STAT 156 Final Presentation

Clearing the Air? The Effects of Gasoline Content Regulation on Air Quality

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Introduction

- **Objective**: Replication of Auffhammer & Kellogg's study, *"Clearing the Air? The Effects of Gasoline Content Regulation on Air Quality"*
- **Focus**: Analyzing the impact of gasoline regulations on reducing ground-level ozone pollution in the U.S
- **Key Pollutant**: Ozone – linked to respiratory diseases and crop damage
- **Background**: Despite decades of emissions regulation, many regions exceed EPA ozone standards
- **Main Regulations**:
    - **Reid Vapor Pressure (RVP)**: Limits on VOC emissions (1989, phased implementation)
    - **Reformulated Gasoline (RFG)**: Federal standards (Clean Air Act Amendments, 1995 & 2000)
    - **California Air Resources Board (CARB)**: Stricter state-specific regulations (1996)
- **Study Hypothesis**: Stricter gasoline regulations significantly reduce ozone concentrations

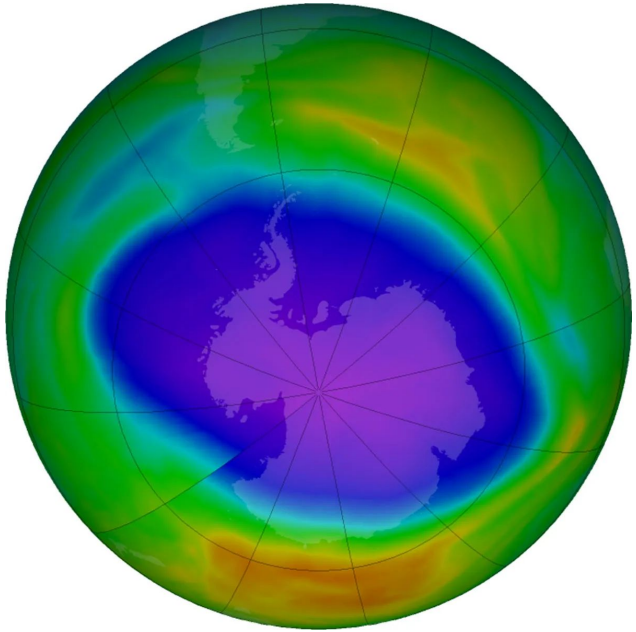


Figure. Ozone Depletion

https://www.britannica.com/science/ozone-depletion

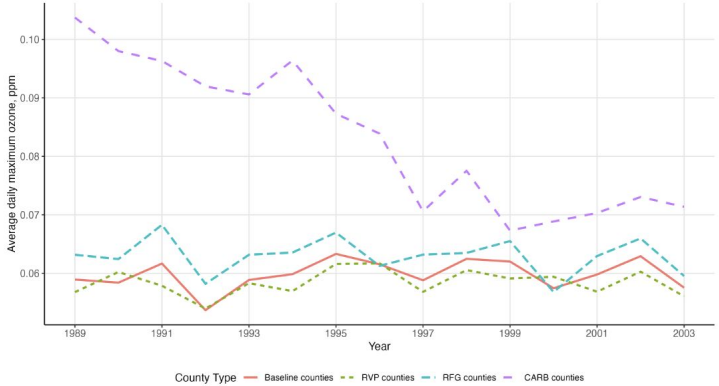
The Data

- **Ozone Data**:
  - Source: EPA (1989-2003)
  - Timeframe: June - August
  - Variables: Daily maximum and 8-hour max ozone concentrations
- **Monitoring Locations**:
  - 1.1 million monitor-days, 80% rural/suburban, 20% urban
  - Counties categorized by regulation type (RVP, RFG, CARB)
- **Weather Data**:
  - Source: NOAA (temperature, rain, snowfall)
- **Controls**:
  - Region-year fixed effects
  - Weather and socioeconomic factors (e.g., income)
- **Summary:**
  - Baseline: 9.0 psi RVP
  - Treatment 1: RVP Phase I (9.5-10.5 psi)
  - Treatment 2: RVP Phase II (7.8 psi or lower)
  - Treatment 3: Federal RFG
  - Treatment 4: CARB

Table 1—Summary Statistics on Monitors and Regulation for the Summer Ozone Season (June–August)

Year	Observations/ (counties)	Counts of active monitors			Regulations			
		Total	Urban	Rural	RVP1	RVP2	RFG95	CARB
1989	63,076/(418)	720	153	244	371	0	0	0
1990	66,108/(436)	751	157	268	381	0	0	0
1991	69,164/(451)	782	151	297	395	0	0	0
1992	69,848/(452)	789	155	300	0	132	0	0
1993	72,606/(469)	815	167	301	0	140	0	0
1994	74,440/(473)	835	163	316	0	140	0	0
1995	77,007/(477)	865	170	330	0	111	111	0
1996	76,462/(471)	854	165	330	0	76	106	48
1997	78,283/(478)	873	166	336	0	76	108	48
1998	79,544/(487)	889	165	344	0	82	108	49
1999	80,750/(485)	899	168	344	0	87	108	49
2000	82,466/(489)	915	178	346	0	97	107	49
2001	83,781/(490)	929	178	355	0	97	108	47
2002	85,230/(495)	943	177	361	0	100	109	49
2003	85,260/(498)	945	180	362	0	101	108	50
Total	1,144,025/(NA)							
Average	76,268/(471)	854	166	322				

Figure 3. Mean Summer Ozone Concentrations
(Broken out by regulation type)



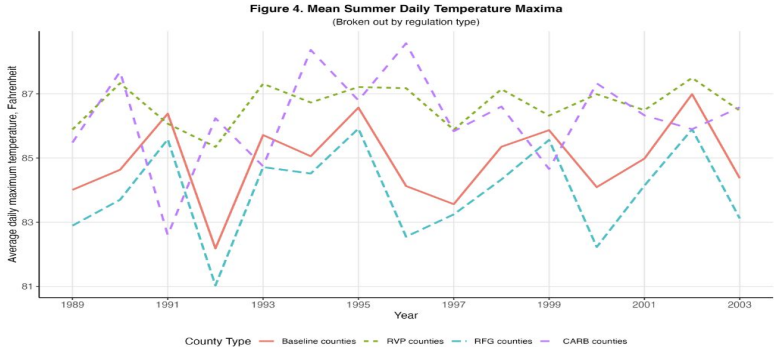
Methods + Assumptions

Methods + Assumptions

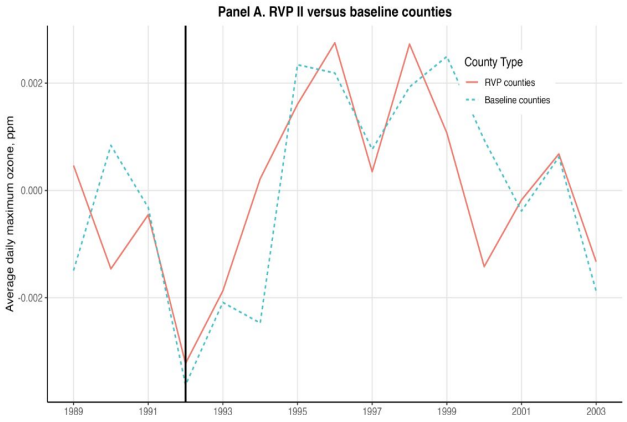
- **Difference-in-Differences (DiD)**:
  - Compares ozone changes before and after regulation across treated vs. control counties
  - Model: log(ozone) ~ regulation + fixed effects (monitor, region-year)
- **Regression Discontinuity (RD)**:
  - Identifies causal effects based on sharp policy changes at regulation implementation dates
  - Control for confounders like weather and county income
- **Key Assumptions**:
  - **DiD**: Parallel trends assumption (untreated counties follow the same trend as treated)
  - **RD**: Discontinuity at regulation implementation without nonlinear trends from unobserved factors

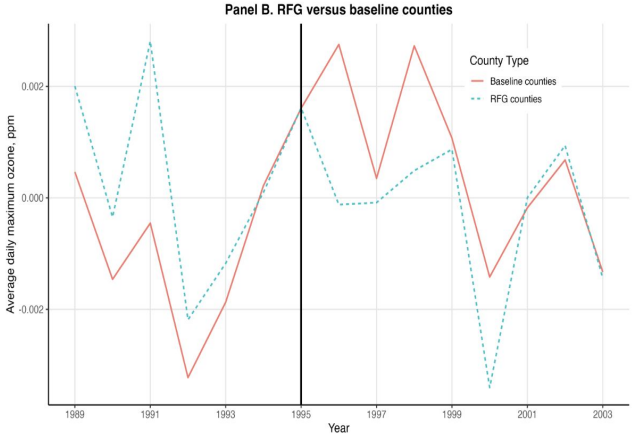
$$\log(\text{ozone\_max}) = \alpha_1 \cdot \text{treat\_rvpI} + \alpha_2 \cdot \text{treat\_rvpII} + \alpha_3 \cdot \text{treat\_rfg} + \alpha_4 \cdot \text{treat\_CARB} + \mu_i + \eta_{ry} + \epsilon_{it},$$

$$\log(\text{ozone\_max}_{it}) = \alpha_1 \cdot \text{treat\_rfg}_{ct} + \alpha_2 \cdot \text{treat\_rvpI}_{ct} + \alpha_3 \cdot \text{treat\_rvpII}_{ct} + \alpha_4 \cdot \text{treat\_CARB}_{ct} + \beta_1 \cdot \text{TempMax}_{it} + \beta_2 \cdot \text{Rain}_{it} + f(\text{income}_{ct}, \text{other\_controls}) + \mu_i + \epsilon_{it}.$$



DiD Results





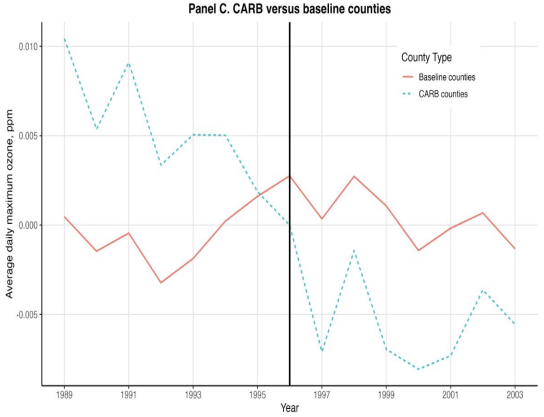


Table 2—Difference-in-Differences Estimation Results

	Dependent var: ln(daily maximum ozone concentration)					ln(daily max 8 hour concentration)		
Regressand	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RVP Phase I:	0.016	0.018	0.020	0.010	0.009	0.018	0.021	0.011
9.5 or 10.5 psi	(0.010)	(0.012)	(0.012)	(0.013)	(0.015)	(0.010)	(0.013)	(0.017)
RVP Phase II:	-0.007	-0.012	-0.008	-0.014	-0.022	-0.005	-0.010	-0.022
7.8 psi or lower	(0.006)	(0.007)	(0.007)	(0.009)	(0.012)	(0.006)	(0.007)	(0.013)
Federal RFG	-0.029***	-0.030***	-0.018*	-0.046***	-0.046***	-0.028***	-0.029***	-0.051***
	(0.006)	(0.007)	(0.007)	(0.012)	(0.013)	(0.006)	(0.007)	(0.014)
CARB gasoline	-0.095***	-0.089***	-0.077***	-0.081**	-0.089**	-0.090***	-0.086***	-0.090**
	(0.014)	(0.016)	(0.016)	(0.032)	(0.020)	(0.013)	(0.016)	(0.033)
County income			-1.281***	-0.206	-0.213			-0.012
($ billion)			(0.337)	(0.260)	(0.251)			(0.258)
Monitor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region–year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region–DOW FEs	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Region FE–DOY interaction	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Weather controls	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Income	No	No	Yes	Yes	Yes	No	No	Yes
Regulation–region trends	No	No	No	Yes	Yes	No	No	Yes
Regulation–region quad trends	No	No	No	No	Yes	No	No	Yes
Observations					1,144,025			
R^2 (within-monitor)	0.315	0.424	0.425	0.258	0.258	0.327	0.433	0.252

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table 3—Difference-in-Difference Estimation Results: Urban versus Suburban versus Rural

	Dependent var: ln(daily maximum ozone concentration)					
	Urban		Suburban		Rural	
Regressand	(1)	(2)	(3)	(4)	(5)	(6)
RVP Phase I:	0.019	0.019	0.029	0.011	0.020	0.004
9.5 or 10.5 psi	(0.025)	(0.019)	(0.019)	(0.014)	(0.022)	(0.018)
RVP Phase II:	0.008	0.005	-0.009	-0.023*	-0.018	-0.016
7.8 psi or lower	(0.018)	(0.014)	(0.009)	(0.011)	(0.012)	(0.011)
Federal RFG	-0.005	-0.038*	-0.025*	-0.058***	-0.025	-0.045***
	(0.017)	(0.015)	(0.010)	(0.015)	(0.014)	(0.013)
CARB gasoline	-0.063	-0.079**	-0.105***	-0.095**	-0.060**	-0.068*
	(0.032)	(0.029)	(0.026)	(0.033)	(0.022)	(0.034)
County income	-1.307**	0.438	-1.513**	-0.677**	-1.438	0.079
($ billion)	(0.445)	(0.445)	(0.549)	(0.234)	(0.835)	(0.853)
Monitor FEs	Yes	Yes	Yes	Yes	Yes	Yes
Region–year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Region–DOW FEs	Yes	Yes	Yes	Yes	Yes	Yes
Region FE–DOY interaction	Yes	Yes	Yes	Yes	Yes	Yes
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
Income	Yes	Yes	Yes	Yes	Yes	Yes
Regulation–region trends	No	Yes	No	Yes	No	Yes
Observations	222,982	222,982	490,539	490,539	430,504	430,504
R^2 (within-monitor)	0.475	0.279	0.420	0.272	0.402	0.236

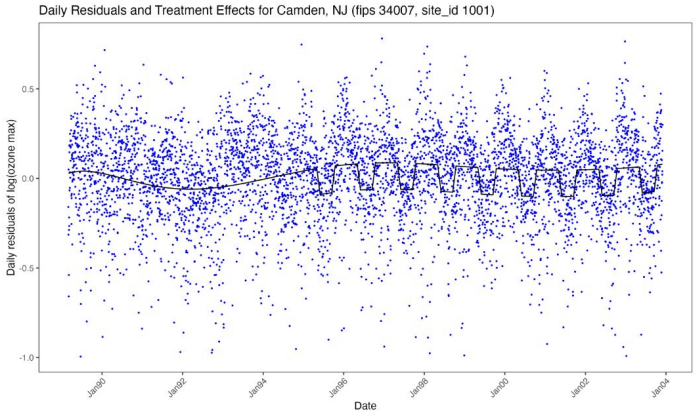
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table 4—Difference-in-Differences Estimation Results: Monitors Recording Data in Every Year

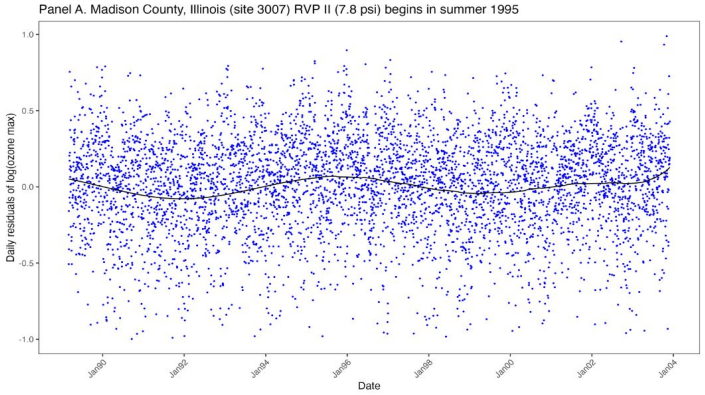
	Dependent var: ln(daily maximum ozone concentration)					ln(daily max 8 hour concentration)		
Regressand	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RVP Phase I:	-0.009	0.000	-0.001	-0.008	-0.007	-0.007	0.003	-0.006
9.5 or 10.5 psi	(0.012)	(0.015)	(0.016)	(0.014)	(0.016)	(0.012)	(0.016)	(0.017)
RVP Phase II:	-0.009	-0.016	-0.011	-0.023*	-0.033*	-0.009	-0.015	-0.033*
7.8 psi or lower	(0.007)	(0.009)	(0.009)	(0.011)	(0.013)	(0.008)	(0.009)	(0.014)
Federal RFG	-0.031***	-0.036***	-0.023*	-0.066*	-0.065***	-0.031***	-0.036***	-0.071***
	(0.007)	(0.008)	(0.010)	(0.014)	(0.016)	(0.008)	(0.009)	(0.017)
CARB gasoline	-0.148***	-0.132***	-0.108***	-0.151***	-0.159***	-0.139***	-0.124***	-0.163***
	(0.022)	(0.027)	(0.027)	(0.035)	(0.037)	(0.021)	(0.027)	(0.039)
County income	–	–	-1.677***	-0.233	-0.252	–	–	-0.042
($ billion)	–	–	(0.439)	(0.278)	(0.251)	–	–	(0.286)
Monitor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region–year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region–DOW FEs	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Region FE–DOY interaction	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Weather controls	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Income	No	No	Yes	Yes	Yes	No	No	Yes
Regulation–region trends	No	No	No	Yes	Yes	No	No	Yes
Regulation–region quad trends	No	No	No	No	Yes	No	No	Yes
Observations					455,084			
R^2 (within-monitor)	0.307	0.429	0.430	0.278	0.278	0.308	0.429	0.271

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

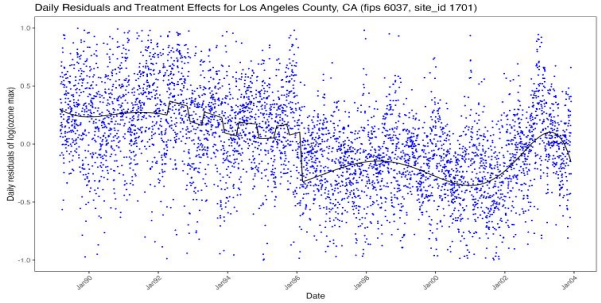
RD Design Results



(a) Camden, NJ (fips 34007, site_id 1001)



(b) Madison County, IL (site 3007), RVP II



(e) Los Angeles County, CA (site 1701)

Summary of Results

- **Geographic Differences**:
  - **Urban/Suburban Areas**: CARB and RFG regulations showed the most significant reductions in ozone levels
  - **Rural Areas**: The impact of CARB and RFG regulations was less pronounced, with many results being statistically insignificant due to lower baseline ozone levels
- **Regulation Effectiveness**:
  - **CARB regulations** were the most effective in reducing ozone, especially in areas with higher pollution levels.
  - **RFG regulations** showed moderate but consistent reductions across different areas

Robustness Overview

- **Purpose of Robustness Checks:**
  - Validate the reliability of estimated effects and test if results hold under different assumptions.
  - Address potential confounding factors such as time-varying unobservables (e.g., economic activity, technological advancements, other policies).
- **Importance of Robustness Checks:**
  - Original DiD model assumes parallel trends between treated and untreated counties.
  - Adding **linear and quadratic regulation-specific time trends** controls for potential differential temporal dynamics.
- **Methodology:** Augmented the original DiD model with:
  - **Linear time trends**: Control for gradual temporal changes.
  - **Quadratic time trends**: Capture nonlinear dynamics over time.

  Incorporated **weather covariates** to account for known influences on ozone levels.

Robustness Results

- **Key Findings**:
  - **Linear Time Trends**:
    - Effects for RVP and CARB remained **stable and statistically significant.**
    - Suggests robustness to gradual, linear temporal variations.
  - **Quadratic Time Trends**:
    - RFG results showed sensitivity:
      - Linear trend effect: Significant reduction of **−0.036**.
      - Quadratic trend effect: Reduced to **−0.019** and became **statistically insignificant**.
    - Indicates potential bias in original RFG estimates due to **unaddressed nonlinear trends**
- **Conclusion**:
  - **RVP and CARB regulations**: Effects are robust across models.
  - **RFG regulation**: Results are sensitive to model specifications, necessitating cautious interpretation and further investigation.

Reanalysis: IPW Estimators

- **Purpose of Reanalysis with IPW Estimators:**
  - To correct for confounding bias in DiD models
- **Assumption:**
  - Urbanization introduces confounding bias
- **Methodology:**
  - Calculated propensity scores using the data of the degree of urbanization
  - Adjusted weights on regression models

- **Conclusion:**

ln(Daily Max Ozone Concentration)		
	Model	**IPW**
RVPI	-0.007	-0.008
RVPII	-0.033	-0.031
RFG	-0.065	-0.063
CARB	-0.159	-0.164
Income	-0.252	0.104

ln(daily max 8 hour concentration)		
	Model	**IPW**
RVPI	-0.006	-0.006
RVPII	-0.033	-0.030
RFG	-0.071	-0.069
CARB	-0.163	-0.165
Income	-0.042	0.322

  - Correcting for the confounding bias from urbanization revealed a positive relationship between ozone concentration and income.

Conclusion

- **CARB Regulations:**
  - Most effective in reducing ozone levels, particularly in urban and suburban areas
    - Achieved reductions of 8-16% in high-pollution areas like Los Angeles
    - Highlights the importance of stringent, regionally-targeted policies
- **RFG and RVP Regulations:**
  - **RFG:**
    - Modest ozone reductions of 3-5%
    - Sensitive to model specifications, with some results becoming statistically insignificant
  - **RVP:**
    - Minimal or no significant impact on ozone levels
    - Indicates limited effectiveness of flexible compliance mechanisms

Limitations

- **Temporal Trends and Bias:**
  - Challenges in fully accounting for unobserved time-varying factors
    - Additional environmental policies or economic activities might confound results
  - Sensitivity of RFG effects to nonlinear trends suggests potential bias
- **Generalizability:**
  - Findings may not extend to other pollutants affected by gasoline regulations
- **Nonlinear Effects:**
  - Overlapping policy impacts may obscure the true effects of regulations
  - Results for RFG suggest the need for caution when interpreting treatment effects

References

https://pubs.aeaweb.org/doi/pdfplus/10.1257/aer.101.6.2687

Remark: The data sources are provided by the author, Prof. Maximilian Auffhammer, and were, according to him, downloaded from AER.

We would also like to extend our sincere gratitude to Prof. Auffhammer. It is a great honor to have the opportunity to replicate his paper.

Questions?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