	0.463	0.674
N households	2,496,644	2,496,644	2,496,644	2,496,644
Household composition	X	X	X	X
Dwelling type and location		X	X	X
Income and employment status			X	X
Number of cars				X

Columns (1) to (4) report estimates from four different regression models estimated using OLS. The model in column (1) predicts household fuel taxes only using a set of variables on household composition. These include dummies for the size of the household, number of people under 18 years old, number of people at least 18 or 65 years old, total number of children, number of children under 18, 7 or 3 years old, number of men and women, and number of families living in the household. Column (2) adds variables related to dwelling type and location, including dummies for owner-occupied and rental dwellings, type of building, region and municipality of residence, and degree of urbanization of the home location. Column (3) adds variables on income and employment status. The income variables include linear controls on household wages, entrepreneurial income, property income, transfers received, and total income both before and after tax, as well as dummies for every €5000 of each income measure. The employment status variables include dummies for the number of employed, unemployed or retired people, number of students, and number of other people outside the labor force. The model also includes an estimate of the total commuting distance of all household members. Finally, column (4) adds a linear control for the number of cars in the household.

Table 2 reports the predictive power of regressing household fuel taxes paid on an increasingly rich set of variables from the administrative data. In column (1), we only use variables that describe the composition of each household, e.g. household size, the number of people in specific age groups, and the number of children. With this information, we manage to explain only 30.7 percent of the variation in fuel taxes paid. With the average household fuel tax being 599 euros, our predictions are off by about 411 euros on average.

In column (2), we add information on where and in which kind of dwelling households live. The household location information is very detailed and ranges from the region and municipality of residence to a seven-level urban-rural classification. The urban-rural classification, constructed by the Finnish Environmental Institute, divides the entire country into 250 meters by 250 meters grid cells that do not follow municipality borders, and assigns each of these squares into one of seven classes based on a number of indicators of the degree of urbanization of that square. Adding these explanatory variables increases the precision of our model, but we are still only able to explain 39.4 percent of the variation in fuel taxes. The average absolute prediction error decreases from 411 euros to 379 euros.

Column (3) adds variables on household income, using a variety of measures from total income before and after tax to wages and transfers. The model in column (3) also includes variables describing the employment status of the people living in the household, as well as the total commuting distance of all household members based on estimates by Statistics Finland. These variables improve our predictions only by a little, as the average absolute prediction error decreases from 379 euros to 350 euros, and the fraction of variation in household fuel taxes explained rises to 46.3 percent. Column (3) includes most of the relevant variables available in our data. Experimenting with including some additional variables does not seem to result in more accurate predictions. However, it is conceivable that a nonlinear prediction method such as a neural network might improve the predictions somewhat.

With most variables on household characteristics exhausted in column (3), column (4) adds the number of cars used in the household as an explanatory variable. Only after doing this, the model succeeds in explaining more than half of the variation in fuel taxes, with the R-squared now being 67.4 percent. The average absolute prediction error also decreases clearly and drops from 350 euros to 254 euros. The increase in predictive power is not that surprising, given that the number of cars has more of a mechanical relationship with fuel taxes paid, unlike most of the household characteristics in column (3). From the perspective of horizontal inequity, it would be more interesting to understand how households decide on the number of cars to own.

Considering that our population data are extremely detailed and contain practically all the relevant information that public authorities have on individuals, the R-squared values of 46.3 percent and 67.4 percent in our best predictions seem surprisingly low. In comparison, using a similar approach with consumer expenditure survey data from the United States, Sallee (2019) manages to explain 35.6 percent of the variation in fuel taxes paid with household characteristics and increases the share to 45.6 percent by adding the number of cars as a predictor.

5 Compensating Households to Address Inequity

To address the distributional concerns raised by fuel taxes or other policies that put a price on environmental externalities, the policies may be combined with transfer schemes that aim to compensate those who suffer from their introduction. For example, in addition to the Social Climate Fund included in the EU ETS2, Austria, Canada and Switzerland have already implemented a "carbon dividend" system in which a portion of the carbon tax revenue is redistributed back to individuals in the form of direct payments (Austria and Canada), tax credits (Canada) or a discount on mandatory health insurance payments (Switzerland).

In this section, we illustrate how various transfer schemes would affect both the vertical and horizontal inequity arising from fuel taxation in Finland. It should be noted that in Finland the revenue raised by fuel taxation currently goes towards the general government budget, and a variety of transfers meant to aid low income households are funded from that budget. However, without an explicit link between the two, it is difficult to say what part of a given transfer is attributable to fuel taxation. Hence, we proceed as if the existing transfers were entirely independent of fuel taxation. We also assume that the transfers do not affect households' fuel consumption. This should be a reasonable approximation given how small the transfers ultimately are relative to annual incomes.

5.1 Vertical Inequity

Because the Finnish fuel tax appears regressive among car-owning households, as shown in section 3.1, a policymaker might wish to compensate households in order to make the fuel tax burdens more equal among car-owners. Figure 11 presents three example transfer scenarios that could be used to achieve this goal. The lines in Figure 11 represent average net fuel tax burdens after a transfer among car-owning households. For reference, the solid line replicates the distribution of average tax burdens without transfers from Figure 3.

The long-dashed line shows the "equal rebate" scenario, in which the entire tax revenue is split equally among all households, with each household receiving almost 600 euros annually. The short-dashed line, on the other hand, represents a scenario where 50 percent of the revenue is recycled, again equally between all households, resulting in a transfer of nearly 300 euros. Finally, in the scenario represented by the shortest-dashed line only 12.7 percent of the revenue is redistributed but the transfers are progressive. This scenario with progressive transfers is designed in such a way that the resulting distribution of tax burdens is symmetrical across income deciles. The transfers range from about 350 euros in the first decile to 200 euros in the second decile, 130 euros in the third decile, 70 euros in the fourth decile, 30 euros in the fifth decile, and zero in the five highest deciles.

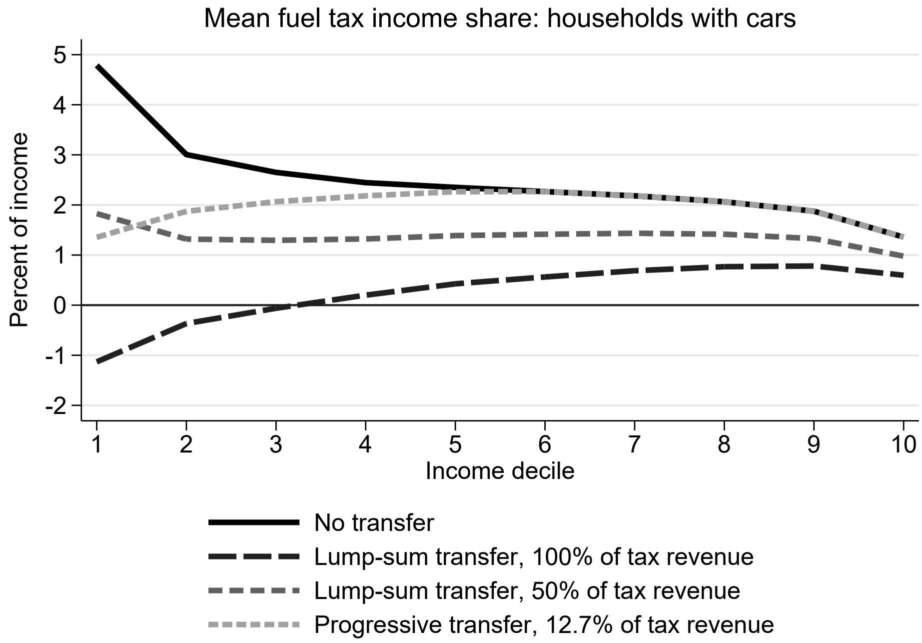

Figure 11: Vertical equity in different compensation schemes

The scenarios presented in Figure 11 exemplify the fact that the vertical distribution of tax burdens can be manipulated practically arbitrarily according to the preferences of the society. For fuel taxes, a progressive distribution can be achieved revenue-neutrally, or even with just a small share of the tax revenue, because high-income households consume significantly more fuel than low-income ones. This finding is likely to hold for countries other than Finland, and for other environmentally harmful goods as well. Indeed, several studies have found similar results in a wide variety of contexts (see e.g. Eliasson, Pyddoke, and Swärdh 2018; Cronin, Fullerton, and Sexton 2019; Ohlendorf et al. 2021).

A transfer scheme that would minimize vertical inequality in the sense that the average net tax burden would be zero at every income level could of course also be achieved easily. Rebating each income level the average tax paid at that level would by construction end up costing exactly the revenue raised by the tax. However, such a transfer scheme would imply higher compensations for high-income households due to the fact that they consume more fuel. This highlights the point that a “fair” distribution is not necessarily one that places the same relative burden on everyone, which is important to keep in mind in the following discussion on transfer schemes that aim to address the horizontal dimension of the inequality in fuel tax burdens.

5.2 Horizontal Inequity

As discussed in section 3.2, a policymaker might also wish to reduce the within-decile variation in fuel tax burdens, whether due to concern over the welfare impacts of horizontal inequity or political economy reasons. In this section, we demonstrate the extent to which horizontal inequity could be diminished with tax revenue recycling. Figure 12 shows the variation in fuel tax burdens net of transfers within each income decile among car owners for two different transfer schemes. The first is the equal rebate scenario in which all of the fuel tax revenue is redistributed as lump-sum transfers. The second is a targeted scenario in which the transfers correspond to the predicted fuel taxes in our fuel tax prediction model in column (3) of Table 2. The model succeeds in predicting 46.3 percent of the variation in household fuel taxes with an average absolute prediction error of 350 euros. For reference, the leftmost box plot within each income decile in Figure 12 shows the distribution of fuel tax burdens without any transfers. The middle box plots correspond to the equal rebate scenario, while the rightmost box plots depict variation under targeted transfers.

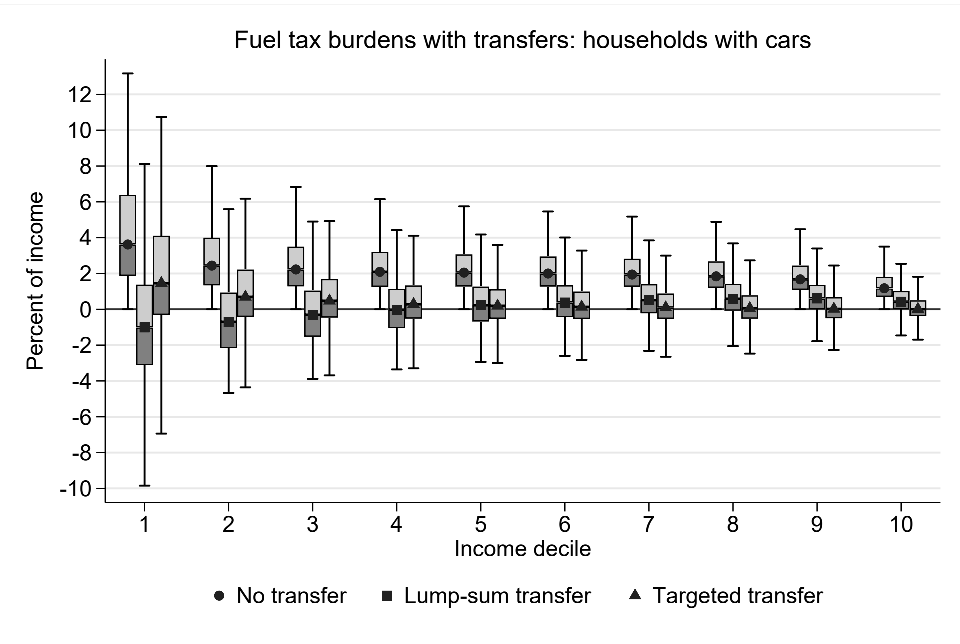

Figure 12: Horizontal equity in different compensation schemes

Two observations are evident from Figure 12. First, even though an equal transfer to all households decreases the net fuel tax burden for everyone, the within-decile variation in tax burdens actually increases in nearly every decile. The increase in variation stems from many households receiving a transfer that exceeds fuel taxes paid. Second, targeting has a very limited impact on the horizontal distribution of tax burdens. This is ultimately not surprising given the large share of variation in fuel taxes that remains unexplained in our prediction model, as discussed in section 4. Their poor performance together with potential challenges in their implementation make highly targeted transfers a fairly unappealing tool compared to equal rebates or rebates only tied to income.[16] Furthermore, the targeted transfers in our example could also be viewed more unfavourable because, relative to equal rebates, they decrease fuel tax burdens less in the lowest income deciles.

An obvious problem related to targeted transfers is that they might create incentives to increase fuel consumption, if the targeting is done based on factors highly correlated with car use. This, in turn, would make fuel taxation a weaker instrument in fighting climate change. Compared to the targeted transfers used in Figure 12, a targeting scheme based also on car ownership would be more accurate in identifying households with high fuel tax burdens. However, if car owners received a larger transfer, non-car owners would be directly incentivized to purchase a car. Equal or income-dependent rebates, on the other hand, would most likely not have as large an effect on fuel consumption, as they do not depend on car use.

Because of the challenges related to minimizing horizontal inequity, policymakers might instead want to more narrowly target the most vulnerable households to minimize excessive burdens. This is, for example, one of the explicit objectives of the EU ETS2 Social Climate Fund. As there is no standard definition for a vulnerable household or transportation poverty, we use two admittedly ad-hoc definitions and discuss what targeting based on them might look like. First, we consider the groups of households identified as potentially vulnerable in section 4.1. These are households with below median income who live outside inner urban areas, have children or include employed household members. A potential transfer scheme could be one which somehow equalized tax burdens between vulnerable and non-vulnerable households. As an example, we construct transfers that lower the average tax burden among vulnerable car-owners in each decile to match the average burden among non-vulnerable car-owners. These decile-specific lump-sum transfers, if handed out to all vulnerable households regardless of car ownership, would cost about 12 percent of total fuel tax revenue.

Second, if we define transportation poverty as a state in which fuel tax burdens exceed a given share of income at low incomes, we can ask how much it would cost to eliminate it by directly paying the excess fuel bills. To illustrate this idea, we calculate a set of household-specific transfers that would limit fuel tax burdens among households with below median income to 2–4 times the median burden. With a median burden of 1.1

16. Using a predictive model such as the ones presented in Table 2 to create the targeted transfers also has another distinctly unappealing feature: the predicted fuel taxes are negative for some households, meaning that the targeted transfer for these households would actually translate into an extra fuel tax. In our case, approximately 6 percent of households would receive a negative transfer, with the overwhelming majority of them being households that are in the lowest income deciles and in reality pay zero fuel taxes because they do not own a car.

percent of income, capping burdens at two times the median among households in the lower half of the income distribution would cost about 9 percent of total fuel tax revenue. The cost falls to less than 5 percent with a threshold of three times the median and further to around 1.5 percent with a threshold of four times the median.

Implementing a rebate system that places a cap on fuel tax burdens is obviously an extreme example and could substantially diminish the incentives created by fuel taxes to reduce fuel consumption. However, some form of higher compensation aimed at high-polluting low-income households may be worth the trade-off, given that low-income households consume relatively little fuel to begin with and the welfare cost on them can be substantial. This line of thinking ties closely to the theoretical framework of Pigouvian income taxation proposed by Ahlvik, Liski, and Mäkimattila (2024). They argue that income and externality taxation should be determined together because the efficiency-equity trade-offs related to both aspects are interconnected. They show that if a policymaker has aversion for inequality in cost burdens arising from an externality tax and the cost burdens are related to income, making the tax income-dependent would increase both the efficiency and equity of externality taxation.

6 Conclusion

In this paper we analyze the vertical and horizontal distribution of fuel tax burdens in Finland. We define fuel tax burdens as the share of disposable household income spent on fuel taxes and estimate the burdens using car-level data on vehicle kilometers traveled and fuel economy along with individual-level information on the Finnish population. Contrary to the common belief that fuel taxes are regressive, we find that fuel tax burdens are on average highest in the upper-middle income deciles. However, the fuel tax is regressive among the 67 percent of households that have a car. This difference between all households and car-owning households is explained by the fact that most households in the lowest-income deciles do not own a car.

The variation in fuel tax burdens across income deciles is dwarfed by variation within deciles. Only 1.5 percent of the overall variation in fuel tax burdens is explained by differences between income deciles. Within income deciles, households that live outside inner urban areas, have children, or include employed people face larger fuel tax burdens. Around 5.5 percent of households are in the lower half of the income distribution and fall into all three of these categories. These households could thus be considered vulnerable to further increases in fuel taxes.

If public attitudes towards fuel taxation are influenced by distributional concerns, the observed differences in fuel tax burdens across households could be compensated by redistributing the tax revenue. Average fuel tax burdens across income deciles can be easily equalized by redistributing only a small fraction of the fuel tax revenue. The within-decile variation in tax burdens, on the other hand, is nearly impossible to eliminate using lump-sum or even targeted transfers. What makes targeting difficult is that less than 50 percent of the overall variation in fuel taxes paid can be explained by observable household characteristics.

While vertical equity is a commonly accepted policy guideline, the extent to which the horizontal inequity of fuel taxation should be a concern from a fairness perspective is less clear. This is because the horizontal distribution of fuel taxes ultimately depends on consumption choices made by individuals based on their preferences. Nevertheless, from a political perspective the case remains that some individuals stand to lose much more from increases in fuel taxation or other climate policies, and it may be in the society's interest to compensate such individuals to promote the acceptability of these policies. If societies have aversion for horizontal inequity, drawing more attention to the large horizontal variation in fuel tax burdens is also important because addressing it via income redistribution is much more challenging than using the same tools to address vertical inequity.

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