Differential demand response to gasoline taxes and gasoline prices in the US

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Motivation

- A growing literature questions the standard assumption in public finance that consumers respond to commodity tax changes in the same way as they do to any price changes (Chetty *et al*., 2009; Goldin and Homonoff, 2013; Davis and Kilian, 2011; Li *et al*., 2014; Rivers and Schaufele, 2015).

- The implication for Pigouvian taxes is that their effectiveness may be inaccurately valued if price elasticities are considered instead of tax elasticities.

Literature (1)

- Consistent empirical evidence that consumers react more to gasoline tax changes than to gasoline price changes:

✓ Davis and Kilian, 2011

"Estimating the effect of a gasoline tax on carbon emissions", Journal of Applied Econometrics.

✓ Li *et al.*, 2014

"Gasoline taxes and consumer behavior", American Economic Journal: Economic Policy.

✓ Rivers and Schaufele, 2015

"Salience of carbon taxes in the gasoline market", Journal of Environmental Economics and Management.

Literature (2)

- Three non-mutually exclusive explanations for differential demand response to gasoline tax changes and price changes:

✓ Greater persistence of tax changes

✓ Greater salience (media attention) of tax changes

✓ Tax aversion

Our contribution

- Investigate the question within a demand system framework.

- Posit that tax changes have two effects on demand: *a)* the price effect, related to the tax as price component, and *b)* the signal effect, related to the tax as policy instrument. Market-induced price changes only cause the price effect.

- Simulate differential demand response by *a)* carbon tax level, *b)* household income level, *c)* US region.

The empirical model

- The Quadratic Almost Ideal Demand System (Banks et al., 1997) expenditure share equations:

$$w_i^h = \alpha_i + \sum_k \alpha_{ik} d_k^h + \sum_j c_{ij} \ln p_j + \beta_i \ln \left[\frac{y^h}{A(p)} \right] + \frac{\lambda_i}{B(p)} \left\{ \ln \left(\frac{y^h}{A(p)} \right) \right\}^2$$

Total expenditure

Expenditure share

Demographics and gasoline taxes

Translog price index

Cobb-Douglas price index

Prices (indices)

- Parameter restrictions:

$\sum_i \alpha_i = 1; \sum_i \beta_i = \sum_i c_{ij} = \sum_i \lambda_i = 0; \sum_i \alpha_{ik} = 0$ *for each k – "Adding up"*

$\sum_j c_{ij} = 0$ *– "Homogeneity"*

$c_{ij} = c_{ji}$ *for each i and j – "Symmetry"*

Gasoline taxes in the demand system

- Gasoline taxes as price component are embedded in the gasoline price index.

→ Tax changes alter relative prices and, hence, affect consumption.

- Gasoline taxes as policy instrument enter the model as intercepts adjusting equilibrium demands.

→ Tax changes affect long-run consumer decisions (e.g., buying a more fuel efficient car, changing transport mode) over and above the change in relative prices.

- In demand systems, the "conditioning variable approach" has been used to analyze the effect of information (Jensen *et al*., 1992; Chern *et al*., 1995), innovation (Moro *et al*., 1996) and advertising (Duffy, 1995; Brown and Lee, 1997).

Data (1)

- Expenditures, income and demographics

✓ U.S. Consumer Expenditure Survey rounds 2007, 2008 and 2009, supplied by the Bureau of Labor Statistics (BLS).

✓ The sample spans 13 quarters, from Jan 2007 to March 2010, and 20 Metropolitan Statistical Areas (MSA).

✓ Our system of demand comprises current expenditures on:

1) Home food
2) Electricity
3) Natural gas
4) Other home fuels
5) Motor fuels (gasoline)
6) Public transport
7) All other current expenditures

Summary statistics (1)

Summary statistics of total current expenditure shares.

Variable	Observations	Mean	Standard deviation	Coeff. of variation	Min	Max[a]	Zeros
Food at home	43,457	22.8%	13.7%	0.60	0.0%	100.0%	0.9%
Electricity	43,457	5.8%	5.3%	0.92	0.0%	100.0%	8.5%
Natural gas	43,457	2.9%	4.3%	1.50	0.0%	63.4%	38.5%
Other home fuels	43,457	0.7%	3.1%	4.59	0.0%	72.8%	91.2%
Motor fuels	43,457	9.1%	7.7%	0.84	0.0%	100.0%	12.9%
Public transport	43,457	2.0%	5.4%	2.63	0.0%	81.4%	73.4%
All other expend.	43,457	56.7%	17.5%	0.31	0.0%	100.0%	0.1%

Summary statistics of demographics and total current expenditure.

Variable	Obs.(#)	Mean	Standard deviation	Min	Max
Single	43,457	0.28	0.45	0	1
H&W	43,457	0.19	0.40	0	1
H&W, child(ren) <6	43,457	0.05	0.21	0	1
H&W, child(ren)<18	43,457	0.14	0.34	0	1
H&W, child(ren) >17	43,457	0.08	0.27	0	1
Other households	43,457	0.26	0.44	0	1
Northeast	43,457	0.31	0.46	0	1
Midwest	43,457	0.20	0.40	0	1
South	43,457	0.24	0.43	0	1
West	43,457	0.26	0.44	0	1
Composition income earners	43,457	0.23	0.42	0	1
Education of reference person	43,457	5.44	1.82	1	9
Number of cars	43,457	0.91	0.89	0	15
Total current expenditure, $	43,457	7,178	7,298	35	321,316

Data (2)

- Prices and taxes

✓ We use monthly price indices varying by MSA, supplied by the BLS.

✓ Three layers of excise taxes apply to US consumption of gasoline and auto diesel: federal taxes, State taxes and local taxes.

✓ The federal tax rate on gasoline is 18.4 cents per gallon and has not changed since 2006.

✓ We use monthly rates of State taxes published by the Federation of Tax Administrators.

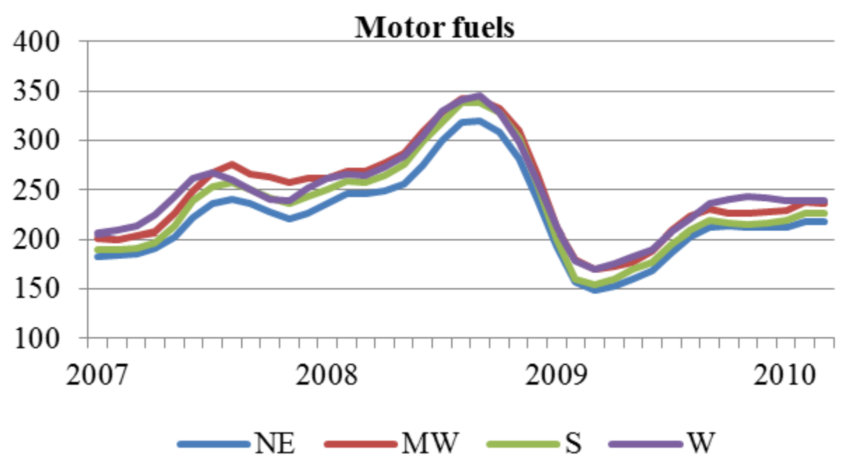
✓ Local taxes are not considered.

Summary statistics (2)

Price indices (1982-84 = 100) and gasoline excise taxes (sum of federal and state taxes).

Price indices[a]/taxes	Obs.(#)	Unit	Mean	St. deviation	Min	Max
Food at home	43,457	index	208.40	24.61	124.23	236.79
Electricity	43,457	index	195.16	42.81	102.03	311.82
Natural gas	43,457	index	214.95	38.67	112.18	371.55
Other home fuels	43,457	index	273.30	44.96	228.03	384.30
Motor fuels	43,457	index	233.48	49.92	143.60	453.11
Public transport	43,457	index	237.77	10.85	219.86	267.72
All other expenditures	43,457	index	177.12	17.11	123.00	222.55
Gasoline taxes, nominal	43,457	cents/gallon	39.22	4.75	32.90	55.40
Gasoline taxes, real (1982-84 prices)[b]	43,457	cents/gallon	18.52	2.27	15.00	25.75

a: All indices are Laspeyres price indices, for all urban consumers, not seasonally adjusted; **b**: Nominal taxes deflated by the U.S. CPI (1982-84 = 100).



Two-step estimation

- To deal with the presence of zeroes in the dependent variables, we use the two-step estimator proposed by Shonkwiler and Yen (1999):

✓ The procedure involves a probit estimation in the first step and a selectivity-augmented equation system in the second step.

✓ The system of equations is thus estimated (by ML) in the following form:

$$s_i = \Phi(z_i' t_i)\, w_i(p, w, v) + \delta_i \varphi(z_i' t_i) + \xi_i$$

- s_i: Observed budget share
- Φ: Normal c.d.f. from first-step probit
- w_i: Original model
- δ_i: Coefficient of the correction factor
- φ: Normal p.d.f. from first-step probit

Estimation results (1)

Estimated QAIDS coefficients.

	i=1	i=2	i=3	i=4	i=5	i=6
Coefficient	Food	Electricity	Natural gas	Other fuels	Gasoline	Pub. transp.
α_i	**0.197**	**0.043**	**0.046**	**0.049**	**0.108**	**0.090**
	0.002	0.002	0.002	0.011	0.001	0.010
β_i	**-0.038**	**-0.004**	**-0.007**	**-0.008**	**-0.008**	**-0.006**
	0.001	0.001	0.002	0.002	0.001	0.002
λ_i	**-0.004**	**-0.001**	**-0.001**	**-0.002**	**-0.001**	**-0.001**
	0.001	0.000	0.000	0.000	0.000	0.000
$\alpha_{i,NE}$	**0.030**	-0.000	**-0.006**	**0.045**	**0.008**	-0.003
	0.002	0.001	0.001	0.00	0.001	0.004
$\alpha_{i,SO}$	**0.020**	**0.034**	**-0.023**	-0.005	**0.015**	0.005
	0.002	0.001	0.001	0.009	0.001	0.004
$\alpha_{i,WE}$	**0.043**	**-0.008**	**-0.039**	-0.009	**0.019**	**0.019**
	0.002	0.001	0.001	0..011	0.001	0.004
$\alpha_{i,NCAR}$	**-0.017**	**-0.001**	**0.001**	**0.009**	**0.009**	**-0.008**
	0.001	0.000	0.000	0.001	0.001	0.001
$\alpha_{i,TWOE}$	**-0.004**	-0.000	-0.000	**0.015**	**0.010**	0.003
	0.001	0.001	0.001	0.004	0.001	0.003
$\alpha_{i,N1}$	**-0.039**	-0.012	**0.008**	0.048	**0.018**	**-0.011**
	0.003	0.002	**0.001**	0.005	0.002	0.004
$\alpha_{i,N3}$	**0.032**	-0.004	**-0.003**	**0.016**	**0.013**	**-0.015**
	0.003	0.001	0.002	0.006	0.001	0.005
$\alpha_{i,N4}$	**0.043**	**0.006**	**-0.002**	-0.007	**0.012**	**-0.009**
	0.002	0.001	0.001	0.004	0.001	0.004
$\alpha_{i,N5}$	**0.039**	**0.008**	**-0.004**	-0.008	**0.014**	-0.014
	0.002	0.001	0.001	0.005	0.001	0.004
$\alpha_{i,N6}$	**0.033**	**0.002**	0.003	0.005	**0.020**	**-0.015**
	0.002	0.001	0.001	0.004	0.001	0.003
$\alpha_{i,EDUC}$	**-0.009**	**-0.003**	**-0.002**	**-0.004**	**-0.008**	**0.005**
	0.000	0.000	0.000	0.001	0.000	0.001
$\alpha_{i,\ TAX}$	**-0.053**	**0.013**	**-0.013**	**0.176**	**-0.062**	**0.035**
	0.006	0.003	0.003	0.010	0.004	0.008
LogLikelihood	337.700					
R^2	0.19	0.13	0.10	0.07	0.12	0.03
N obs	43,308					

Note: Standard errors below coefficients. Bold entries indicate rejection of $H_0: e=0$ at the 5% significance level for a two tailed test.

Estimation results (2)

Estimated budget shares, income- and compensated price elasticities.

	j=1	j=2	j=3	j=4	j=5	j=6	j=7
	Food	Electricity	Natural gas	Other fuels	Gasoline	Pub. transp.	Other goods
w_j	0.223	0.057	0.028	0.007	0.090	0.021	0.576
e_j	**0.860**	**0.942**	**0.855**	**0.919**	**0.938**	**0.929**	**1.080**
	0.004	0.007	0.009	0.023	0.006	0.021	0.002
e^C_{1j}	**-0.445**	**-0.139**	**0.076**	**-0.100**	**0.081**	-0.008	**0.535**
	0.037	0.012	0.009	0.022	0.015	0.027	0.050
e^C_{2j}	**-0.443**	**-0.876**	**0.058**	-0.013	**-0.359**	**-0.500**	**2.129**
	0.041	0.026	0.015	0.032	0.027	0.049	0.061
e^C_{3j}	**0.504**	**0.089**	**-0.160**	**0.115**	**-0.296**	**-0.167**	-0.086
	0.045	0.022	0.037	0.034	0.031	0.041	0.072
e^C_{4j}	**-0.131**	0.028	**0.075**	**-0.477**	**0.207**	**0.118**	**0.180**
	0.055	0.025	0.019	0.165	0.040	0.038	0.123
e^C_{5j}	**0.214**	**-0.220**	**-0.142**	**0.107**	**-0.435**	**-0.447**	**0.923**
	0.033	0.016	0.013	0.030	0.027	0.037	0.058
e^C_{6j}	0.003	**-0.382**	**-0.113**	**0.087**	**-0.563**	**-0.385**	**1.353**
	0.080	0.041	0.023	0.038	0.051	0.145	0.134
e^C_{7j}	**0.160**	**0.183**	-0.002	**0.021**	**0.104**	**0.142**	**-0.607**
	0.020	0.007	0.005	0.011	0.010	0.015	0.030

Note: Standard errors below coefficients. Bold entries indicate rejection of $H_0: e = 0$ at the 5% significance level for a two tailed test.

Simulation (1)

- Two scenarios are simulated and compared: the Tax increase scenario and the Market-induced price increase scenario.
- Tax increase scenario – Given Δt, set new levels of gasoline price index and tax, p_b and t_b, and obtain demand change:

✓ $P = \pi + t$

✓ $p_{b,0} = p_{a,0} (1 + \Delta t/P_{a,0})$

✓ $t_{b,0} = t_{a,0} + \Delta t$

✓ $\Delta q_0/q_0 = [(w_{b,0}\, y_{a,0}/p_{b,0}) - (w_{a,0}\, y_{a,0}/p_{a,0})]/\ w_{a,0}\, y_{a,0}/p_{a,0}$

Simulation (2)

- Market-induced price increase scenario – Given $\Delta\pi = \Delta t$, set new level of price index, p_b, and obtain demand change:

✓ $p_{b,0} = p_{a,0} (1 + \Delta\pi/P_{a,0})$

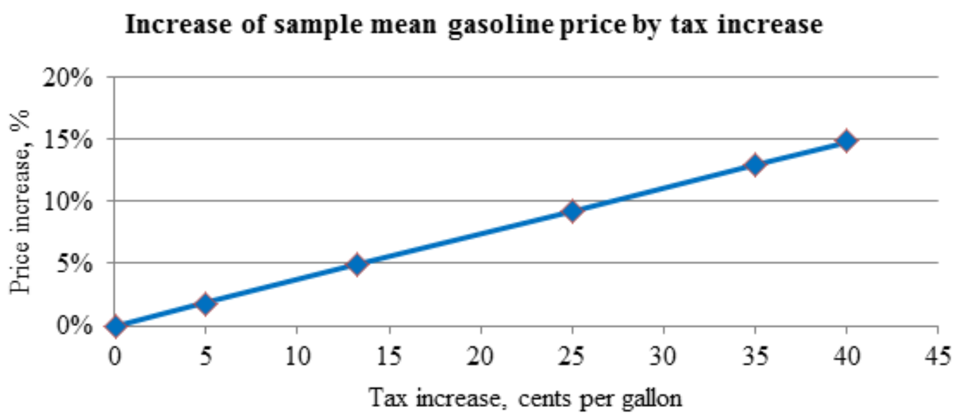
✓ $\Delta q_0/q_0 = [(w_{b,0}\, y_{a,0}/p_{b,0}) - (w_{a,0}\, y_{a,0}/p_{a,0})]/\ w_{a,0}\, y_{a,0}/p_{a,0}$

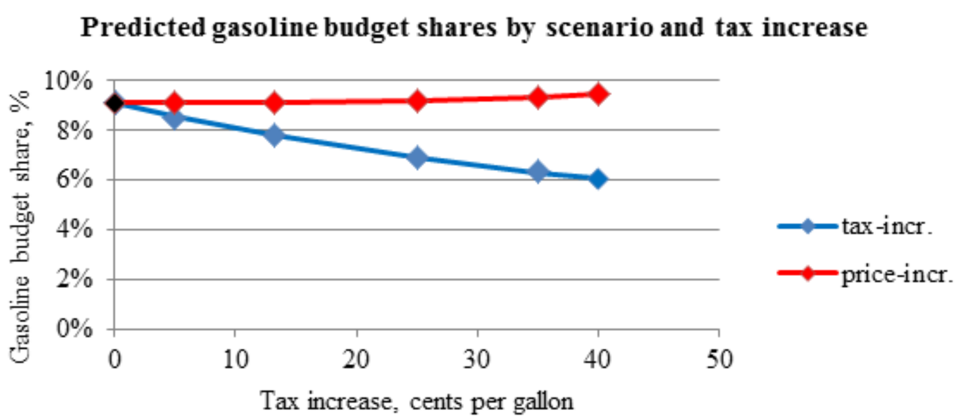
- Finally, compare demand changes in the two scenarios:

✓ ϑ_0 = Ratio of the two demand percentage demand changes.

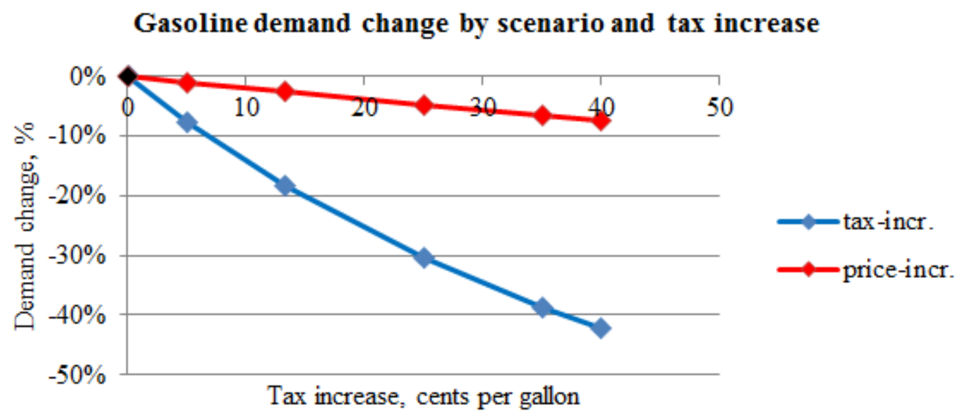
→ $\vartheta_0 = n$ means that, in the long run, at the given point 0, an increase in gasoline taxes is n-times as effective in reducing gasoline demand as an equal-in-size market-induced price increase.

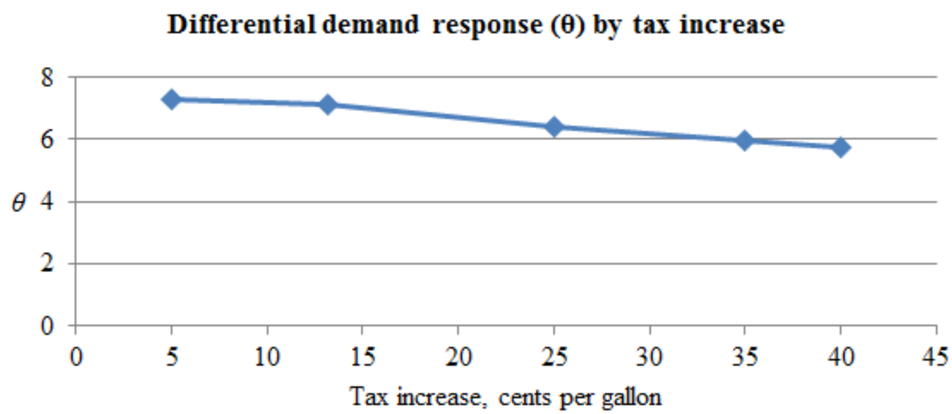
Simulation results (1)





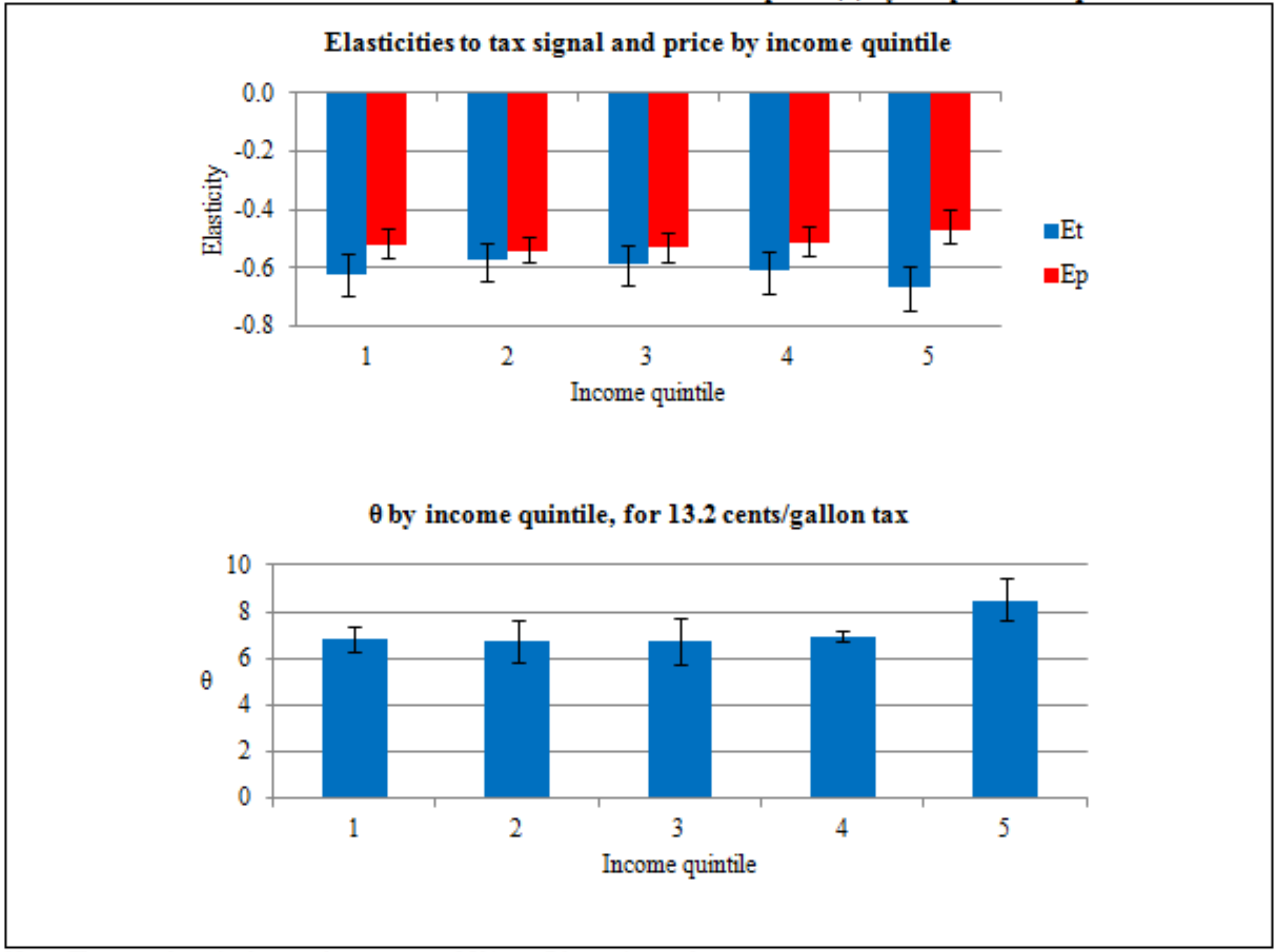
Simulation results (2)





Simulation results (3)

Estimated elasticities and simulated differential demand response (θ) by sample income quintile.



Note: The error bars in the graphs represent 95% confidence intervals.

Conclusions

- New evidence confirming differential demand response to gasoline taxes and prices.
- In the long run, gasoline taxes much more effective in reducing gasoline demand than price elasticities indicate.
- The carbon tax rate that would reduce CO2 emissions to any targeted level could be set lower than predicted by the literature.
- Lower carbon tax rates would be perceived as more acceptable, thus enhancing the effectiveness-acceptability tradeoff.

Extension (work in progress)

- We are extending the study in multiple directions:
- ✓ Twice as big dataset: from 2007 to 2013 rounds of the CE.
- ✓ Model specification: gasoline taxes interacted with total expenditure.
- ✓ Rigorous separability test.
- ✓ Welfare effects (Compensating Variation, possible only for the Price Increase scenario).
- ✓ Distributional analysis (tax burdens in the two scenarios).