Paying for Pollution? The effectiveness of Episodic Appeals for Car Trip Reduction and Free Transit Rides

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Motivation

- Just under 50% of counties that monitor ground-level ozone are in non-attainment
- Its a seasonal problem
- Episodic controls may be cheaper than permanent ones
- Voluntary programs in some cities get mixed results

Ozone

- Ozone is caused by rxn of NOx and VOCs in atmosphere, facilitated by high temps and sunlight
- It is seasonal and can be forecasted
- Deleterious to human respiratory health
- Among the 6 criteria pollutants regulated by EPA

Reducing Ozone

- Regs mandating reduced NOx emissions from point-sources
- Cleaner fuels, improved transit, smog checks for mobile sources.
- Controlling VOC emissions from mobile sources is most effective in some locales, like San Francisco.
- Episodic abatement can be more effective than continuous abatement

Voluntary Control

- Cummings and Walker 2000: traffic count data and linear regression methods suggest no significant effect in Atlanta
  - alert day endogeneity
- Henry and Gordon 2003: survey data find significant reductions in trips and VMT by government workers in Atlanta
  - Yay saying? Interviewer bias?
- Welch, Gu and Kramer 2005: turnstile counts on Chicago transit show no significant effect of alerts on transit demand

Voluntary Control

- Schreffler 2003: telephone surveys indicate 4.8% car trip reduction in San Francisco
- Cutter and Neidell 2009 (C-N): some evidence of significant 3-3.5% reduction in traffic volume using traffic count data in San Francisco with an RD design
  - no significant effect on BART ridership
  - RD corrects for endogeneity of STA assignment
  - BUT are RD assumptions satisfied?

This paper

- Data from 2002-2009 (C-N stopped in 2004)
- Provides evidence suggesting RD is not valid for evaluation of San Francisco "Spare the Air" (STA) days
  - "smoothness" assumption is violated
- Evaluate "Free Fare" STA days
  - assumed exogenous conditional on STA status
- Do people carpool on STA days?
- STA fatigue or salience on consecutive days?

STA Program

- 1991-present
- declared 1 day in advance if forecasted AQI>100
- Appeals for car trip avoidance through free and paid media
- ~65% of motorists are aware of any STA day
- Free fares on STA days from 2004-2008 subject to budget constraints

STA Response - Theory

- Reduced car pollution if STA induces carpooling, substitution to transit, or trip avoidance
  - relies on altruism
- But indirect effects could undermine:
  - health risk avoidance
  - congestion/crime avoidance
  - travel time considerations

STA Response - Theory

- Carpooling yields unambiguously higher utility on STA due to less congestion (shorter travel time) and warm glow.
- Private car yields shorter travel time but no warm glow
- Transit yields warm glow but also disutility from congestion (nuissance and travel time), exposure to health risk
- FREE should increase utility from transit, but may crowd out intrinsic motivations
- Consumer decisions based on expectations

Empirical Methods

- STA is not randomly assigned
  - Determined by forecasted AQI and correlated with weather charactersistics that influence travel demand and mode choice
  - AQI may directly influence demand/mode choice
  - Hence reliance on RD framework for “as good as random” assignment of STA

Empirical Methods

- Free Fare (FREE) is randomly assigned conditional on STA because of budget constraints:
  - variation within and across years due to budget that is independent of trip demand, STA expectations, etc.
  - Hence, reliance on the standard overlap assumption in standard parametric methods
- Carpool effects estimated via differencing framework, not RD.

Data

- aggregate traffic volumes from PeMS (CalTrans/UC Berkeley): 2002-2009
  - of 1,275 stations, use 10 randomly selected stations from each of 40 hwy segments except where there are fewer than 10; yields 316 stations
- BART ridership from turnstile counts: 2002-2008
- Contemp. weather vars (high and low temp, precip.) from NCDC's Surface Summary of the Day
- Forecasted weather from NCDC's coded city forecasts
- STA days and ozone forecasts from BAAQMD

Table 1: Summary Statistics: Number of STA days by year

				Bandwidth	
			All	Wide	Narrow
Year	STA=1	FREE=1	STA=0	STA=0	STA=0
2002	7	0	172	35	6
2003	8	0	172	83	21
2004	4	2	176	43	8
2005	2	1	176	66	12
2006	11	6	169	77	13
2007	2	2	178	42	12
2008	14	0	165	103	26
2009	12	0	168	63	15
Total	60	11	1376	512	113

RD STA and FREE Response

$$
\begin{aligned}
q_{it} \quad = \quad & \beta_1 STA_t + \psi_1 g(o3_t) + \varphi q_{it-1} \\
& + STA_{t-1} + \boldsymbol{\delta} \mathbf{Z_t} + \boldsymbol{\xi} \mathbf{D_t} + \epsilon_{it}
\end{aligned}
$$

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\begin{aligned}
q_{it} \quad = \quad & \beta_1 STA_t + \psi_1 g(o3_t) + \psi_2 g(o3_t) * STA_t \\
& + \varphi q_{it-1} + STA_{t-1} + \boldsymbol{\delta} \mathbf{Z_t} + \boldsymbol{\xi} \mathbf{D_t} + \epsilon_{it}
\end{aligned}
$$

Table 3: Effect of STA Day on All Day Traffic: Pre-2005

	(1)	(2)	(3)
	All observations	±0.02 of threshold	±0.01 of threshold
		C-N (2009)	
Monitor and station random effects	-1105.97	-2332.26**	-2009.98*
	(823.08)	(857.49)	(1010.08)
	-[1.7]	-[3.5]	-[3.0]
No. obs.	70,805	24,073	8,768
No. of days	536	179	67
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Table 4: STA and Free Effects in the Regression Discontinuity Design

Bandwidth		(1)	(2)	(3)	(4)	(5)	(6)
All Observations	STA	338.17	-516.51***	-8535.61**	-5627.14***	-125,812.9	-34,553.35***
		(1876.61)	(84.55)	(3684.71)	(1612.46)	(155,857.3)	(7819.96)
No. of obs.: 379,815							
No. of monitors: 316	Free	1224.67**	866.61***	1244.03**	887.78***	1277.18**	884.80***
Mean No. of days: 1201.9		(554.41)	(156.11)	(548.21)	(156.52)	(646.27)	(159.07)
±0.02 of threshold	STA	3369.90	-729.89***	5887.31	14,272.01**	-125,812.9	-117,092***
		(3667.84)	(62.12)	(29,998.51)	(6387.07)	(155,857.3)	(48,762.82)
No. of obs.: 146,785							
No. of monitors: 316	Free	1436.58**	1219.3***	1480.44**	902.13***	1277.18**	1093.47***
Mean No. of days: 464.5		(664.49)	(83.97)	(686.94)	(156.28)	(646.27)	(171.75)
±0.15 of threshold	STA	1919.92	-562.45***	91,138.56	18,906.94***	680,518.6	-5763.50
		(3795.05)	(66.04)	(76,685.8)	(7129.51)	(1,235,961)	(65,563.37)
No. of obs.: 108,468							
No. of monitors: 316	Free	971.2264	1179.09***	1277.32*	843.78***	1295.26*	226.33
Mean No. of days: 343.5		(689.02)	(84.48)	(775.06)	(156.09)	(768.39)	(145.96)
±0.01 of threshold	STA	2058.66	-674.52***	224,864.6**	112,909***	680,518.6	-3310840***
		(3831.17)	(108.94)	(100,195.6)	(24,958.71)	(1235961)	(621048.5)
No. of obs.: 40,952							
No. of monitors: 316	Free	971.23	-395.83***	5.45	-214.21	1295.26*	221.81
Mean No. of days: 129.6		(689.02)	(107.65)	(1011.83)	(207.91)	(767.63)	(236.34)
S.E. Correlation Correction		Cluster	RE	Cluster	RE	Cluster	RE
Order of O3 ppm polynomial		1	1	2	2	3	3

RD Validity

- RD STA estimates are not robust to various bandwidths and functional form assumptions
- RD FREE is more stable, significant, and positive: 1.4-2.5% increase in cars
- Likely no endogenous sorting
  - motorists cannot control AQI forecasts
  - regulators have little incentive to manipulate assignment
- BUT conditional distribution of outcome (and conditional expectation) must evolve smoothly in AQI
- OR discontinuities away from threshold must be explained

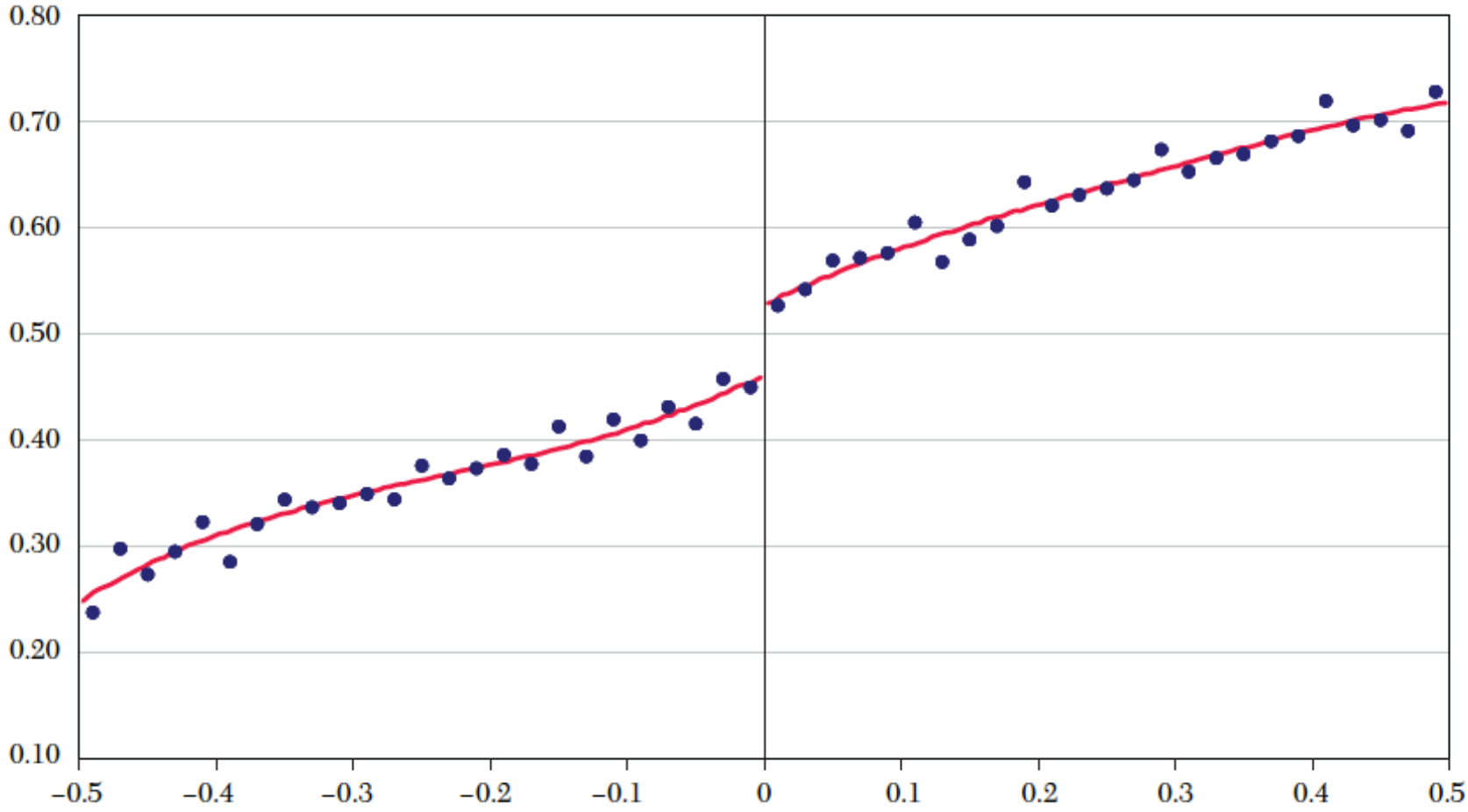


Figure 6. Share of Vote in Next Election, Bandwidth of 0.02 (50 bins)

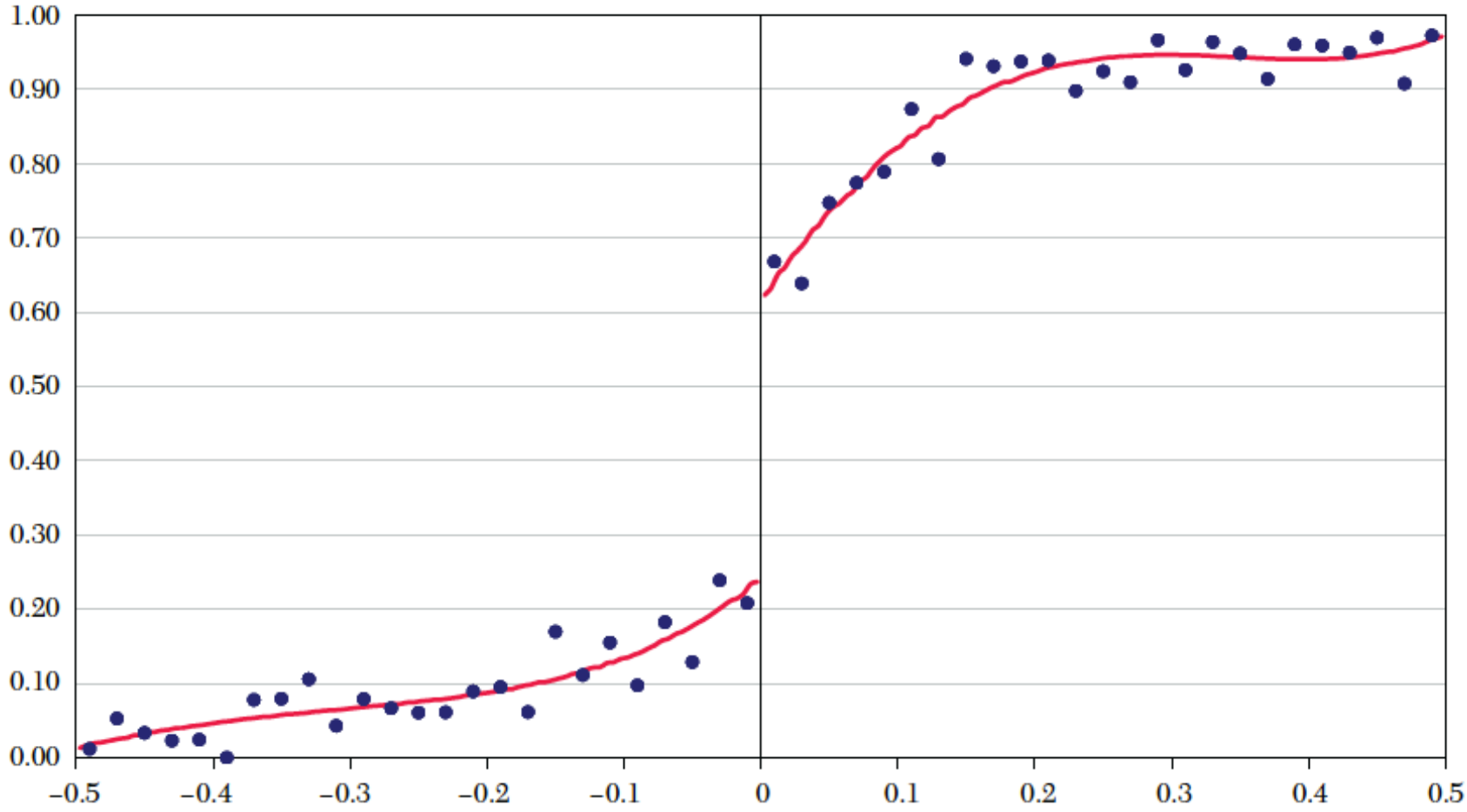
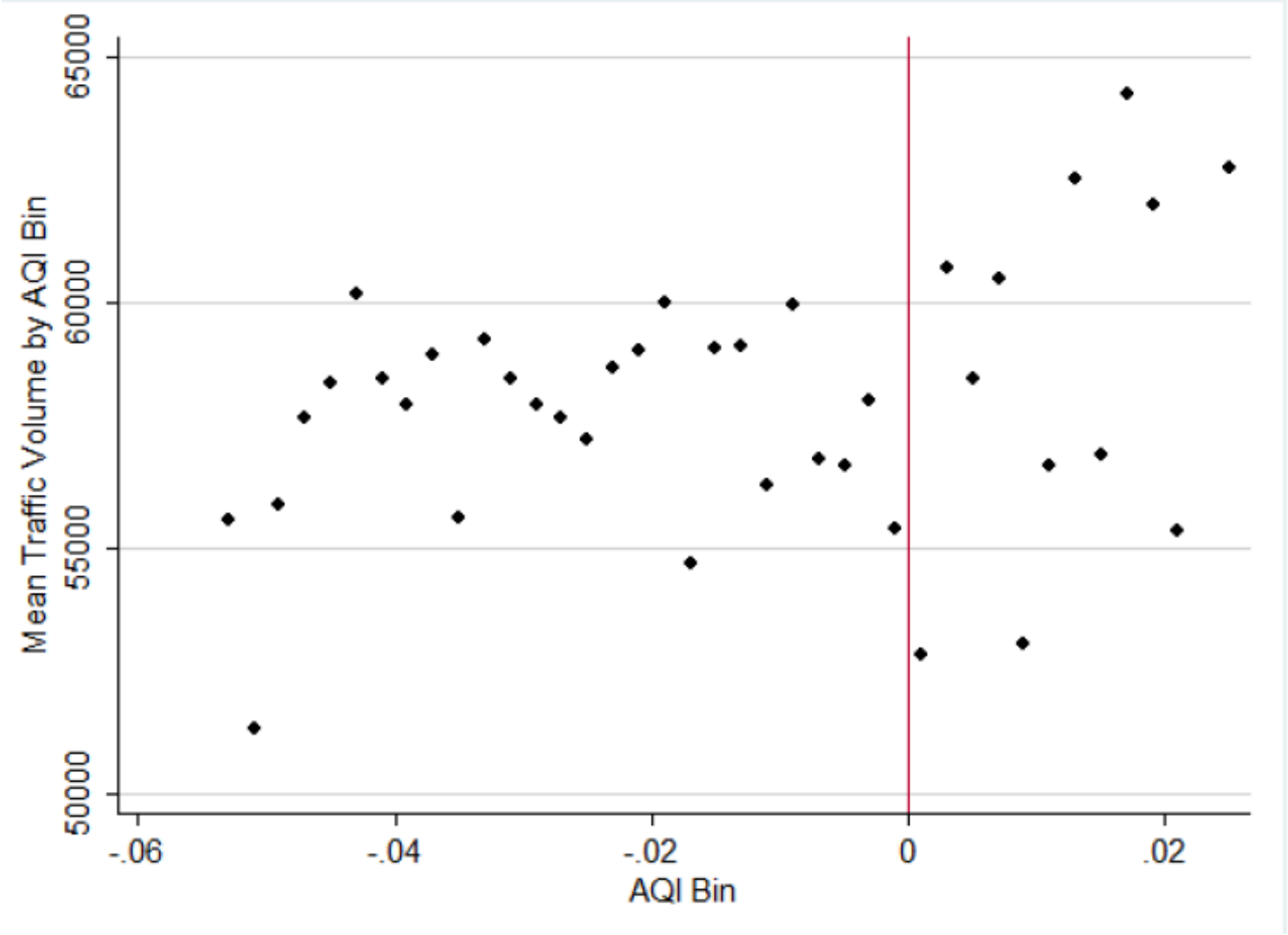


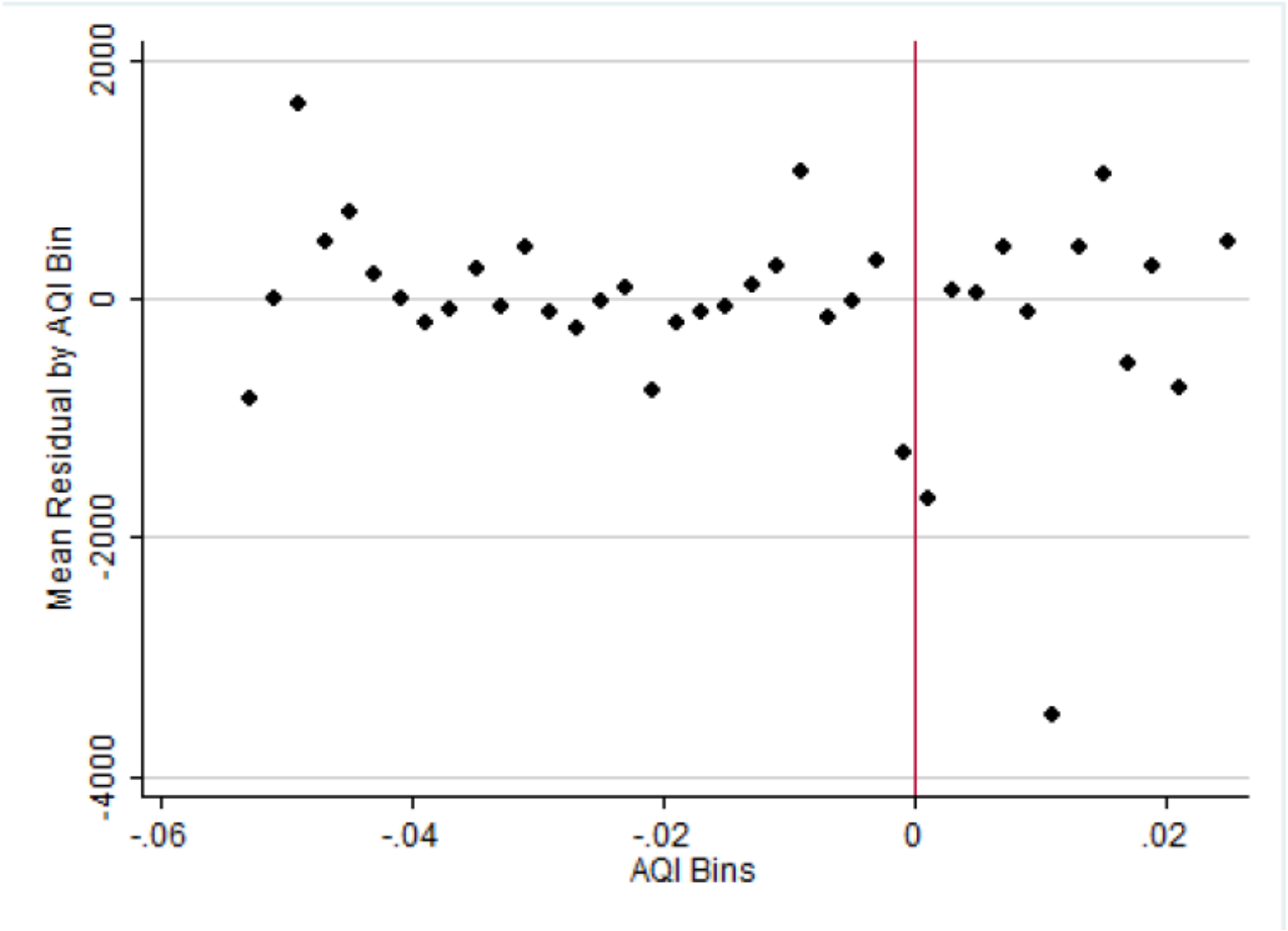
Figure 9. Winning the Next Election, Bandwidth of 0.02 (50 bins)

Figure 1: Conditional Distribution of Traffic Volume

(a) Unrestricted Mean Traffic Volume by AQI Bin



(b) Mean Residuals by AQI Bin (from regressing traffic volume in full complement of covariates except STA and $FREE$)



RD Validity

- Formal tests of pseudo outcomes also raise concern:
  - One and two-day lags of dep var finds significant drop in traffic volumes
  - Arbitrary treatment thresholds yield significant results in various specifications
- RD STA estimates are problematic
- FREE identification relies on diff't assumptions

Parametric FREE Response

$$
\begin{aligned}
q_{it} \quad = \quad & \beta_1 STA_t + \beta_2 FREE_t + \psi_1 g(o3_t) \\
& + \varphi_1 q_{it-1} + \varphi_2 STA_{t-1} \\
& + \varphi_3 FREE_{t-1} + \boldsymbol{\delta} \mathbf{Z_t} + \boldsymbol{\xi} \mathbf{D_t} + \varepsilon_{it}
\end{aligned}
$$

Table 5: Contemporaneous effects of Free fares on traffic volumes and BART ridership

	(1)	(2)	(3)	(4)	(5)	(6)
	Traffic Volume			Transit Ridership		
STA	-366.99	-476.95	-304.57	99.03***	98.41***	113.82***
	(429.21)	(453.97)	(450.43)	(27.47)	(27.35)	(29.02)
	–	–	–	[1.5]	[1.5]	[1.8]
Free	1025.93**	1008.18*	1054.29**	234.31***	234.32***	234.19***
	(519.66)	(527.99)	(519.86)	(42.52)	(43.18)	(47.69)
	[1.8]	[1.7]	[1.8]	[3.6]	[3.6]	[3.6]
Order of O3 ppm polynomial	1	2	3	1	2	3
No. obs.	379,815	379,815	379,815	42,714	42,714	42,714
No. of days	1202	1202	1202	1017	1017	1017
No. of monitors	316	316	316	42	42	42

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Std. errors in parentheses.

Change as a percent of mean in brackets where statistically significant.

Table 6: Lagged Effects of STA, Free and Treatment Dynamics on Traffic and Transit Demands

	(1)	(2)	(3)	(4)	(5)	(6)
	Traffic Volumes			Bart Ridership		
STA	-630.33	-700.78	-568.75	-15.05	-4.88	14.98
	(567.77)	(570.79)	(555.36)	(23.94)	(23.79)	(28.54)
	–	–	–	–	–	–
Free	1596.71***	1573***	1681.52***	409.40***	409.76***	415.33***
	(639.76)	(657.08)	(634.06)	(57.68)	(58.55)	(62.69)
	[2.74]	[2.7]	[2.9]	[6.3]	[6.3]	[6.4]
L.STA	221.41	209.32	187.14	17.88	19.66	15.08
	(395.44)	(397.32)	(395.99)	(37.54)	(38.10)	(38.17)
	–	–	–	–	–	–
L.Free	467.65	461.38	433.48	-96.82	-96.16	-98.98
	(375.85)	(374.33)	(377.46)	(116.54)	(119.35)	(121.17)
	–	–	–	–	–	–
L.STA x STA	894.01	869.91	1144.06*	348.01***	351.62***	395.59***
	(684.26)	(689.39)	(395.99)	(69.05)	(62.88)	(57.29)
	–	–	[2.0]	[5.4]	[5.4]	[6.1]
L.Free x Free	-1060.51	-988.57	-1521.87	-453.07***	-453.17***	-461.19***
	(951.51)	(992.55)	(1012.67)	(71.38)	(74.66)	(87.52)
	–	–	–	[7.0]	[7.0]	[7.1]
L.Free x STA	-1389.76**	-1432.54**	-995.53	-233.52***	-236.10***	-241.10***
	(613.12)	(636.01)	(691.01)	(51.27)	(48.06)	(44.27)
	[2.3]	[2.5]	–	[3.6]	[3.6]	[3.7]

Carpooling

- Rely on self-selection of carpools into HOV and others out of HOV
- Triple and quadruple differencing allows for arbitrary treatment patterns
- Control for lane change inertia

$$
\begin{aligned}
q_{it} \quad = \quad & \alpha_0 + \alpha_1 HOV_i + \alpha_2 STA_j + \alpha_3 ACT_t \\
& + \alpha_4 HOV_i * STA_j + \alpha_5 HOV_i * ACT_t + \alpha_6 STA_j * ACT_t \\
& + \alpha_7 HOV_i * ACT_t * STA_j + \varepsilon_{itj}
\end{aligned}
$$

Discussion

- RD estimates of STA effect may be invalid; little compelling evidence of a significant car-trip response to STA-type programs
- Some evidence of transit response driven by consecutive STA alerts
  - Nets out FREE, so likely driven by altruism-induced mode substitutions, not additional trips

Discussion

- Free fares increase car trips 1.7-1.8% or 300,000 trips
- Free fares increase BART trips 3.6% or 12,600 trips
- => free fares induce additional transit trips and likely substitution from transit toward cars
    - discretionary trips on transit
    - crowding/crime/health risk averting behaviors
    - crowd out of intrinsic motivations

Discussion

- Mind the GE effects!
- $2.5M cost per free fare day makes it the most costly pollution control program in BAAQMD by an order of magnitude--even using their optimistic, survey-based estimates!
- Impact on the poor
- Altruism may not be enough to elicit prosocial behavior

Thanks!

And thanks to Energy Biosciences Institute

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