Winners and Losers from Mileage-Based Reforms to the Gas Tax

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Abstract

An increasingly common policy proposal is to tax vehicle miles driven rather than consumption of motor fuels. This paper investigates the distributional consequences of an efficiency-enhancing policy reform in which a gasoline tax is replaced or supplemented by a mileage tax. Using National Household Travel Survey data, I show that household burdens from a gas-to-mileage tax swap are harder to predict than those from the initial gas tax. This result arises because demographic and geographic covariates poorly predict household fuel economy. Consequently, most losers from the swap cannot be compensated. While such reforms may thus be considered unfair from the perspective of compensation, a revenue-equivalent tax swap is not regressive.

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1 Introduction

The efficiency, equity, and revenue implications of taxing automobile use have long been the subject of debate in economics and public discourse. Historically, federal taxes on motor fuels have served as the primary mechanism for both mitigating the externalities that driving creates - which include greenhouse gas emissions, congestion, local air pollution, and road accidents - and for raising revenue to fund transportation infrastructure. The current federal tax on gasoline is 18 cents per gallon and, across states, the average combined state and federal tax is 48 cents per gallon (EIA, 2021).

Another approach to correcting externalities and raising revenue from driving is to tax vehicle miles traveled (VMT). This option has gained attention from both policymakers and economists. In the policy sphere, improvements in vehicle fuel economy and increasing penetration of electric vehicles have generated concern about funding for transportation spending. For more than a decade, federal tax revenues from motor fuels have failed to keep pace with federal highway spending (CBO, 2019). The state of California recently mandated that, by 2035, all new cars and light trucks must be zero-emissions vehicles; other states will likely follow this example. Existing and anticipated revenue shortfalls have prompted some states to consider introducing mileage taxes, with Oregon and Utah having already enrolled drivers in preliminary programs (Duncan, 2021).

The efficiency consequences of replacing or supplementing the gasoline tax with a mileage tax are poorly understood. Some economists have argued that a mileage tax can offer efficiency gains over a gas tax because congestion, local air pollution, and accident externalities are more tightly correlated with distance traveled than with fuel consumption (Parry and Small, 2005; Langer, Maheshri, and Winston, 2017). Such results depend on the assumed magnitude of different driving externalities and on the details of the fuel and mileage taxes being considered. For example, Anderson and Auffhammer (2013) estimate external costs per gallon from accidents that are more than twice Parry and Small (2005)'s estimates of the total external costs per gallon from driving. The relative ability of a mileage or a gas tax to correct this accident externality depends on how the mileage tax varies by vehicle weight, since accident externalities are a function of both distance and weight, which is itself closely correlated with fuel consumption. A related illustration of the sensitivity of efficiency results to instrument design is Davis and Sallee (2020), who show that even the sign of the optimal mileage tax on electric vehicles is ambiguous as it depends on the extent to which the pre-existing gas tax is inefficiently low and the degree of substitution between gas and electric cars.

Few papers have explored the relative distributional impacts of a fuel versus a mileage tax. Langer, Maheshri, and Winston (2017) compare the loss in consumer surplus from a gas tax and a revenue-equivalent urban-rural differentiated mileage tax. They find that, while the loss in consumer surplus from the mileage tax is larger for every income group, this difference is increasing in income. The reason for this is that externalities from VMT are larger in urban areas where drivers are more likely to be higher-income. The authors interpret this as evidence that the mileage tax has favorable distributional effects. Focusing on a slightly different question, West (2005) studies the incidence of a vehicle-specific mileage tax and a revenue-equivalent uniform mileage tax that specifically target local air pollutants. She finds that, whereas the uniform tax is less efficient, it is also less regressive. This result is driven by the fact that vehicles driven by low-income households emit more local air pollution than vehicles driven by high-income households.

Replacing a gas tax with a mileage tax would create winners and losers. If such a policy is indeed efficiency-enhancing, then by the definition of Kaldor-Hicks efficiency, it can generate a Pareto improvement under some hypothetical transfer scheme. A recent paper, Sallee (2019), shows that, in practice, such a transfer scheme can be impossible to actualize. When the burdens from a policy are heterogeneous across households, a policymaker may simply not have enough information to compensate losers. Sallee (2019) formalizes this intuition by deriving a condition under which a Pareto improvement from an efficiency-enhacing policy is not possible. The paper then illustrates this result by estimating the impacts of imposing a 10 cent per gallon gas tax as an initial externality-correcting policy. Sallee finds that a transfer scheme based on readily-available exogenous household covariates would still leave more than a third of households as net losers under the tax.

In reality, an externality-correcting policy is rarely introduced from a baseline of no policy; rather, it typically reforms or supplements some pre-existing policy. The possibility of a mileage tax is one such example. In this paper, I extend the analysis in Sallee (2019) to explore the distribution of burdens, compensation of losers, and the possibility of achieving a Pareto improvement under mileage-based policy reforms to a gas tax. I consider three potential gas-to-mileage tax swaps as well as a supplemental mileage tax, and ask: who are the winners and losers from these reforms? I find that the ability of household observables to predict burdens is extremely poor, especially for tax swaps, and thus all reforms preclude a Pareto improvement. Although this finding casts doubt on the political feasibility of mileage-based reforms, one advantage of a revenue-equivalent swap is that it is not regressive.

2 Theoretical Framework

2.1 Sallee (2019)'s model of Pareto transfers and terminology

This paper uses Sallee (2019)'s model of Pareto-improving transfers from an efficiency-enhancing policy. Such a policy generates efficiency gains from G and imposes costs or "burdens" C on heterogeneous households indexed by $i = 1, ..., N$. In the paper's focal application of a gas tax, G represents an "externality gain": the reduction in social costs from carbon emissions. C represents the sum of tax revenue paid by households and the tax-induced reduction in consumer surplus born by households. Total revenue raised by the policy, R, can be redistributed through a transfer scheme $\mathbf{T}(\mathbf{X_i}) \leq R$ where $\mathbf{X_i}$ represents household covariates. Since the policy is assumed to be efficiency-enhancing, $C < R + G$.

$\bar{g} = G/N$ is the average externality gain experienced by a household due to the tax, where the entire externality gain is assumed to accrue to the households in existence when the tax goes into effect. Since the majority of climate benefits from a reduction in CO2 that occurs in the U.S. will be realized by future generations and populations outside the U.S., this assumption is conservative toward finding a Pareto improvement. The burden born by each household is denoted c_i, where $\sum_i^N c_i = C$.

Households for whom $\bar{g} - c_i \geq 0$ are initial "winners" from the policy; other households are initial "losers". The "net gains" experienced by a household are $\bar{g} - c_i + T(\mathbf{X_i})$ and represent the impact of the policy on a household after a compensating transfer is made. Households for whom $\bar{g} - c_i + T(\mathbf{X_i}) \geq 0$ are net winners; other households are net losers.

The key result of the paper is that for a policy such that

$$\frac{1}{N} \sum_i^N |c_i - T(\mathbf{X_i})| > 2\bar{g} - \frac{C - R}{N}$$

a Pareto improvement is not possible. I refer to this result as the "Sallee impossibility condition."

2.2 Predicting burdens from a policy reform

Common externality-correcting policy instruments including taxing or banning (e.g. through a standard) the harmful good, subsidizing a less harmful alternative, and requiring product labels or imposing a standard on a group of goods. Such measures (and policies in general) are often implemented as reforms to pre-existing policies. In this setting, compensating losers requires predicting the *difference* in burdens from a reform.

To fix ideas, let X be a matrix of household-level covariates used to predict policy burdens. Let $f(X)$ and $g(X)$ be the household-level burdens from some initial policy and some alternative policy (i.e., a reform), respectively. The predictability of $g(X) - f(X)$ relative to the predictability of $g(X)$ or $f(X)$ depends on the relationship between $g(X)$ and $f(X)$. If $g(X)$ were identical to $f(X)$, predicting $g(X) - f(X) = 0$ would no more difficult than predicting burdens from either policy individually. If $g(X)$ were completely random, predicting $g(X) - f(X)$ would be at least as difficult as predicting $g(X)$. As such, the likelihood that Sallee, 2019's impossibility condition applies to a given policy reform is not obvious ex-ante.

2.3 The case of a fuel versus a mileage tax

This paper studies mileage-based policy alternatives to a gas tax, focusing on a mileage tax (that generates burdens $g(X)$) that replaces a gas tax (that generates burdens $f(X)$). In this setting, under the simplifying assumption of linear demand and supply, $g(X) - f(X)$ only depends on a household's fuel economy (gallons per mile) and its mileage. As such, the predictability of $g(X) - f(X)$ collapses to how well X predicts those two variables.

To see this, note that if (as I assume in the next section) the tax swap causes only a negligible change in driving behavior and if cost per mile is solely determined by the price of gas, the change in cost per mile under the tax swap is:

$$\left(\frac{\$}{\text{mile}}\right)_{\tau_m} - \left(\frac{\$}{\text{mile}}\right)_{\tau_g} = \left[\left(\frac{\$}{\text{gal}}\right)\left(\frac{\text{gal}}{\text{mile}}\right) + \tau_m\right] - \left[\left(\frac{\$}{\text{gal}} + \tau_g\right)\left(\frac{\text{gal}}{\text{mile}}\right)\right] = -\tau_g\left(\frac{\text{gal}}{\text{mile}}\right) + \tau_m$$

That is, the change in cost per mile is mediated by fuel economy. Those with high (i.e. good) fuel economy fare worse under a mileage tax, and those with low (i.e. bad) fuel economy fare better. The total change in burden under the swap is the difference in cost per mile times miles driven after the swap.

In summary, fuel economy determines how much each household gains or loses on per-mile basis and annual mileage scales that effect to determine how much households gain or lose in total under the swap.

2.4 Income distribution versus predictability of burdens

Household income is likely to be one of a limited number of covariates included in any realistic transfer scheme. Income may or may not be predictive of burdens. If a policy is highly regressive, one might expect that income is predictive of burdens, since being highly regressive means that the ratio of burdens to income is larger for low-income households.[1] To the extent that this holds, losers are easier to compensate and regressivity might be a less objectionable policy feature.

3 Modeling Assumptions

3.1 Estimating household impacts from an initial 10 cent gas tax

Following the set-up of Sallee (2019), I first estimate household-level gains and losses from the introduction of a 10 cent gas tax. The 10 cent gas tax is intended to approximate an infininitesimal tax, which is conservative toward finding a Pareto improvement since it maximizes externality gains and minimizes burdens.

Following Sallee, I calculate impacts of the tax at the household level using triangle approximations assuming perfectly elastic supply of gas. I assume a uniform gas elasticity of -0.442, which is Knittel and Sandler (2010)'s estimate of the U.S. VMT elasticity. The authors estimate this elasticity using within-year variation in gasoline prices over a two-year period.

In terms of Figure 1, I calculate the change in gallons under the tax as the elasticity times the percent change in the price of gas times the quantity of gallons consumed at point A. I calculate revenue (the blue box) as the tax times the quantity of gallons consumed at point B and consumer surplus (the orange triangle) as one-half times the tax times the change in gallons. Burdens are the sum of the blue box and the orange triangle.

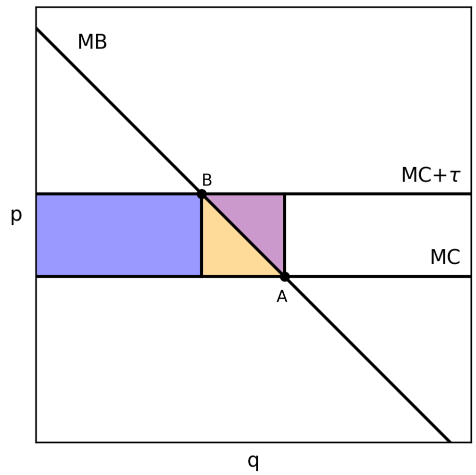
The purple triangle represents the externality gain due to the tax. I assume per-gallon externalities are constant for all values of gasoline consumption and compute each household's contribution to the externality gain as the marginal external damage per gallon times the change in gallons. Following Sallee, I use EPA conversion factors for tons of carbon emitted per gallon of fuel consumed.[2] I assume a marginal external damage of CO_2 (i.e., social cost of carbon) of \$40 per metric ton of carbon and estimates of per urban mile and per rural mile externalities from Langer, Maheshri, and Winston (2017).[3]

[1] In my setting, household burdens are equal to the tax's revenue impacts minus an externality gain that is constant across households. So, if revenue is a large share of income for lower-income groups (the definition of of regressivity), burdens are also a large share of income for those groups.

[2] Specifically, I assume 17.6 pounds per gallon and 2,205 pounds per metric ton of gasoline and 22.5 pounds per gallon and 2,205 pounds per metric ton of diesel.

[3] Adapted from Small and Verhoef (2007), these estimates are \$0.129 (\$0.023); \$0.073 (\$0.013), and \$0.016 (\$0.002) per urban (rural) mile for congestion, accidents, and local air pollution externalities, respectively.

Figure 1: Welfare Impacts of a Gas Tax



The figure illustrates the approximations used to estimate revenue (blue box), lost consumer surplus (orange triangle), and externality gain (purple triangle) from an externality-correcting tax.

3.2 Calculating equivalent mileage taxes

I next compute three mileage taxes that - if implemented from a baseline of no policy - would respectively yield equivalent revenue, an equivalent CO2 externality gain, and an equivalent total externality gain to the 10 cent gas tax. The total externality gain includes CO2, congestion, local air pollution, and accident externalities. In each of these three cases, I follow the same steps as for a gas tax, set the target equivalent quantity in question (e.g. revenue) equal to the sum of that quantity over all households, and solve numerically for the mileage tax that yields that target quantity. I assume that the uniform VMT elasticity is -0.442, the same as the gas elasticity. If cost per mile were solely determined by the price of gas and fuel economy and if consumers did not adjust their fuel economy in response to a change in cost per mile, these elasticities would indeed be identical. This follows from the fact that:

$$\epsilon_{VMT} = \frac{\%\Delta\text{miles}}{\%\Delta(\frac{\text{cost}}{\text{mile}})}$$
$$\epsilon_{gas} = \underbrace{\frac{\%\Delta\text{gal}}{\%\Delta(\frac{\text{cost}}{\text{gal}})} = \frac{\%\Delta\text{gal}}{\%\Delta(\frac{\text{cost}}{\text{mile}}\frac{\text{mile}}{\text{gal}})}}_{\text{If ignoring non-gas per-mile costs}} = \frac{\%\Delta\text{gal}}{\%\Delta(\frac{\text{cost}}{\text{mile}})}$$

In reality, fuel economy is a possible margin of adjustment. My elasticities do not capture changes in VMT demand that arise due to general equilibrium effects of changing cost per mile. When a mileage tax is introduced, a high fuel economy offers smaller cost savings and the price of new and used high-MPG vehicles may decrease. This could increase demand for new low-MPG vehicles and the scrappage rate of used high-MPG vehicles (similar to the scrappage consequences of fuel efficiency standards identified by Jacobsen and Van Benthem (2015). Both effects would eventually reduce the fuel economy of the overall fleet, which would in turn affect gas and VMT elasticities.

3.3 Calculating the optimal uniform supplemental mileage tax

Given that gasoline taxes in the U.S. are generally thought to be smaller than the externalities they generate, another plausible policy reform is to preserve the gas tax and simply add a mileage tax on top of it. If every consumer had the same fuel economy, this supplemental tax would recover the first best. Concretely, supposing a uniform fuel economy, let

$$\begin{aligned}
\phi_c^g &= \frac{\text{\$ damages from CO2}}{\text{gal}} \\
\phi_c^m &= \phi_c^g \frac{\text{gal}}{\text{mile}} \\
\phi_o^m &= \frac{\text{\$ non-CO2 damages}}{\text{mile}}
\end{aligned}$$

Assuming constant per-unit external damages, every mile driven generates $\phi_c^m + \phi_o^m$ dollars in damages. Under the initial policy of a gas tax τ_g, every mile driven is taxed at $\tau_g^m < \phi_c^m$ where $\tau_g^m = \tau_g \frac{\text{gal}}{\text{mile}}$. In this case, a supplemental mileage tax of $\tau_o^m = \phi_c^m + \phi_o^m - \tau_g^m$ recovers the first best under the assumptions of quasilinear utility and competitive markets for the production of miles.

I compute an approximation of τ_o^m using a mileage-weighted fleet average of fuel economy. Since the per-unit externalities from carbon that I use vary for diesel and gas miles and the per-unit externalities from, congestion, accidents, and local air pollution that I use vary for urban and rural miles, I compute weighted averages of externalities where the weights are the diesel- and urban-share of households in the dataset.

3.4 Estimating household impacts from reforms

For each of the three tax swaps, I calculate the change in burden from the reform by subtracting the burden associated with the initial 10 cent gas tax from the burden associated with an initial equivalent mileage tax. I then compute the gain from the reform (prior to any transfers) as the change in burden minus the average externality gain from the gas tax plus the average externality gain from the mileage tax. For the supplemental mileage tax, the gain from the reform (prior to any transfers) is simply the burden from the mileage tax plus the average externality gain from the mileage tax.

4 Data

I use data from the U.S. Department of Transportation's 2009 and 2017 National Household Travel Survey (NHTS), a nationally representative household survey on travel behavior that includes linked household and vehicle characteristics. The two datasets do not comprise a panel and my results are similar for 2009 and 2017, so throughout the paper I report only 2017 results. The 2017 data consist of 255,266 vehicles and 129,696 households. NHTS data are collected from a stratified random sample of U.S households, so I use sampling weights throughout my calculations.

The main vehicle-level data I use are fuel type (gasoline, diesel, hybrid, electric, or alternative fuel), fuel economy, price per gallon of gasoline, annual mileage, and annual gallons of gasoline consumed. Fuel economy, gas price, and gas consumption values for non-motor fuel vehicles are populated in the dataset based on gallon-equivalent approximations and retail electricity prices. I compute impacts as described in the previous section at the vehicle level, excluding electric vehicles from fuel tax burdens, and subsequently aggregate to the household level, taking care to omit households without vehicles from burden calculations while still assigning them average externality gains. The primary household-level data I use are U.S. state, income range, and whether the household is located in an urban area. Tables 1 and 2 provide summary statistics of household motor fuel expenditures and characteristics.

Table 1: Annual Household Motor Fuel Expenditures

Mean	\$2,375
Median	\$1,782
St. Dev.	\$2,504
Pct. 0	0.09

The table reports summary statistics of household motor fuel expenditures in the NHTS (2017) dataset.

Table 2: Summary Statistics of Demographic Variables

	Mean	Median	St. Dev.	Min	Max
Income Range	-	\$50,000-\$74,999	-	$\leq$ \$10,000	$\geq$ \$200,000
Household Size	2.5	2	1.4	1	13
Urban indicator	0.2	1.0	0.4	0	1

The table reports summary statistics of household demographics in the NHTS (2017) dataset.

5 Results

5.1 At least a third of households are initial losers under tax swaps

Under the assumptions in Sections 3.1 and 3.2, the mileage taxes that generate equivalent revenue, CO2 externality gain, and total externality gain to a 10 cent per gallon gas tax are \$0.004877/mile, \$0.004926/mile, and \$0.004531/mile, respectively. Tables 3 and 4 summarize household-level and aggregate impacts from each swap prior to any transfer. Since these mileage taxes are replacing a gas tax of only 10 cents per gallon, most households do not win or lose by much. However, the impacts in Table 3 would scale with the size of the initial gas tax.

As shown in Table 4, each swap creates a sizable share of losers, prior to any transfers. The mean revenue from the revenue-equivalent swap is, by construction, \$0. Holding revenue constant under a mileage tax yields a modest average carbon externality gain relative to the initial gas tax. By the same token, holding the carbon externality gain constant under a mileage tax raises less revenue from households on average than the initial gas tax. The mean revenue from the total externality-equivalent swap is negative because the mileage tax is a more effective mechanism for holding the externality gain constant than the gas tax. Given that none of the swaps raises revenue on average, any transfer would need to involve either winners compensating losers or some outside source of funds.

Table 3: Summary of Household-Level Policy Impacts

	Rev equiv		CO2 equiv		Tot equiv	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Change in gallons	0	5	0	5	1	6
Change in miles	-28	132	-32	134	1	122
Gallons consumed	984	1,040	983	1,040	985	1,041
Miles driven	20,169	19,846	20,165	19,842	20,198	19,874
Burden	\$0.07	\$30.43	\$1.04	\$30.36	-\$6.94	\$31.78
Revenue	\$0.00	\$29.87	\$0.95	\$29.80	-\$6.87	\$31.24
Avg CO2 ext. gain	-\$0.06	\$0.00	\$0.00	\$0.00	-\$0.49	\$0.00
Avg total ext. gain	\$2.27	\$0.00	\$2.59	\$0.00	\$0.00	\$0.00

The table reports household impacts from three gas-to-mileage tax swaps that would, respectively, hold constant the revenue, carbon externality gain, and total externality gain generated by an original 10 cent gas tax.

Table 4: Summary of Aggregate Policy Impacts

	Rev equiv	CO2 equiv	Tot equiv
Gains ($ millions)	$260.81	$183.09	$820.37
Pct. losers	0.43	0.43	0.36

The table reports the aggregate gains (the sum of household-level burdens and externality gains, summed across all households) from the three gas-to-mileage tax swaps and the percent of households that are initial losers under each swap.

5.2 Robustness to elasticity assumptions

For robustness, I also calculate equivalent mileage taxes using heterogeneous, MPG quartile-specific estimates of the VMT elasticity from Knittel and Sandler (2010). These estimates range from -0.625 for the bottom MPG quartile to -0.288 for the top MPG quartile. I use these estimates for both the VMT and the gas elasticity, since I am unaware of existing MPG quartile-specific estimates of the gas elasticity. The resulting revenue, CO2 externality gain, and total externality gain equivalent mileage taxes are $0.004864/mile, $0.005273/mile, and $0.004869/mile, respectively.

Tables A1 and A2 illustrate that, although mileage taxes calculated using heterogeneous elasticities are within half a cent of mileage taxes calculated using uniform elasticities, the choice of elasticities substantially affects policy impacts. Under the assumption of heterogeneous elasticities, the sign of the average household externality gain is negative for the revenue-equivalent swap and household burdens are much larger for the two externality-equivalent swaps. Although these results expose the sensitivity of impacts from a policy to the choice of elasticities, the main takeaway is unchanged: tax swaps generate heterogeneous burdens, making a Pareto improvement unlikely.

5.3 Burdens from tax swaps are highly unpredictable

Table 5 reports results from estimating the following equation using weighted least squares (WLS) and least absolute deviations (LAD):

$$Y_i = \alpha + \beta_1 Size_i + \beta_2 \mathbb{1}(Urban)_i + \psi_i + \phi_i \tag{1}$$

where Y_i represents the burdens resulting from a given policy, $Size$ is the number of individuals in the household, $\mathbb{1}(Urban)_i$ is an indicator for whether the household is located in an urban area, ψ_i is a state fixed effect and ϕ_i is an income range fixed effect.

These covariates were chosen because households are unlikely to manipulate them in response to a tax and because they are the observable characteristics in the NHTS dataset that a government would be likely to use when determining a transfer scheme. Column three of Table 5 indicates that miles per gallon is nearly impossible to predict with these observables. I verify that, when the transfer scheme consists of the fitted values from these regressions, the Sallee impossibility condition holds for all three swaps. That is, a Pareto improvement is not possible.

Table 6 reports results from a lasso regression of the difference in burdens from a revenue-equivalent tax swap and the same regressors as in Table 5. The penalty parameter is selected using five-fold cross validation on 80 percent of the data with 20 candidate parameters. The training data used to estimate coefficients and the test data used to predict burdens are the same for the WLS and LAD regressions as for the lasso model. As such, the r-squared and least absolute deviation values from all three models are directly comparable. Using lasso does not improve predictability. Although not shown, the same finding holds for the other mileage-based reforms.

Table 5: Predictability of Burdens with WLS and LAD

	Init gas	Rev equiv	CO2 equiv	Total equiv	Supplemental
<u>WLS</u>					
Avg. abs. error	\$57.97	\$15.85	\$15.84	\$16.6	\$643.92
R^2	0.196	0.014	0.013	0.029	0.21
<u>LAD</u>					
Avg. abs. error	\$55.8	\$15.41	\$15.43	\$15.86	\$625.56
R^2	0.17	0.009	0.009	0.016	0.185

The table reports the average absolute error and R^2 from estimating equation (1) using weighted least squares and least absolute deviations. Each column represents a regression where the dependent variable is the burden from a particular policy: the initial 10 cent gas tax, the three gas-to-mileage tax swaps, and the optimal uniform supplemental mileage tax.

Table 6: Predictability of Burdens with Lasso for Revenue-Equivalent Tax Swap

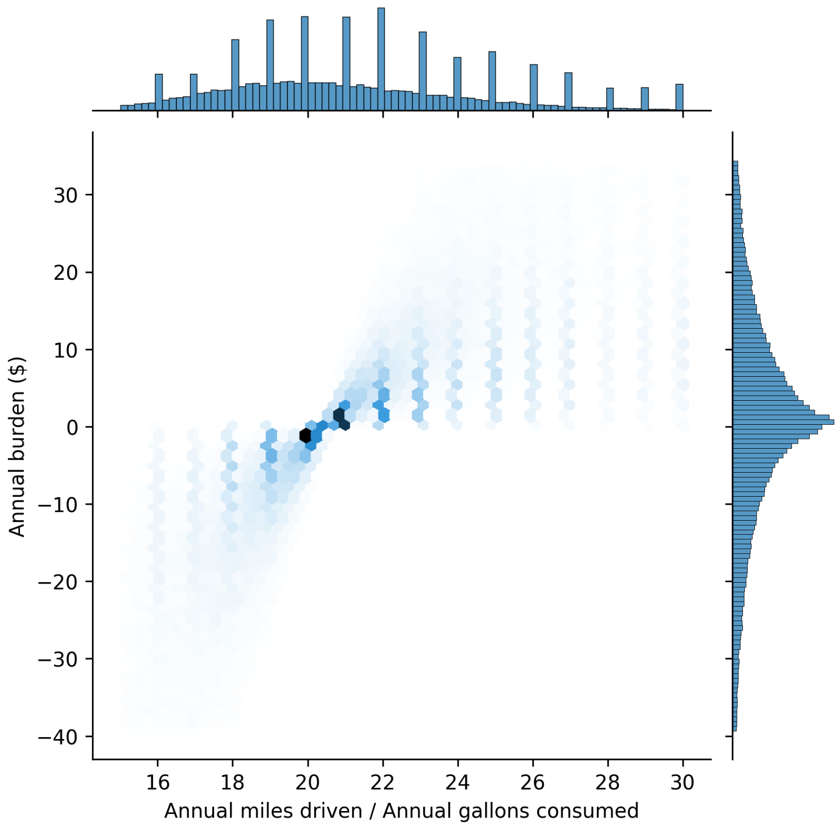
	Rev equiv
WLS	
Avg. abs. error	\$15.85
R^2	0.014
Lasso	
Avg. abs. error	\$15.73
R^2	0.014
Vars. Supplied	65
Vars. Selected	54

The table reports the average absolute error and R^2 from estimating equation (1) with burdens from the revenue-equivalent tax swap as the dependent variable using weighted least squares (reproduced from Table 5) and from running a Lasso regression on the same right-hand side variables.

Per the discussion in Section 2, the poor predictability of burdens from tax swaps relative to burdens from the initial gas tax must be explained by an inability to predict fuel economy with the observable covariates. Indeed, WLS estimates for an alternate specification of equation (1) that includes household fuel economy as a covariate yields an average absolute error of \$11.65 and an R^2 of 0.37 - a significant improvement over the baseline specification. Still, to be able to predict burdens well enough to compensate losers, a policymaker would ideally want access to panel data on historical household consumption.

Figure 2 illustrates the per-mile effect of fuel economy, as well as the scaling effect of mileage, on burdens. The per-mile effect is reflected in the fact that households with an MPG below roughly 20 have negative burdens and those with an MPG above 20 have positive burdens ($\frac{\$0.10}{\text{gal}} / \frac{\$0.0049}{\text{mile}} \approx 20$ miles per gallon). The scaling effect is reflected in the fact that, within each fuel economy band, households have differential burdens. The households with the largest burdens in absolute value are those who drive the most; these households trace out a downward-sloping diagonal line. The households with zero burdens are those who don't drive; these households trace out a horizontal line at $y = 0$.

Figure 2: Household-level Gains from Revenue-Equivalent Tax Swap by Fuel Economy



The figure reports the relationship between calculated household-level burdens and household fuel economy as reported in the NHTS dataset. Hexagon shade represents the number of observations in that region (with darker hexagons corresponding to more observations). The observed distributions of burdens and fuel economy are shown along the sides of the figure, with the bottom and top five percent omitted for visual clarity. The bunching at certain fuel economies is due to the fact that vehicle-level fuel economy is reported as an integer in the data and many househoulds have only one vehicle.

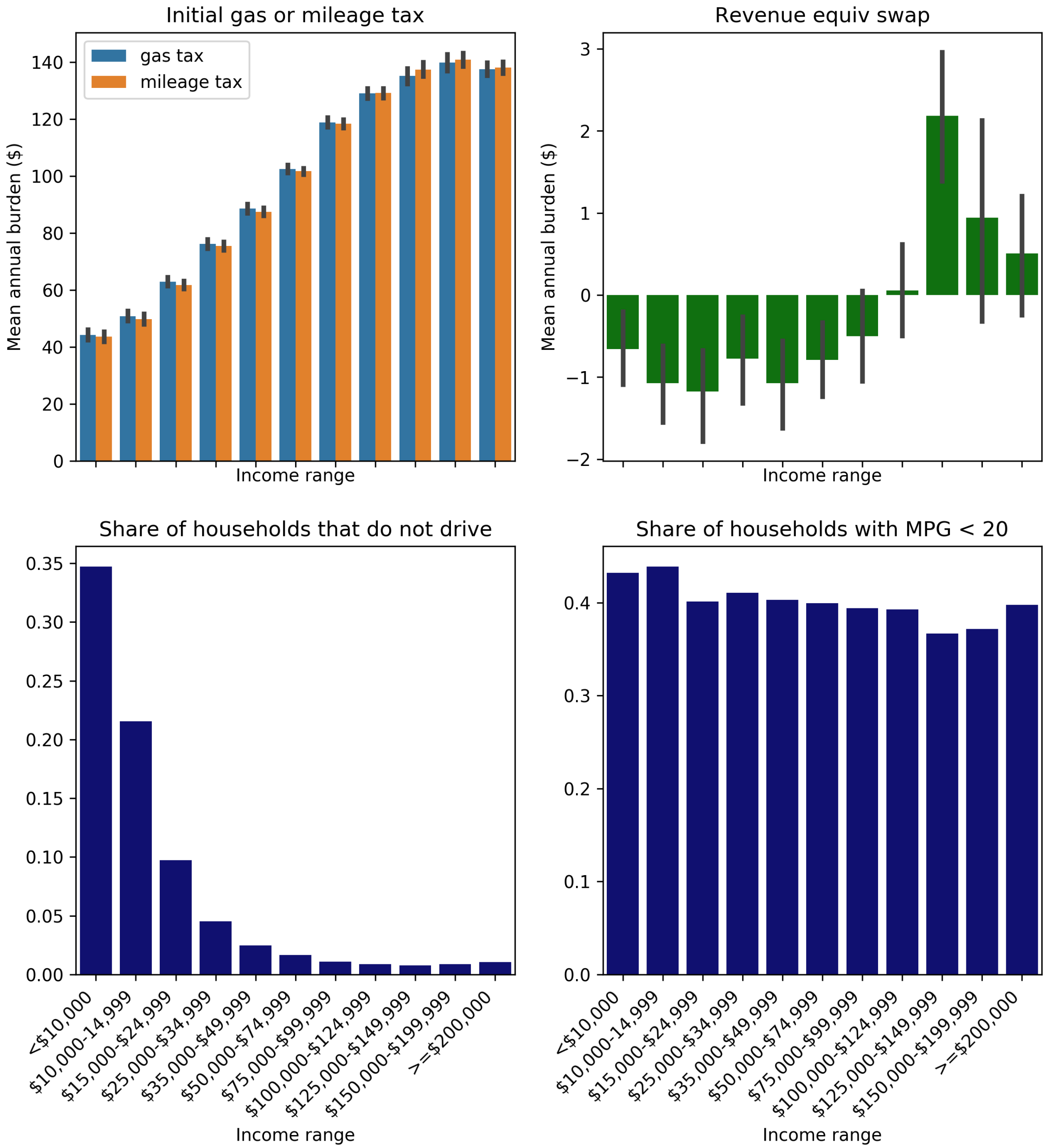
5.4 A revenue-equivalent tax swap is not regressive

Externality-correcting policies are often opposed on the basis that they are regressive. Figure 3 compares the burden by income group of the different policies considered. The upper left and bottom right quadrants illustrate that an initial gas, an initial mileage tax, and a supplemental mileage tax are all regressive. For example, those in the highest income bracket earn at least 20 times as much as those in the lowest income bracket yet have a mean burden only three times larger.

In contrast, the upper-right quadrant illustrates that the revenue-equivalent swap is not regressive. On average, low-income households benefit marginally from the swap and high-income households are marginally burdened by the swap. Again, these quantities would scale with the size of the initial gas tax. The two externality gain-equivalent swaps, not shown in the figure, are both regressive in the sense that burden reductions are smaller for lower income brackets.

The bottom panels of Figure 3 clarify the two key mechanisms that make the revenue-equivalent swap not regressive. As mentioned above, households rendered losers by the swap on a cost-per-mile basis are those with a household-level MPG lower than 20. The share of such households is uniform across income groups. Meanwhile, households that do not drive at all benefit from the swap because they receive a positive average externality gain (by construction of the infinitesimal tax) without paying anything. A much larger share of households in low-income brackets do not drive than in high-income brackets.

Figure 3: Mean Burden and Driving Characteristics by Income Bracket

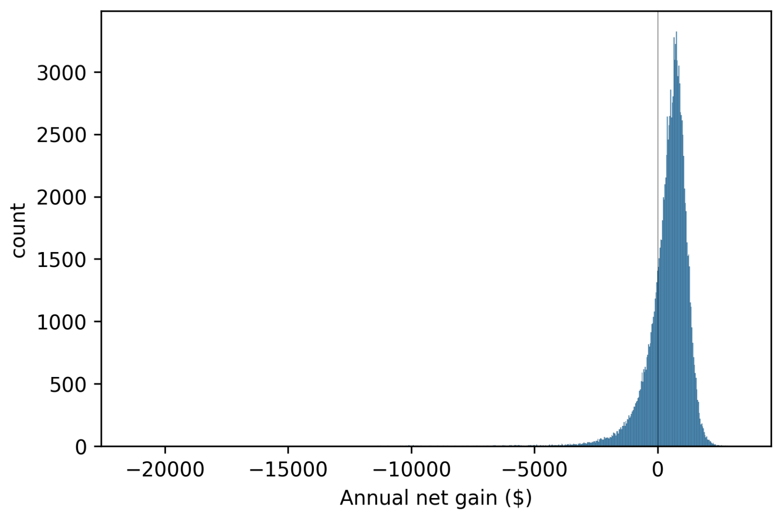


The upper panels of the figure report household-level burdens among different income range groups for an initial gas or mileage tax (left) and for a revenue-equivalent gas-to-mileage tax swap (right). The bottom panels report driving characteristics of households in different income range groups.

5.5 Even after compensation, the optimal uniform supplemental mileage tax creates losers

Under the assumptions in Section 3.3, the optimal uniform mileage tax to be added to a 10 cent per gallon gas tax is \$0.065/mile. Predictability of burdens from this tax is similar to that of the initial 10 cent gas tax considered in Sallee (2019). Since the supplemental mileage tax is the only reform I consider that generates revenue, for completeness I follow Sallee (2019) in documenting the distribution of gains following a transfer. Figure 3 shows results, where the transfer considered consists of the fitted values from the WLS regression of burdens on the covariates. Similar to the finding in that paper, the impossibility condition applies to this reform - a Pareto improvement is not possible. 80 percent of households are initial losers and 23 percent remain losers after the transfer.

Figure 4: Distribution of Post-Transfer Household Net Gains



The figure reports the distribution of household-level net gains - which are the sum of a household's burden, average externality gain, and compensating transfer - resulting from a policy that supplements the initial 10 cent gas tax with the optimal uniform mileage tax.

6 Conclusion

This paper follows the approach of Sallee (2019) to analyze the equity implications of mileage-based reforms to a gas tax, emphasizing policies that replace a gas tax with a mileage tax. The key finding is that compensating losers from such policies is not possible if the transfer scheme is only conditioned on basic demographic and geographic covariates. In the absence of compensation, such a reform benefits households with low fuel economy and harms households with high fuel economy. In the case of a revenue-equivalent mileage tax that replaces a 10 cent gas tax, the critical point is a fuel economy of 20 miles per gallon.

Given that externalities from driving depend significantly on where and how a vehicle is driven, one might ask how this critical point changes for reforms wherein the mileage tax is differentiated based on characteristics of the miles being driven. In principle, vehicle-level taxes on driving could target specific driving externalities extremely precisely if the information that vehicles record on fuel consumption and driving speeds, acceleration, location, and other conditions were made available. However, it is more likely that a mileage tax would be differentiated on the basis of vehicle registration location or fuel economy rating. Either such tax would likely yield more nuanced relationships between household burdens, fuel economy, and mileage. Exploring how mileage tax differentiation affects burdens and compensation of losers is an important area for future research.

Future work should explore equilibrium effects associated with gas-to-mileage tax swaps. Replacing a gas tax with a mileage tax may work to lower fleet-wide fuel economy, but this effect is likely mitigated by the fact that households with high fuel economy (at least those with electric vehicles, i.e. a high MPG-e) tend to drive less (Davis, 2019). Thus, the extent of fuel economy "backslide" that a tax swap would induce, and thereby change the elasticities needed for welfare analysis, is an empirical question.

Another area for future research concerns how the burdens from a tax swap would interact with other vehicle policies. Corporate Average Fuel Economy Standards implicitly subsidize light trucks. To the extent that a mileage tax exacerbates this distortion by benefiting households with a fuel economy lower than 20 miles per gallon, which roughly corresponds to the fuel economy cutoff between cars and light trucks, a seemingly efficient tax swap may actually reduce welfare.

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7 Appendix

Table A1: Summary of Household-Level Policy Impacts Using Heterogeneous Elasticities

	Rev equiv		CO2 equiv		Tot equiv	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Change in gallons	1	7	0	6	1	7
Change in miles	1	115	-30	117	0	115
Gallons consumed	984	1,038	982	1,037	984	1,038
Miles driven	20,202	19,871	20,170	19,839	20,201	19,871
Burden	-\$0.07	\$30.42	\$8.18	\$30.80	\$0.02	\$30.41
Revenue	\$0.00	\$29.81	\$8.08	\$30.21	\$0.09	\$29.81
Avg CO2 ext. gain	-\$0.50	\$0.00	\$0.00	\$0.00	-\$0.49	\$0.00
Avg total ext. gain	-\$0.03	\$0.00	\$2.43	\$0.00	\$0.00	\$0.00

The table is a reproduction of Table 3 using heterogeneous, MPG quartile-specific gas and VMT elasticities instead of a uniform elasticities.

Table A2: Summary of Aggregate Policy Impacts Using Heterogeneous Elasticities

	Rev equiv	CO2 equiv	Tot equiv
Gains (\$ millions)	\$5.26	-\$679.19	-\$2.02
Pct. losers	0.57	0.57	0.52

The table is a reproduction of Table 4 using heterogeneous, MPG quartile-specific gas and VMT elasticities instead of a uniform elasticities.