How Regressive are Mobility-Related User Fees and Gas Taxes?

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Abstract

Economists have long recognized the efficiency properties of Pigouvian taxes to address environmental externalities and user fees for funding transportation infrastructure. A persistent concern with such policies is their distributional burden. The gasoline tax, which funds highways in the US, is widely viewed as regressive, and it is likely to become more so over times as higher-income households transition more rapidly than their lower-income counterparts to fuel-efficient or electric vehicles. This paper presents new evidence on the distributional burdens of the gasoline tax and other transportation-related user fees such as bus and light rail charges and a vehicle miles traveled (VMT) tax. While gasoline tax payments as a share of household income decline with income, this pattern is attenuated when these taxes are measured as a share of total expenditures. If the US were to switch from a gasoline tax to a household-level VMT tax, which would place a greater relative burden on hybrid and electric vehicles, the tax burden would increase, on average, for households in the top income and expenditure deciles. At the current level of hybrid and electric vehicle penetration in the light duty vehicle fleet, the distributional burden of the VMT tax and the gasoline tax would be very similar. If non-internal combustion vehicles were one third of the fleet, however, and current patterns of ownership persisted across income and expenditure groups, the VMT tax would place higher burdens on those in the upper income and expenditure deciles. An expanded commercial VMT would place a larger burden, as a share of expenditures, on low-expenditure households than on their high-expenditure counterparts, because the better off group consumes more non-tradable goods that do not require transportation. User charges for airports, subways and commuter rail are progressive: low-income households use them less than middle- and upper-income households. Bus fees, in contrast, loom much larger for low- than high-income households.

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Transportation decisions are replete with externalities such as carbon emissions, traffic congestion, and motor vehicle fatalities. Economists have long embraced user fees to address these externalities. Adam Smith (1776) wrote that user fee financing would promote efficient investment decisions, for if transportation infrastructure is "made and supported by the commerce which is carried on by means of them, they can be made only where that commerce requires them, and consequently where it is proper to make them." William Vickrey (1952) called for taxes and time-varying charges for subways to address congestion externalities, and Small, Winston and Evans (1989) were early advocates of a commercial Vehicle Miles Traveled (VMT) tax to charge truckers for the marginal damages they impose on roads. Yet Pigouvian mobility charges such as highway tolls and gas taxes remain politically unpopular. This may be due to their salience to those who use transportation infrastructure – Finkelstein (2011) suggests that raising such taxes is easier when they are collected by less visible means, such as electronic tolling – and to the belief that they are regressive.

Transportation infrastructure in the U.S. is funded through a combination of user fees and general government resources. User fees can refer to direct charges, such as tolls to access a bridge or highway, or to gasoline taxes. When purchasing an airline ticket, for example, a consumer will pay a variety of user fees to different government entities, including taxes or fees to the Federal Aviation Administration (FAA), the Environmental Protection Agency (EPA), the Department of Homeland Security (DHS), and the local airport.

Transportation-related user fees do not contribute a large share of total revenues for any level of government. Most state and local governments rely heavily on intergovernmental transfers, states from the federal government, localities from states, to fund infrastructure. However, user fees play a significant role in funding airports and public transportation. Gasoline and diesel taxes at the federal level have declined in real value over time, since nominal tax rates have been fixed since 1993 and total fuel consumption has plateaued for the last two decades. The U.S. Energy Information Agency (2022) reports that total U.S. consumption of gasoline was 2.73 billion barrels in 1993, and rose to a peak of 3.39 billion in 2007, but has been stable since then. In 2019, the last year before pandemic disruptions, it was 3.40 billion barrels; it declined to 2.95 billion during the lockdown year of 2020.

The gap between transportation-related revenues and expenditures has generated interest in new funding sources. This paper considers the distributional impact of mobility-related user fees, including charges for airports, subways, commuter rail, and buses, with particular attention to gasoline taxes and Vehicle Miles Traveled taxes (VMT taxes). The analysis of these different strategies for funding infrastructure is particularly timely in light of recent policy developments. The Infrastructure Investment and Jobs Act of 2021 (IIJA) provides grants for states and localities to build vehicle charging infrastructure, to replace or update public buses with low- or no-emission vehicles, and to explore options for electrification of commercial trucking at U.S. ports. As electric vehicles replace cars and light trucks powered by internal combustion engines, the revenue from gasoline taxes, which currently fund the Highway Trust Fund, will grow more slowly and eventually decline. The VMT tax, which can be levied both on households and on commercial drivers, offers a way of avoiding this decline.

We investigate the distribution of gasoline taxes and VMT taxes across households. The rise of electric vehicles (EVs), which so far have been disproportionately purchased by high income or expenditure households, can make the gasoline tax more regressive. Stone (2018) reports, based on the 2017 National Household Travel Survey, that 42% of households owning an electric or plug-in hybrid electric vehicle have household income of more than $150,000, while only 14% of all households are in this income range. Another 25% of the EV and plug-in hybrid electric (PHEV) owners are in the $100-150,000 income range, while only 19% of US households are in this range. Owners of EVs do not pay gasoline taxes, and owners of hybrids and PHEVs are likely to pay much less in gasoline tax per mile driven than their internal combustion engine (ICE) driving counterparts.

This paper begins by presenting information on the distribution of outlays on several current user charges that support transportation infrastructure such as public transportation user fees and the federal gasoline tax. We consider the frequently-used measure, payments relative to income, as well as relative to household expenditures. When household income is subject to transitory shocks, household expenditure may provide a more revealing measure of long-term well-being than current income, and permanent income, than annual income. Previous research including Chernick and Reschovsky (1997) and Poterba (1991) has compared these alternatives. We rely more on the expenditure measure but also report income-based measures for completeness and in some cases because of data limitations.

The share of expenditure devoted to public transportation declines with total expenditure over much of the expenditure distribution, although it rises at high expenditure levels as a result of commuter rail and air travel usage. Bus trip counts are much higher for low income individuals. Commuter rail and air travel usage increase with expenditure, and in areas with developed systems, subway trips are relatively independent of expenditure in those areas with developed systems.

With regard to expenditures on gasoline taxes, households in the highest income or spending category devote a smaller share of their budget to gasoline expenditures than do less-well-off households. Among those spending less than $30,000, outlays on gasoline account for close to 5 percent of total expenditures, compared with less than 2 percent among the highest-expenditure households. In contrast to the gasoline tax, a household-level VMT tax directly charges for road usage, and eliminates the implicit subsidy to hybrid vehicles (HV) and EVs associated with a gasoline tax. A household with two cars, each delivering 24 miles per gallon, that drives a total of 18,000 miles per year purchases 750 gallons of gasoline annually. With an 18.4 cent per gallon federal gasoline tax, and an average state gasoline tax of 26 cents per gallon, this household would pay $333 in gas taxes. Replacing both vehicles with EVs would save this annual outlay. Imposing a VMT would eliminate the implicit tax benefit given to electric vehicles (EVs); it would also charge drivers for their impact on road wear and tear.

EVs currently account for only about three percent of the US auto fleet, so even with the skew toward higher income owners, the distributional pattern of payments for a VMT tax would be very similar to that for an equal-revenue gasoline tax. The share of hybrid and electric vehicles in the fleet is, however, rising. In the fourth quarter of 2021, for example, the Energy Information Agency (2022) reports that 6.1% of new sales were hybrids, 3.4% were electrics, and 1.4% were PHEV. We therefore consider the relative distribution of burdens from a gasoline and a VMT tax in a future year in which HEVs account for one third of the vehicle fleet. If the new HEVs are distributed across the households in roughly the same way as current HEVs, the distributional burdens of the gasoline tax and VMT tax will diverge, with substantially lower burdens for gasoline taxes than for VMT taxes at high income or expenditure levels.

We also consider a commercial VMT (CVMT) tax. Four states, Kentucky, New York, Oregon and- New Mexico, have already adopted such taxes. Under the assumption that trucking costs are fully passed through to consumers of tradeable goods, and that CVMT tax charges are added to trucking costs, a household's burden from a commercial VMT tax depends on its budget share for tradeable goods that need to be transported. Our estimates suggest that as a share of household expenditures, the current diesel tax as well as an expanded commercial VMT tax fall more heavily on less-well-off households than on those in the upper strata of the income or expenditure distribution. This is due to better-off households consuming more services, which do not require much transportation, and devote a smaller budget share to tradeable goods.

This paper builds on a long literature on the distributional impacts of transportation-related Pigouvian taxes. Metcalf (1999) noted that environmental taxes meant to mitigate the social damage of pollution tend to be regressive. Metcalf (2022), which is very similar to this study in the questions asked and overall results, compares the distributional impact of the VMT tax versus a gasoline tax. Our paper differs from Metcalf (2022) in the way we project the growth of EVs in the vehicle fleet, and how we compare households at different points in the income distribution. Our overall conclusions, however, are very similar. Other related research includes Levinson (2019), which notes the relative regressivity of regulating fuel efficiency and imposing fuel taxes. Davis and Sallee (2020), Langer, Maheshri and Winston (2017), and van Dender (2019) all study the VMT. Weatherford (2012) finds that moving from a gasoline tax to a VMT will have little distributional impact. Our analysis does not consider the distributional effects of transportation related externalities, which Banzhaf, Ma and Timmins (2019) find to place disproportionate burdens, primarily through pollution, on low-income households.

The remainder of this paper is divided into six sections. The first introduces the two main data sets, the Consumer Expenditure Survey (CEX) and the National Household Travel Survey (NHTS), that underlie our analysis. Section 2 presents our core findings on the distributional impacts of current public transportation user fees. Section 3 discusses the current gasoline expenditure and gasoline tax burdens, as well as highlights changes in the vehicle fleet. The fourth section considers the difference in the distribution burden of a VMT tax and a gasoline tax, both with the current level of HEV penetration in the vehicle fleet and a higher level. Section 5 examines the impact of a CVMT tax on consumer prices and ultimate consumer spending. There is a brief conclusion.

1. Data Sources on Consumer Transportation Outlays: NHTS and CEX

Our household travel and expenditure analysis draws on two primary datasets. One is the National Household Travel Survey (NHTS), which includes information on transportation utilization by mode, vehicle characteristics, and driving behavior. It also includes information on household income. The NHTS is conducted every 8 years to study household travel patterns, and is a key input into national, state, and regional infrastructure planning. The survey recruits households and asks them about their trips in a 24 hour period, including mode, purpose, trip length, time of day, among other characteristics. These surveys are then linked to a suite of demographic and socio-economic, vehicle, and location characteristics. We use data from three 2017 NHTS products: the household survey, the trip level survey, and the vehicle survey. This survey covers roughly 139,000 households who use 256,000 distinct vehicles and make nearly 925,000 trips on the survey date. The data are collected at the person-level, and then aggregated to households. The survey also provides weights used to aggregate households to population level statistics. We use this data set to estimate the number of households in various income ranges who are using each mode of transportation, to calculate their driving behavior, and examine vehicle characteristics. We focus on data from the 2017 NHTS, but in some cases we also draw on comparative data from the 2001 survey.

We use data on trips to study outlays on infrastructure user charges of various types. We focus on private vehicle, bus, subway, commuter rail, and airplane. The NHTS also includes data on the vehicles owned by each household, including their age, fuel type, and annual miles traveled. The NHTS has information on travel mode utilization, but not on travel expenditure, or total expenditures.

The second data set that we utilize, the Consumer Expenditure Survey (CEX), is a nationwide survey conducted quarterly by the Bureau of Labor Statistics. It provides estimates of annual expenditures on a variety of consumer goods and services, as well as total household expenditure and income. We convert CEX data from the 2019 survey, the primary focus of our analysis, to real 2017 dollars for comparability with the NHTS data. We verify, and report in Appendix Table A1, that aggregate measures computed from the public use microdata version of the CEX are comparable to the published tabulations from the Bureau of Labor Statistics.

The CEX reports tax-inclusive expenditures on gasoline, but it does not distinguish tax payments from the retail cost of gasoline. To calculate how many gallons of gasoline households have purchased and back out total federal plus state taxes paid on them, we complement the CEX sample with annual data on state gasoline prices and taxes. State motor fuels tax rates data come from the Brookings-Urban Tax Policy Center. Our focus is on the total federal gasoline user fee levied in each state in each year. To estimate gasoline costs per gallon, we use the "all grades all formulations" retail price average as reported by the Energy Information Administration (EIA). The EIA reports annual data for nine states. For the other 41 states and Washington, D.C., we use the averages that EIA reports for each of seven regions assigned by the EIA.

Most studies of household spending on gasoline and other transportation-related outlays report expenditures as a share of income. Reported income in the lowest decile of the household income distribution is substantially below household expenditure. This likely reflects the omission of some transfer program receipts in the measure of income, transitory fluctuations in income that render current income below permanent income, which is more likely to drive expenditures, and measurement error. At the highest income levels, the transitory versus permanent income distinction may also apply, leading reported income to overstate permanent income, for example if a household realizes substantial capital gains in a particular year. These issues with reported income suggest that scaling outlays on transportation by total expenditure, rather than total income, as in Poterba's (1991) study of excise tax incidence, may provide a more informative measure of relative burdens than scaling by income.

The first panel in Figure 1 shows the ratio of expenditures to income for households in the 2017 CEX, with households grouped into deciles based on total household income.

[Insert Figure 1]

This ratio is nearly three in the lowest income decile, dropping to 1.5 in the second decile and declining smoothly to less than 0.6 in the top decile. To provide some context for the distribution, households in the lowest income decile have annual incomes below $12,158 ($2017), those in the fifth decile have incomes up to $52,147, and those in the top decile have incomes of at least $160,044.

The second panel in Figure 1 shows the expenditure-to-income ratio when households are ranked by total expenditures. It is much more stable, ranging from between 1.25 and 1.5 at the lowest two deciles, to values just above one in the middle of the distribution, and rising again at the highest expenditure decile. This may reflect the presence of infrequent outlays, such as car purchases, at the top of the expenditure distribution. Households in the lowest expenditure decile report total spending of less than $16,620. Those at the median (just above the fifth decile) report expenditures of up to $39,774, while those in the top decile have expenditures of at least $107,256. These break points for the deciles may clear that the gradient in expenditure is not as steep as the gradient in income.

Table 1 shows the distribution of CEX households across income and expenditure deciles. Nearly half of the households in the bottom income decile are in the bottom expenditure decile, and vice versa. The same is true for the top decile of each distribution. However, one third of those in the bottom income decile are in the third or higher expenditure decile, while almost one fifth of those in the highest income decile are in the eighth or lower decile of expenditures. In the middle of both the income and expenditure distribution, the share of households in the same decile of both distributions is lower, in part reflecting the narrower band of incomes or expenditures that correspond to each decile.

[insert Table 1]

Since we are analyzing expenditures for various transportation services, total household expenditures, rather than income, provide a natural benchmark for ranking households. We therefore focus on expenditures on gasoline taxes, and on user fees such as public transit fees, relative to total expenditures for households ranked by expenditure levels. For transportation outlays reported in the CEX, we can compute the expenditure share directly. For transportation outlays or utilization measures drawn from the NHTS, we need to impute total expenditures; the NHTS records household income in intervals, but it does not report expenditures. We use variables other than expenditure that are observed in both the CEX and NHTS, as well as the full range of expenditure data in the CEX, to predict total expenditures in the CEX, and we then use the resulting model to impute total expenditures to NHTS households.

We impute total expenditures as a function of reported household characteristics using data from all CEX surveys for 2000 through 2019. We estimate Engel curves for total expenditure using weighted regression, with population weights in the CEX, of total expenditure on state and year fixed effects, a fourth order polynomial in household income, indicators for the household head's race, Hispanic status, employment, retirement, student status, gender, and homeowner status. We include information on education level and age by grouping households into five-year age bins, and interact the education categories with each of the age bins. We include indicator variables for families with each number of household members, along with indicators for number of children, the head of household's marital status, and the interactions between marital status and number of children.

The R^2 for total expenditure in our estimating equation is 0.41, so the correlation between actual and fitted outlays is about 0.64. Figure 2 shows the scatterplot of actual and fitted total expenditure in the CEX. For a CEX household in 2017 with an income of $73,590, the average in our sample, the estimated marginal propensity to spend out of income is 0.33.

[Insert Figure 2]

We predict total expenditures for NHTS households using the estimated Engel curves by harmonizing variables between the NHTS and CEX. For example, we define the income for each NHTS household as the income value at the midpoint of the income ranges in that survey. As one way of judging the similarities between the imputation of total expenditures across income classes in both the CEX and the NHTS, we regressed predictive expenditures on reported income in the CEX, and on our measure of income (midpoint of intervals) in the NHTS. The coefficient on reported income in the CEX is 0.41 and in the NHTS it is 0.41, suggesting some broad similarity between the two fits. Tabulations reported in Appendix Figure A1 show that the expenditure shares on gasoline from actual expenditure in the CEX and imputed expenditure in the NHTS exhibit a similar pattern, providing some validation for our exercise.

2. Heterogeneity in the Use of Public Transit and Airports

We begin our analysis by reporting utilization and outlays for a number of public transportation modes. Information on utilization is essential to assessing the potential distributional impacts of levying increased fees on the use of these transport modes. While the CEX documents expenditure on public transportation, it does not differentiate modes. Detailed utilization information by mode is reported in the NHTS. As such, our baseline results focus on NHTS households classified by predicted total expenditures. The NHTS reports the number of trips taken on different modes of transportation, not the charges associated with these trips. Trip counts are nevertheless a key determinant of the distribution of potential burdens from user fees.

Figure 3 reports the average number of trips taken each day per household for three types of public transit – bus, subway, and commuter rail – as reported in the NHTS. We plot two bars in each case. The lighter corresponds to cities with at least 10% of the population commuting by public transit (New York, Chicago, Washington, Boston, Philadelphia and San Francisco), while the darker bars correspond to all the other major metro areas and sub-metro areas in the NHTS.

[Insert Figure 3]

Bus utilization declines as total household expenditure rises, reflecting a substitution of private for public transit. Households in the lowest expenditure decile use the bus approximately

0.7 times each day in high public transit cities, and about 0.2 times per day in other locations. In contrast, households in the highest expenditure decile use the bus only about 0.1 times each day in the high public transit cities, and about half that often elsewhere.

In contrast to riding the bus, using the subway is very popular for households in all expenditure deciles in major public transit cities. In contrast to bus usage, subway use increases with expenditure. This reflects the combination of reliance of low-income inner city neighborhoods on public transit and the use of subways in many high-income neighborhoods, for example in Manhattan, where proximity to a subway is highly valued.

Commuter rail use is the most progressive of the various forms of land-based public transit. In high public transit cities, utilization is sharply higher, averaging about 0.15 trips per day, for households in the top three deciles of the expenditure distribution than for other households, for whom the average is less than one third this level. Commuter rail tends to be co-located with wealthy suburbs surrounding dense cities, and fare costs are higher than public bus or subways.

The distribution of trips across expenditure deciles for different transit modes is important for assessing how higher user fees would be distributed. The National Transit Database (2019) reports that for the 50 largest transit authorities in the US, passenger fares cover only about 40 percent of operating costs. Thus even before considering capital costs, which are critical in public transportation, these systems are not covering costs. At least for commuter rail, it may be possible to raise revenues without placing disproportionate burdens on households lower in the economic distribution.

In addition to bus, subway, and commuter rail, where many of the services providers are public authorities, we also consider the distribution of air travel. While it involves substantial use of public infrastructure in the form of airports and air traffic control, the service providers are private firms. Figure 4 presents the distribution of airplane trips by NHTS expenditure decile.

[Insert Figure 4]

Air travel is even more progressive than commuter rail use. Households in the highest expenditure decile report roughly 22 times as many trips as those in the lowest deciles, where utilization is negligible. Households in the top decile report roughly one airline trip each month. Households in the top two expenditure deciles are about twice as likely to use air travel as those in the next two deciles. These four deciles account for most airline trips. This provides guidance on the potential incidence of higher user fees for airlines, or ticket taxes for airline travel.

3. Gasoline Tax Burdens by Expenditure and Income Groups

While user fees for public transit are important source of revenue for the bus, subway, and rail systems, and more revenue could be collected from them, the transportation-related user charge that attracts the most attention is the gasoline tax. The CEX has information on household outlays on gasoline, so we can compute gasoline expenditures as a share of total expenditures without any imputation. We can impute gasoline taxes based on gasoline expenditure by converting expenditures to gallons based on average per-gallon prices, and then applying the average federal or federal plus state tax rate.

3.1 The Distribution of Gasoline and Gasoline Tax Outlays

Figure 5 shows outlay shares on gasoline for households across expenditure deciles. For households in the lowest expenditure decile in 2017, gasoline accounts for about four percent of total expenditures, while for those in the highest expenditure decile, it accounts for about 2 percent. The expenditure share for gasoline is highest in the middle of the expenditure distribution, where it rises to five percent, more than twice the level of the highest decile.

[Insert Figure 5]

The figure shows the expenditure shares for two years: 2001 and 2017.[1] The two years are similar in the real ($2017) price of a gallon of gasoline: $2.27 and $2.14, respectively. Higher gasoline prices reduce gasoline demand. Levin, Lewis and Wolak (2017) suggest that a price elasticity of about -0.30 as a middle-range value based on many studies. While the expenditure share does not rise or fall in exact proportion to movements in gasoline prices, but higher gasoline prices are associated with higher expenditure shares.

One factor that has limited the increase in the expenditure share of gasoline, despite rising miles driven, is the rising fuel efficiency of vehicles. The average fuel economy of the

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[1] 2001 CEX says gasoline and motor oil = 3.2% of total expenditure
https://www.bls.gov/cex/research_papers/pdf/consumer-expenditures-in-2001.pdf
2017 CEX says 3.3% for the whole population
https://www.bls.gov/opub/reports/consumer-expenditures/2017/home.htm#:~:text=As%20first%20reported%20in%20the,2016%20to%20%2460%2C060%20in%202017
In 2020 expenditure share for gas and motor oil was 2.56%, presumably way down because of low gas prices and low driving during pandemic.

light duty vehicle fleet was substantially higher in 2017 – 22.3 miles per gallon– than in 2001, when it was 20.2, or 1994, 19.2, when the current federal gasoline tax rates was set.[2] Thus the amount of gasoline needed, on average, to drive a mile declined by about 14 percent since the 1994. The average fuel economy for new vehicles is currently much higher than for the existing stock, 39.4 mpg for cars in 2017 and 28.6 for light trucks, suggesting continued increase in future years in the average fuel economy of the light duty fleet.

Data from the 2017 NHTS show that the average household drives about 12,000 miles per year or about 33 miles per day. There is substantial heterogeneity, with the 25th percentile driving 15 miles per day, and the 75th nearly triple that at 42 miles per day. Higher expenditure households tend to drive more per annum than their low-expenditure counterparts; this is a factor pushing toward progressivity in the distribution of gasoline tax burdens. However, the expenditure share on gasoline depends not only on how many miles households drive, but also on how many gallons are needed per mile. On average, lower-expenditure households drive older and less fuel efficient vehicles. This counterbalances the pattern of miles driven per household, and in extreme cases – when the high-expenditure household owns an electric vehicle – get result in no gasoline tax burden. We revisit the ownership of electric vehicles below when we consider vehicle miles taxes below.

Figure 5 shows annual expenditure on gasoline, not gasoline taxes, as a share of total expenditure. To place the tax burden in perspective, in 2017 the federal gasoline tax was 18.4 cents per gallon, when average gasoline prices were $2.53, so federal taxes were approximately seven percent of the total cost of gasoline. The average state gasoline tax in 2017 was $0.28. The total tax burden therefore represents about 18 percent of the retail, tax-inclusive price of gasoline. Figures 6(a) and 6(b) present our estimates of expenditures on gasoline taxes by expenditure decile.

[Insert Figure 6]

These are estimates because we must recover gallons of gasoline purchased from the amount spent on gasoline, divided by the mean state gasoline price provided by the EIA. We then multiply those gallons by the federal and state tax rates to compute expenditure on gasoline taxes.

[2] Bureau of Transportation Statistics 2022 https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles

If the federal gasoline tax had been indexed for inflation when it was set in 1993, today it would be over 34 cents per gallon. Inflation in the cost of building new highways has outpaced general inflation (Brooks and Liscow (2019) and Mehrotra, Turner and Uribe (2021)), so even had the tax kept up with overall inflation, its buying power would have diminished. There is a growing gap between federal gasoline tax revenues, which are dedicated to the Federal Highway Trust, and federal highway outlays. In 2021, the former was $43.4 billion, while the average expected outlay for the FY2021-25 period was $60.4 billion (Kirk and Mallett, 2020). If the federal gasoline tax rate were increased to a level that would cover average expected federal highway revenues, it would be approximately 26 cents per gallon, and the expenditure shares for federal taxes would be about one third greater than those shown in Figure 6.

To illustrate the importance of focusing on annual expenditure rather than annual income as the denominator when measuring gasoline expenditure burdens, Figure 7 presents the share of gasoline expenditures relative to reported income in the CEX for the same two years that are shown in Figure 5.

[Insert Figure 7]

The data show that gasoline expenditures account for almost ten percent of income in the lowest decile, compared with only two percent in the highest groups. For those in the second lowest decile, however, gasoline expenditure as a share of income falls to about six percent. Gasoline tax burdens appear regressive in both Figures 5 and 7, but the relative burden on less-well-off relative to better-off households is greater in Figure 7, in part because the income measure for those in the lowest income decile may not be a complete measure of economic well-being.

A common observation in discussions of gasoline tax burdens is that rural households are likely to face greater burdens because they rely more on light duty vehicles for transportation services. Figures 8(a) and 8(b) compare the expenditure share, and income share, distributions for households by city size. In our sample, 25% of households live in cities with populations higher than 5 million, 28% live in cities between 1 and 5 million, and 48% live in cities smaller than 1 million residents. In both the income and expenditure share distributions, those living in smaller cities spend higher shares on gasoline.

[Insert Figure 8]

The difference ranges from about three percentage points – a near doubling – in some of the lower deciles, to a very small disparity in the top two deciles. With the income metric, in Figure

8b, households in smaller cities are also higher across the distribution, but the average disparity is smaller in most of the distribution. This is because expenditure is less than income, on average. It also appears that when households are ranked by total expenditure the disparity between urban and rural households at the bottom of the distribution is larger than when households are ranked by income.

3.2 Changing Vehicle Ownership Attributes and Gasoline Tax Burdens

The foregoing analysis noted that miles driven by households in different groups, as well as the amount of gasoline needed per mile, determine the pattern of gasoline taxes by expenditure category. Historically, when all vehicles were powered by internal combustion engines (ICEs), the central question was how average fuel economy varied across deciles. More recently, as electric vehicles (EVs) have entered the market in the last two decades, some households have reduced their gasoline expenditures to zero while still consuming light duty vehicle transportation services. Whether this is currently an empirically important phenomenon is a key issue in our comparison of the VMT tax and the gasoline tax.

Better-off households tend to drive newer vehicles, which in the last few decades has corresponded to more fuel efficient vehicles. Figure 9 shows the vehicle age distribution, based on data from the NHTS, in 2017 for households ranked by expenditure class. It also plots the average miles per gallon (MPG) for the vehicles owned by households in each part of the expenditure distribution.

[Insert Figure 9]

These distributions highlight that vehicles are being kept for more years over time, with households owning vehicles on average 2 years older in 2017 than in 2001. Additionally, we can see that fuel efficiency not only rose at every point in the expenditure distribution, but relatively more so at higher expenditure deciles. In 2001, the MPG-expenditure profile was nearly flat, with both the highest and lowest deciles owning cars that ran around 20 miles per gallon. By 2017, the highest expenditure households drove cars that were 1.5 MPG more efficient than the lowest decile households.

Contrasting the recent NHTS data with older travel surveys reveals another shift in the composition of the vehicle fleet owned by well-off, and less-well-off, households. In the 1977

National Personal Travel Survey (NPTS), higher income households owned *less* fuel efficient vehicles.[3]

[Insert Table 2]

On average, households in the top income bracket – more than $50,000, about $250,000 with CPI adjustment to 2022 – owned cars that averaged 2.9 fewer miles per gallon than those in the lowest income group, less than $5,000 in 1977 or about $25,000 today. The lowest income group owned cars on average that were four years older than those in the highest income group.

The relationship between vehicle age and income is similar in the 2017 and the 1977 data. In 2017, the average age of a vehicle owned by a household with income of less than $25,000 was 13.0 years. It was 11.5 for income $25,000-49,999, 10.7 for $50,000-74,999, 9.9 for $75,000-99,999, and 8.9 for households with incomes above $100,000.[4] But the pattern of fuel economy was different in 2017 and 1977.[5] The most recent reports from the 2017 NHTS show that the highest income households own vehicles that run, on average, 1.5 more miles per gallon than those in the lowest income categories, consistent with the expenditure results in Figure 9. This pattern provides a countervailing force to the tendency for better-off households to drive more miles than their less-well-off counterparts. For the same miles driven, the higher income households consume less gasoline, and pay less in gasoline taxes.

A recent trend that accentuates the shift in miles per gallon for vehicles powered by internal combustion engines (ICEs) is the rise of hybrid and electric vehicles, which have been adopted at higher rates by higher income than lower income households. Figure 10 shows the HEV fraction of the light duty vehicle fleet by household expenditure category in 2017.

[Insert Figure 10]

The emergence of EVs – a fuel-efficient technology that allows the driver to avoid paying gasoline taxes – raises an interesting conceptual issue. In the presence of two technologies, the distributional burden of a tax on an input to one of them will depend on the nature of the technologies and the resulting pattern of use across income classes. When better gas mileage meant reducing car weight and power, then the poor were more likely to take advantage of that

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[3] US Department of Transportation, Federal Highway Administration, 1977 Nationwide Personal Transportation Study, Household Vehicle Ownership (Report 2), Table 28. Available at https://babel.hathitrust.org/cgi/pt?id=uc1.c101759152&view=1up&seq=85

[4] See https://www.eia.gov/todayinenergy/detail.php?id=36914

[5] The NPTS, like the NHTS, only provides reports based on income, so we are unable to compare vehicle characteristics by expenditure across the two datasets.

possibility, so in the 1970's, gas taxes were paid disproportionately by the rich driving heavy cars. When better mileage means buying a relatively expensive electric vehicle with higher up-front capital costs than an ICE-powered car, then gas taxes become a disproportionate burden on the poor, who cannot afford the upfront cost of the cleaner technology. Appendix A presents a simple model illuminating the interplay between household income and the adoption of an energy-saving technology. When well-to-do households demand more transportation services, the consumer good that is produced using energy as an intermediate good, than less-well-off households, a tax on energy inputs will place greater burdens on the well-to-do unless the well-do-to are more likely to adopt the greener, and less-heavily-taxed, alternative technology.

4. Comparing the Distributional Impact of a Gasoline Tax and a Household VMT Tax

All-electric vehicle sales alone have grown from 0.1% of all sales in 2011, to 1.7% in 2020, none of which pay any federal gas tax (Davis and Boundy, 2019). As this market continues to grow, policymakers have increasingly considered switching to the vehicle miles traveled tax, which would tax drivers based on their road usage rather than gas consumption. This would ensure that electric car drivers would contribute to paying for the infrastructure maintenance costs that they impose on the system, especially given estimates that battery powered cars are anywhere from 10-40% heavier than gasoline powered vehicles. Given the interest in the VMT tax, we compare the distribution of the 2017 federal gasoline tax with an equal-revenue vehicle miles traveled tax (VMT) applied to households in 2017. We also consider the distribution of both taxes at a hypothetical future date when hybrid and electric vehicles (HEVs) represent one third of the stock of light-duty vehicles. In this section, we consider replacing the federal gasoline tax with a VMT levied on personal vehicles. We exclude commercial vehicles that burn diesel fuel. Additionally, we keep state gasoline taxes unchanged.

4.1 Modeling the Driving Response to a VMT Tax

Shifting from a gasoline tax to an equal-revenue VMT would change the cost of driving a mile for all drivers. Those with EVs and hybrid vehicles would experience an increase in their cost-per-mile, while those driving ICE-powered cars would experience a decrease because some taxes would now be collected from EV drivers. To estimate how miles driven would respond to adopting a VMT tax, , and how the new distribution of miles would map into a distribution of taxes paid, we assume that each household i has a quasi-linear separable utility with the utility from travel in miles, T_i, generated through a power function:

$$U_i(T_i) = Y_i - pT_i + AT_i^{\sigma} \tag{1}$$

Households earn income Y_i, and purchase T_i at price per mile, p. The first order condition $\frac{\partial U_i}{\partial T_i} = 0$ can be rewritten as

$$ln(T_i) = \frac{1}{1-\sigma} ln(\mathrm{A}\sigma) - \frac{1}{1-\sigma} ln(p) \tag{2}$$

The price elasticity of demand for travel miles is $\varepsilon_g = -\frac{1}{1-\sigma}$. We assume a value for this parameter of $\varepsilon_g = -0.31$ based on Levin, Lewis, and Wolak (2017).

We estimate that the average current price per mile driven, inclusive of the gasoline tax, is $0.12. Importantly, it varies across households. It is lower for households with fuel-efficient vehicles, and for those who live in areas with low gasoline prices, than for those who live in states with high gasoline prices and drive gas guzzlers. Each household is assigned a gas price per mile, p_i, and a tax rate per mile, τ_i,. The former is calculated using the miles per gallon for each vehicle and our estimate of the tax-inclusive price of gasoline in the household's area as well as the federal gasoline tax. For example, a household driving a 30 MPG vehicle in 2017, paying $2.53 per gallon, would have τ_i= 8.4¢, while a household driving a 20 MPG vehicle would pay 52% more, or 12.7¢ per mile. Adopting a VMT tax eliminates the heterogeneity in the per-mile cost across households.

[Insert Table 3]

Table 3 show that a VMT tax which raises as much revenue as the current gasoline tax would set the per-mile tax at 0.89 cents per mile, equal to the current mean fuel tax per mile. For ICE-powered cars, this would make the price per mile driven with a VMT tax the original gas price per mile paid at the pump, p_i, less the original gas tax per mile, τ_i, plus the proposed VMT tax per mile, t.

Hybrid vehicle drivers pay relatively little, and EV drivers no, federal gasoline tax. To calculate the cost per mile for EVs, p^e, we assume an HEV travels 3 miles per kWh, at the average rate for electricity of 11.7 cents per kWh (Advanced Vehicles Testing Activity, 2011). This yields a fuel cost of 4 cents per mile. For hybrid vehicles, we assume an average gasoline price of $2.41/gallon, taken from the NHTS sample, and an efficiency of 45 mpg, yielding a hybrid cost per mile of p^h = $0.055 (5.5 cents). We use these prices for all households with EVs or HVs. We calculate miles driven under a VMT tax as initial miles driven, T_i, plus the change in miles associated with and increase or decrease in the price per mile relative to the gasoline tax regime status quo:

$$T_i' = T_i + T_i\left(\frac{t_- \tau_i}{p_i}\right)\varepsilon_g. \quad (3)$$

The tax revenues collected by the VMT tax equal $R^{VMT} = t \times \sum_i T_i'$. To find the VMT tax rate that will raise the same revenue as the current gasoline tax we solve for the value *t* that equates $R^{GAS} = \sum_i \tau_i T_i$, where R^{GAS} refers to the revenue collected by the current gasoline tax and $\sum_i T_i'$ is the total number of miles driven under the VMT tax regime with tax rate *t*. We can calculate the distributional impact of various policy changes by using equation (3) to work out the change in miles driven for each policy.

To illustrate the impact of a gas tax-to -VMT swap, Figure 11 shows the distributional burden of the current federal gasoline tax, as well a revenue-neutral VMT tax.

[Insert Figure 11]

The average number of miles driven per household remains virtually unchanged under this policy, staying around 11,200 on average. Additionally, all expenditure deciles pay marginally less in annual federal fuel taxes, except the top three deciles which pay marginally more after the tax policy swap.

Figure 11 shows that at current levels of hybrid and electric vehicle penetration of the light duty vehicle fleet, the distributional patterns of the gasoline excise tax and the VMT tax are very similar. This reflects the relatively small number of HEVs in the current vehicle fleet. About 2.1% of the US light duty vehicle fleet in 2017 was composed of HEVs. Even if all of these vehicles were owned by households in the top decile of the expenditure distribution, the impact would be modest, because households in the top decile own 13% of all vehicles (by comparison, the lowest expenditure decile households own 4% of all vehicles). This means at least 84% percent of the vehicles owned by those in the top decile would still be ICE-powered.

4.2 Projecting a Future Vehicle Fleet with Higher HEV Penetration

Although the current differences between the distributional incidence of a gasoline excise tax and a VMT tax are small, hybrid and electric vehicles are entering the vehicle fleet at a rising rate. By the next decade, the comparison between the two taxes could look quite difference. To explore this, we create a counterfactual future scenario in which HEVs account for 1/3rd of the stock of light duty vehicles Some forecasters expect this vehicle mix by the mid-2030s. A key issue in assessing how such a vehicle fleet would affect the difference between the distribution of the VMT tax and the gasoline tax is whether drives in high or low income and expenditure strata will switch from ICE vehicles to HEVs as the composition of the fleet evolves.

There is substantial uncertainty about the distribution of household EV buyers across expenditure or income strata. It depends on model introduction decisions by manufacturers, who will make choices about offering high-end versus less expensive HEV models, as well as public policies. The Inflation Reduction Act of 2022 significantly altered the pattern of tax incentives for HEV purchase across households, eliminating tax credits for households with incomes above $150,000 (married couples above $300,000). The HEV penetration patterns of the last few years, which arose under a regime of tax credits that were available even to very high income households, may not be a guide to the coming decade. To illustrate how the growing share of HEVs in the fleet would affect the distribution of tax burdens, we develop a calculation that is grounded in the recent purchase patterns for these cars.

We need to project purchases of HEVs across household groups, vehicle retirements, and trickle-down of ICE vehicles across groups. IHS Markit (2022) reports that the average age of US cars in 2022 was 13.1 years. This underscores the slow impact of changes in the composition of new car sales on the vehicle stock.

We fit a time trend to light duty vehicle sales and registrations for the 2000-2020 period (*Transportation Energy Data Book, Edition 39* Oak Ridge National Laboratory). Annual vehicle registrations grew at an average rate of 0.7% over this period. We use the fitted trends to project both data series forward. The projected change in annual registrations yields the net change in the vehicle fleet, after accounting for sales and retirement.

There are a range of commercial forecasts of the share of future auto sales that will be accounted for by HEVs. For example, Deloitte predicts 27% of sales will be HEV by 2030, Ford predicts 40%, and KPMG predicts 52%. We fit a logistic curve to the data on the growth of the HEV share of new vehicle sales over the 2000-2020 period, and to calibrate the intercept, we assume that 50 percent of the light duty sales are HEV by 2032.[6] This shape and endpoint parameters define a unique logistic curve, which we show in the first panel of Figure 12.

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[6] The logistic curve takes the form $SalesShare_t^{HEV} = \frac{1}{1+e^{-0.25(t-2032)}}$

[Insert Figure 12]

This curve implies that HEV sales outstrip gas vehicle sales after 2032 and sales of ICEs nearly vanish by the mid 2040's. The second panel shows the changes in both the fraction of new car sales accounted for by HEVs and the share of these vehicles in the car fleet. While sales of HEV pass 50% in 2032, the stock of vehicles is less than 20% HEV at that point. It takes another 5 years for HEVs to reach one third of the vehicle stock; when that happens, HEV sales comprise 80% of all sales.

We cumulate the number of HEVs sold in each year between 1999 and 2017 and estimate that there were 5.39 million HEVs in the US fleet in 2017, compared with 243.54 million ICE-powered cars. We compute vehicle retirements from projected total sales, HEV sales, and net new registrations:

$$Retire_t = Sales_t^{HEV} + Sales_t^{gas} - \Delta registrations_{t+1,t}$$

We assume that all retirements from 2017 through 2037 are ICE-powered vehicles. While there are some aging HEVs in the 2017 fleet, most are relatively young and the EVs in particular may have longer lives than ICE-powered cars. By assuming that there are no HEV retirements, we likely to overstate the HEV share of the future fleet. Table 4 reports the evolution of the vehicle fleet from 2000 to 2037, a period over which 92.4 million HEVs and 205.7 million ICE-powered vehicles will be added to the fleet, while 260.7 million vehicles will be retired.

[Insert Table 4]

In our projections, between 2017 and 2037, the total vehicle fleet grows by 15 percent, from 248.9 million to 286.3 million, while the HEV fleet grows from 5.4 to 97.8 million. The ICE-powered vehicle fleet contracts from 243.5 million in 2017 to a projected 188.5 million in 2037. HEVs represent just over 34 percent of the projected 2037 vehicle fleet.

Only about 90 percent of vehicles are driven in a given year. In 2017, for example, when there were 248.9 million vehicles, the NHTS reported 229.3 million, 92.1 percent of the fleet, with positive miles. Only vehicles that are driven in a given year expose their owners to gasoline taxes or VMT. We limit our analysis to vehicles with positive miles driven, and assume that the fraction of vehicles driven in 2037 will be the same as in 2037, so project a 15 percent increase from 229.3 million in 2017 to 263.7 million driven vehicles in 2037. We assume that driven vehicles are 34 percent HEVs, with 27% hybrid and 7% electric (reflecting a 60/40 EV/HV mix of new adoptions), and 66 percent ICE-powered. This mix compares with 2017, when 97.5% of the vehicle fleet was gasoline-powered, 2.3% hybrid, and 0.1% electric.

To distribute the stock of HEVs and gasoline vehicles across expenditure deciles in our projected 2037 fleet, we assume that the greater propensity for high than for low income households to purchase HEVs, which has been observed in the last two decades, will continue. This reflects both the tendency for new cars to be purchased by higher rather than lower income households, and the pricing, particularly of EVs, to date. These patterns may not continue for the fifteen years, and if they change, the distribution of the gasoline excise tax and VMT may be different than what we report.

Table 5 reports the 2017 NHTS vehicle composition by expenditure decile. The share of vehicles owned by households in an expenditure decile that are HEVs rises monotonically with expenditure level.

[Insert Table 5]

In 2017, about 27% of all HEVs were owned by households in the highest expenditure decile, while only 1% of these vehicles were owned by those in the lowest decile. We apply these shares to the number of HEVs that we project in the 2037 vehicle fleet, thereby predicting HEV^{2037} by decile, and then we compute the number of ICE-powered vehicles by decile as $Gas^{2037} = (Vehicles^{2037} - HEV^{2037})$.

To determine which households within a decile are net purchasers of additional vehicles between 2017 and 2037, we proceed in three steps. First, for every vehicle that is owned in the 2017 NHTS, we assign a 15 percent probability that the owner will have one more vehicle in 2037. This randomly assigns an increase in the vehicle fleet of 15 percent across households that currently own vehicles. We do not assign any of the net increase in vehicle ownership to households that did not own cars in 2017. Second, when we assign a net new vehicle to a household, if the 2017 vehicle being "cloned" was an HEV, we assume the new vehicle was also an HEV. If the 2017 vehicle was ICE-powered, we assign the new vehicle either HEV or ICE status based on the fraction of net new vehicles that need to be HEV in order to achieve the overall share of HEVs in the expenditure decile. This means that the probability that a new vehicle is assumed to be an HEV varies across the expenditure deciles. Finally, after we have allocated all net new vehicles, if the share of HEVs in the vehicle fleet for a decile is still below the share of HEVs that result from our aggregate projections, we randomly reassign a fraction of the ICE-powered vehicles in the 2037 fleet to HEV status. This swapping of ICE-powered cars for HEVs is required in the top seven expenditure deciles, but is concentrated in the top two.

4.3 Comparing Gasoline Tax and VMT Tax Burdens

We begin by comparing the distributional burden of the current gasoline tax with a gasoline tax that would raise the same revenue per vehicle in 2037, under the future fleet composition. In 2017, we estimate that the federal gasoline tax raised about $20 billion. With the 15% increase in the vehicle fleet, we adjust this target to a tax that can raise $23 billion in revenues. This involves setting the future gasoline tax to $0.258 per gallon, roughly 40% higher than the current federal gasoline tax, and corresponds to an average of 1.15 cents per mile. We also consider the effect of using the VMT tax to raise the same $23 billion. We calculate that the required VMT tax rate is 0.93 cents per mile.

[Insert Figure 13]

Figure 13 shows the distributional results of adopting a VMT tax vs. adjusting the gasoline tax. Panel (a) shows drops in mileage in the top six deciles of the expenditure distribution under a VMT tax scheme relative to a fuel tax, but these average out to a decline of only 1.2%. Panel (b) shows the average taxes paid by household, by tax scheme. The first through six deciles pay significantly less under the VMT tax than under the fuel tax. Taxes even out in the seventh expenditure decile, and increase monotonically through the rest of the distribution. At the lowest decile, households save on average $32 per year in federal fuel taxes with the VMT tax, while the highest expenditure decile sees its tax burden increase by more than 50%, from $191 to $305.

We also explore average taxes paid by vehicle type (gasoline, hybrid, electric), under the VMT tax with the future fleet, and examine how driving behavior responds to the tax policy. Table 6 shows the annual average taxes paid per household, by expenditure decile and vehicle type. We present payments under the 2017 composition and baseline taxes, the future fleet VMT proposal without allowing for the behavioral response outlined in Equation 3, and the full model under the future VMT tax proposal.

[Insert Table 6]

Under the current tax policy, hybrid and electric vehicles pay significantly less or even no gasoline tax relative to households with gasoline vehicles. Comparing the second and third columns, for gasoline vehicles the increase in per mile costs under the future VMT induce an increase in taxes paid, with little adjustment after allowing behavioral response, due to the low relative change in the price paid before and after policy adoption. In contrast, for the group with the largest increase in per mile costs, the electric vehicle owners, they would pay around 8% more taxes if we did not allow for driving behavior to respond to the per-mile price increase.

None of these calculations include the potential benefits of reducing other taxes that are currently levied to fund highway maintenance, or the lower driving externalities, such as reduced congestion and emissions, that might be associated with higher taxes. We note that a VMT tax would not be levied at the gas pump, but rather might be paid in a few installments each year. This could affect price salience and might change the value of ε_g we have assumed in this analysis.

5. Distributional Effects of a Commercial VMT Tax

The last section focused on a VMT tax levied on household vehicle use, but we can also consider a commercial VMT (CVMT) tax as a replacement for or addition to the current federal excise tax on diesel fuel. The current tax rate is \$0.24 per gallon of diesel. The effective tax rate on commercial transportation services is not related to the attributes of the truck, in particular its weight, since in addition to diesel charges there are some per-truck fees levied for interstate highway use. This results in trucks often maximizing their loads, which can result in significant road damage. In most states, the majority of trucking taxes paid are fuel taxes, registration fees, and tire taxes. Small, Winston and Evans (1989) note that in a handful of states, taxes have varied by miles traveled or by vehicle weight. New Mexico, New York and Oregon have adopted a VMT tax for commercial trucks that varies with the trucks' maximum load capacity. The tax varies from 1 to 29 cents per mile, as a function of the weight of the truck. Kentucky, in contrast, has adopted a flat fare CVMT of 3 cents per mile, regardless of truck weight.

Our analysis of the CVMT tax differs from that of the personal driver VMT tax in two ways. First, consider the CVMT as an addition to, not a replacement for, the existing diesel tax. This allows us to start from the status quo costs-per-miles driven and add the new tax per mile. Second, we analyze how adopting a commercial CVMT tax would affect the end-user price of traded goods. This unifies our analysis of the commercial and personal VMT tax policies by considering how each of them would affect households. For the CVMT, we first estimate the current share of trucking costs and indirect diesel taxes in household expenditure, and then explore how an add-on CVMT tax would impact household expenditures. We incorporate data from the Bureau of Economic Analysis' (BEA) Total Requirements tables, specifically the "Industry by Commodity/After Redefinitions/Producer Value" table for 2012, the most recent data available. These tables provide estimates of the amount of inputs required, measured in dollars, to produce one dollar's worth of a given output. We focus on the trucking transportation inputs needed to produce various consumer products listed in the CEX Table 1203.[7] We outline the crosswalk from the CEX to the Total Requirements table in Appendix Table A2, and show crosswalk coverage in Appendix Figure A2.

5.1 Current Distributional Burdens of the Federal Diesel Excise Tax

Before considering a CVMT tax, we examine the distribution of burdens associated with the current diesel fuel tax. The total requirements tables list inputs and outputs by industry code, NAICS, or by commodity code. We link these to CEX expenditure categories. When necessary, we average the trucking costs of various products in the BEA table that are aggregated within a given CEX category. We match between 70 and 88% of expenditure for those in the bottom eight deciles of the spending distribution, but somewhat less in the top two deciles. For the highest decile, we match 59% of spending, reflecting higher expenditure shares at high incomes on non-tradable goods and services we were unable to crosswalk. We check that these gaps in coverage are driven by non-tradable goods and services expenditure by excluding outlays to retirement and pension, and find we cover more than 90% of expenditure for the bottom eight deciles, and at least 78% for the top two deciles. For consistency with the VMT analysis, we calculate shares as fraction of total expenditure.

Across all CEX categories, we find that truck transportation accounts for about 0.72 cents of each dollar of household expenditure. There is substantial variation in the trucking share across commodities. Consumer goods with low trucking shares include rental dwellings (0.04 cents per dollar of expenditure); high-trucking goods include gas and petroleum products (1.7 cents per dollar of household expenditure). To place the CEX values in context, we note that trucking contributes to 0.8% of GDP (Bureau of Transportation Statistics, 2018). Since our

[7] For a breakdown of consumers' expenditure groups, please refer to https://www.bls.gov/cex/tables/calendar-year/mean-item-share-average-standard-error/cu-income-before-taxes-2019.pdf

estimates from the Total Requirements analysis fall a bit below this, we inflate all our trucking shares upward by about 10 percent to match this GDP metric.

To calculate a household's indirect diesel tax burden, we combine the micro expenditures on trucking with macro data on revenue collected by diesel taxes. The Congressional Budget Office reports that in 2020, the federal government collected $10.5 billion in diesel tax revenues. Bieder and Austin (2019) estimate that households spend, indirectly, between 0.02 and 0.06% of their income on diesel taxes. Our earlier estimates from the CEX suggest that households spend about 0.3% of income on the federal gasoline tax. These statistics would place the diesel tax burden on households at about 15 percent of the gasoline tax burden, even though federal diesel revenues are about 40% of gasoline revenues. We estimate that consumers contribute about approximately 1/3rd of the diesel revenues.

To determine the burden of diesel taxes across the distribution of households, we allocate the diesel tax revenue to households based on our estimate of the trucking expenditures that they consume. This reflects in all cases indirect consumption. The diesel expenditure share for household i is $DieselExp_i = \frac{TruckExp_i}{\sum_i TruckExp_i} \times \frac{3.5}{w_i}$, where w_i denotes the household's sample weight. We also calculate indirect diesel share of expenditures as $DieselShare_i = \frac{DieselExp_i}{\sum_c Exp_{ic}}$, where we sum across all spending categories, c, within a household.

The two panels in Figure 14 provide information on the distribution of average indirect diesel tax expenditure shares and diesel taxes paid by expenditure decile. The first panel shows that the total share of diesel taxes in the average household's expenditures ranges from 0.020% of total expenditure at the highest decile to 0.027% in the 4th decile. The share of imputed diesel taxes in total expenditures generally declines with total expenditures. The bottom panel shows that households in the lowest expenditure decile can expect to purchase goods each year that include about $3 of federal diesel taxes each year. These households contribute less than 3% of total diesel fuel purchases. The highest expenditure households consume goods, on average, that include $31 per year in diesel taxes, and sum to just over 25% of total household diesel costs.

[Insert Figure 14]

5.2 Distributional Burdens of a Commercial VMT Tax

We consider a flat-rate CVMT tax similar to that in place in Kentucky. The tax rate is 3 cents per mile. To place this in context, assuming that the average diesel truck delivers a fuel efficiency of about 6.65 miles/gallons, the federal diesel excise tax of 24.4 cents per gallon translates to a per-mile charge of about 3.8 cents. Adding a 3 cent per mile CVMT tax would raise the total tax burden by about 81% increase.

To analyze the impact of adopting a commercial VMT, we calculate the change in expenditures needed to purchase a household's original consumption bundle under the assumption that the CVMT tax is fully passed forward in the prices of consumer goods. Final expenditure on any item, e_{ic}^{t}, can be decomposed into expenditure on the good, and the expenditure on the diesel tax component necessary to ship the good to the purchaser: $e_{ic}^{t} = good_{ic}^{t} + tax_{ic}^{t}$ If each household, indexed by *i,* spends a portion of its consumption basket α_c^t on trucking-related diesel taxes, then the burden of the new CVMT tax can be computed from the difference between α_c^0 (no CVMT tax) and α_c^1 (CVMT tax in place). We can distribute the CVMT burden based on these patterns across households. In order to calculate how required expenditure changes, we need to estimate the impact of the CVMT tax on α_c^t.

We assume that the distribution of the CVMT tax across trucking service providers is the same as the distribution of the current diesel tax. We estimate that consumers spend $12, on average, per year on diesel taxes, while they spend $312 on average on trucking services. Diesel taxes therefore comprise about 4% of trucking costs. Assuming that all other costs are constant, the increment to trucking costs from a CVMT tax that raises the tax burden on trucking by about 81 percent must be $\Delta TruckingCost_c^0 = (0.81) * (0.04) * TruckingCost_c^0$. This expression implies that the total cost of trucking rises by about 3.2%, and taxes rise to just over 7% of the trucking costs, with the adoption of the CVMT tax. In the language used above, this implies that $\alpha_c^0 = 0.04 \times (TruckingCost_c^0)$ and $\alpha_c^1 = 0.07 \times (1.0324 \times TruckingCost_c^0)$ where $TruckingCost_c^0$ refers to the dollars of trucking required to produce final good *c*.

Figure 15 displays the results of implementing a CVMT tax on the required expenditures of households in different expenditure deciles. For those in the lowest expenditure decile, total expenditure needs to increase by 0.0245% in order to accommodate the near doubling of per-mile federal trucking taxes. This declines to 0.02% for the middle expenditure deciles, and falls further to 0.0195% for the top deciles. In dollar terms, the implied federal tax burden associated with taxes on trucking rises, for those in the lowest decile, from $3.12 to $5.65 per year. Those in the highest expenditure decile see their payments rise from $31.40 to $56.75.

[Insert Figure 15]

6 Conclusion

Our analysis of taxes on transportation services, either personal transportation services associated with the light duty vehicle fleet or trucking services that are intermediate inputs to household consumption, suggests several conclusions. First, with the current light-duty vehicle fleet, the distributional burden of a VMT tax is similar to that of a gasoline excise tax, because only 2 percent of the vehicle stock is hybrid or electric. Even though these vehicles are skewed toward the highest income and expenditure households, and households that own these vehicles pay less in gasoline excise taxes, when viewed at the level of income or expenditure deciles, the impact of a VMT tax – for – gasoline tax swap would be small. The federal gasoline excise tax currently raises about $25 billion per year.

Second, in about 15 years, when current projections suggest that about one third of the vehicle fleet will be made up of hybrid and electric vehicles, the choice between a gasoline tax and a VMT tax is more important from the standpoint of tax burden distribution. If households at the top of the income and expenditure distribution continue to be the primary buyers of HEVs, then the gasoline tax will become more regressive over time, and the VMT tax, by expanding the tax base to all vehicles, will both preserve the revenue stream associated with the current gasoline tax and distribute the burden of the tax in a less regressive fashion.

Third, a commercial VMT tax, levied on the trucking sector that currently pays the diesel fuel excise tax, is a potential complement to a household-level VMT tax. A CVMT tax that raised about $3 billion per year, levied at the rate of 3 cents per mile for commercial trucking, if fully passed through to consumers in the form of higher goods prices for products that required truck transportation, would place burdens on households that vary with their total expenditures. The burden of the price increases associated with such a tax would vary from roughly $4 per year from households in the lowest expenditure decile, to about $45 per year in the highest decile. The burden as a share of total expenditures is modestly higher in the bottom half than the top half of the expenditure distribution, reflecting the larger budget share of tradeable goods (which are transported) in the budgets of low-income households.

As various policies encourage alternatives to driving, such as public transit, the role of user fees and other means of financing this infrastructure will attract greater attention. We also find that user charges for various forms of public transportation vary in their distributional burdens. Many public transit authorities already offer discounts based on life stage, such as student or senior discounts, in line with reduced fare requirements for authorities that receive federal funding (CFR Title 49, Section 609). Some also offer low-income fare adjustments. These provisions have important effects in improving the progressivity of user fees for financing these transportation modes. The IIJA includes more than $100 billion for public transportation, with equity and modernization highlighted as key policy goals. User fees financing could provide a way of expanding the revenue base for new public transit projects. We hope to consider in future work how various public transportation policies that create differentials in user fees across households with different average incomes affect the progressivity or regressivity of these fees.

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Appendix A: Technological Adoption and the Progressivity of the Gas Tax

This appendix presents a stylized model to inform the interplay between household income and adoption of an energy-saving technology, such as a hybrid or electric vehicle. The model assumes that individuals choose one of two technologies as well as the number of miles to drive. The choice of technology determines the energy use per mile (denoted g_i), the fixed cost of purchase (denoted k_i) and the enjoyableness of driving (denoted α_i). Utility from using technology *i* is defined as

$$(1)\ \ U = \left(Y - p_g g_i d - k_i\right)^{1-\rho} + \alpha_i d^{1-\rho},$$

where *Y* is income, p_g represents the price of gas, *d* is the endogenous distance travelled and $\rho > 0$. We assume a benchmark technology "0" and an energy-saving technology 1, where $g_0 > g_1$. Condition upon the choice of technology *i*, the total spending on energy equals $\frac{(Y-k_i)}{1+\left(p_g^{\rho-1} g_i^{\rho-1} \alpha_i\right)^{\frac{-1}{\rho}}}$.

It increases with income and the composite term $\alpha_i g_i^{\rho-1}$, which captures the the combined impact on the technology's marginal parameter on driving. It is possible for energy use to decline with income if high-income households are more likely to adopt the energy saving technology. The following proposition describes the link between energy-saving technology adoption and income.

Proposition:

(a) If $k_0 > k_1$ and $\frac{\alpha_1}{\alpha_0} > \left(\frac{g_1}{g_0}\right)^{1-\rho}$, then all individuals adopt the energy saving technology and energy consumption rises with income. If $k_0 < k_1$ and $\frac{\alpha_1}{\alpha_0} < \left(\frac{g_1}{g_0}\right)^{1-\rho}$, then no one adopts the energy saving technology and energy consumption rises with income.

(b) If $k_0 > k_1$ and $\left(\frac{g_1}{g_0}\right)^{1-\rho} > \frac{\alpha_1}{\alpha_0}$, then individuals adopt the energy-saving if and only if *Y*>*Y**, where *Y** is a finite value of $Y > k_0$. Energy consumption rises continuously everywhere with Y, except at the point *Y**. At *Y*=*Y**, energy consumption increases discontinuously with *Y* if and only if $1 > \frac{Y*-k_0}{Y*-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}}$.

(c) If $k_0 < k_1$ and $\left(\frac{g_1}{g_0}\right)^{1-\rho} < \frac{\alpha_1}{\alpha_0}$, then individuals adopt the clean technology if and only if *Y*>*Y***, where *Y*** is a finite value of $Y > k_1$. Energy consumption rises everywhere with *Y*, except at the point *Y***. At *Y*=*Y***, energy consumption decreases discontinuously with *Y* if and only if $\frac{Y{**}-k_0}{Y{**}-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}} > 1$.

The conditions $\frac{Y{**}-k_0}{Y{**}-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}}$ and $\frac{Y{*}-k_0}{Y{*}-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}}$ are equivalent to the condition $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} > \left(\frac{(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}}\right)^{1-\rho}$, which is written only in terms of exogenous variables.

This proposition details three possible scenarios for energy-saving technologies and the relationship between income and energy use. In the parameter ranges covered in Part (a) of the Proposition, the green technology is either adopted for all values of *Y* or not adopted for all values of *Y*. As all individuals use the same technology, and hence richer people use more energy.

The parameters discussed in Part (b) seem relevant for the 1970s and 1980s. Energy-saving cars, such as the Honda Civic, were typically much smaller and less expensive, than gas-intensive cars, like Cadillacs. The energy saving was created primarily by having less weight and less power. Consequently, the green technology is adopted by the poor rather than the rich. Energy use rises with income almost everywhere, and it may jump up with income at the point of technology adoption, as long as the price gap between the two cars isn't too large. If the up-front cost of two technologies is similar, which is guaranteed by $\frac{Y{*}-k_0}{Y{*}-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}}$, then the post-purchase parameter aggregate ($\alpha_i g_i^{\rho-1}$) determine the change in energy use, and we have assumed $\alpha_0 g_0^{\rho-1} > \alpha_1 g_1^{\rho-1}$ in part (b).

If the up-front cost difference is larger, then this cost will have effectively an "income effect," which means that the Cadillac buyer is pushed to drive less. The condition that $\frac{Y{*}-k_0}{Y{*}-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}}$ ensures that the "substitution effects" associated with the Cadillac (more fun to drive and more gas per mile) overwhelm that income effect

The parameters discussed in Part (c) are oriented towards new expensive technologies that reduce energy use, but cost more. Tesla reduce energy use, but they are also typically more powerful and quieter. The proposition predicts that if $k_0 < k_1$ and $\left(\frac{g_1}{g_0}\right)^{1-\rho} < \frac{\alpha_1}{\alpha_0}$, then the green technology is adopted by the rich. Again, energy use is rising almost everywhere with income, but in this case, energy use jumps downward with income at the point of adoption if k_0 low relative to k_1, that $\frac{Y{*}{*}-k_0}{Y{*}{*}-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}} > 1$ holds. In this case, price inequality is needed to generate the added income effect that pushes driving down for the Tesla driver. It is not enough for the Tesla just to be gas efficient to satisfy this condition, given our functional form, because improvements in gas mileage are offset by extra driving.

Proof of Proposition:

(a) Conditional upon adopting technology i, the optimal level of driving satisfies $d_i^* = \frac{\alpha_i^{\frac{1}{\rho}}(Y-k_i)}{(p_g g_i)^{\frac{1}{\rho}}+p_g g_i \alpha_i^{\frac{1}{\rho}}}$, which implies that welfare is $\left(1+(p_g g_i)^{\frac{\rho-1}{\rho}}\alpha_i^{\frac{1}{\rho}}\right)^{\rho}(Y-k_i)^{1-\rho}$.

Consequently the net benefit of adoption technology 1 can be written as:

$$F(Y) = \left(1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}\right)^{\rho}(Y-k_1)^{1-\rho} - \left(1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}\right)^{\rho}(Y-k_0)^{1-\rho},$$

which is positive if and only if $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} > \left(\frac{Y-k_0}{Y-k_1}\right)^{\frac{1-\rho}{\rho}}$.

If $k_0 > k_1$ and $\frac{\alpha_1}{\alpha_0} > \left(\frac{g_1}{g_0}\right)^{1-\rho}$, then $1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}} > 1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}$ and $(Y-k_1)^{1-\rho} > (Y-k_0)^{1-\rho}$ for all values of Y and consequently all income groups adopt.

If $k_0 < k_1$ and $\frac{\alpha_1}{\alpha_0} < \left(\frac{g_1}{g_0}\right)^{1-\rho}$, then $1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}} < 1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}$ and $(Y-k_1)^{1-\rho} < (Y-k_0)^{1-\rho}$ for all values of Y and consequently no income groups adopt.

(b) If $k_0 > k_1$ and $\frac{\alpha_1}{\alpha_0} < \left(\frac{g_1}{g_0}\right)^{1-\rho}$, then $0 < \frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} < 1$, and the inequality can be written as $Y < \frac{\left(1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}}k_0-\left(1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}}k_1}{\left(1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}}-\left(1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}}} = Y*$.

Hence there is a value of Y, denoted Y^*, at which $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} = \left(\frac{Y-k_0}{Y-k_1}\right)^{\frac{1-\rho}{\rho}}$. For all values of $Y>Y^*$, welfare is higher with technology 0. For all values of $Y<Y^*$, welfare is higher with technology 1. Miles travelled and hence gas consumption is increasing continuously at all levels of Y other than Y^* (because within a technology $d = \frac{\alpha_i^{\frac{1}{\rho}}(Y-k_i)}{(p_g g_i)^{\frac{1}{\rho}}+p_g g_i \alpha_i^{\frac{1}{\rho}}}$) but at Y^*, gas consumption jumps from from $g_1 d_1^*$ to $g_0 d_0^*$,, where $g_i d_i^* = \frac{\left(\alpha_i g_i^{\rho-1}\right)^{\frac{1}{\rho}}(Y-k_i)}{(p_g)^{\frac{1}{\rho}}+p_g\left(\alpha_i g_i^{\rho-1}\right)^{\frac{1}{\rho}}}$. Using the fact that $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} = \left(\frac{Y*-k_0}{Y*-k_1}\right)^{\frac{1-\rho}{\rho}}$, then inequality simplifies to $\frac{Y*-k_0}{Y*-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}}$, or $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} > \left(\frac{(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}}\right)^{1-\rho}$

(c) If $k_0 < k_1$ and $\frac{\alpha_1}{\alpha_0} > \left(\frac{g_1}{g_0}\right)^{1-\rho}$, then $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} > 1$, and the inequality can be written

$$Y > \frac{\left(1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}} k_1 - \left(1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}} k_0}{\left(1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}} - \left(1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}\right)^{\frac{\rho}{1-\rho}}} = Y** .$$

Hence there exists a value of Y, denoted Y^{**} at which $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} = \left(\frac{Y-k_0}{Y-k_1}\right)^{\frac{1-\rho}{\rho}}$ and for all values of Y below Y^{**}, individuals choose technology 0 and for all values of Y above Y^{**}, individuals choose technology 1. Gas consumption will drop discontinuously down as income rises at the point if and only if $\frac{Y**-k_0}{Y**-k_1} > \frac{\alpha_1 g_1^{\rho-1}}{\alpha_0 g_0^{\rho-1}} > 1$ or $\frac{1+(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{1+(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}} > \left(\frac{(p_g g_1)^{\frac{\rho-1}{\rho}}\alpha_1^{\frac{1}{\rho}}}{(p_g g_0)^{\frac{\rho-1}{\rho}}\alpha_0^{\frac{1}{\rho}}}\right)^{1-\rho}$.

Tables

Table 1: Joint Distribution of Expenditure and Income Deciles

Income Decile	Expenditure Decile 1	2	3	4	5	6	7	8	9	10
1	49	18	11	7	5	3	3	2	1	2
2	32	28	15	9	5	4	3	2	1	1
3	12	25	20	15	11	6	4	3	2	3
4	4	14	22	18	15	9	6	4	3	3
5	2	8	16	20	18	15	9	5	4	3
6	1	4	10	15	18	18	14	9	6	5
7	0	1	4	9	15	20	20	15	8	7
8	0	1	2	5	8	15	22	23	17	8
9	0	0	1	2	4	9	16	23	29	18
10	0	0	0	0	1	2	5	11	28	51
Expenditure Decile	**Income Decile 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	50	31	11	4	2	1	0	0	0	0
2	19	28	25	14	8	4	1	1	0	0
3	12	15	19	22	16	10	4	2	1	0
4	7	9	15	19	20	15	9	5	2	0
5	5	4	11	15	18	18	16	8	4	1
6	3	3	5	9	14	18	20	15	9	2
7	3	3	4	6	9	13	20	23	15	5
8	2	2	3	5	5	9	16	24	23	12
9	1	1	2	3	4	6	8	17	29	28
10	2	1	2	3	3	5	7	8	17	51

Notes: Entries in each panel denote the percentage of customer units in the income or expenditure decile listed in the row that are found in the income or expenditure decile in the column, as in Poterba (1990). Calculations based on the 2017 Consumer Expenditure Survey.

Table 2: Vehicle Characteristics by Income

	1977 Nationwide Personal Transportation Survey		
Income (1977 $'s)	Average Vehicle Age	Average MPG	Average Curb Weight
<$5,000	8.38	19.7	3,469
$5,000–$9,999	7.23	19.1	3,572
$10,000–$14,999	6.54	18.9	3,630
$15,000–$24,999	6.04	19.0	3,639
$25,000–$34,999	5.56	19.1	3,728
$35,000–$50,000	5.32	18.4	3,796
>$50,000	4.56	16.8	3,835
Average	6.4	19.0	3,640
	2017 National Household Travel Survey		
Income (2017 $'s)	Average Vehicle Age	Average MPG	
<$10,000	12.99	21.38	
$10,000–$14,999	12.96	20.97	
$15,000–$24,999	12.19	21.49	
$25,000–$34,999	11.38	21.41	
$35,000–$49,999	11.07	21.49	
$50,000–$74,999	10.34	21.55	
$75,000–$99,999	9.48	21.73	
$100,000–$24,999	9.28	21.89	
$125,000–$149,999	8.57	22.18	
$150,000–$199,999	8.38	22.17	
>$200,000	7.82	22.52	
Average	10.11	21.73	

Notes: Data in the top panel from the 1977 Nationwide Personal Transportation Survey "Household Vehicle Ownership: Report 2," 1980. Data in the lower panel based on author's calculations using the 2017 NHTS vehicle survey, for vehicles with positive miles driven.

Table 3: Tax per Mile ($'s), by Tax Scheme

Proposal	τ/gallon (cents)	τ/mile (cents)
Baseline Federal Gas Tax	18.4	μ=0.89*
Match Current Effective Tax/Mile (τ_1)		0.89
Future Fleet: Gasoline Tax (τ_2), 60/40 EV/HV	25.8	μ=1.15*
Future Fleet: VMT (τ_3), 60/40 EV/HV		0.93

Notes: Top two rows use data from the National Household Travel Survey, 2017, vehicle level dataset. Future fleet forecasted using NHTS panel. This table summarizes the taxes used in the proposals outlined in section 5. *mean τ/mile only calculated for hybrid and gasoline vehicles as electric do not pay the tax.

Table 4: Forecasting Vehicle Registrations, Sales and Retirement

Year	$\Delta Registrations_{t,t-1}$	$\widehat{Sales}_t$	$\widehat{share^{HEV}}_t$	$Sales_t^{HEV}$	$Sales_t^{Gas}$	$Retire_t$
2017	3249	16827	3.3	555	16272	13578
2018	673	16919	3.9	660	16259	16246
2019	2931	16630	4.2	698	15932	13699
2020	1768	14114	5.4	762	13352	12346
2021	1781	15055	6.6	995	14060	13275
2022	1793	15015	8.1	1215	13800	13222
2023	1805	14975	9.9	1483	13492	13169
2024	1818	14934	12.2	1810	13124	13117
2025	1830	14894	14.8	2210	12685	13064
2026	1843	14854	18.2	2697	12157	13011
2027	1856	14814	22.2	3293	11521	12958
2028	1869	14774	27.2	4019	10755	12905
2029	1882	14734	33.3	4906	9828	12851
2033	1936	14573	56.2	8193	6380	12638
2034	1949	14533	62.2	9046	5487	12584
2035	1963	14493	67.9	9843	4650	12530
2036	1976	14453	73.1	10566	3887	12476
2037	1990	14413	77.7	11203	3210	12422
		Totals		92,407	205,730	260,748

Notes: Data on vehicle registrations and sales by fuel type from *Transportation Energy Data Book, Edition 39* produced by Oak Ridge National Laboratory for the Department of Energy. Sales and share hybrid/electric based on data up to 2020; registration data through 2019. Additional years authors' forecast. Registrations, sales, and retirement in 1000's.

Table 5: Creating a Forecast for 2037 NHTS Data

Decile	(1) Vehicles^{2017}	(2) HEV^{2017}	(3) Gas^{2017}	(4) P(Decile|HEV)	(5) Vehicles^{2037}	(6) HEV^{2037}	(7) Gas^{2037}	(8) $\Delta Vehicles$	(9) Δ HEV	(10) Δ Gas
1	11013	41	10972	0.72	12665	646	12019	1652	605	1047
2	15093	113	14980	1.99	17357	1784	15573	2264	1671	593
3	18100	174	17926	3.05	20815	2735	18080	2715	2561	154
4	20072	251	19821	4.42	23083	3963	19120	3011	3712	-701
5	22312	356	21956	6.25	25659	5604	20055	3347	5248	-1901
6	25896	491	25405	8.63	29780	7738	22042	3884	7247	-3363
7	28177	713	27464	12.55	32404	11253	21151	4227	10540	-6313
8	28658	859	27799	15.11	32957	13549	19408	4299	12690	-8391
9	30005	1161	28844	20.44	34506	18328	16178	4501	17167	-12666
10	29998	1526	28472	26.85	34498	24075	10423	4500	22549	-18049
	229324	5685	223639	100.01	263723	89665	174056	34399	83990	-49591

Notes: Data in columns 1–4 based on 2017 NHTS vehicle level survey aggregated to households, by authors' household expenditure deciles. Data in columns 5–7 based on 2037 stock of HEV and Gas vehicles according to authors' forecast, assuming constant distribution of HEVs across expenditure deciles. Columns 8–10 difference the 2017 and 2037 findings.

Table 6: Mean Taxes Paid by Expenditure Decile: Future Fleet with VMT

	Gasoline Vehicles		
	Baseline ($'s)	Paid (no ΔMiles) ($'s)	Paid (ΔMiles) ($'s)
1	91	103	103
2	121	129	129
3	151	158	158
4	177	181	181
5	192	193	192
6	207	194	193
7	231	197	197
8	235	193	192
9	255	184	183
10	256	158	157
	Hybrid Vehicles		
	Baseline ($'s)	Paid (no ΔMiles) ($'s)	Paid (ΔMiles) ($'s)
1	29	88	82
2	67	99	92
3	57	106	98
4	71	119	110
5	54	143	133
6	59	153	142
7	59	161	149
8	58	157	146
9	66	165	154
10	70	178	165
	Electric Vehicles		
	Baseline ($'s)	Paid (no ΔMiles) ($'s)	Paid (ΔMiles) ($'s)
1	0	88	82
2	0	99	92
3	0	106	98
4	0	119	110
5	0	143	133
6	0	153	142
7	0	160	149
8	0	157	146
9	0	165	154
10	0	178	165

Notes: This table shows the mean amount of federal taxes paid per household, by vehicle type and expenditure decile, for three scenarios. In the first column, we present annual federal fuel taxes paid by vehicle type under the current federal gasoline tax. In the second column, we present annual taxes paid under our VMT proposal, assuming no change in driving behavior after the policy change. In the final column, we present annual user fees paid under our VMT proposal, allowing for driving behavior to respond to changes in per mile driving costs induced by the tax change. We calibrate the VMT tax to match current revenues inflated by 15%, use the 2037 forecasted vehicle fleet, with a 60/40 EV/HV breakdown of new vehicles. For households with multiple types of vehicles (i.e. a gasoline vehicle and a hybrid vehicle), total payment is split across the categories.

Table 7: Comparing Out-of-Pocket Costs for Households (annual $'s)

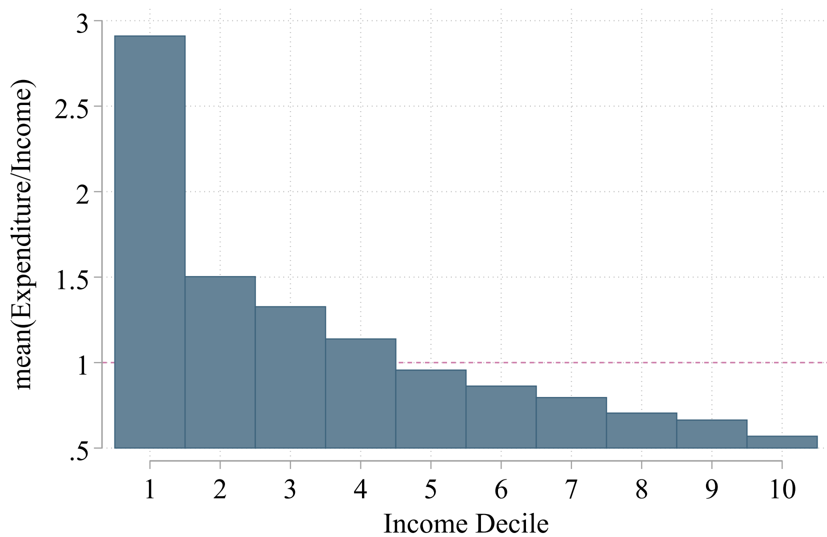
Expenditure Decile	1	2	3	4	5	6	7	8	9	10
Gasoline Tax (Future Fleet)	138	177	218	252	256	265	270	259	245	191
VMT (Future Fleet)	106	142	178	205	227	243	272	282	306	305
Diesel Taxes	6	10	13	15	18	21	24	28	35	57

Notes: This table shows annual out-of-pocket costs for households, in $'s, for the various fuel-related user fees considered. The top row shows the mean gasoline tax paid annually, using the 2037 forecast vehicle fleet. The second row show the mean VMT paid annually, using the 2037 forecast vehicle fleet. The bottom row shows the mean user fees paid by consumers of final goods that use truck transportation, assuming an additional $0.03 VMT added to commercial trucking, on top of the existing diesel tax.

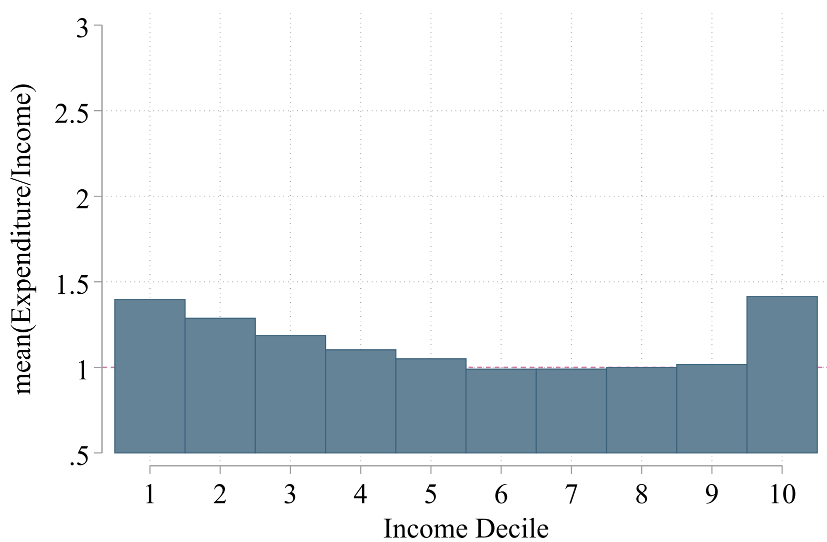
Figures

Figure 1: *Expenditure/Income* by Income and Expenditure Decile, 2017 CEX

(a) Income Deciles

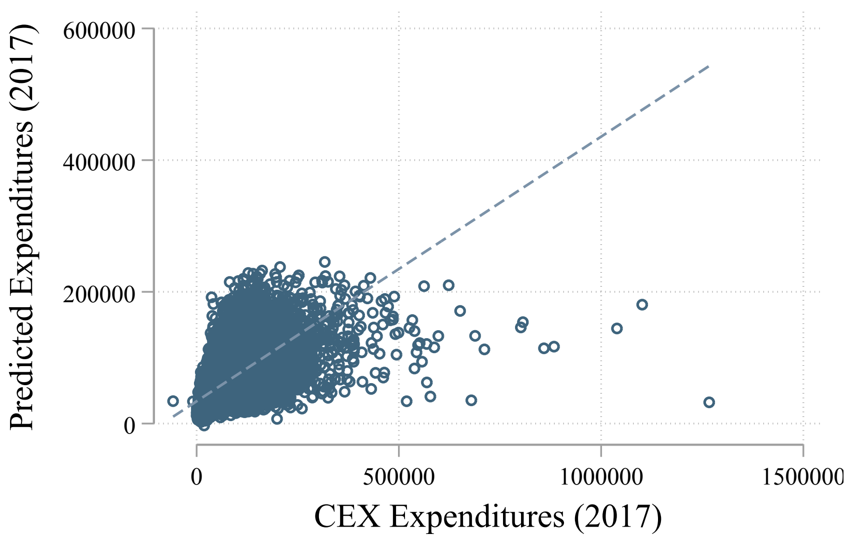


(b) Expenditure Deciles



Notes: Data from the Survey of Consumer Expenditures, 2017. Panel (a) shows the average *Expenditure/Income* ratio within income deciles. Panel (b) shows the same ratio, averaged within expenditure deciles. All ratios winsorized at the 5^{th} and 95^{th} percentiles, for ease of inspection.

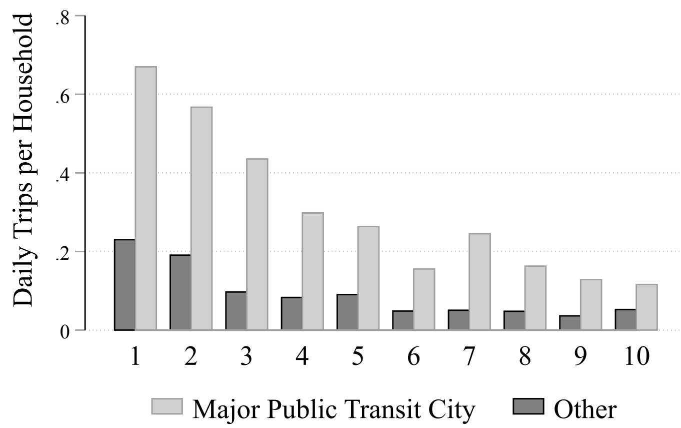
Figure 2: Model Fit: Actual and Predicted Expenditures in CEX (2017)



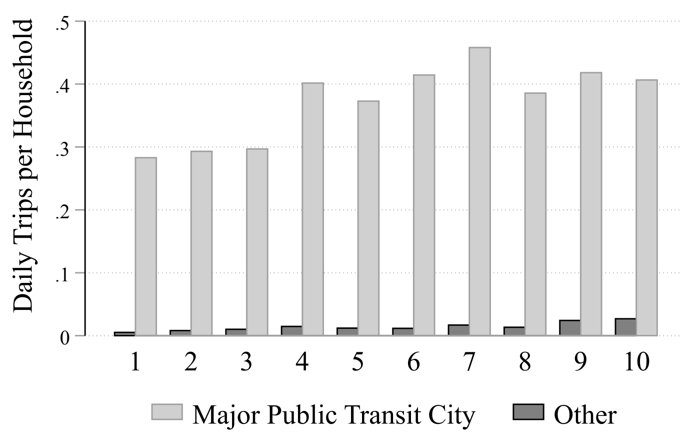
Notes: This figure shows the model fit for predicting total expenditures in the CEX. The horizontal axis measures observed expenditures for one year in our data, 2017. The vertical axis shows the expenditures predicted from our model. The dots each map to one household, and the dashed line shows the linear fit, weighted by each households respective population weight.

Figure 3: Public Transit Utilization in the NHTS, by Expenditure Decile

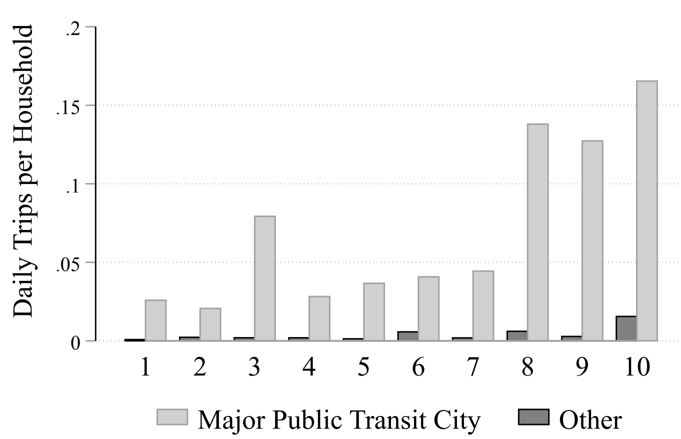
(a) Bus



(b) Subway

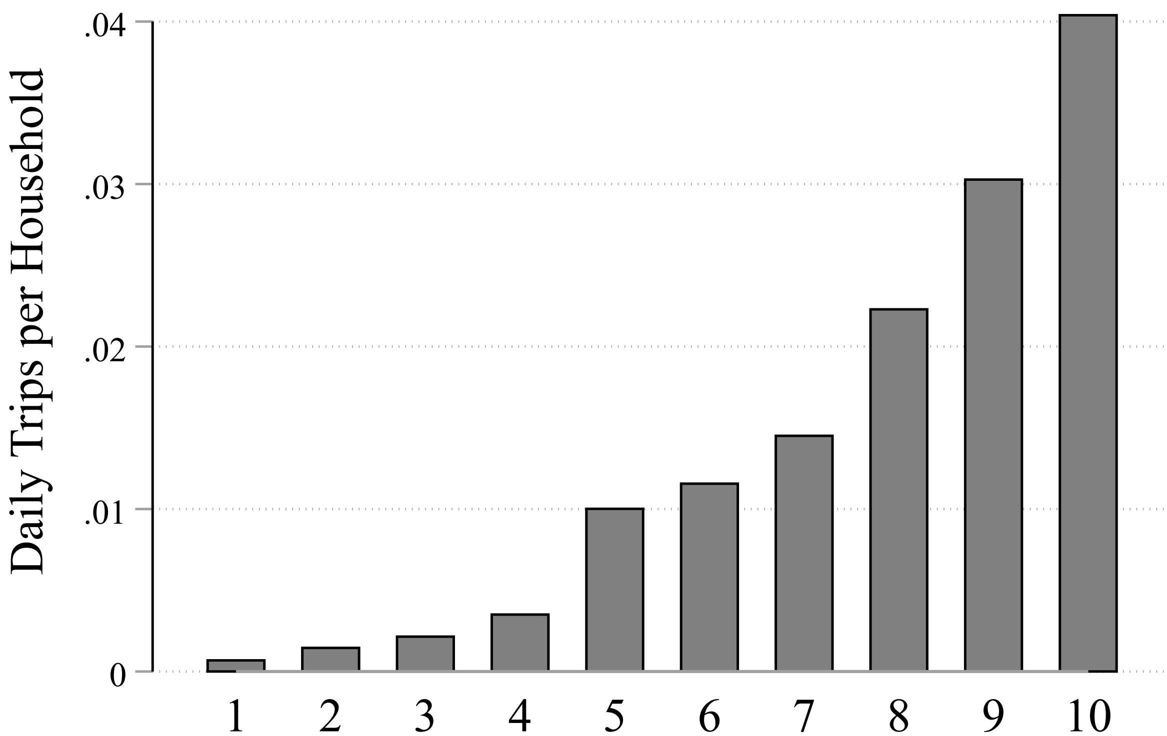


(c) Commuter Rail



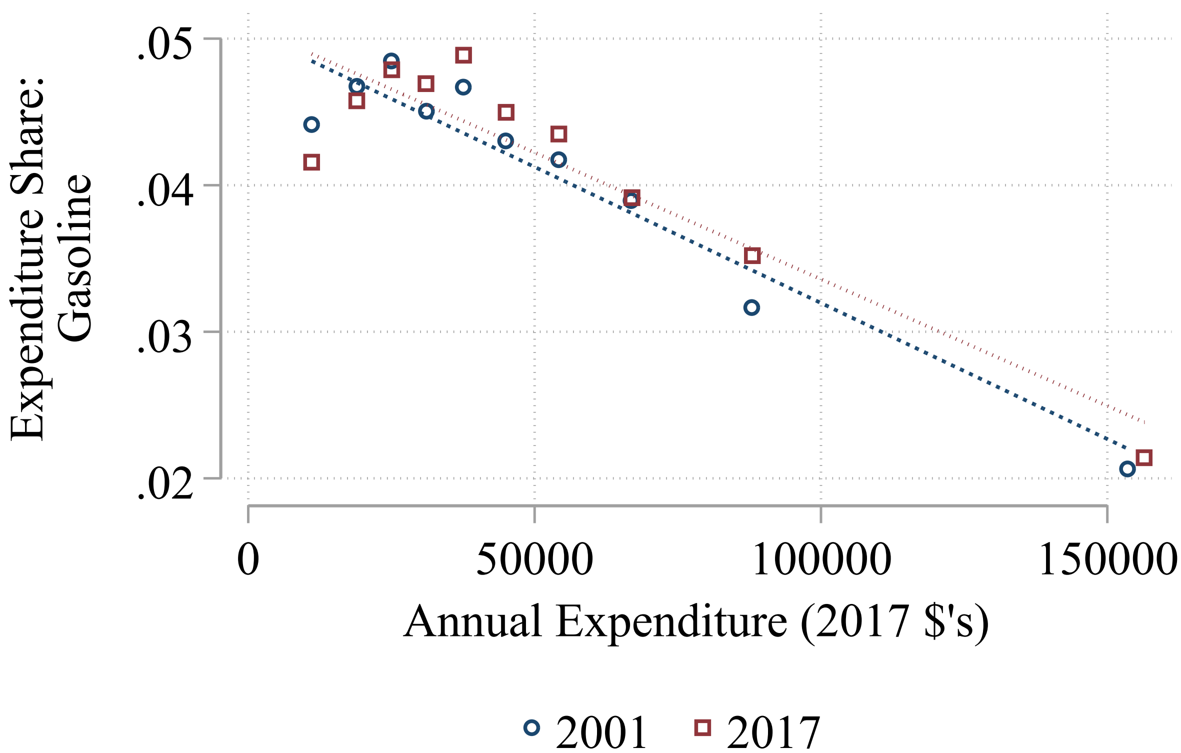
Notes: Data from the National Household Travel Survey, 2017, trip level dataset aggregated to households. Panel (a) shows the distribution of daily household trips by bus, panel (b) by subway, panel (c) by commuter rail. Figures do not include households with negative expenditure. All figures split by a city's status as a major public transit city: New York City, Chicago, Boston, Washington, DC, Philadelphia and San Francisco.

Figure 4: Air Travel Utilization in the NHTS, by Expenditure Decile



Notes: Data from the National Household Travel Survey, 2017, trip level dataset aggregated to households. Figure shows the distribution of daily household trips by air. Figures do not include households with negative expenditure.

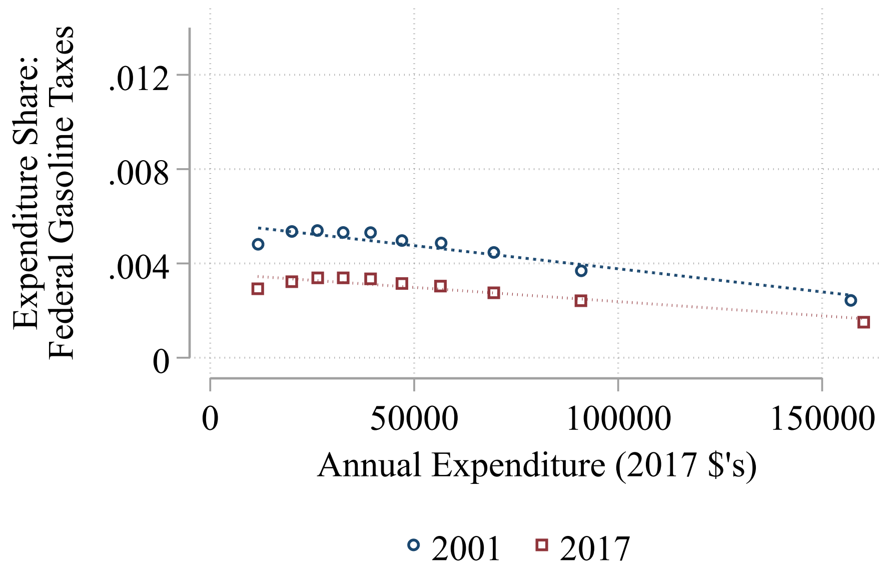
Figure 5: Gasoline Expenditures in the CEX, by Expenditure Level



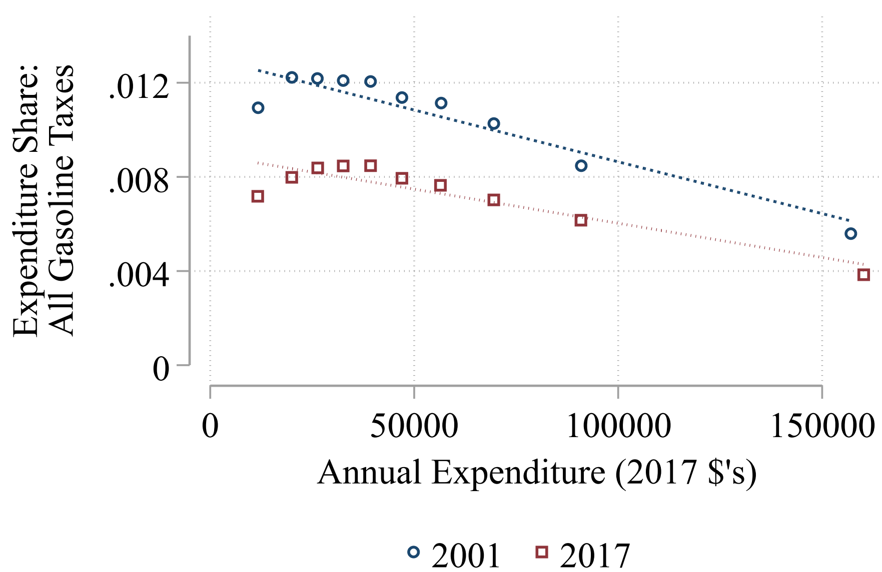
Notes: Data from the 2001 and 2017 CEX waves. The figure plots binned scatters and their associated linear fits.The figure shows the average expenditure share devoted to gasoline by expenditure decile. Expenditure is winsorized at the 1^{st} and 99^{th} percentiles prior to binning, for positive values of expenditure. Data on annual fuel prices by state or region from the Energy Information Administration's "all grades all formulations" retail price average.

Figure 6: Federal and State Fuel Tax Expenditure Shares in the CEX

(a) Expenditure Share: Federal Taxes

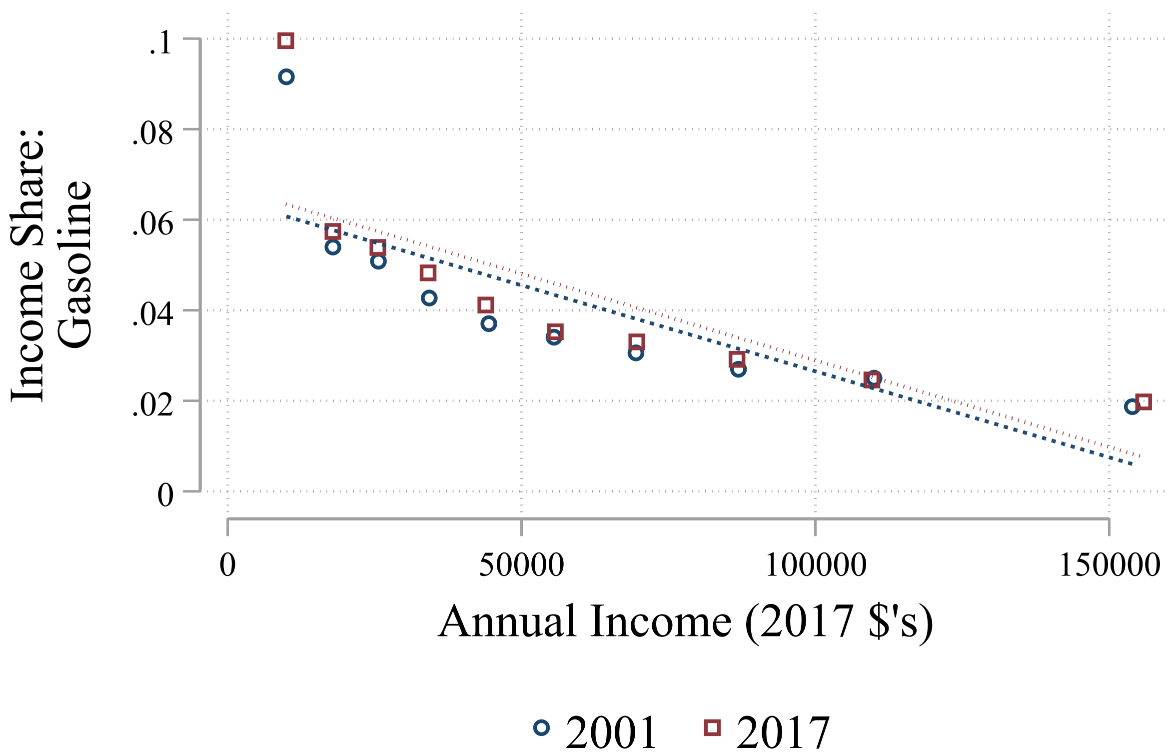


(b) Expenditure Share: All Taxes



Notes: Data from the 2001 and 2017 CEX waves. All panels plot binned scatters and their associated linear fits. Panel (a) shows the average expenditure share devoted to federal gasoline taxes by income decile. Panel (b) plots the expenditure share devoted to total taxes, state and federal, by expenditure decile. Expenditure is winsorized at the 1^{st} and 99^{th} percentiles, prior to binning, for positive values of expenditure. Data on annual fuel prices by state or region from the Energy Information Administration's "all grades all formulations" retail price average. State motor fuels tax rates data come from the Brookings-Urban Tax Policy Center.

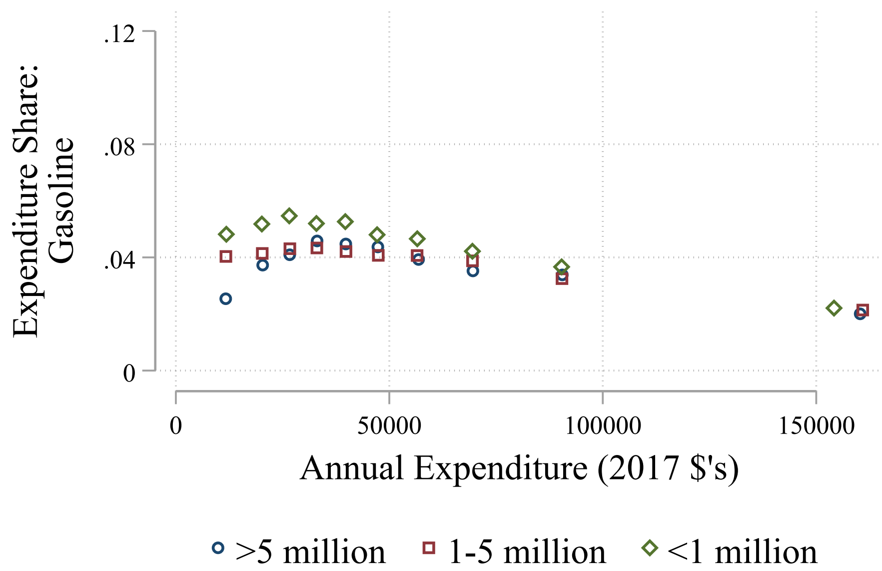
Figure 7: Gasoline Income Shares in the CEX, by Income Decile



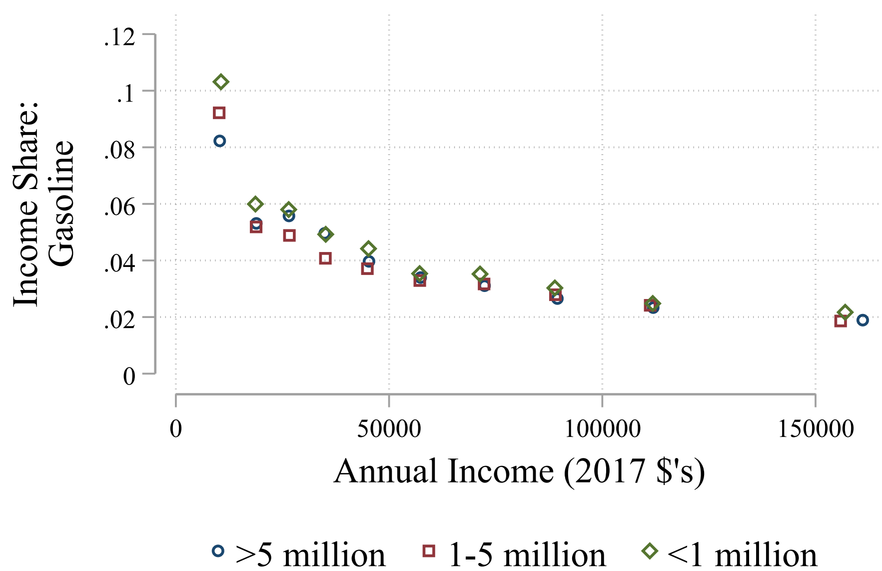
Notes: Data from the 2001 and 2017 CEX waves. The figure plots binned scatters and their associated linear fits, and shows the average income share devoted to gasoline expenditures by income decile. Income is trimmed at the 5^{th} and 95^{th} percentiles prior to binning, for positive values of income. Data on annual fuel prices by state or region from the Energy Information Administration's "all grades all formulations" retail price average.

Figure 8: Gasoline Expenditure and Income Shares, by City Size

(a) Expenditure Share



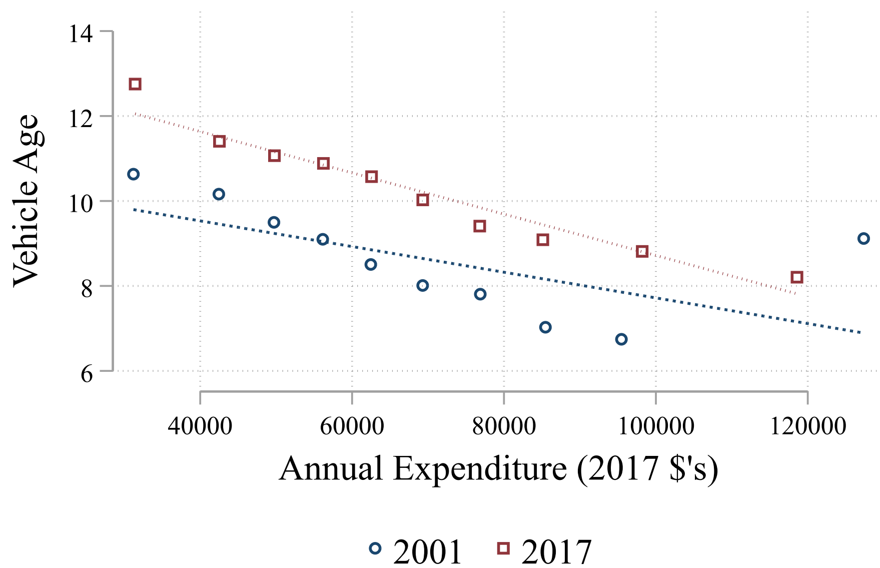
(b) Income Share



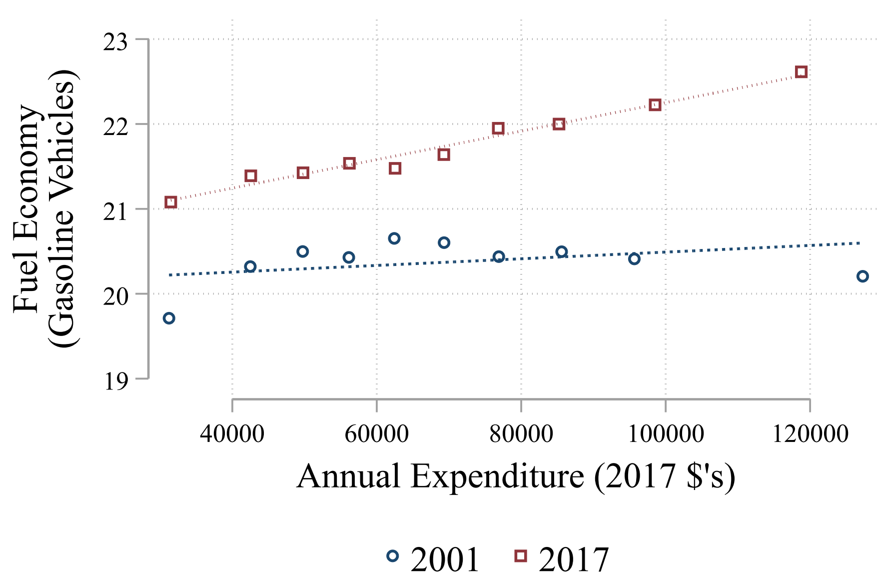
Notes: Data from the 2017 CEX. All panels plot binned scatters and their associated linear fits. Panel (a) shows the gasoline expenditure share, by expenditure decile and city size. Panel (b) shows gasoline income share, by income decile and city size. Expenditure is winsorized at the 1^{st} and 99^{th} percentiles prior to binning, for positive values of expenditure. Income is trimmed at the 5^{th} and 95^{th} percentiles prior to binning, for positive values of income.

Figure 9: Vehicle Characteristics in the NHTS, by Expenditure Level

(a) Vehicle Age

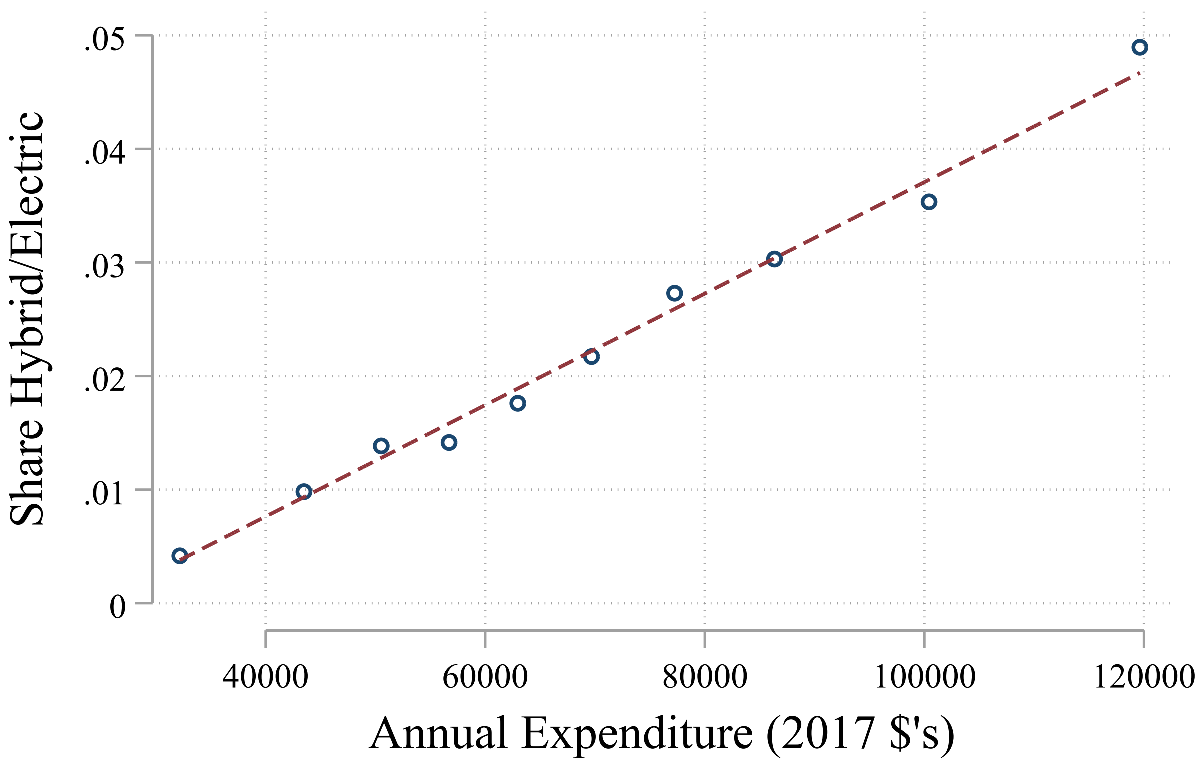


(b) Fuel Economy



Notes: Data from the NHTS waves from 2001 and 2017, only vehicles that run on gasoline ar considered, including hybrid vehicles. All panels plot binned scatters and their associated linear fits. Panel (a) shows vehicle age by expenditure decile. Panel (b) shows mean fuel economy, calculated as observed miles driven divided by gallons purchased, by expenditure decile. Expenditure is winsorized at the 1^{st} and 99^{th} percentiles prior to binning, for positive values of expenditure.

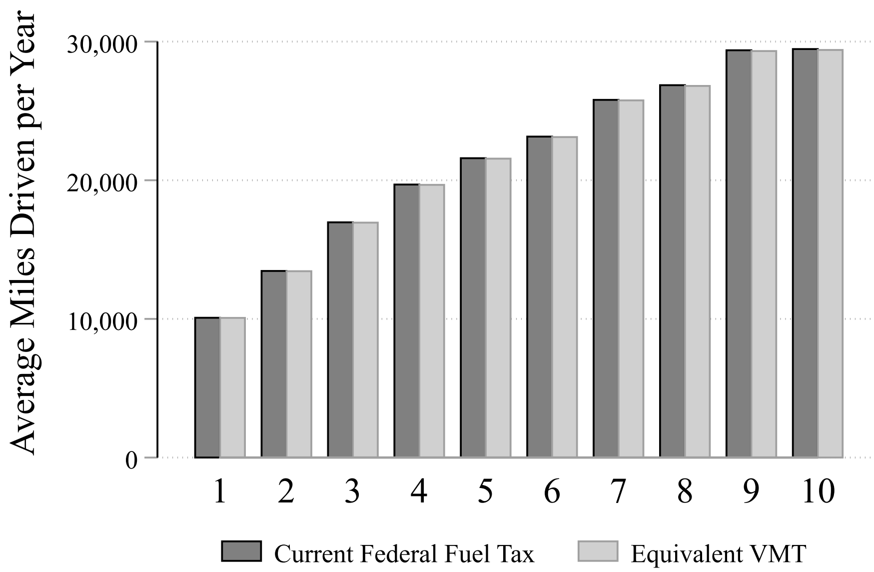
Figure 10: Share of Vehicles Hybrid or Electric in the NHTS, by Expenditure Level



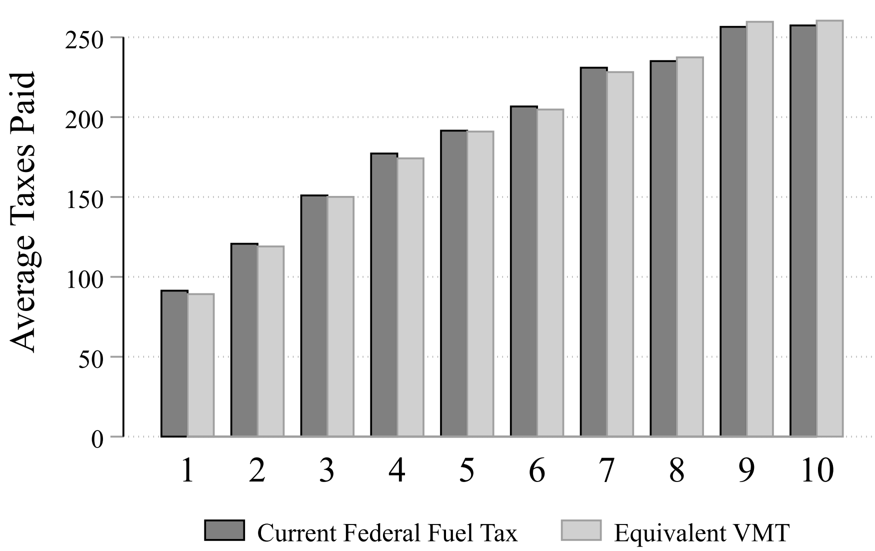
Notes: Data from the 2017 NHTS; the 2001 NHTS did not ask about hybrid or electric vehicle status. Figure shows the binned scatter and associated linear fit for the share of hybrid and electric vehicles, by expenditure decile. Expenditure is winsorized at the 1^{st} and 99^{th} percentiles prior to binning, for positive values of expenditure.

Figure 11: Baseline (2017) vs. Revenue Neutral VMT (2017)

(a) Mean Miles



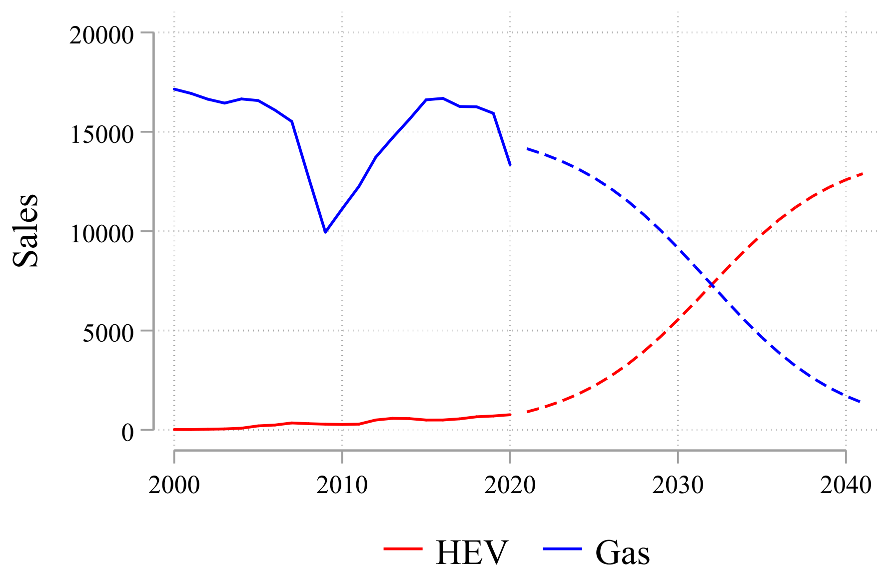
(b) Mean Federal Taxes Paid



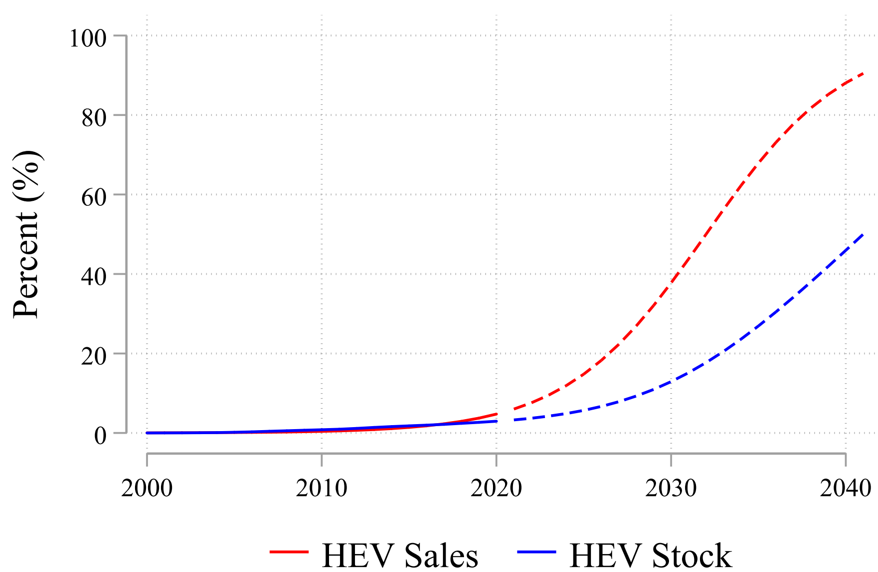
Notes: Data from the 2017 NHTS. Panels show the mean miles traveled and mean federal taxes paid, comparing the current gasoline tax and proposed revenue-neutral vehicle miles tax (VMT). All results conditional on having positive predicted expenditures.

Figure 12: Hybrid and Electric Vehicle Adoption Curves

(a) Sales



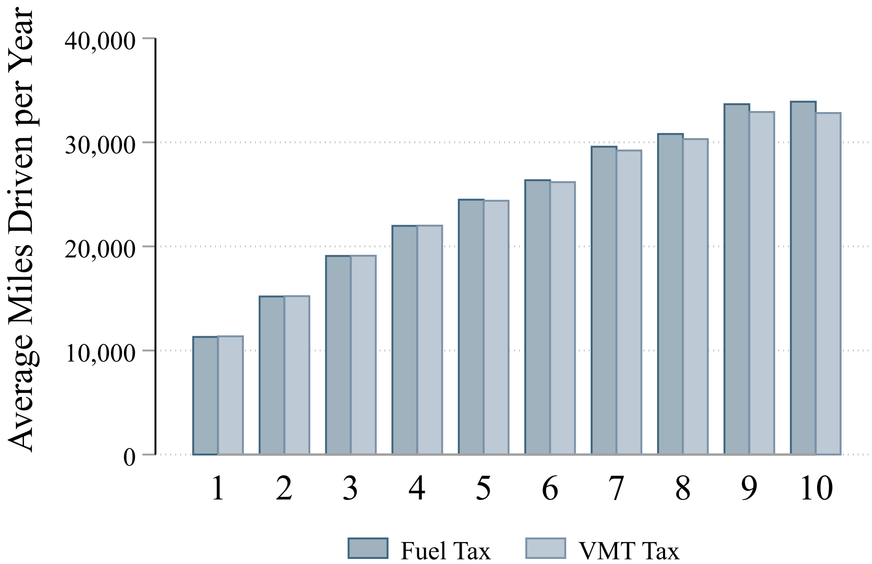
(b) Share



Notes: Data on vehicle registrations and sales by fuel type from *Transportation Energy Data Book, Edition 39* produced by Oak Ridge National Laboratory for the Department of Energy. Sales and share hybrid/electric based on data up to 2020; registration data through 2019. Additional years authors' forecast. Registrations, sales, and retirement in 1000's. Solid lines denote observed data, while dashed lines denote forecasts.

Figure 13: Raising Constant Revenues with Gas Tax vs. VMT (Future Fleet)

(a) Mean Miles

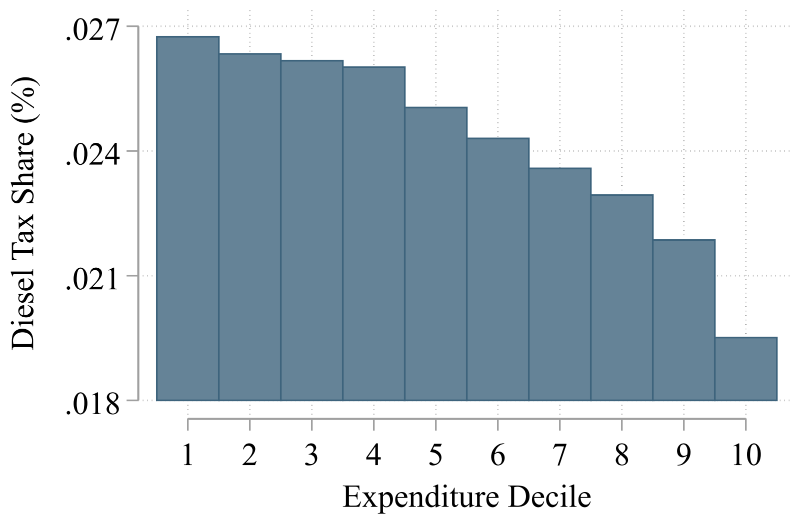


(b) Mean Federal Taxes Paid

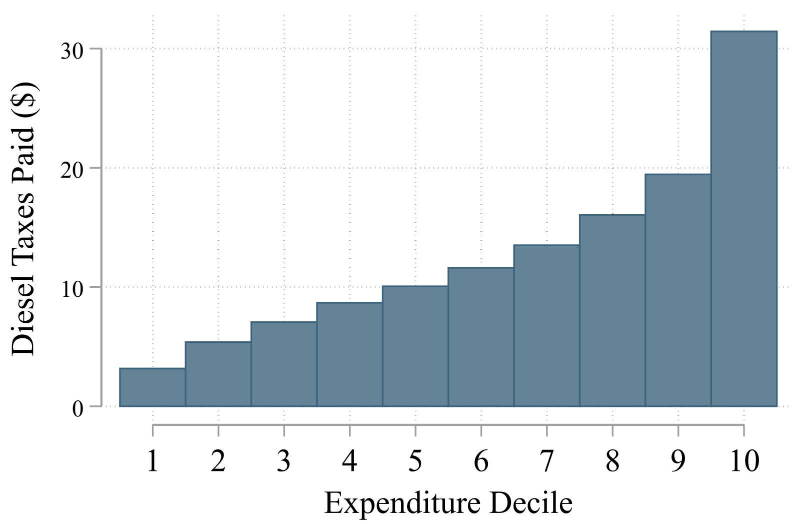
Notes: Data from the 2017 NHTS. Panels show the mean miles traveled and mean federal taxes paid, comparing a gasoline tax and a vehicle miles tax calibrated to match current revenues inflated by 15% in line with the vehicle fleet expansion. The figures use the forecasted vehicle fleet, assuming a 60/40 split of new non-gasoline vehicles by electric and hybrid. All results conditional on having positive predicted expenditures.

Figure 14: Diesel Tax Shares and Amount Paid Annually, by Expenditure Decile

(a) Diesel Tax Share of Total Expenditures



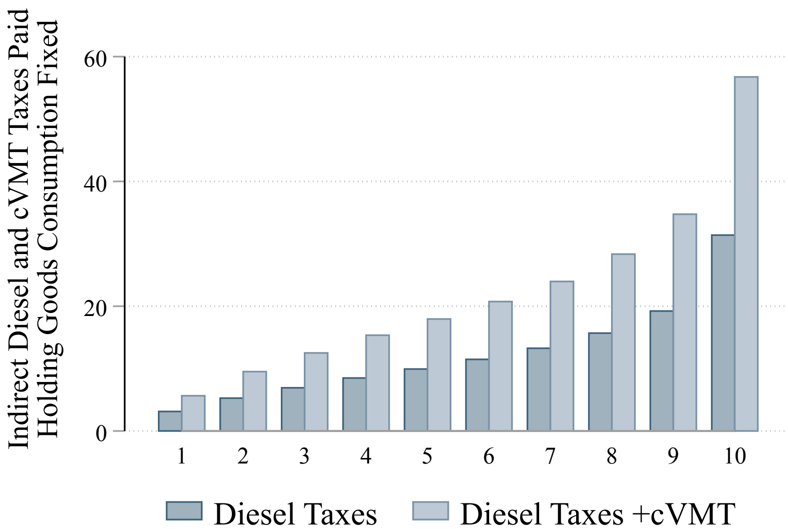
(b) Diesel Tax Expenditures ($'s)



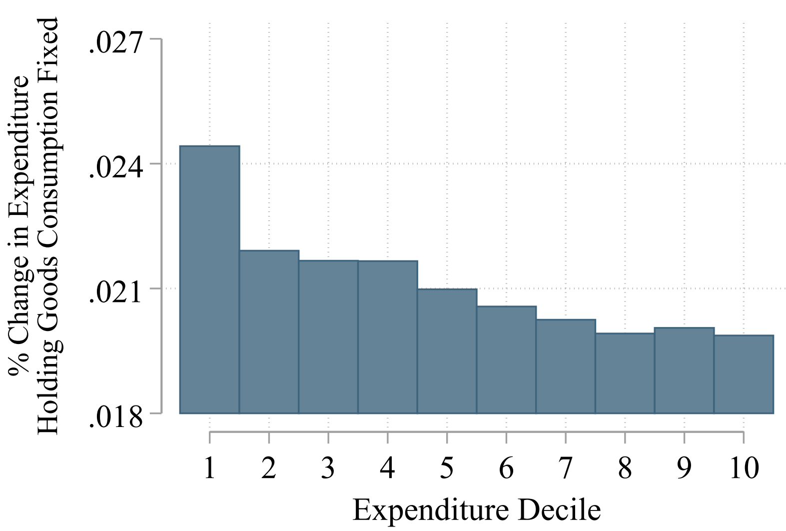
Notes: Data from the BEA's 2012 Input-Output tables, crosswalked to the CEX 2017 household expenditure categories. Panel (a) plots the diesel taxes paid indirectly as a share of household expenditure, by expenditure decile. Panel (b) shows the average annual indirect expenditures, in dollars, for households by expenditure decile.

Figure 15: Change in Expenditure Needed to Maintain Original Consumption Basket, by Expenditure Decile

(a) $'s in Expenditure



(b) % Change in Expenditure



Notes: Data from the BEA's 2012 Input-Output tables, crosswalked to the CEX 2017 household expenditure categories. The figure presents the amounts of additional expenditure needed to purchase the original consumption bundle observed in the CEX, under the adoption of a new federal VMT of $0.03/mile. Panel (a) presents the results in dollars, comparing the baseline scenario (analogous to FIgure 15(b)) to the tax scheme with both diesel taxes and CVMT taxes. Panel (b) presents the percent change in expenditure needed to accomodate this change in indirect diesel tax exposure, in order to keep consumption bundles constant.

Appendix Tables

Table A1: Replication of 2019 Consumer Expenditure Survey, Table 1203

Item	All	< $15,000	$15,000-$29,999	$30,000-$39,999	$40.000-$49,999	$50,000-$69,000	$70,000-$99,999	$100,000-$149,000	$150,000-$199,999	$200,000+
Table 1203										
Number of CU's	132,242	15,848	19,856	12,991	11,208	17,470	19,119	18,225	8,266	9,260
Pre-Tax Income	$82,852	$7,574	$22,189	$34,772	$44,831	$59,328	$83,558	$121,433	$171,061	$343,498
Annual Expenditure	$63,036	$26,194	$34,201	$40,942	$47,299	$54,212	$66,801	$84,994	$109,020	$160,318
Gas, other fuels, motor oil	$2,094	$970	$1,170	$1,699	$1,864	$2,153	$2,496	$2,927	$3,181	$3,283
Replication of Table 1203 using PUMD										
Number of CU's	132,242	15,742	19,720	12,910	11,145	17,432	19,044	17,885	7,477	10,815
Pre-tax Income	$82,451	$7,368	$22,048	$34,643	$44,679	$59,122	$83,592	$120,952	$170,183	$309,772
Annual Expenditure	$59,280	$24,716	$31,944	$39,308	$44,086	$50,980	$63,647	$79,859	$99,337	$142,784
Gas, other fuels, motor oil	$2,094	$961	$1,171	$1,701	$1,863	$2,142	$2,507	$2,911	$3,177	$3,223

Notes: This table replicates Table 1203 from the Survey of Consumer Expenditures annual release, for the year 2019. Replication errors occur due to sampling and adjustments made to the public use microdata in order to maintain consumer unit anonymity.

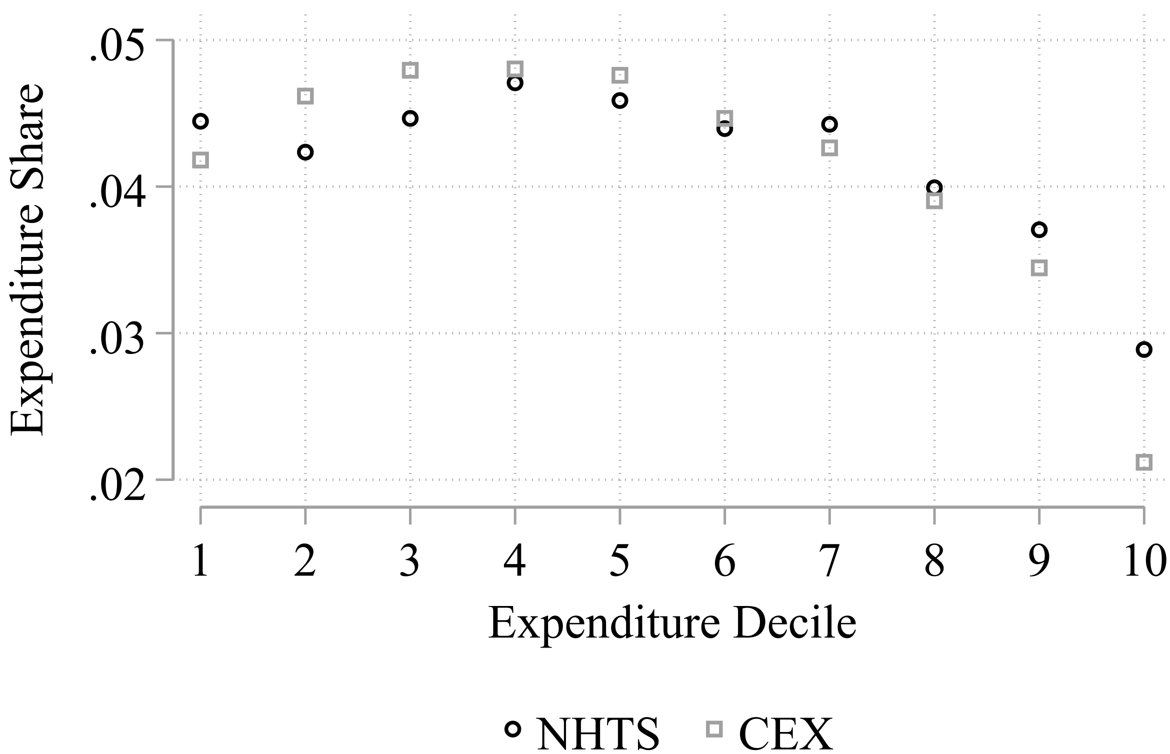
Table A2: Crosswalk from BEA's Total Requirements to CEX Expenditure Categories

BEA IO Commodity	CEX Category	Truck transportation Share
All other food and drinking places	food away from home	0.0070593
Amusement parks and arcades	fees and admissions	0.0090132
Automotive equipment rental and leasing	vehicle rental, leases, licenses and other charges	0.0043736
Automotive repair and maintenance	vehicle maintenance and repairs	0.0077437
Book publishers	reading	0.0110228
Child day care services	education	0.0078640
Civic, social, professional, and similar organizations	cash contributions	0.0070915
Clothing and clothing accessories stores	apparel and services	0.0090630
Direct life insurance carriers	life and other personal insurance	0.0009194
Dry-cleaning and laundry services	household operations	0.0094253
Elementary and secondary schools	education	0.0054672
Food and beverage stores	alcoholic beverages	0.0108911
Food and beverage stores	food at home	0.0108911
Full-service restaurants	food away from home	0.0093778
Gasoline stations	gasoline, other fuels, and motor oil	0.0154538
General merchandise stores	household operations	0.0099524
Grantmaking, giving, and social advocacy organizations	cash contributions	0.0048319
Health and personal care stores	personal care products and services	0.0055965
Health and personal care stores	drugs	0.0055965
Health and personal care stores	medical supplies	0.0055965
Home health care services	medical services	0.0052707
Hospitals	medical services	0.0072299
Independent artists, writers, and performers	fees and admissions	0.0008481
Insurance carriers, except direct life	vehicle insurance	0.0010972
Insurance carriers, except direct life	health insurance	0.0010972
Junior colleges, colleges, universities, and professional schools	education	0.0053413
Limited-service restaurants	food away from home	0.0116851
Medical and diagnostic laboratories	medical services	0.0050679
Motor vehicle and parts dealers	vehicle purchases	0.0112025
Museums, historical sites, zoos, and parks	fees and admissions	0.0070809
Newspaper publishers	reading	0.0065464
Nonstore retailers	household operations	0.0072482
Nursing and community care facilities	medical services	0.0067906
Offices of dentists	medical services	0.0048821
Offices of other health practitioners	medical services	0.0044240
Offices of physicians	medical services	0.0033476
Other ambulatory health care services	medical services	0.0080157
Other amusement and recreation industries	fees and admissions	0.0167363
Other educational services	education	0.0060345
Other personal services	household operations	0.0041878
Outpatient care centers	medical services	0.0050748
Owner-occupied housing	owned dwellings	0.0013106
Performing arts companies	fees and admissions	0.0044224
Periodical Publishers	reading	0.0080464
Personal and household goods repair and maintenance	household operations	0.0035449
Personal care services	personal care products and services	0.0053846
Religious organizations	cash contributions	0.0084143
Residential mental health, substance abuse, and other residential care facilities	medical services	0.0084259
Services to buildings and dwellings	natural gas	0.0091427
Services to buildings and dwellings	electricity	0.0091427
Services to buildings and dwellings	fuel oil and other fuels	0.0091427
Spectator sports	fees and admissions	0.0031418
Tenant-occupied housing	rented dwelllings	0.0004256
Veterinary services	pets	0.0130759
Waste management and remediation services	water and other public services	0.0307979
Wired telecommunications carriers	telephone services	0.0042030
Wireless telecommunications carriers (except satellite)	telephone services	0.0071040
Mean truck transportation cost share:		0.0072095

Notes: Data on total requirements from the BEA's total requirements table, for truck transportation industry (input) to all other commodities (output). Truck transportation share denotes the dollars of truckign industry input required, both directly and indirectly, to produce one dollar of the final BEA IO commodity for final use. Expenditure categories from the BLS's ***Table 1203.*** *Income before taxes: Annual expenditure means, shares, standard errors, and coefficients of variation, Consumer Expenditure Survey, 2019.* Crosswalked by authors.

Appendix Figures

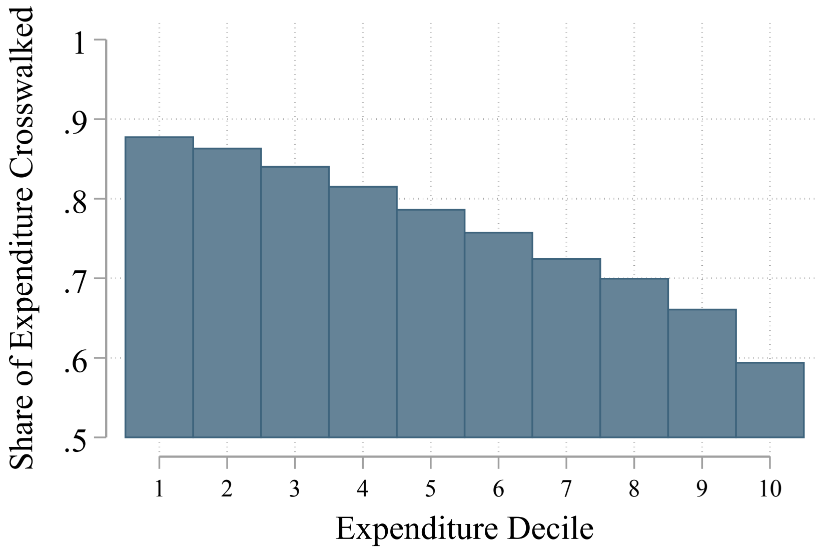
Figure A1: Expenditure Prediction Validation: Comparing Gasoline Expenditure in CEX with NHTS



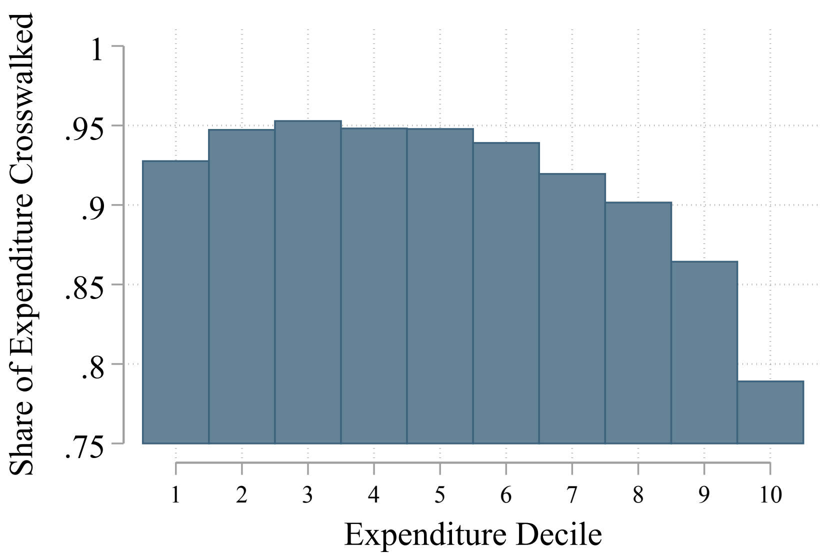
Notes: This figure compares the mean gasoline expenditure shares in the NHTS and CEX data. We use observed expenditures on gasoline, and observed total expenditures from the 2017 CEX. From the 2017 NHTS, we use imputed expenditures from our expenditure model. Gasoline expenditure in the NHTS comes from computing the gas cost per mile, based on fuel efficiency data from the NHTS and regional gas prices from the EIA, and multiplying by the observed miles traveled in the data. We then take the average gasoline shares, weighted by each survey's respective population weights.

Figure A2: Fraction of Expenditures Covered by BEA–CEX Crosswalk

(a) All Expenditures



(b) Excluding Outlays for Pensions & Retirement



Notes: These figures plot the share of total expenditures we are able to account for with the crosswalk constructed from Table 9. Services that are not traded, such as pension outlays, do not crosswalk from the Input-Output tables to the CEX data. Panel (a) plots the share of expenditure we can link to trucking costs, by expenditure decile based on total expenditure, in line with the rest of the results in the paper. Panel (b) plots the share of expenditure we can link, by expenditure decile based on total expenditure less outlays for retirement and pension funds, as these could be classified as "savings," are a major component of outlays in higher expenditure deciles, and will not be impacted by a CVMT tax. Panel (b) shows that we do account for most of household expenditures, especially in the bottom 8 deciles, while at the top end, we continue to miss expenditure on other non-tradable services unrelated to our tax policy.