Consumer demand and environmental taxation: Evidence from gasoline

Econ 3391

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Why do we tax gasoline?

To evaluate the effects of a gas tax, we need to know the demand elasticity

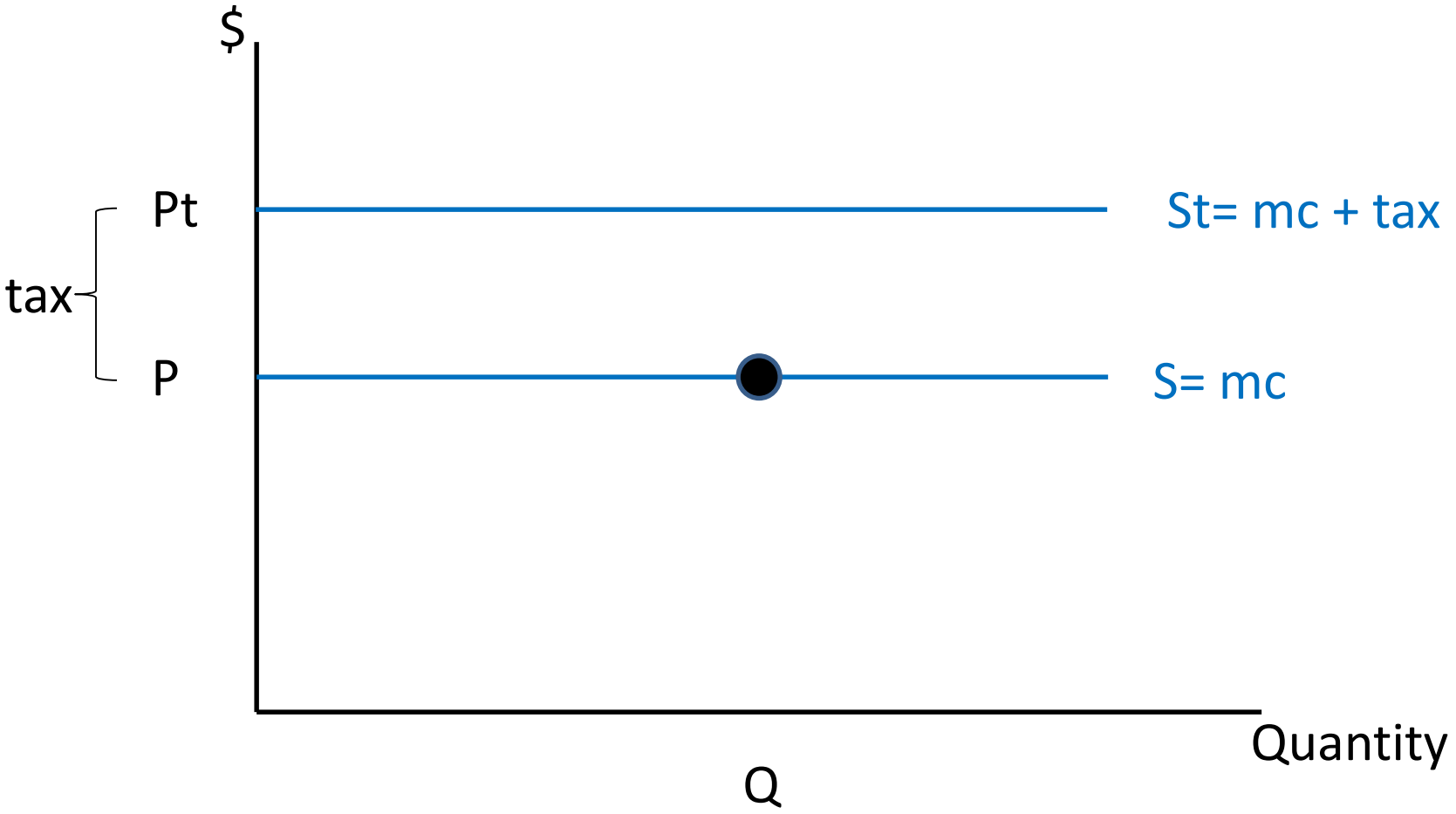
- Say we want to reduce gasoline demand by 10% over the next four years. What tax gets us there?

- **Incidence**: Who bears the burden of gas taxes, consumers or producers?

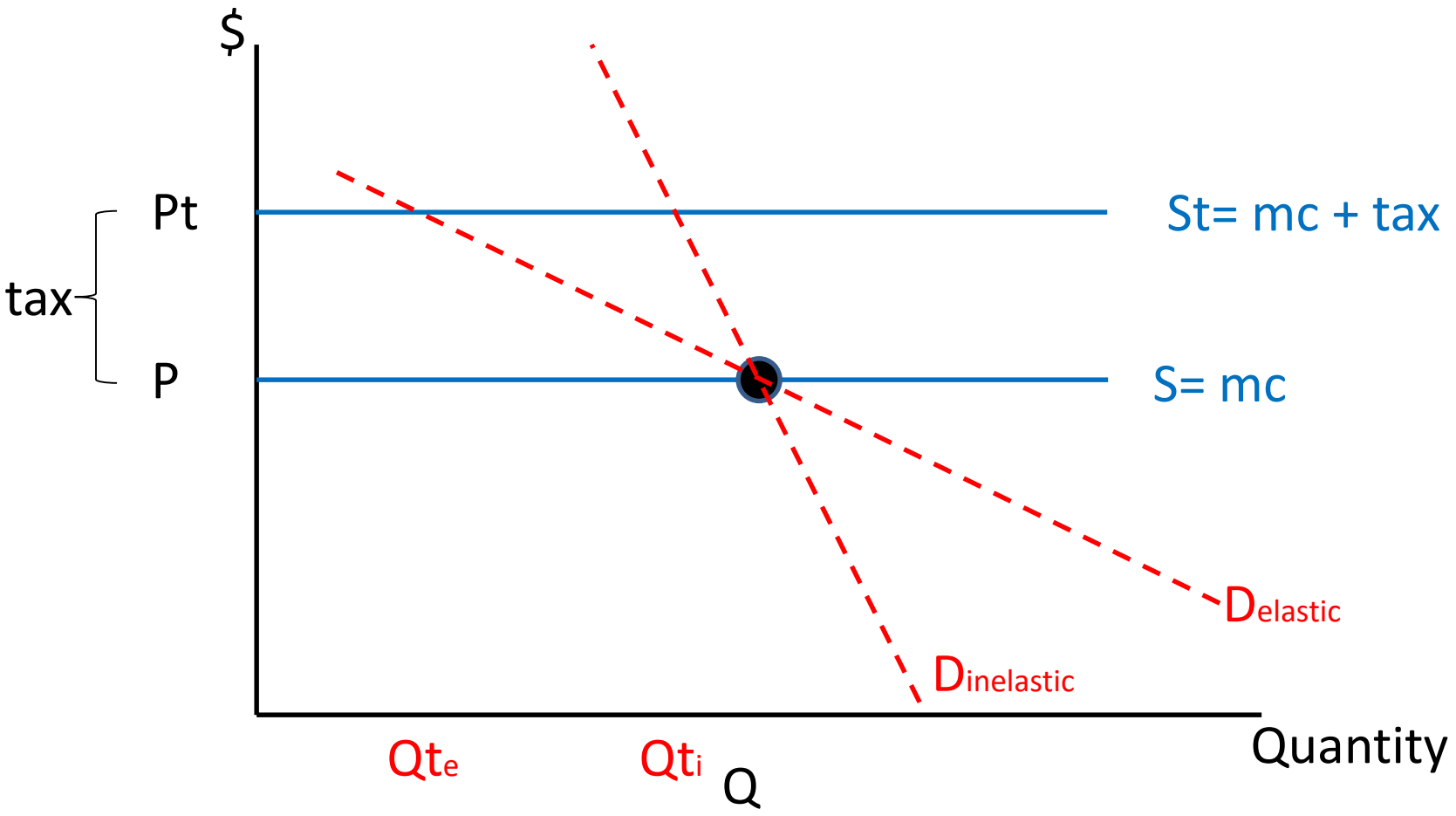
- **Many**, many empirical papers try to estimate this one parameter

- Why is it so hard to estimate?

Policymakers are considering an environmental tax

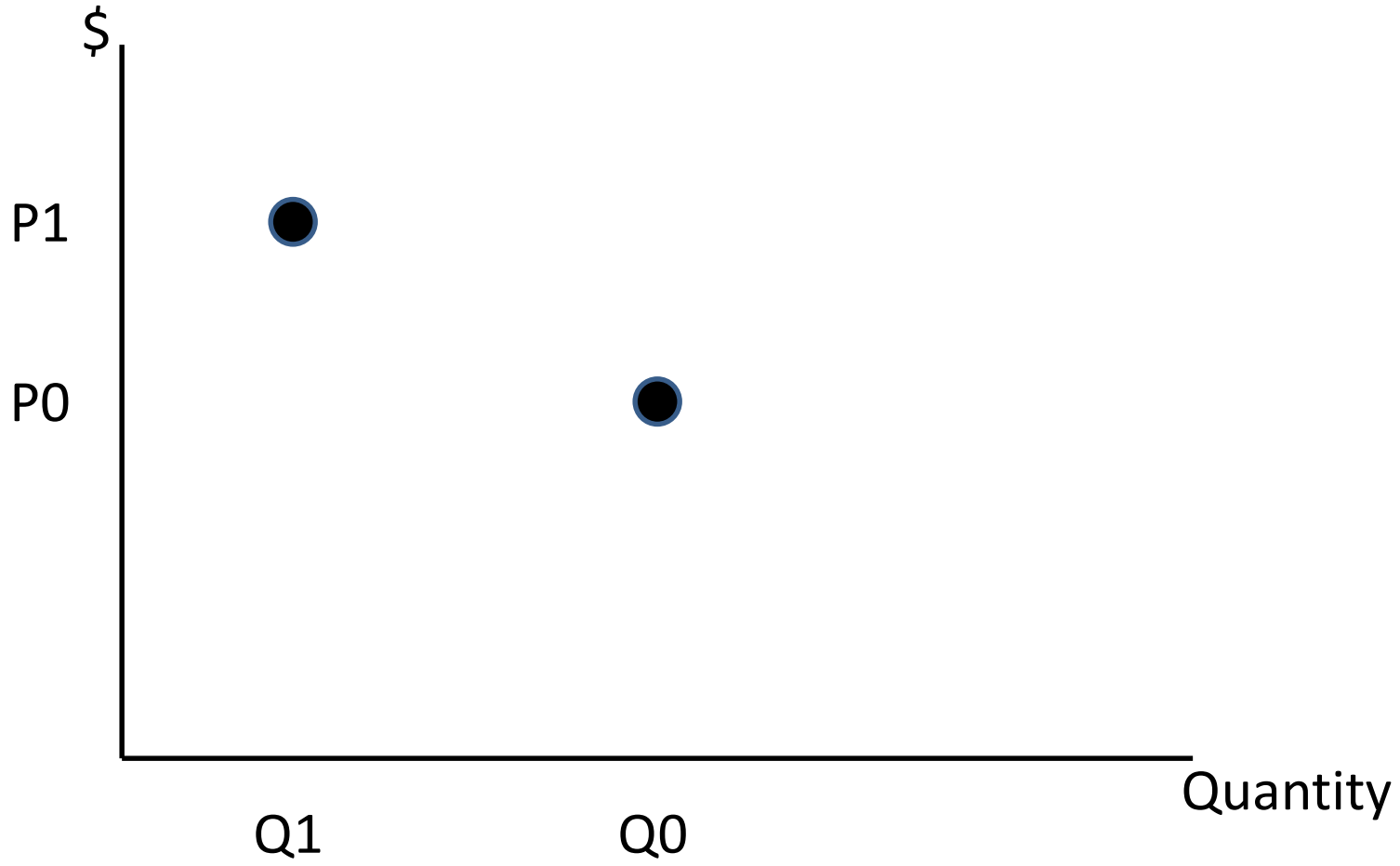


How will this tax effect quantity consumed?



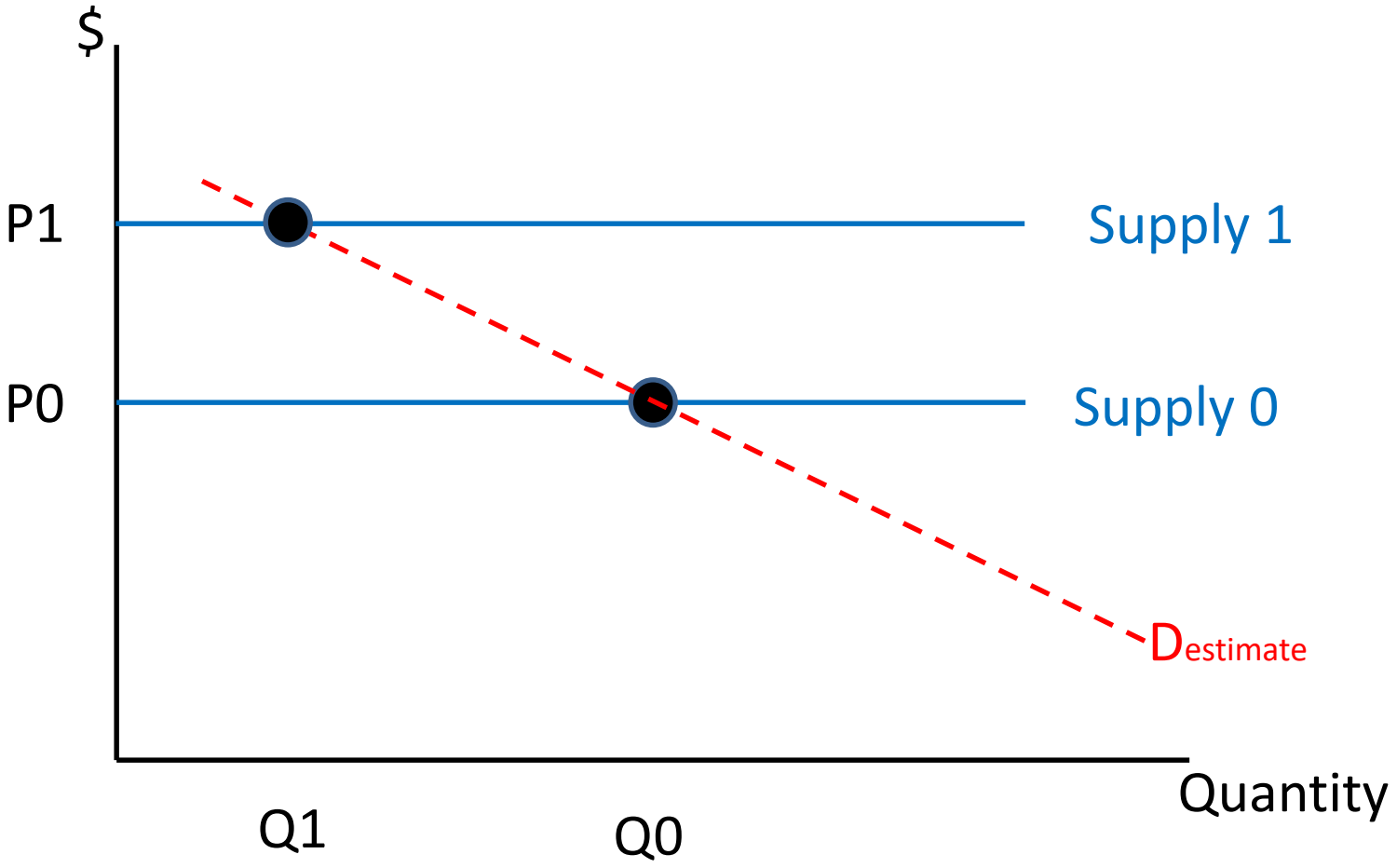
So to answer this question, we need to know the price elasticity of demand

To estimate a demand curve, we can look at how quantity has responded to price changes in the past



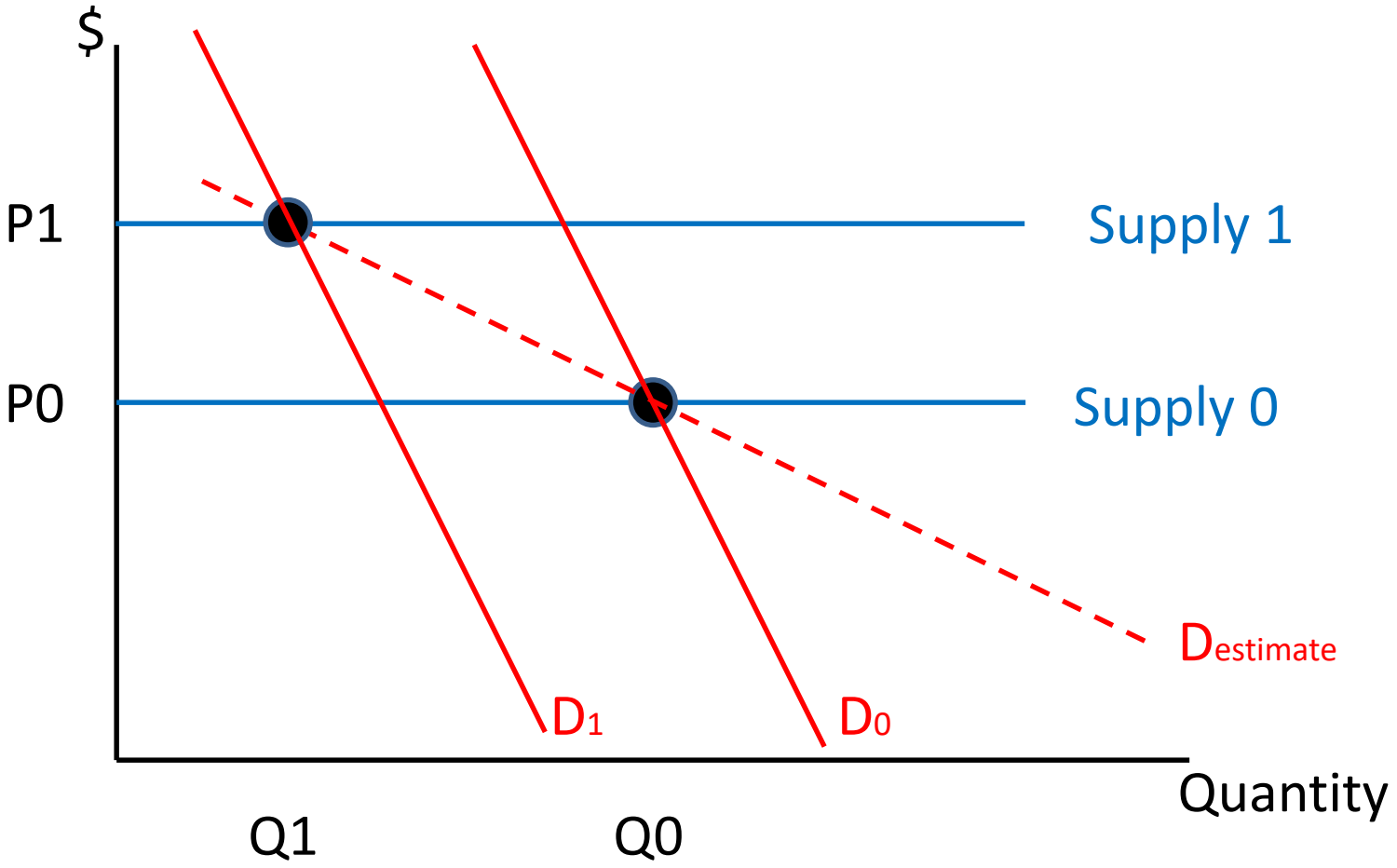
A typical dataset will look like this

It is tempting to draw a curve through those points and call it demand



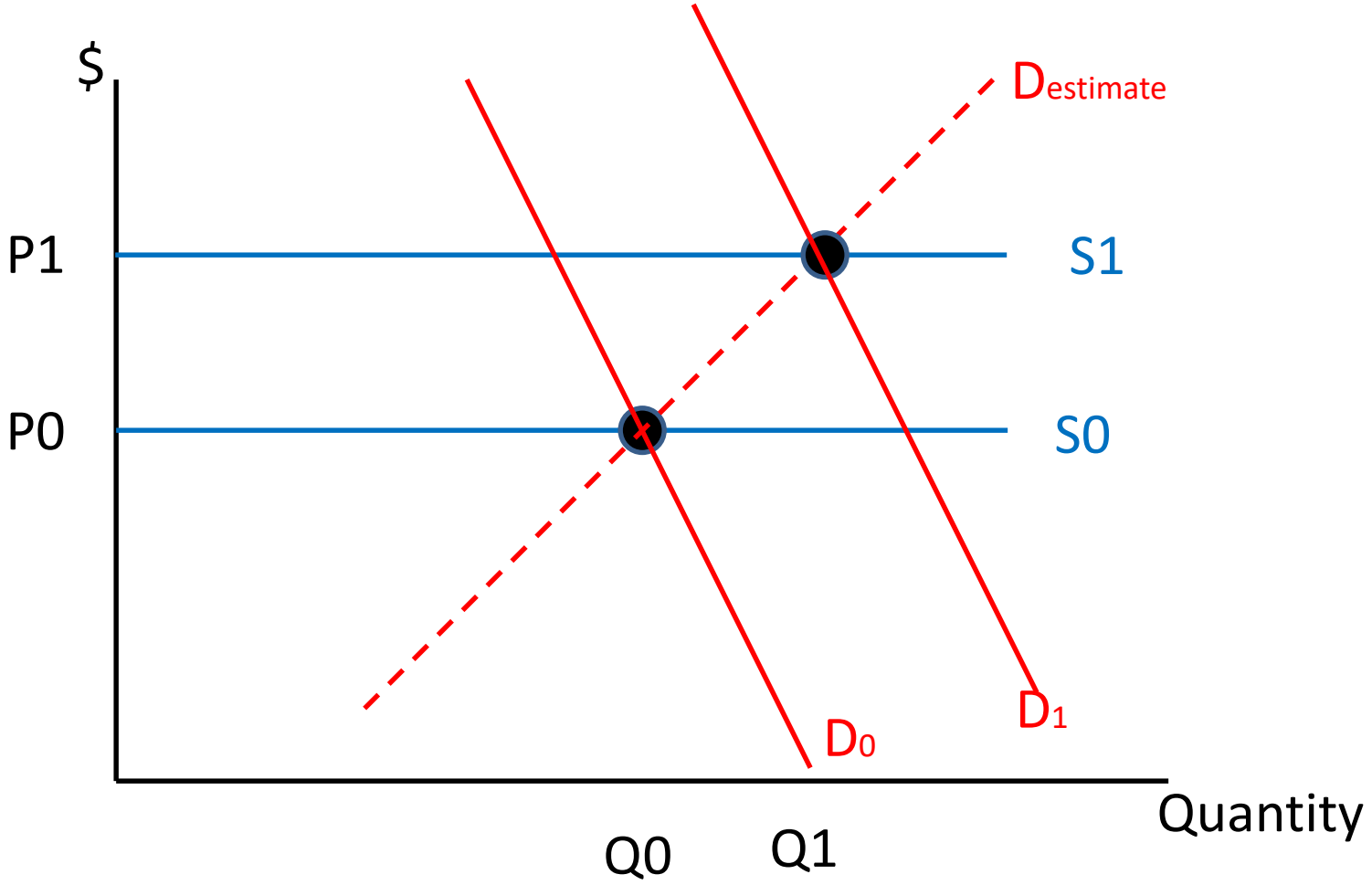
This assumes that only supply changed between periods 0 and 1

However, it is possible that supply *and demand* changed between times 0 and 1



Thus we would have significantly overstated demand elasticity (in this example)

If supply and demand shocks are positively correlated, you could even estimate *upward sloping* demand



Analytical Summary

- Want to estimate how quantity demanded changes with price
  - i.e. want movement *along* a demand curve

- **Challenge:** only observe *equilibrium* (P, Q) pairs

- These pairs are determined by both demand *and supply*
  - This is what we mean by endogeneity in this context

Analytical Summary

- As analysts, our goal is to use econometrics to isolate just the changes in P that are due to changes in supply

- This allows us to “trace out” the demand curve

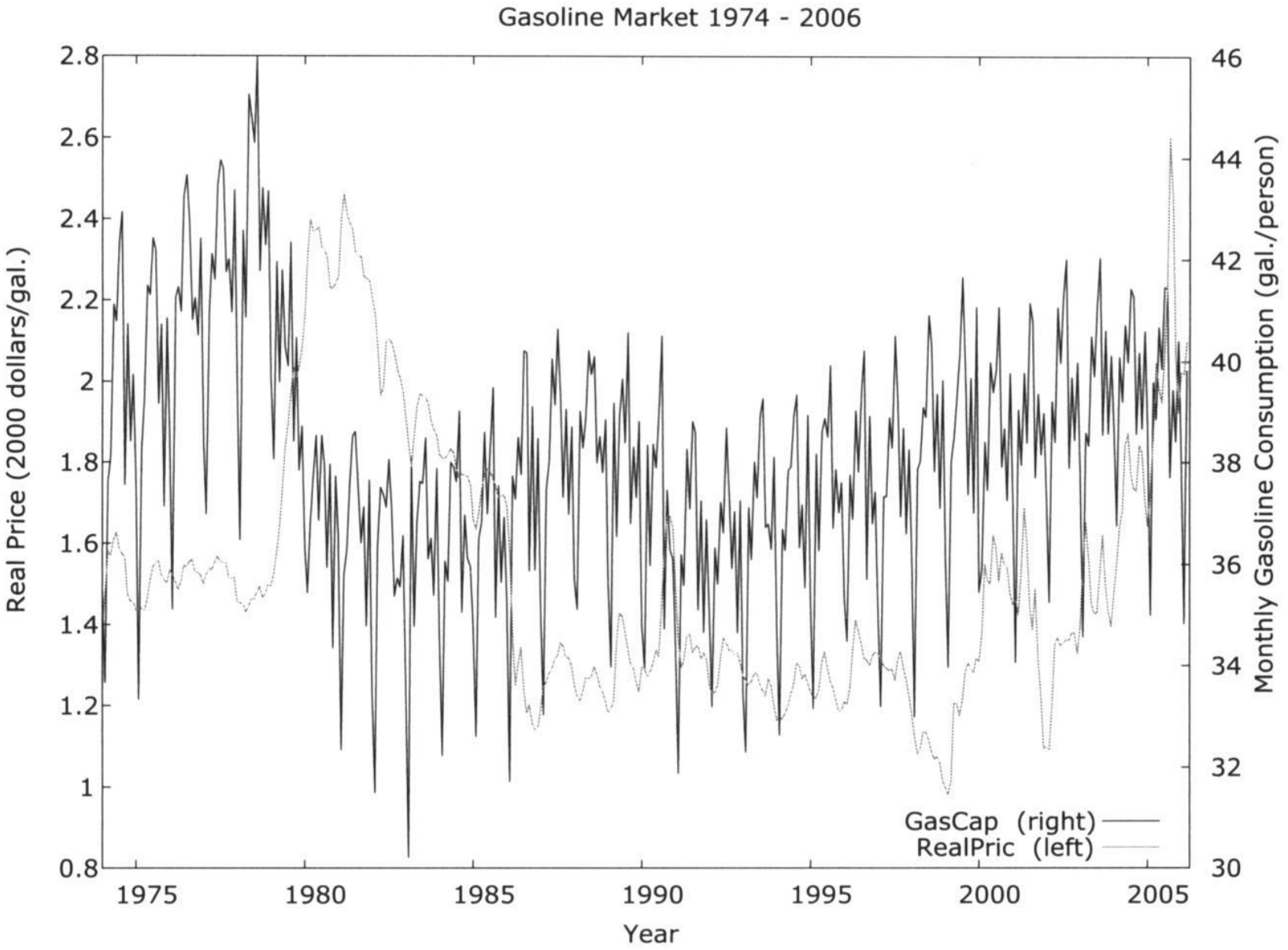
- For class you read three papers with different strategies for doing this

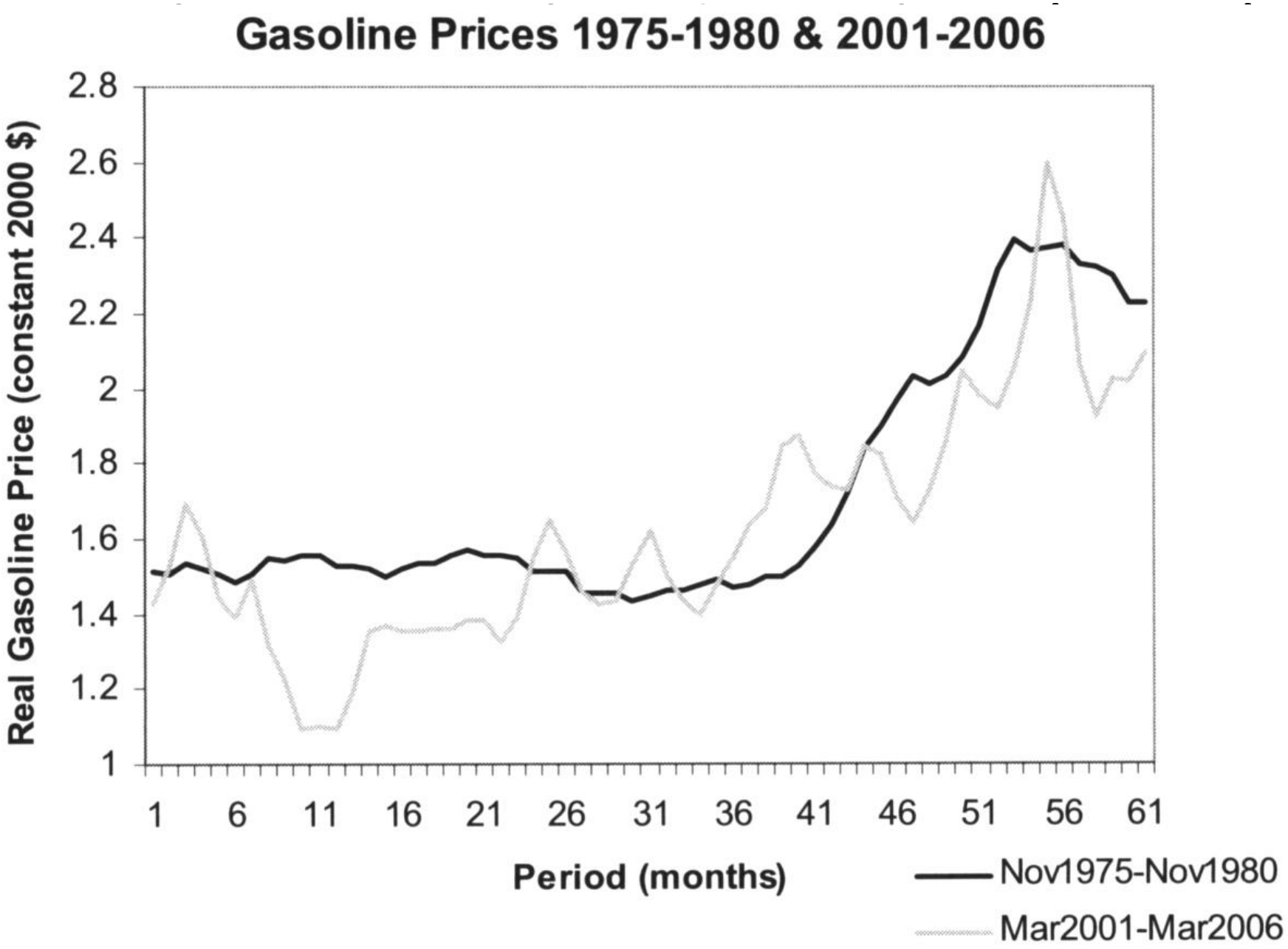
Hughes, Knittel and Sperling (2008)

- What approach does this paper take?
  - What data do they use?
  - What is their identification strategy?

- What do they find?

Hughes, Knittel and Sperling (2008)




Gasoline Prices 1975-1980 & 2001-2006
Real Gasoline Price (constant 2000 $)
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
1
6
11
16
21
26
31
36
41
46
51
56
61
Period (months)
Nov1975-Nov1980
Mar2001-Mar2006

Hughes, Knittel and Sperling (2008)

- Use **national data** from 1975 to 2006 to estimate demand elasticity
  - So basically one observation per time period
  - Concerns about this?

- Compare period from 1975-1980 to 2001-2006
- Find demand looks much less elastic now
- Elasticities for recent period:
  - OLS: -.042
  - IV: -.077

Hughes, Knittel and Sperling (2008)

Table 1. OLS Regression Results – Double-Log Basic Model

	Basic Model: Double Log	
	1975 - 1980	2001 - 2006
β_o	-0.615	-1.697***
	(0.929)	(0.587)
$\ln(P)$	-0.335***	-0.042***
	(0.024)	(0.009)
$\ln(Y)$	0.467***	0.530***
	(0.096)	(0.058)

Instrumental variables

Quantity = a + b*Price + c*W + e

- Price uncorrelated with e → can estimate with OLS

- Problem: There is an omitted variable (W) correlated with both the outcome (Y) and the explanatory variable of interest (X)
  - Coefficient on X contains both the effect of X and the effect of W

- Possible solution: If we had another variable (Z) just correlated with X (and not Y), we can use that as an instrument

Instrumental variables

- Step 1:
  - Regress X on Z
  - Use estimates to predict X just as a function of Z
- Step 2:
  - Regress Y on the *predicted value* of X
  - Since the predicted X is only a function of Z, and Z does not effect Y, we are now all set.
- Key assumptions:
  - Cov(X,Z) <> 0
  - Cov(e,Z) = 0

What's a good instrument?

- What something correlated with price but uncorrelated with demand (ie the intercept of demand)
- Most papers try to come up with "supply" shocks – similar to our picture before.

Hughes et al use crude disruptions as an instrument for crude prices

- Political change in Venezuela; Iraq war; Hurricanes
- What do people think of this idea?

Table 6. 2SLS Regression Results – Instrumental Variable Models

Stage 2: Instrumental Variable Models (2001-2006)		
	Production Disruptions	
	(Venez., Iraq, USA)	(USA only)
β_o	-2.837 (1.185)	-3.910 (1.165)
ln(P)	-0.060 (0.016)	-0.077 (0.013)
ln(Y)	0.642 (0.117)	0.748 (0.115)
ε_j's	y	y
Adj. R-squared	0.94	0.93
S.E. of residuals	0.011	0.012
Durbin-Watson stat	1.544	1.476
Sum squared resid	0.006	0.007

Notes: Figures in parentheses are standard errors, P is the real price of gasoline in constant 2000 dollars, Y is real per capita disposable income in constant 2000 dollars.

Hughes, Knittel and Sperling (2008) Summary

- Elasticities for recent period:
  - OLS: -.042
  - IV: -.077

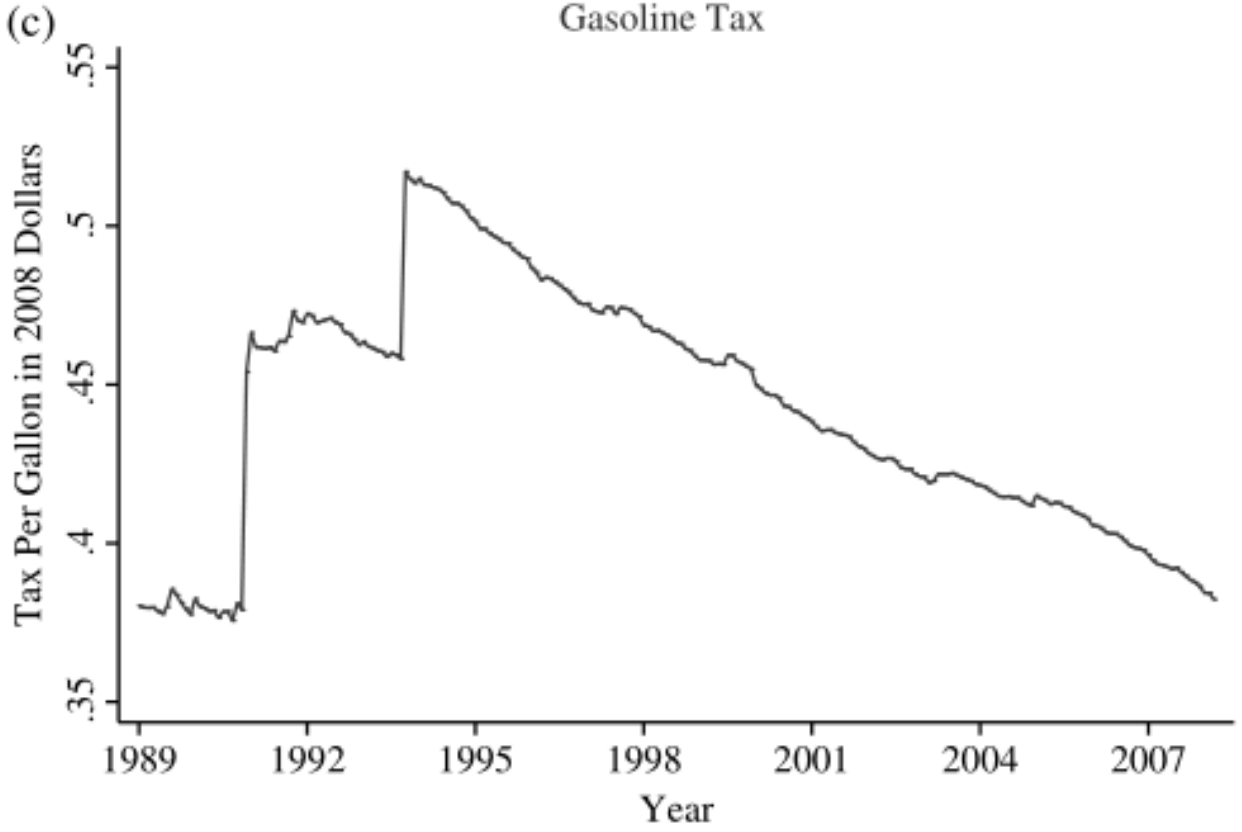
- What does this imply for a carbon tax?

Davis and Killian (2011)

- What approach does this paper take?
  - What data do they use?
  - What is their identification strategy?

- What do they find?

Why not just estimate using taxes?



Source: Data from U.S. Department of Transportation, Highway Statistics, 1991–2008.

- Idea: People only care about their total bill
- Price = cost of the good + tax
- Costs change all the time in ways that might be endogenous, but taxes are inherently supply side (maybe?)

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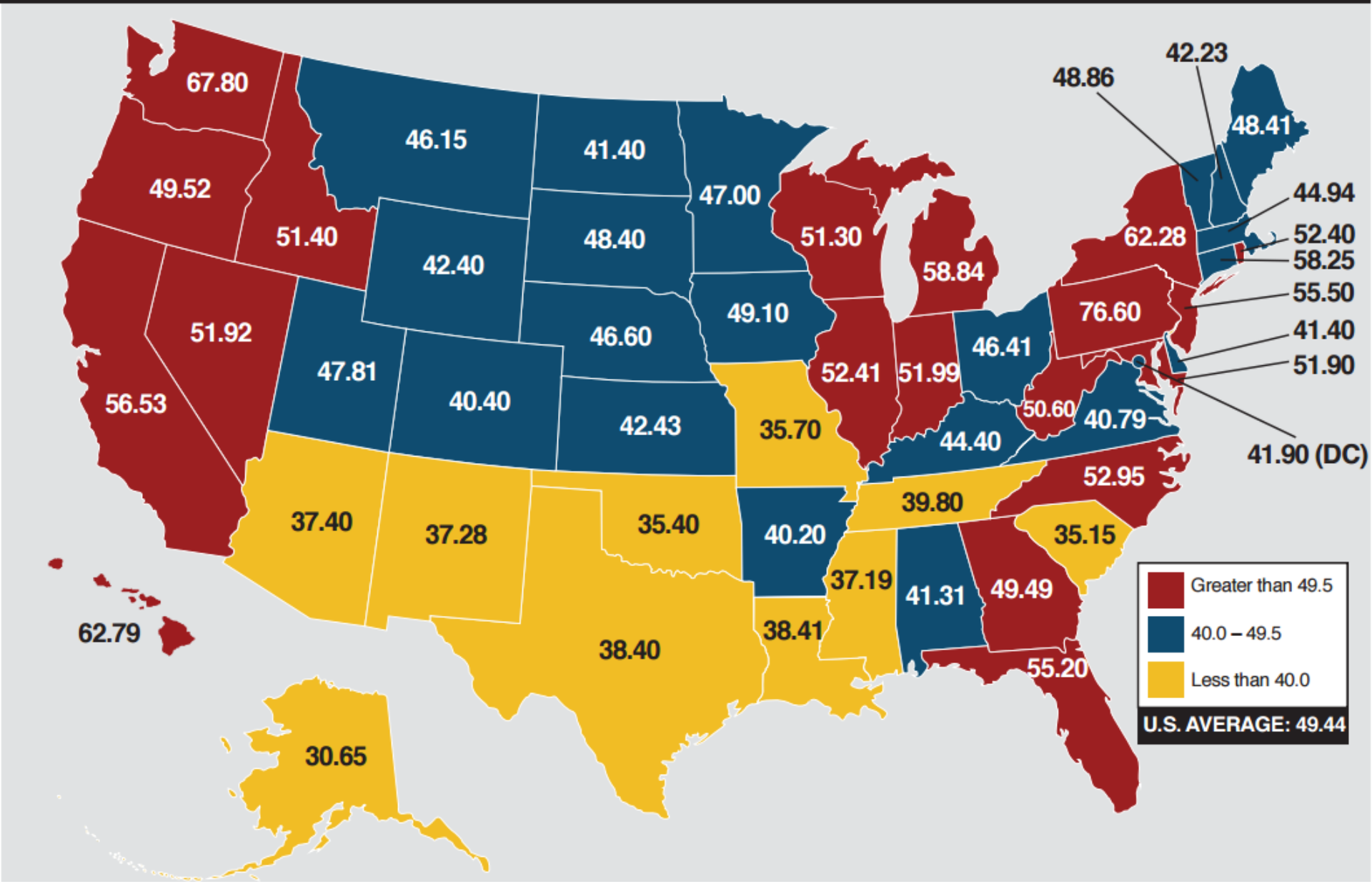
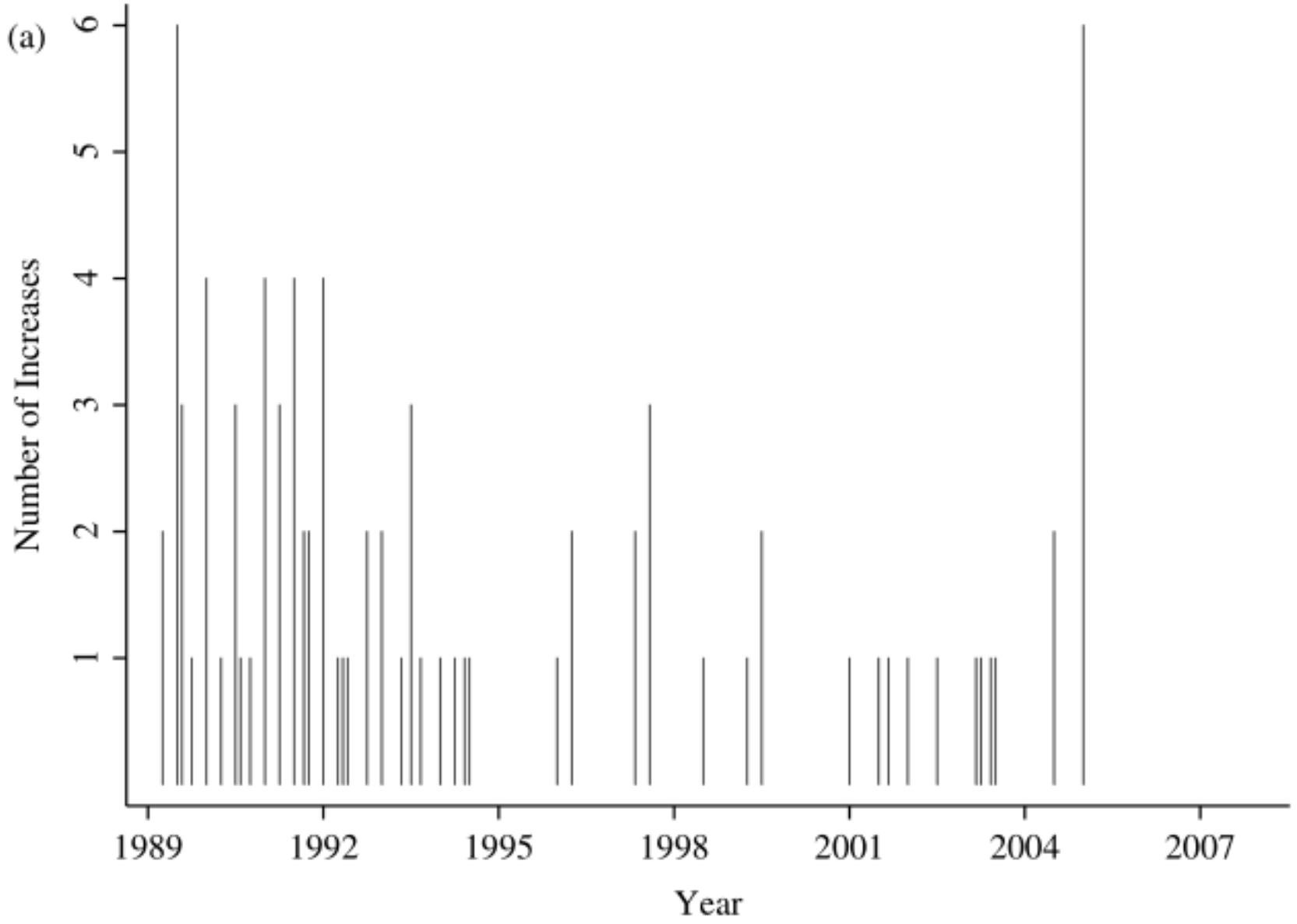
GASOLINE TAXES

COMBINED LOCAL, STATE AND FEDERAL (CENTS PER GALLON)
RATES EFFECTIVE 01/01/2017



State taxes vary over time too



Davis and Killian Results

Table VI. The effect of a 10-cent gasoline tax increase on gasoline consumption: Traditional regression estimates

	(%)
OLS estimate, national aggregate	−0.31
(Standard error)	(0.11)
OLS estimate, state panel	−0.59
(Standard error)	(0.12)
IV Estimate, state panel	−1.43
(Standard error)	(0.72)

Note: The effect of a 10-cent gasoline tax is evaluated at the volume-weighted mean after-tax price of $3.21 in March 2008. The implied effects for OLS are based on the −0.10 and −0.19 elasticities in Table I. The implied effect for state panel IV is based on the −0.46 estimate in column 4 of Table IV.

Li, Linn & Muehlegger (2014)

- What approach does this paper take?
  - What data do they use?
  - What is their identification strategy?

- What do they find?

Same starting point as previous paper

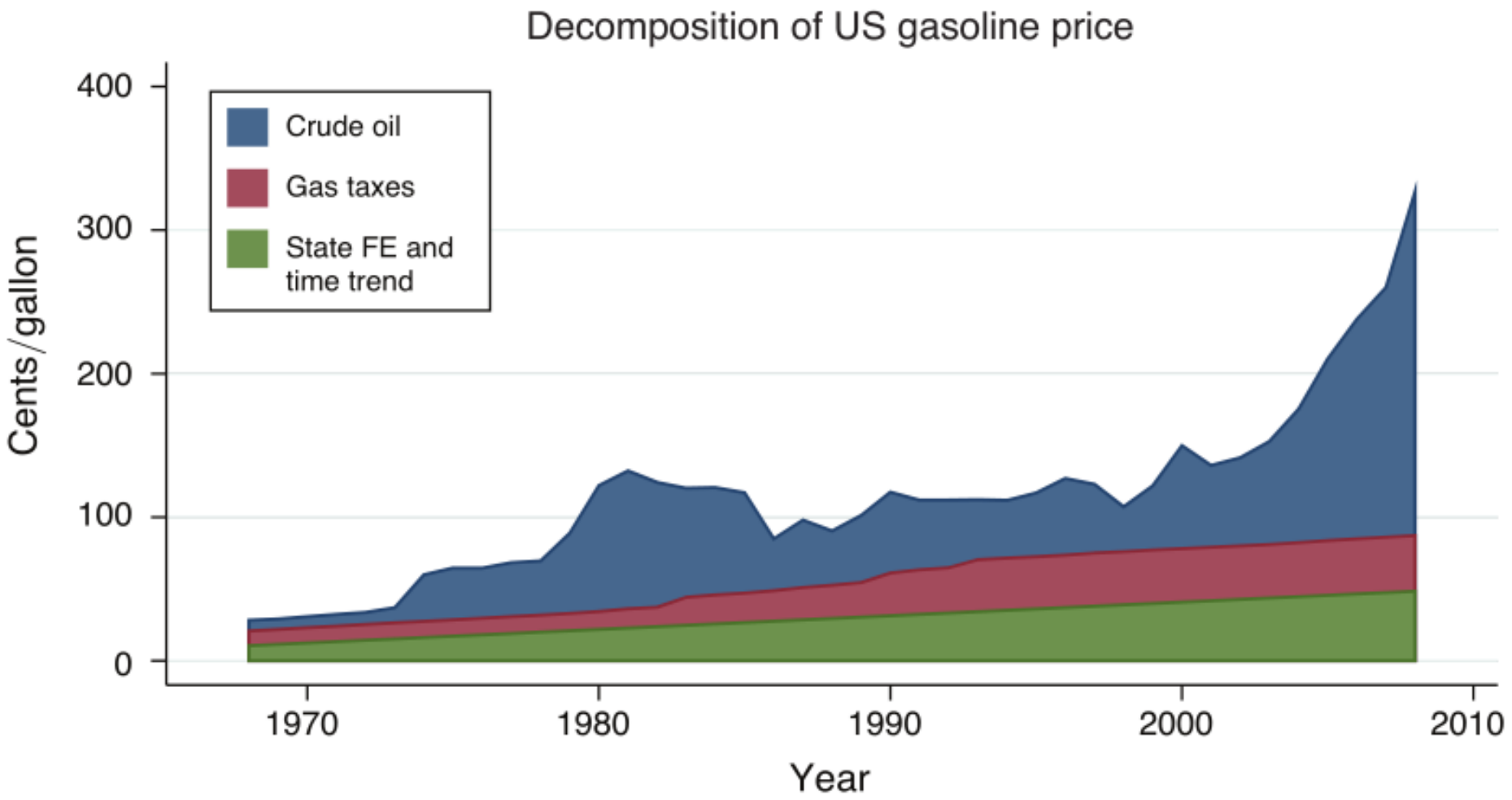


FIGURE 1. GASOLINE PRICE DECOMPOSITION

But notice that taxes play a much smaller role over time

TABLE 1—NOMINAL PRICES AND TAXES (CPG), OVER TIME

Period	Average tax-inclusive retail price	Average state tax	Average federal tax	Tax fraction of retail gasoline price in percent	Percent of retail gas variation explained by tax changes
1966–1970	34.0	6.7	4.0	31.5	48.3
1971–1975	44.6	7.6	4.0	26.0	2.3
1976–1980	80.4	8.4	4.0	15.4	2.1
1981–1985	121.8	11.2	7.0	14.9	19.3
1986–1990	98.0	15.1	10.1	25.7	11.4
1991–1995	113.9	19.1	16.7	31.4	25.5
1996–2000	125.0	20.3	18.4	30.9	2.2
2001–2005	163.3	20.8	18.4	24.0	2.0
2006–2008	278.0	21.8	18.4	14.5	0.6

TABLE 4—IV ESTIMATES OF GASOLINE DEMAND

	Uninstrumented (1968–2008)			Instrumented (1968–2008)		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Coefficient estimates						
log (tax-excl. gas price)	−0.214***	−0.161**	−0.122**	−0.104***	−0.136***	−0.0697**
	(0.0598)	(0.0494)	(0.0382)	(0.0199)	(0.0194)	(0.0240)
log (1 + tax ratio)	−0.732***	−0.469***	−0.290**	−0.795***	−0.501***	−0.323***
	(0.175)	(0.0898)	(0.0895)	(0.179)	(0.0913)	(0.0828)
p-value: $\alpha = \beta$	< 0.001	< 0.001	0.024	< 0.001	< 0.001	0.002
Panel B. Percent changes in gas consumption from a \$0.05/gallon increase in gas price						
Gas price	−0.606***	−0.470***	−0.319***	−0.844***	−0.320***	−0.148*
	(0.171)	(0.144)	(0.111)	(0.254)	(0.063)	(0.076)
Panel C. Percent changes in gas consumption from a \$0.05/gallon increase in gas tax						
Gas tax	−2.163***	−1.385***	−0.856***	−2.350***	−1.479***	−0.955***
	(0.518)	(0.265)	(0.143)	(0.529)	(0.270)	(0.245)
p-value: equal effects	0.004	0.002	0.003	0.010	< 0.001	0.002
State FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
Covariates		X	X		X	X
State quadratic trends			X			X

Explanations?

- LLM find that increases in gasoline taxes are associated with much larger demand response than similar increases in crude costs
  - ~ 3X as large

- What explains that?
  - Persistence
  - Predictability
  - Salience
    - News coverage

Salience and news coverage

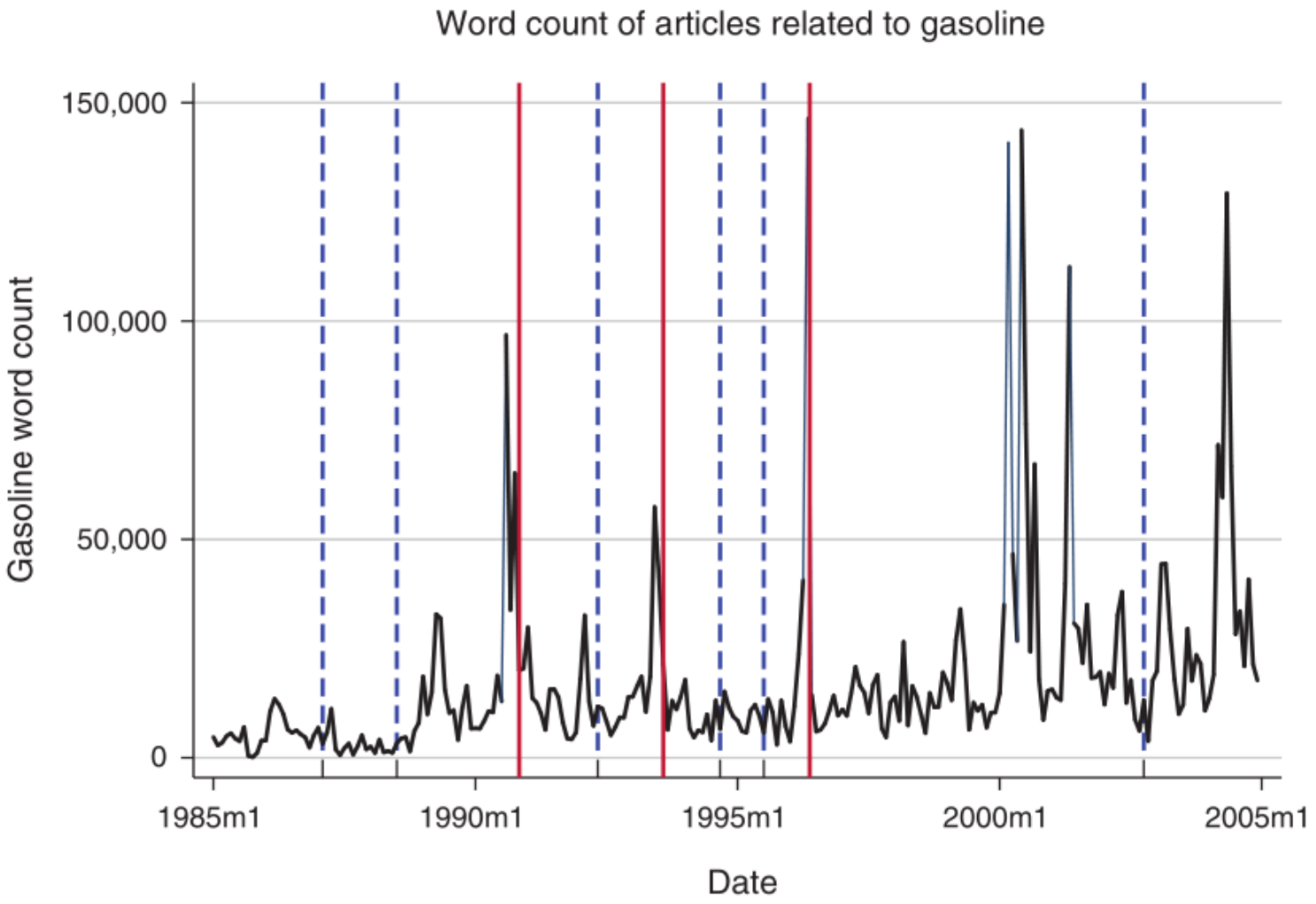


FIGURE 7. PRINT MEDIA COVERAGE, GASOLINE PRICE, AND TAX CHANGES

Discussion

- One take away is that gas tax may be more effective than we think

- Short vs long run