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

Edward L. Glaeser, Harvard University and NBER
Caitlin S. Gorback, University of Texas, McCombs School of Business
James M. Poterba, Massachusetts Institute of Technology and NBER

NBER SI EEE
July 2022

Distributional Consequences of VMTs vs. Gas Taxes

Environmental Pigouvian tax options: gas taxes, VMTs, carbon taxes

–Distributional concerns about these taxes often key impediments to adoption–

This paper: Study impact of VMTs as the vehicle fleet greens:

1. Document current distribution of fuel tax burdens and impact of substituing a revenue neutral VMT
2. Repeat analysis when EV/HV share of vehicle fleet is $\frac{1}{3}^{rd}$, with higher penetration at higher incomes
3. Analyze distributional impact of commercial VMT using input-output tables to compute pass-through patterns

Literature Review

1. Distributional Impacts in User Fees and Externalities
    - Holmes (1976); Kasten and Sammartino (1988); Poterba (1991); Chernick and Reschovsky (1997); Metcalf (1999, 2022); Grainger & Kolstad (2009); Levinson (2019); Banzhaf, Ma and Timmins (2019)
2. Implications of VMT Adoption
    - Davis and Sallee (2020); Langer, Maheshri and Winston (2017); van Dender (2019)
3. Changing Vehicle Fleet Composition
    - Fox (2020); Burlig, Bushnell, Rapson and Wolfram (2021)
4. Infrastructure Funding
    - Brooks and Liscow (2019); Mehrotra, Turner and Uribe (2021)

How to Measure Distributional Burdens

We use a good or service's, c, share of household i's total expenditure, $\frac{Exp_{ci}}{TotalExp_i}$, as our primary measure of tax burden, as in Poterba (1991)

- Many studies use $\frac{Exp_{ci}}{Income_i}$
  - Chernick and Reschovsky (1997), Metcalf (1999, 2022), Levinson (2019)
- $Income_i$ quite noisy at top & bottom of distribution
- Expenditure better captures "permanent income" view

Regressivity: Analyze how $\frac{Exp_{ci}}{TotalExp_i}$ changes over expenditure distribution

Table

Data Sources

Main household-level analysis

1. **CEX (2000-2019):** expenditure on gasoline, other goods and services
2. **NHTS (2001, 2009, 2017):** vehicle characteristics, driving behavior
3. **BEA Total Requirements Tables (2012):** trucking services required by final goods/services

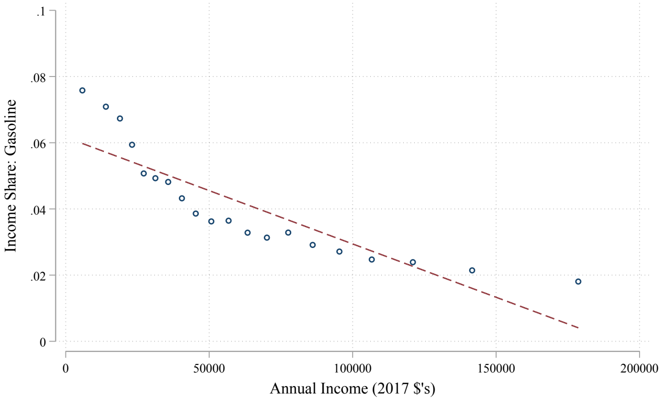
Additional data from:

- Brookings-Urban Tax Policy Center: Gasoline taxes by year and state
- Energy Information Administration: Annual retail gasoline prices
- BTS-ORNL: national vehicle sales, registrations, by fuel type
- American Transportation Research Institute: commercial MPG, trucking costs/mile

NHTS Expenditure

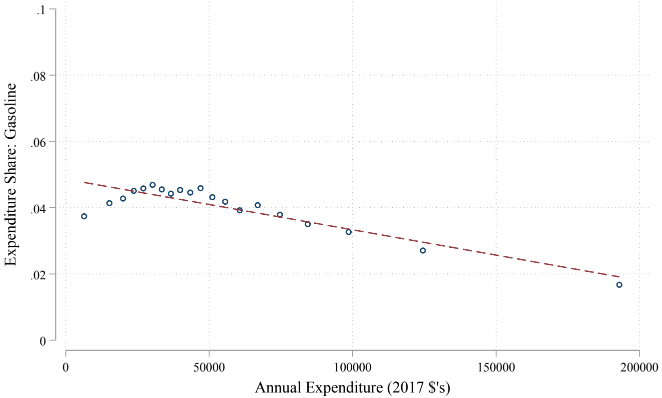
Gasoline Burden measured with $\frac{Exp_{ci}}{Income_i}$

Standard distributional analysis, as in Metcalf (2022):



Income trimmed at 5th and 95th percentiles, for positive values.

Gasoline Burden measured with $\frac{Exp_{ci}}{TotalExp_i}$

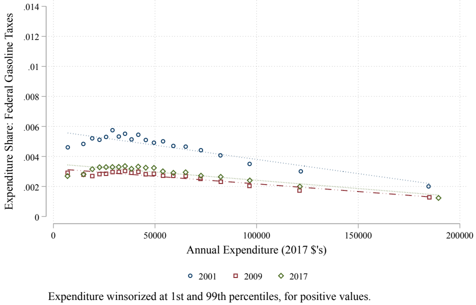


Expenditure winsorized at 1st and 99th percentiles, for positive values.

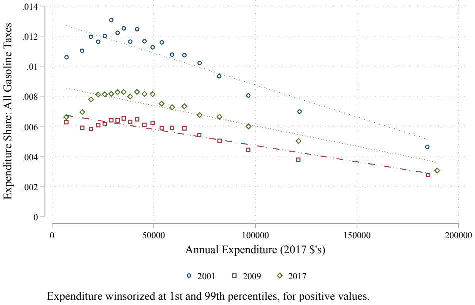
Expenditure/Income Ratios

Federal Gas Tax Burden, measured with $\frac{Exp_{ci}}{TotalExp_i}$

Level shift down between 2001 & 2017: decline in tax's real value



(a) Federal Taxes



(b) Federal + State Taxes

Engel Curve for Miles Driven and MPG

– $TaxBurden = \tau \times gal = \tau \times Miles \times \frac{gal}{mile} = \frac{\tau \times miles}{MPG}$

– Distributional burden depends on how miles and MPG vary across households

– Rich can switch technologies: $\downarrow$ emissions, $\uparrow$ regressivity

1977 NPTS

- MPG $\uparrow$, MPV $\uparrow$ income
- $MPG^{high} = 17,\ MPG^{low} = 20$
- $MPV^{high} = 12k,\ MPV^{low} = 9k$

2017 NHTS

- MPG $\downarrow$, MPV $\uparrow$ income
- $MPG^{high} = 23,\ MPG^{low} = 21$
- $MPV^{high} = 12k,\ MPV^{low} = 10k$

Model

Engel Curve for Miles Driven and MPG

- $TaxBurden = \tau \times Miles \times \frac{gal}{mile} = \frac{\tau \times miles}{MPG}$
- Distributional burden depends on how miles and MPR vary across households
- Rich can switch technologies: $\downarrow$ emissions, $\uparrow$ regressivity

1977 NPTS

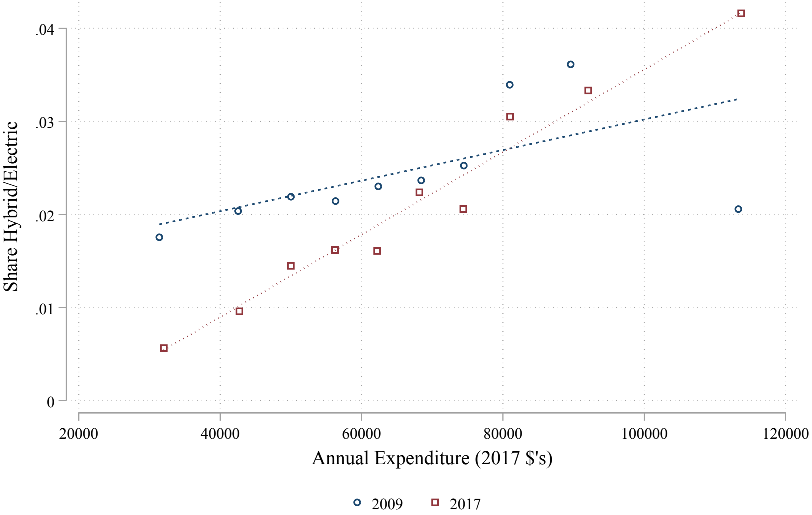
- MPG $\uparrow$, miles $\uparrow$ income
- $MPG^{high} = 17,\ MPG^{low} = 20$
- $MPV^{high} = 12k,\ MPV^{low} = 9k$

2017 NHTS

- MPG $\downarrow$, miles $\uparrow$ income
- $MPG^{high} = 23,\ MPG^{low} = 21$
- $MPV^{high} = 12k,\ MPV^{low} = 10k$

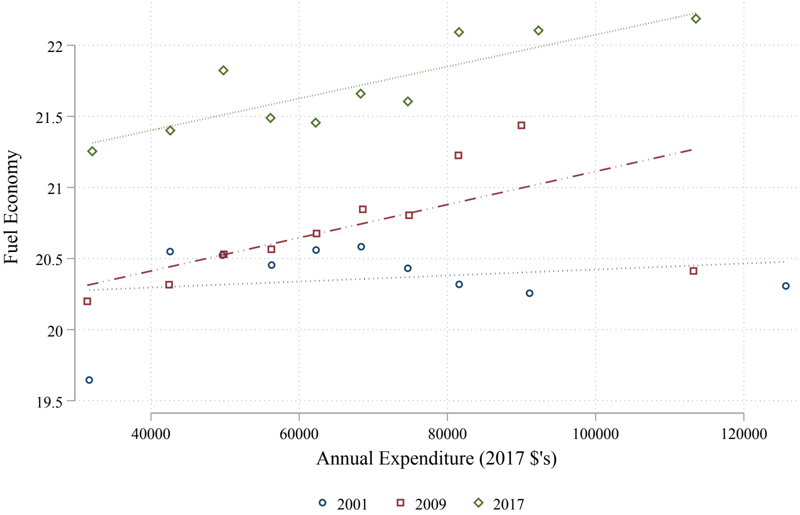
Model

HEV Ownership over Time, by Expenditure



Income

Fuel Economy over Time, by Expenditure



Household Driving Responses to VMT vs. Gasoline Tax

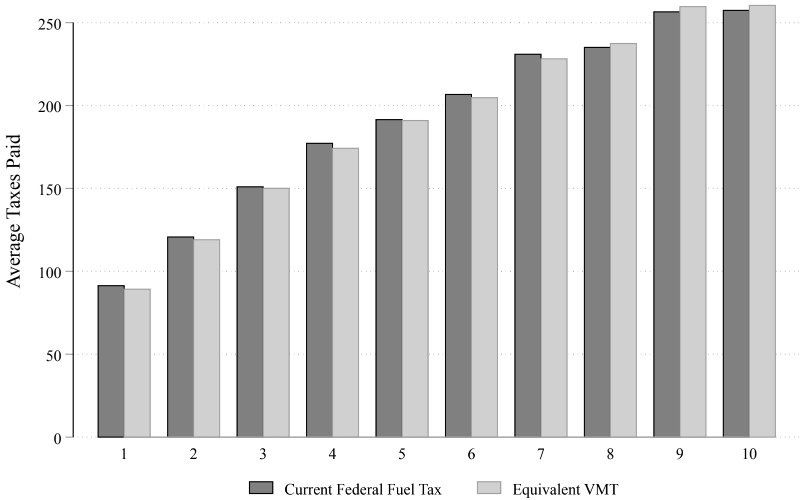
Assume households have quasilinear separable utilities w/ power function for miles traveled, T_i:

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

$$T_i^* = T_i \times \left(1 + \frac{t_i - \tau_i}{p_i}\varepsilon_g\right) \tag{2}$$

- Y_i: income
- p_i: per mile price of travel (inclusive of taxes if applicable)
- $\varepsilon_g = \frac{1}{1-\sigma}$: price elasticity of gasoline demand, -0.31 (Levin, Lewis and Wolak (2017))
- τ_i: current effective gasoline tax per mile (depends on vehicle's fuel efficiency)

Comparing Equal-Revenue VMT to Current Gas Tax



What happens with increased HEV Penetration?

Current HEV penetration doesn't change distribution of tax burden:

- 2017 HEV share: 2%
- 2017 HEV share, highest expenditure decile: 5%

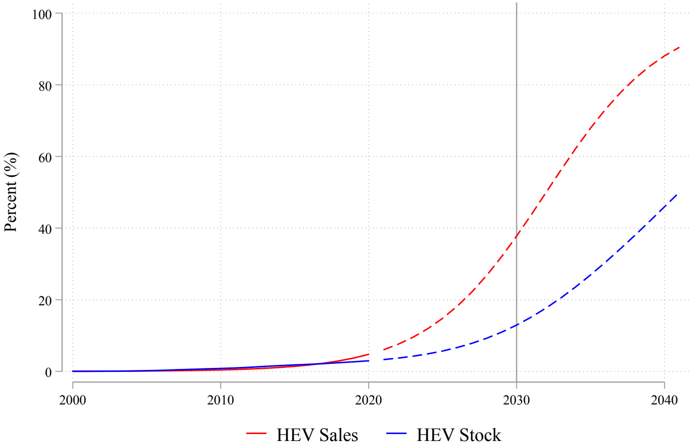
We compare the distributional burden of gas tax and VMT in a future economy in which:

- HEV adoption remains highest among high income/expenditure groups
- All other characteristics of households/vehicles remain the same

Adoption Forecasts: Stock Lags Sales

Sales forecasts by 2030:

- Deloitte: 27% HEV
- Ford: 40% EV
- KPMG: 52% EV



How we forecast

Projecting Distribution of HEV Ownership when HEVs $\sim \frac{1}{3}^{rd}$ of Fleet

We observe 229,324 surveyed vehicles in the 2017 NHTS.

To create our forecast, we draw on preojections for total vehicle fleet growth:

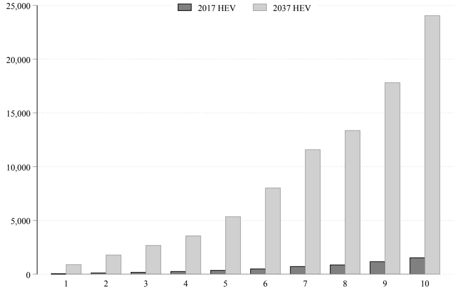
- vehicle type $\in \{HEV, Gas\}$
- expenditure decile, d

Overview of algorithm:

1. Each current vehicle is cloned into 1.15 vehicles
2. Allocate HEV's across deciles based on fraction of HEV's in each decile today
3. Yields how many gas vehicles to add/take away, how many HEV's to add to each decile
4. Randomly replace gas vehicles with HEV's until we achieve the target mix

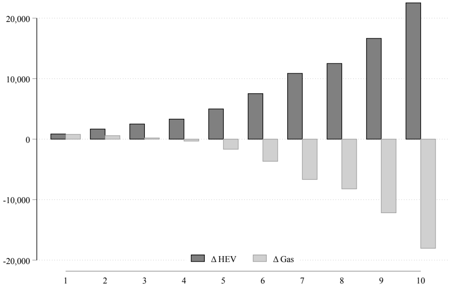
Changes in Vehicle Ownership Patterns: Future Scenario vs. 2017

47% of HEVs owned by top 2 deciles



(a) HEV Stock

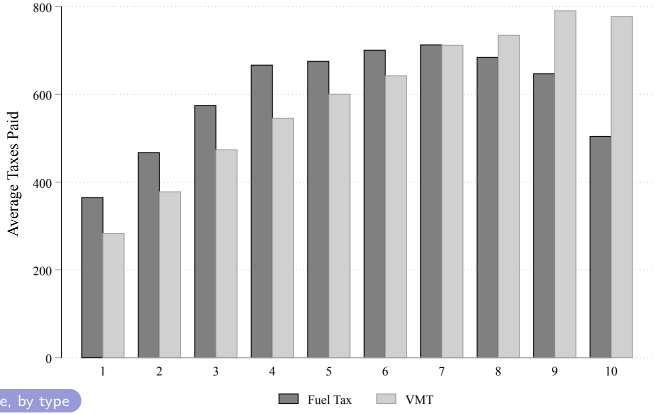
Results sensitive to low-cost EV entry



(b) Vehicle Changes

Comparing the VMT vs. Gasoline Tax in 2037

- Fuel taxes paid ↓ for 30% highest expenditure hholds
- VMT ↑ taxes for high deciles, while ↓ for low deciles



Without behavioral response, by type

Towards a Commercial VMT on Trucking

There are currently no personal VMTs in the U.S., but there are commercial:

- 4 states have adopted commercial VMTs (cVMTs)
- NM, NY and OR range by truck weight and axle count ($0.01-0.29/mile)
- KY set a flat cVMT at $0.03/mile

What is the distribution of adding a federal cVMT at $0.03/mile?

- Commercial vehicle fleet not greening as quickly as personal fleet
- $\therefore$ we add cVMT top of the current diesel tax

Federal Diesel Tax's Share of Household Expenditure

We use data from BEA's Total Requirements Table (TRT) and CEX:

1. \$'s commercial trucking $\rightarrow$ \$1 of commodity c: γ_c
2. Federal diesel tax of \$0.24/gallon, mean MPG of 6.4 $\implies$ diesel tax of \$0.038/mile
3. This is 2.3% of marginal cost of a mile of trucking (ATRI, 2020)

Calculate household i's expenditure on diesel taxes, e_i^{diesel}, as:

$$e_i^{diesel} = 0.023 \times \sum_c e_{ic} \times \gamma_c$$

– Indirect household expenditures of $\sim 0.6\%$ on trucking which generates a very low exposure to diesel taxes $\sim 0.014\%$ $\implies$ *Stay tuned!*

Summary and Conclusion

User fees need to adjust with technology:

- Regressivity of fuel taxes less pronounced when ranking by expenditure
- Greening of the fleet potentially exacerbates regressivity
- Tax base can be broadened by moving from *fuel* tax to *mileage* tax
- cVMTs have potential to raise revenues for highway maintenance, but incidence depends on the passthrough to consumers

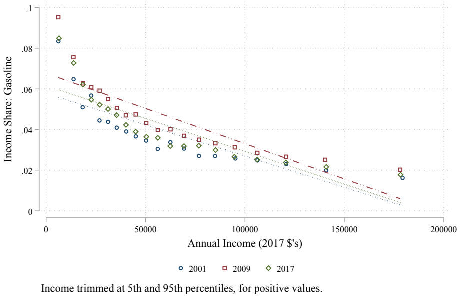
Fuel taxes are part of a system of taxes: combine to lower regressivity:

- Gas tax + other transfers
- VMT+ Carbon tax (carbon tax not very regressive, (Granger & Kolstad, 2009))

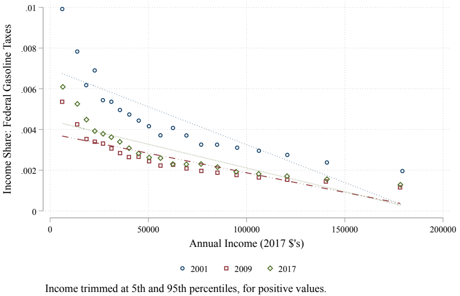
Thanks!

caitlin.gorback@mccombs.utexas.edu

Regressivity in Gasoline Expenditure - by Income



(a) Gasoline

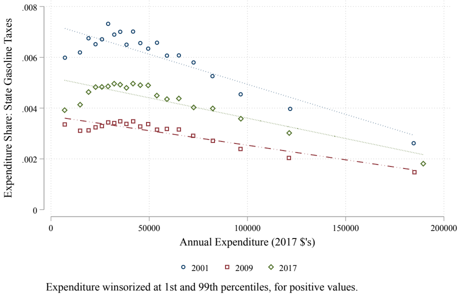


(b) Federal Taxes

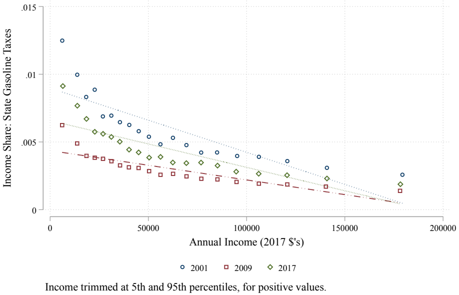
Notes: Data from the CEX waves from 2001, 2009 and 2017. All panels plot binned scatters and their associated linear fits. Panel (a) shows the average income share devoted to gasoline expenditures by income ventile. Panel (b) plots the income share devoted to federal fuel taxes expenditures. Income is 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.

Back

Regressivity in Gasoline Expenditure - State Taxes



(a) Expenditure Share, by Expenditure

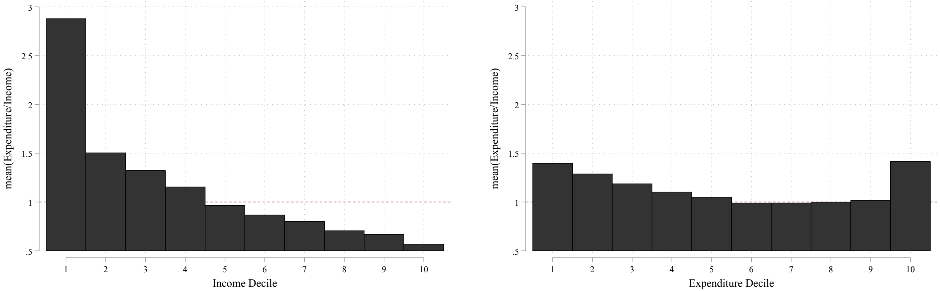


(b) Income Share, by Income

Notes: Data from the CEX waves from 2001, 2009 and 2017. All panels plot binned scatters and their associated linear fits. Panel (a) shows the average income share devoted to state gasoline taxes by income ventile. Panel (b) plots the expenditure share devoted to state fuel taxes by expenditure ventile. Income is trimmed at the 5^{th} and 95^{th} percentiles prior to binning, for positive values of income. 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

Back

$\frac{Exp_{ci}}{TotalExp_i}$ 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.

Back

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. Back

Constructing Expenditure in the NHTS

Impute expenditure in NHTS using CEX data and shared covariates:

$$E_{it}^{CEX} = f(I_{it}^{CEX}) + \Gamma X_{it} + \gamma_s + \delta_t + \varepsilon_{it} \tag{3}$$

$$\hat{E}_{it}^{NHTS} = \hat{f}(I_{it}^{NHTS}) + \hat{\Gamma} X_{it} + \hat{\gamma}_s + \hat{\delta}_t \tag{4}$$

- i indexes households, t indexes years, s indexes states
- X_{it}: suite of socioeconomic and demographic chars., and interactions
- $f(.)$: fourth order polynomial

Expenditure in the NHTS: evaluating model fit

$\widehat{Expenditure} - Income$ profile has similar shape across both datasets

	CEX		NHTS
	E_i^{CEX}	$\widehat{E}_i^{CEX}$	$\widehat{E}_i^{NHTS}$
Inc_i	0.31	0.41	
	(0.003)	(0.000)	
$\widehat{Inc}_i$			0.40
			(0.001)
Constant	8,625	25,542	32,195
	(1879)	(17)	(74)
Covariates	yes	no	no
R^2	0.36	0.90	0.47
N	644,240	644,240	312,204

1. Full CEX specification
2. $\widehat{Expenditure} - Income$ Profile (CEX)
3. $\widehat{Expenditure} - Income$ Profile (NHTS)

Back

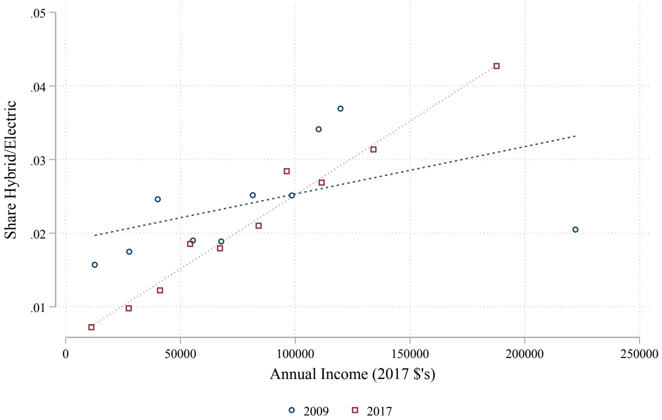
Model of Technology Adoption: Intuition

To explain how the rich went from Cadillacs to Teslas, we build a model:

- For two technologies, $i \in 0, 1$, welfare depends on
  - the energy use per mile, g_i
  - the fixed cost of purchase, k_i
  - the pleasantess of the ride, α_i
- Yielding the following proposition:
  (a) Everyone drives same technology vehicles
  (b) Poor households drive Civics^1, rich households drive Cadillacs^0
  (c) Poor households drive Civics^0, rich households drive Teslas^1
- We can characterize two driving eras
  1. 1970's and 1980's: world (b)
  2. Today: world (c)

$\Longrightarrow$ As rich continue to adopt HEVs, the fuel tax becomes highly regressive Back

HEV Ownership over Time, by Income



Back

Overview of Fleet Forecast

We construct a forecast of the vehicle fleet once it becomes $\frac{1}{3}^{rd}$ HEV[1]:

- We assume an HEV adoption curve: $SalesShare_t^{HEV} = \dfrac{1}{1 + e^{-0.25(t-2032)}}$
- Linearly predict vehicle sales and registrations
- With sales, registrations, and $SalesShare_t^{HEV}$, we calculate vehicle retirement

Year	Registered Vehicles[1]	HEVs	Gas Vehicles
2017	248,926	5,387	243,539
2037	286,314	97,794	188,521
	15% growth	HEVs grow from 2% to 34% of stock	

Back

[1] It takes 15 years to get to 34% HEV stock (2037); this same year sales are forecasted to be 80% HEV.
[2] All vehicle counts in millions.

Mean Taxes Paid by Expenditure Decile: Fully Funding HTF with VMT

Gasoline Vehicles			
	Baseline ($'s)	Paid (no ΔMiles) ($'s)	Paid (ΔMiles) ($'s)
1	91	291	276
5	192	539	511
10	256	450	427

Hybrid Vehicles			
	Baseline ($'s)	Paid (no ΔMiles) ($'s)	Paid (ΔMiles) ($'s)
1	29	221	176
5	54	439	349
10	70	529	421

Electric Vehicles			
	Baseline ($'s)	Paid (no ΔMiles) ($'s)	Paid (ΔMiles) ($'s)
1	0	244	214
5	0	355	311
10	0	452	397

Back