Gasoline Taxes and Consumer Behavior

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Overview

- This paper studies the effect of gasoline taxes on gasoline consumption, vehicle miles traveled and vehicle purchase decisions.
- Two major policies dealing with externalities from gasoline consumption: fuel economy standards and gas tax. U.S. has primarily favored standards
- Two explanations: costs of standards are hidden; gasoline taxes have a very small effect on gasoline consumption
- But there is renewed interest in gasoline taxes: Deficit Reduction Committee, Highway Trust Fund Solvency
- How large is the effect of an tax increase on gasoline consumption? What are the implications for the environment, energy security, and fiscal revenue?

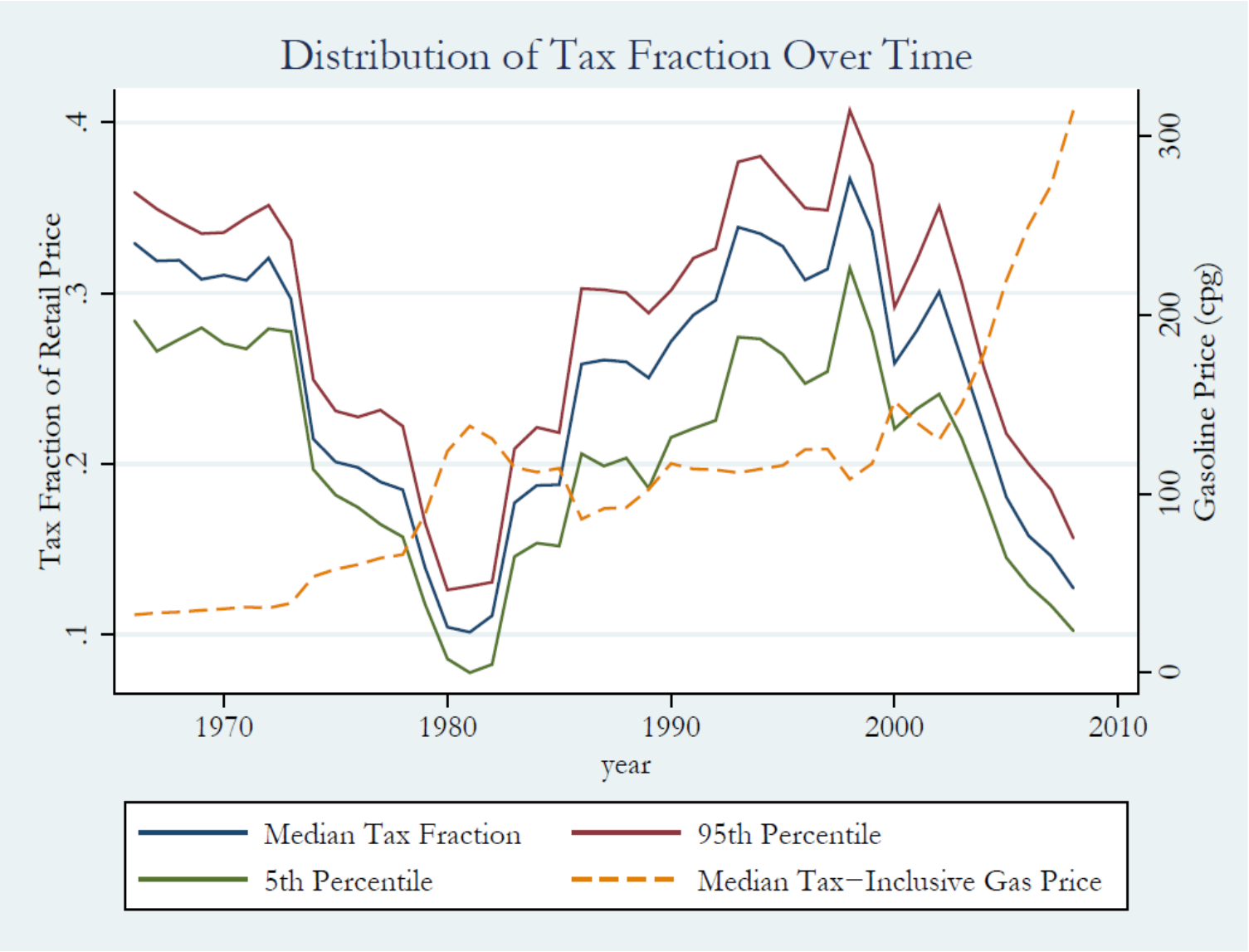
Motivation

- Numerous studies have estimated consumer responses to gas prices (e.g., Small and Van Dender 2007; Hughes, Knittel, and Sperling 2008; Bento et al. 2009; and some of our own work)
- Primarily identify responses based on oil-price driven fluctuations and use gas price elasticities for tax policy analysis
- Because of adjustment costs, consumers may respond more to a (likely permanent) gas tax change than a commensurate change in pre-tax gas price
- By comparison, we examine consumer response gas tax and pre-tax price separately: use variation in taxes across states and over time

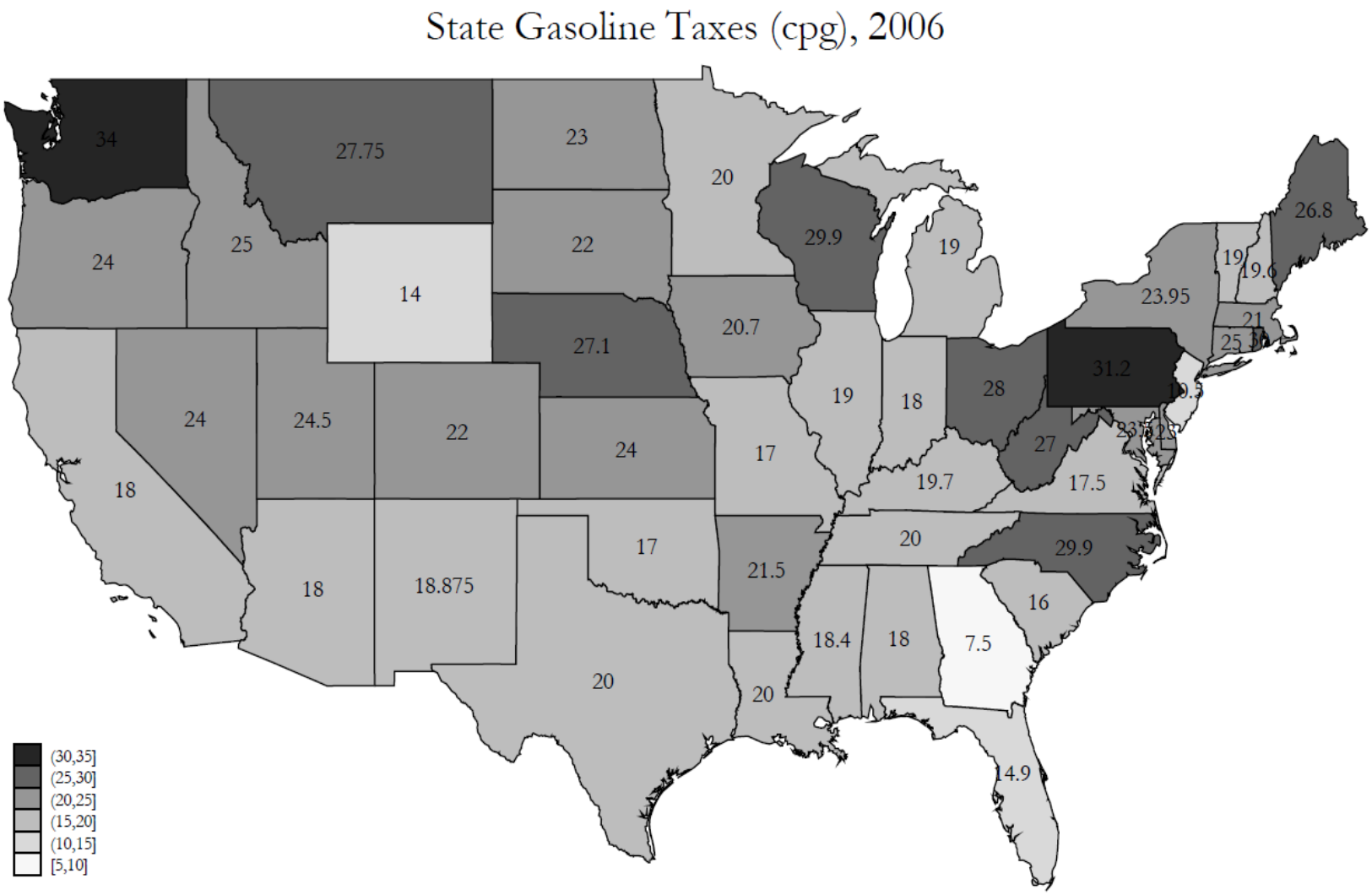
Motivation

- CAFE vs. tax: consumers may undervalue future saving in fuel costs
- Estimate implicit discount rate using the trade-off in vehicle purchases: upfront cost and future fuel costs
- An assumption on consumer expectation of future energy price is usually required (e.g., random walk, Anderson, Kellogg and Sallee 2011)
- We estimate implicit discount rate without relying on the nature of over gas prices.

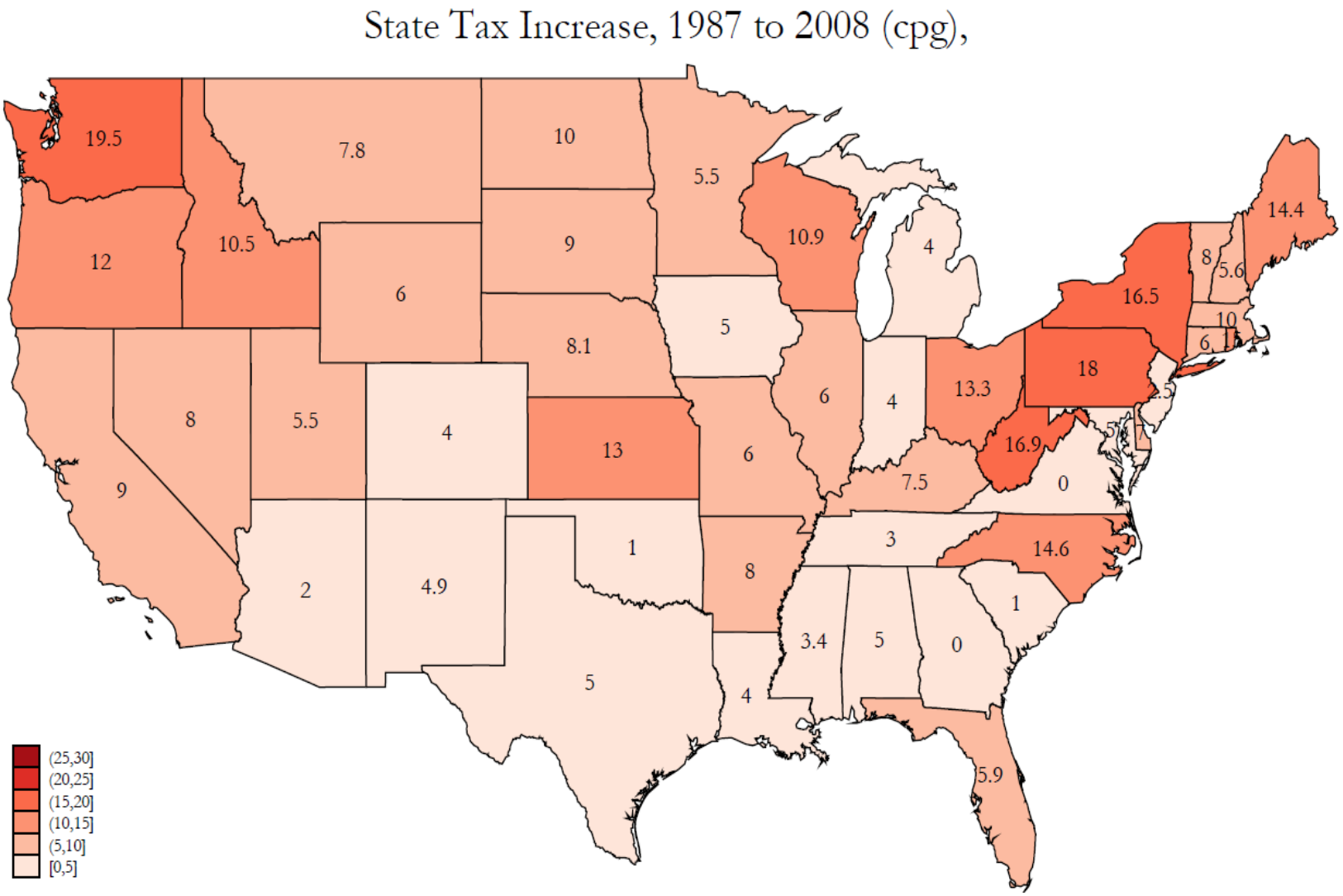
Gas taxes are an important component of gas prices



State Taxes, 2006



State Tax Change, 1987 - 2008



State Tax Changes

- From 1966 - 2008, state tax changed 532 times, 26% of the time.
- Most changes: Nebraska (29), North Carolina (24), Wisconsin (24); Fewest changes: Georgia (2)
- Despite the role of gas taxes, gasoline tax changes are not well predicted by political factors
- Across states, taxes are not strongly correlated with demographics

Aggregate Analysis

- State-level annual panel 1966-2008 (expanding data from Small and Van Dender 2007): total gas consumption, VMT, taxes, tax-inclusive price, demographics
- Examine gas consumption and VMT by allowing taxes and pre-tax prices to enter separately
- We estimate:

$$ln(q_{st}) = \alpha ln(p_{st}) + \beta ln\left(1 + \frac{\tau_{st}}{p_{st}}\right) + \delta_s + \phi_t + x_{st}\gamma + \epsilon_{st}$$

Gasoline Demand: Regression Results

Variables	(1)	(2)	(3)	(4)	(5)
Log(gas price)	-0.052				
	(0.017)				
Log(pre-tax p.)		-0.099	-0.112	-0.087	-0.100
		(0.019)	(0.017)	(0.017)	(0.019)
Log(1 + tax ratio)		-0.287	-0.282	-0.240	-0.300
		(0.042)	(0.040)	(0.038)	(0.042)
	Tax-inclusive gas price	Separate tax & tax-exclusive price	Add controls to (2)	Add quadratic state trends to (2)	Un-weighted

Gasoline Demand: % Δ from 5cpg Increase

Variables	(1)	(2)	(3)	(4)	(5)
Gas price	-0.22				
	(0.07)				
Pre-tax gas price		-0.16	-0.24	-0.23	-0.16
		(0.07)	(0.07)	(0.00)	(0.08)
Gas tax		-1.31	-1.29	-1.12	-1.47
		(0.19)	(0.18)	(0.01)	(0.21)
	Tax-inclusive gas price	Separate tax & tax-exclusive price	Add controls to (2)	Add quadratic state trends to (2)	Un-weighted

VMT: Regression Results

Variables	(1)	(2)	(3)	(4)	(5)
Log(gas price)	-0.026				
	(0.019)				
Log(tax-excl p.)		-0.027	-0.042	-0.022	-0.030
		(0.020)	(0.020)	(0.019)	(0.020)
Log(1 + tax ratio)		-0.033	-0.037	-0.009	-0.050
		(0.047)	(0.046)	(0.043)	(0.046)
	Tax-inclusive gas price	Separate tax & tax-exclusive price	Add controls to (2)	Add quadratic state trends to (2)	Un-weighted

VMT: % Δ from 5cpg Increase

Variables	(1)	(2)	(3)	(4)	(5)
Gas price	-0.11				
	(0.08)				
Pre-tax price		-0.10	-0.18	-0.11	-0.10
		(0.08)	(0.08)	(0.07)	(0.08)
Gas tax		-0.15	-0.17	-0.04	-0.24
		(0.21)	(0.21)	(0.20)	(0.23)
	Tax-inclusive gas price	Separate tax & tax-exclusive price	Add controls to (2)	Add quadratic state trends to (2)	Un-weighted

IV Estimates of Gasoline Demand

	OLS	2SLS
Log(pre-tax price)	-0.125	-0.070
	(0.030)	(0.005)
Log(1 + tax ratio)	-0.321	-0.339
	(0.073)	(0.076)

- Instrument for pre-tax price: price of imported oil (available since 1968) *pre-tax price in 1966
- Instrument for 1 + tax ratio: 1 + tax /oil price
- Identification assumption: initial differences in pre-tax prices in 1966 are not correlated with future unobserved time-varying factors that affect gas consumption and VMT

Additional Analyses

Are state taxes correlated with omitted variables?

- Compare observable demographics in sates with high / low taxes: Not much difference
- Test for the presence of time trends before tax change: No
- Are there similar findings using first-differenced data?: Yes

Do we observe larger responses when states change taxes infrequently?: Yes

Data

- National household travel survey: 1995, 2001, 2009
  - Household level data on vehicle stock, travel behavior, and demographics; merge in fuel economy information
  - Average MPG of recent purchases (during 12 months prior to the survey)
  - VMT based on two odometer readings (months apart), available only in 1995 and 2001 survey
- Tradeoffs compared to aggregate data:
  - Can control for rich demographics
  - Odometer-based VMT, method consistent across all households
  - Limited time series variation in gas taxes; do not observe gasoline consumption

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Household Average MPG of Recent Purchases

	Sample 1 All Purchases	Sample 2 Newer Purchases
% Δ in MPG: 5c $\uparrow$ pre-tax price	0.117	0.123
	(0.050)	(0.072)
% Δ in MPG: 5c $\uparrow$ gas tax	0.798	1.124
	(0.348)	(0.410)
Difference in % Δ	0.682	1.001
	(0.361)	(0.433)
Observations	52,128	30,363

Note: Dependent variable is log(average MPG). Regressors include state, year, month dummies, and household demographics.

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Household VMT from Odometer Readings

% Δ in VMT: 5c $\uparrow$ pre-tax price	-1.312
	(0.448)
% Δ in VMT: 5c $\uparrow$ gas tax	-1.924
	(2.595)
Difference in % Δ	-0.511
	(2.634)
Observations	28,303

Note: Dependent variable is log(Daily VMT). Regressors include state, year, month dummies, and household demographics.

Implicit Discount Rate

- Vehicle purchases response stronger to gasoline taxes than to pre-tax gasoline prices
- This suggests traditional approaches may overstate true implicit discount rate
- Examine this using new vehicle sales data
  - Total sales by vehicle model in each of 22 selected MSAs from 1999-2006
  - Vehicle attributes include average retail prices, vehicle type, weight, horsepower, size

Vehicle Demand

- Multinomial logit demand with market-level data

$$log(s_j/s_0) = \alpha c_j + X_j\beta + \epsilon_j$$

$$\begin{aligned} c_j &= vp_j + \sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{p_t^e * VMT_t}{MPG_j} \\ &= vp_j + \sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{(\tau_t^e + ep_t^e) * VMT_t}{MPG_j} \\ &= vp_j + \frac{\tau}{MPG_j} \sum_{t=1}^{T} \frac{VMT_t}{(1+r)^t} + \frac{ep}{MPG_j} \sum_{t=1}^{T} \frac{VMT_t}{(1+r)^t} \frac{ep_t^e}{ep} \end{aligned}$$

Vehicle Demand

- Estimate the following equation:

$$log(s_j/s_0) = \alpha vp_j + \gamma_1 \frac{\tau}{MPG_j} + \gamma_2 \frac{ep}{MPG_j} + X_j\beta + \epsilon_j$$

- r can be recovered based on $\gamma_1 = \alpha \sum_{t=1}^{T} \frac{VMT_t}{(1+r)^t}$
- Instrument for vehicle price: characteristics of competing vehicles (BLP)
- Instrument for pre-tax gas price: crude oil price * average pre-tax price 1986-1995 at MSAs

Vehicle Demand Results: tax-inclusive gas price

	OLS	2SLS
Vehicle price/Income	-0.088***	-0.520***
Dollars per mile/Income	-19.181***	-16.820***
Own price elasticities	-0.769	-4.537
Implied discount rate	-0.033	0.416

Note: Regressors include MSA dummies*type dummies, year dummies*type dummies, manufacturer dummies*type dummies.

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Vehicle Demand Results: gas tax and pre-tax price

	OLS	2SLS
Vehicle price/Income	-0.088***	-0.522***
Tax $ per mile/Income	-78.702***	-44.396***
Pre-tax $ per mile/Income	-7.671***	-10.477***
Own price elasticities	-0.769	-4.537
Implied discount rate	-0.143	0.109

Note: Regressors include MSA dummies*type dummies, year dummies*type dummies, manufacturer dummies*type dummies.

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Additional Implications

Estimation of gasoline demand elasticity:

- Percent of gas price variation attributable to tax changes vary substantially over time
- Estimates of short-run price elasticity based on total gas price are correlated with magnitude/frequency of tax changes

Fiscal Impacts:

- Effect of 5 cpg federal tax increase based on gas price elasticity: 26.9% increase in revenues ($ 6.82 billion)
- Estimate based on tax-elasticity: 25.5% increase in revenues ($ 6.47 billion)

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Conclusion

- Main findings:
  - Gas taxes have a larger short-run effect on gas consumption than pre-tax prices
  - The differential effect is mainly through vehicle purchase decisions but not VMT decisions
- Implications:
  - Taxes may be more effective than we thought at reducing gasoline consumption (5 times more)
  - Taxes may be (slightly) less effective at generating revenue
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