Regulating Untaxable Externalities: Are Vehicle Air Pollution Standards Effective and Efficient?

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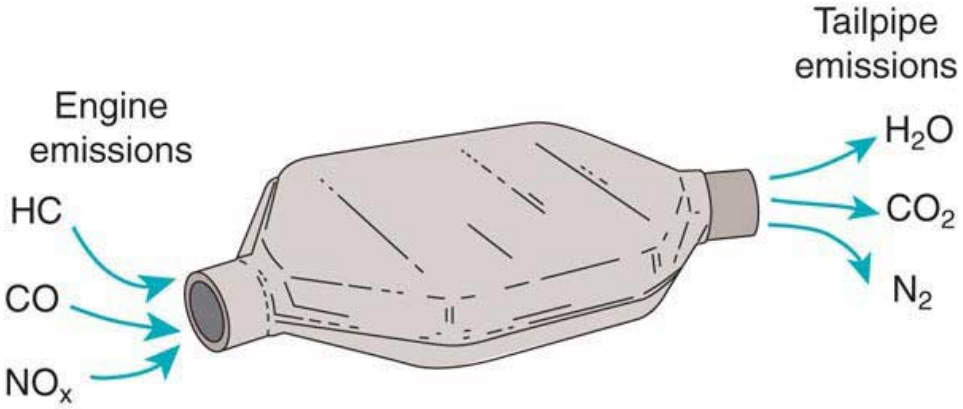
March 30, 2022
RFF/EPA Workshop



Why write this paper?

In broad strokes, the story of vehicle emissions reductions and the role of policy is well understood

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Our goals are to:

1. Quantify the dramatic reductions in air pollution from automobiles over several decades
2. Use modern econometric strategies to validate causal role of policy
3. Evaluate the economic efficiency of the exhaust standards
4. Explain how policy can be improved, qualitatively and quantitatively

Background

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  - Central part of policy in US, EU, China, India, ...
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- **Most countries instead use exhaust standards**
  - Central part of policy in US, EU, China, India, ...
  - Many have done so for decades
- **In spite of this, much is unknown**
  - Standards controversial (three requests to National Academies)
  - Efficacy uncertain (e.g., VW scandal)
  - Sparse attention paid to evaluating exhaust standards as compared to stationary sources or CAFE in economics literature

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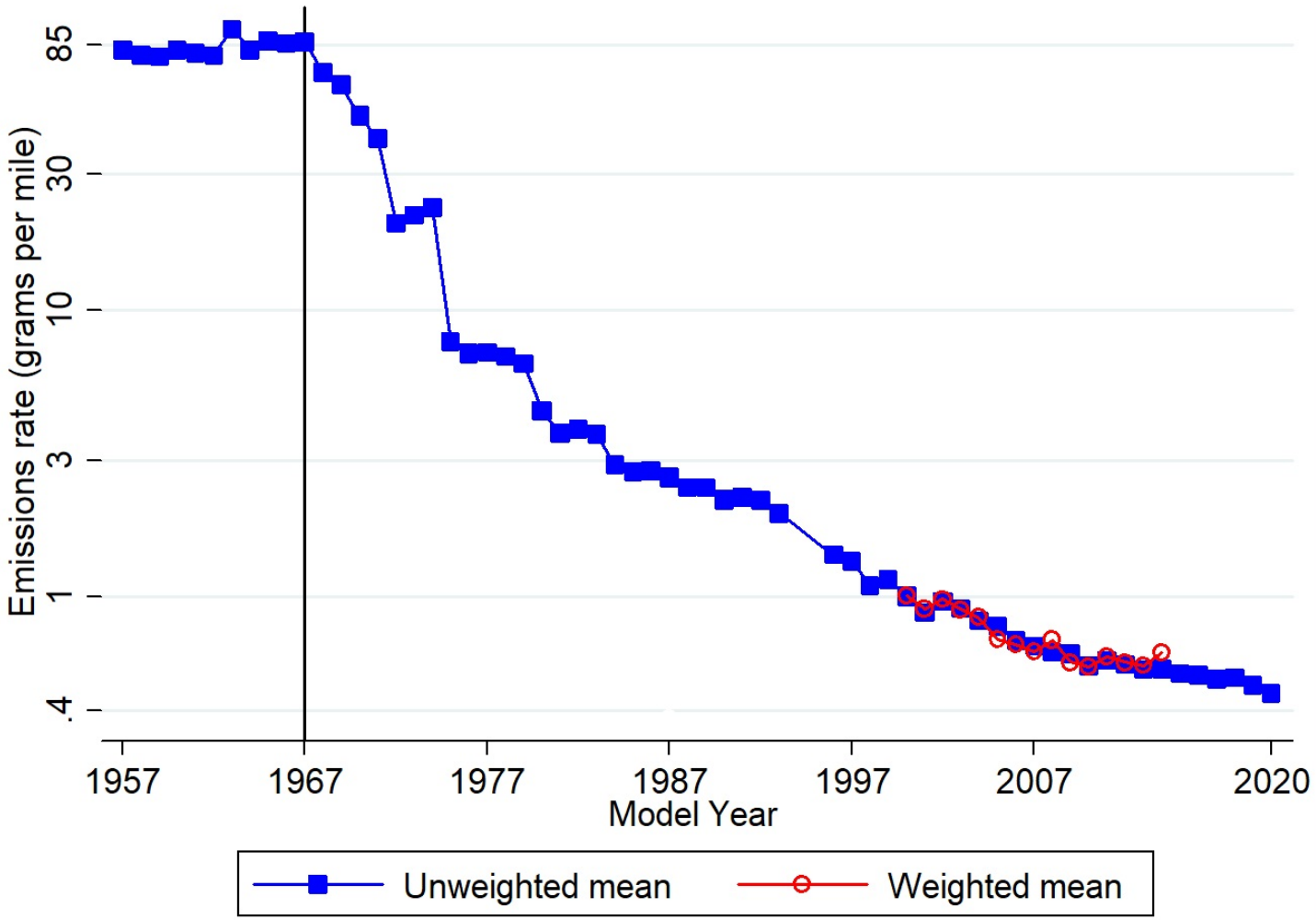
To answer these, we collect data from **60 years** of new-vehicle emissions tests and **millions** of used-vehicle inspections

To analyze additional polices, we build a new analytical model and a numerical **quantitative model** of the new and used-vehicle fleet

Data

- **New vehicle emission tests (EPA)**
  - Model years 1973-2019 (also some data for 1957-1972)
  - Fully comparable (Federal Register specifies test)
  - Longest high-quality data on emission rates for any country, sector
  - N≈20,000
- **Inspection & maintenance, a.k.a. smog check (Colorado, others)**
  - Comparable to new vehicle tests (IM240)
  - N≈12,000,000
- **Remote sensing (Colorado, others)**
  - Defeats the "defeat devices"
  - N≈50,000,000
- **In-use vehicle tests (EPA, CARB)**
  - N≈10,000

Emissions across vintages: carbon monoxide



- CO first regulated in 1968; flat trend before policy
- Log scale; more than 99% reduction

Causal effect of standards

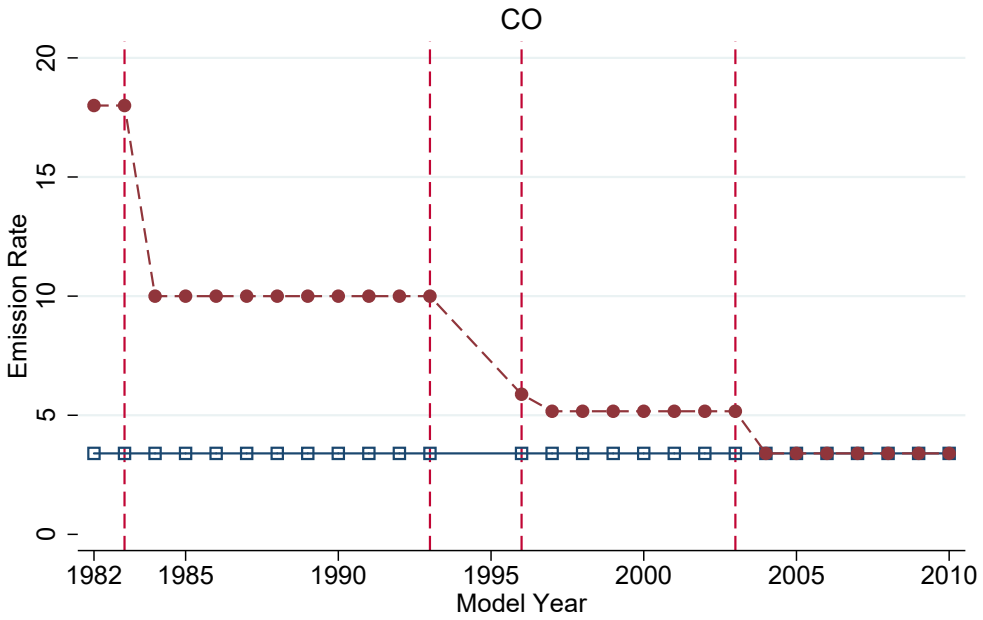
- We use several comparisons to test the causal role of policy in inducing the observed declines, including:
  - Regulated vs. unregulated pollutants before and after rule changes
  - Cars vs. light-duty trucks (separately regulated) before and after rule changes
  - Between California and the federal standards

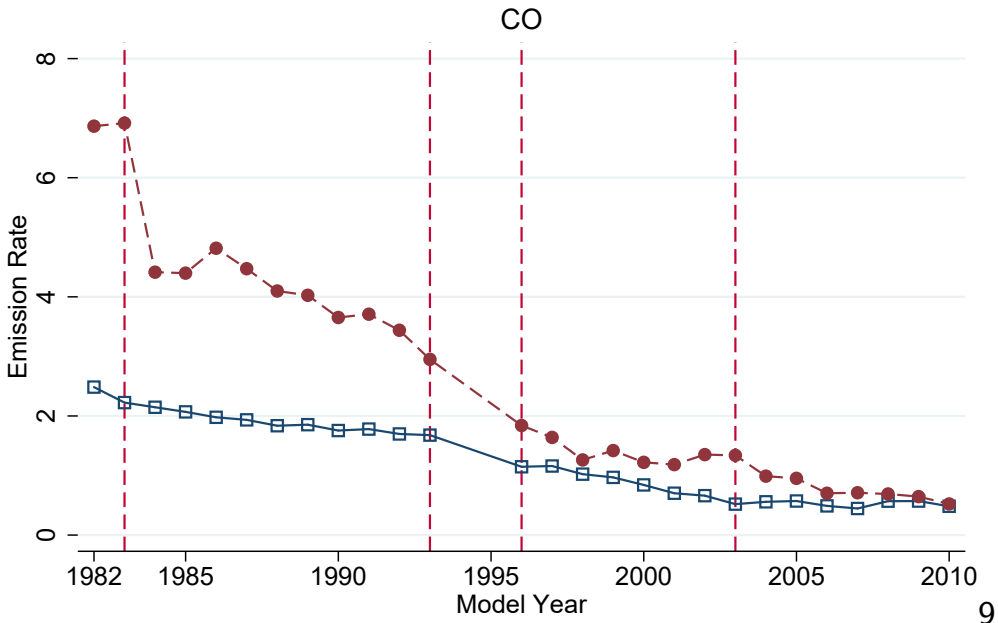
Causal effects of standards (CO)

- Top is standard
- **Blue** line is for cars
- **Red** line is for trucks
- Vertical lines show policy changes

- Bottom is new-vehicle emissions

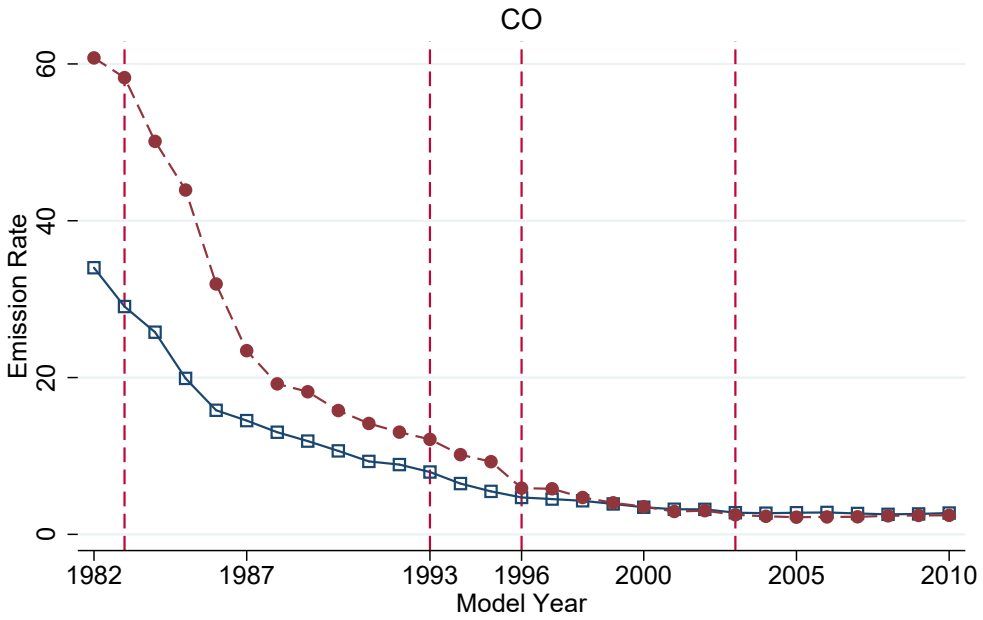
- <u>Scales differ</u>



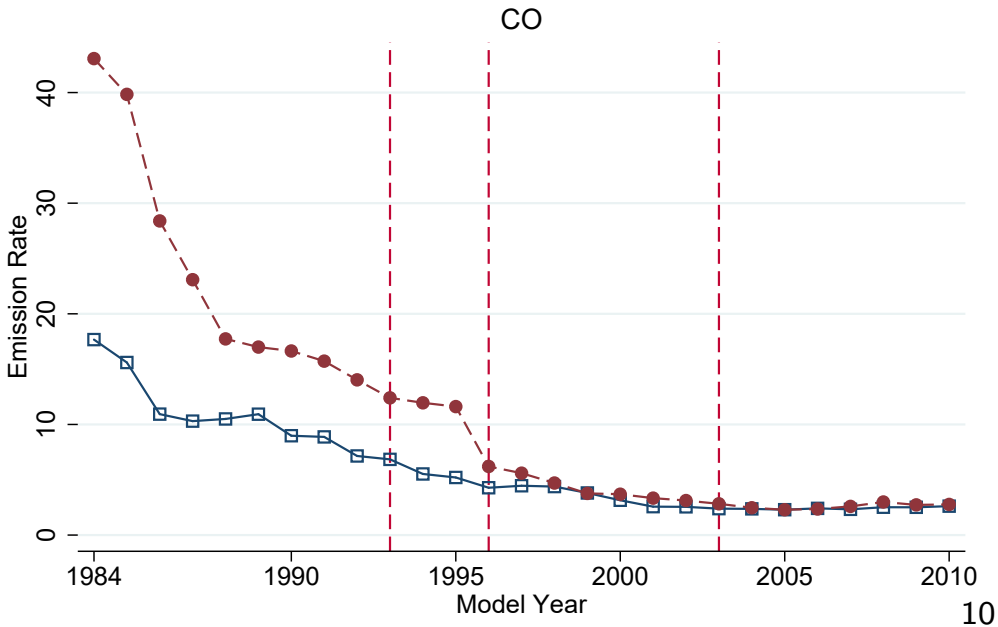


Causal effects of standards (CO)

- Top is used-vehicle emissions (smog check)



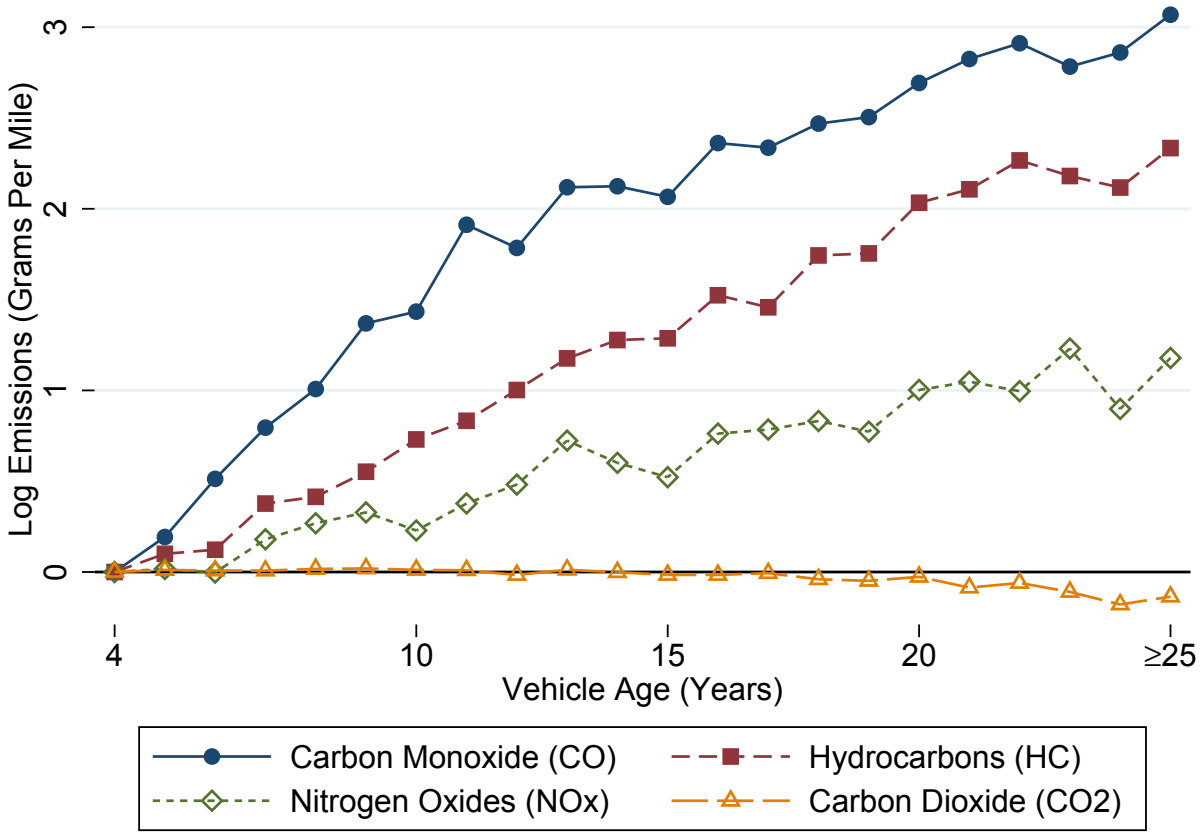
- Bottom is used-vehicle emissions (remote sensing)



Policy evaluation

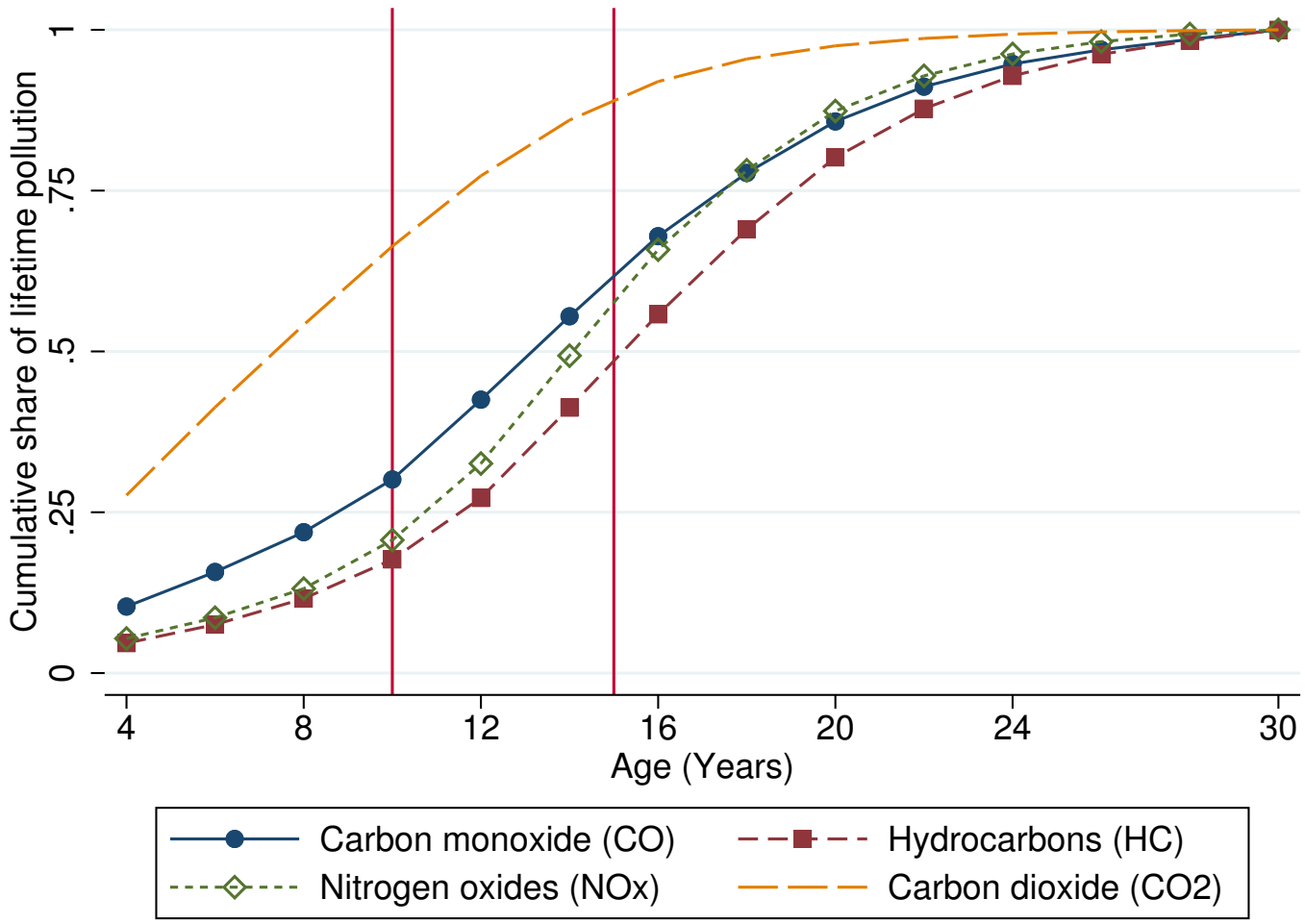
1. Assess whether recent standards pass cost-benefit test
2. Ask whether even tighter standards are worthwhile
3. Ask how other policies might complement standards—focus on optimizing vehicle retirement

Optimizing retirement is important because old vehicles account for a large share of pollution



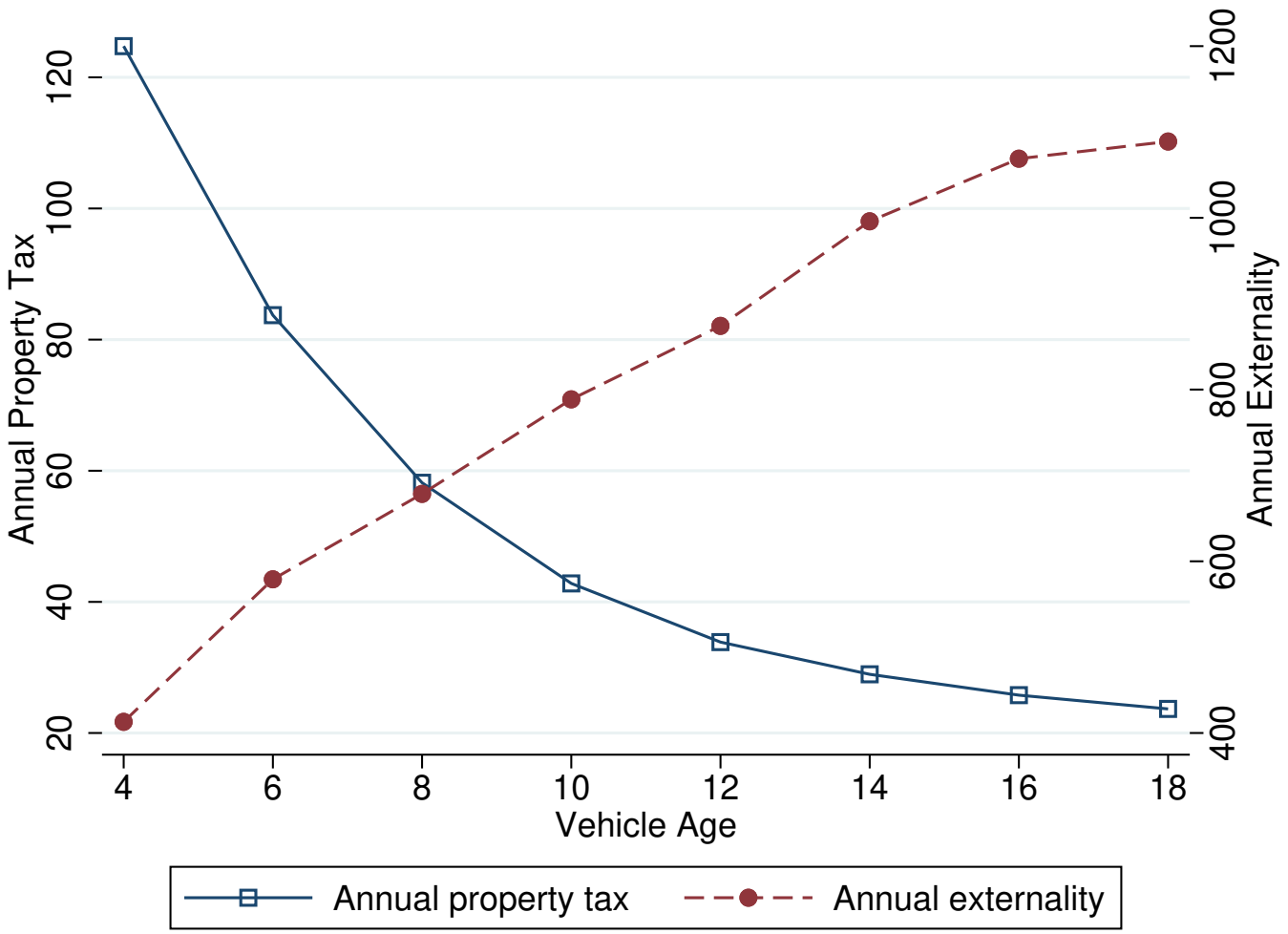
- Older vehicles emit more b/c (a) newer vintages have better control equipment and (b) equipment degrades
- Graph shows estimated effect of age on emissions, <u>conditional on odometer</u>

Older Vehicles Account for Most Pollution



- A logical policy then is to tax older vehicles more, thus accelerating retirement in favor of newer (cleaner) models

Dirtier Vehicles Face Lower Registration Fees



- Current policy gets this backwards because older cars have lower registration fees
- This exacerbates inefficiencies from fleet turnover

Policy analysis

- Analytical model of vehicle fleet to understand scrappage/retirement inefficiencies
  - Demonstrate that market scrap decision is inefficient
  - Show that exhaust standards exacerbate this inefficiency (Gruenspecht effect)

- Quantitative simulation to model counterfactual policies
  - Evaluate recent exhaust standards
  - Ask if tighter standards still justified
  - Quantify gains from registration fees that correct scrappage inefficiency

Analytical model

- **Basic setup**
  - One type of car, either new or used
  - A new car has to be repaired (at some cost) or scrapped after being driven new
  - Consumer chooses whether to buy a new or used car, and whether to scrap or repair used cars
  - Competitive supply of new and used vehicles
  - Endogenous price of used vehicles clears market—price determines scrap rate and new vs used demand

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- **Pollution**
  - New cars have production emissions plus in-use emission
  - Used cars have higher in-use emission (both vintage and age effects)

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  - Tighter exhaust standards act like a new vehicle tax (raise price)

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- **Results**
  - As long as production emissions "small," efficient policy is to tax **used** vehicles, because they pollute more
  - Higher new vehicle tax (or standards that raise cost) exacerbate scrap inefficiencies by decreasing scrap rate (Gruenspecht effect)
  - This formalizes our call for registration fees on used vehicles

Quantitative model

- Representative agent demands portfolio of cars
- Used vehicles have repair costs, scrappage is optimal given costs and equilibrium prices
- Equilibrium prices of new and used vehicles clear market
- Overlapping vintages and ages by class and automaker—532 vehicle prices (28 emissions rates, 14 vintages x truck/car)
- Used vehicle market is competitive; new vehicle either competitive or Bertrand

Counterfactual Exhaust Standards: Model-Based Estimates

TABLE 5: Model-Based Estimates: Effects of Counterfactual Exhaust Standards and Registration Fees

	Change in market surplus	Change in pollution damages	Total change in social welfare = (1) - (2)	New tax revenue	Percent change in cumulative emissions		
					CO	HC	NOx
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Counterfactual Exhaust Standards							
1. Delay Tier 2 by four years	8.4	120.6	-112.3	0.0	8.0	4.8	10.7
2. Delay Tier 2 by eight years	13.6	207.0	-193.4	0.0	15.6	8.3	18.4
3. Accelerate Tier 2 by four years	-10.5	-127.7	117.2	0.0	-6.3	-4.9	-11.1
4. Accelerate Tier 2 by eight years	-22.4	-202.5	180.1	0.0	-9.7	-7.7	-17.5
5. Tighten standards 10 percent	-2.4	-27.9	25.5	0.0	-1.4	-1.1	-2.4

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- **Synopsis of Tier 2 exhaust standards**
  - $30 billion in annual environmental benefits
  - Like preventing 3,000 deaths/year (at VSL=10mn)
  - Benefit/cost ratio of 10 to 15

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	Panel B. Counterfactual Registration Fees						
6. Age×type fee	-176.4	-509.7	333.2	1,181.2	-43.4	-43.2	-24.8
7. Age×type fee, revenue neutral	-115.4	-350.8	235.4	0.0	-34.0	-33.6	-15.3
8. New vehicle fee	-19.7	1.4	-21.1	407.1	1.7	1.8	-0.5
9. Flat registration fee	-3.7	-21.9	18.2	0.0	-1.9	-1.9	-1.2

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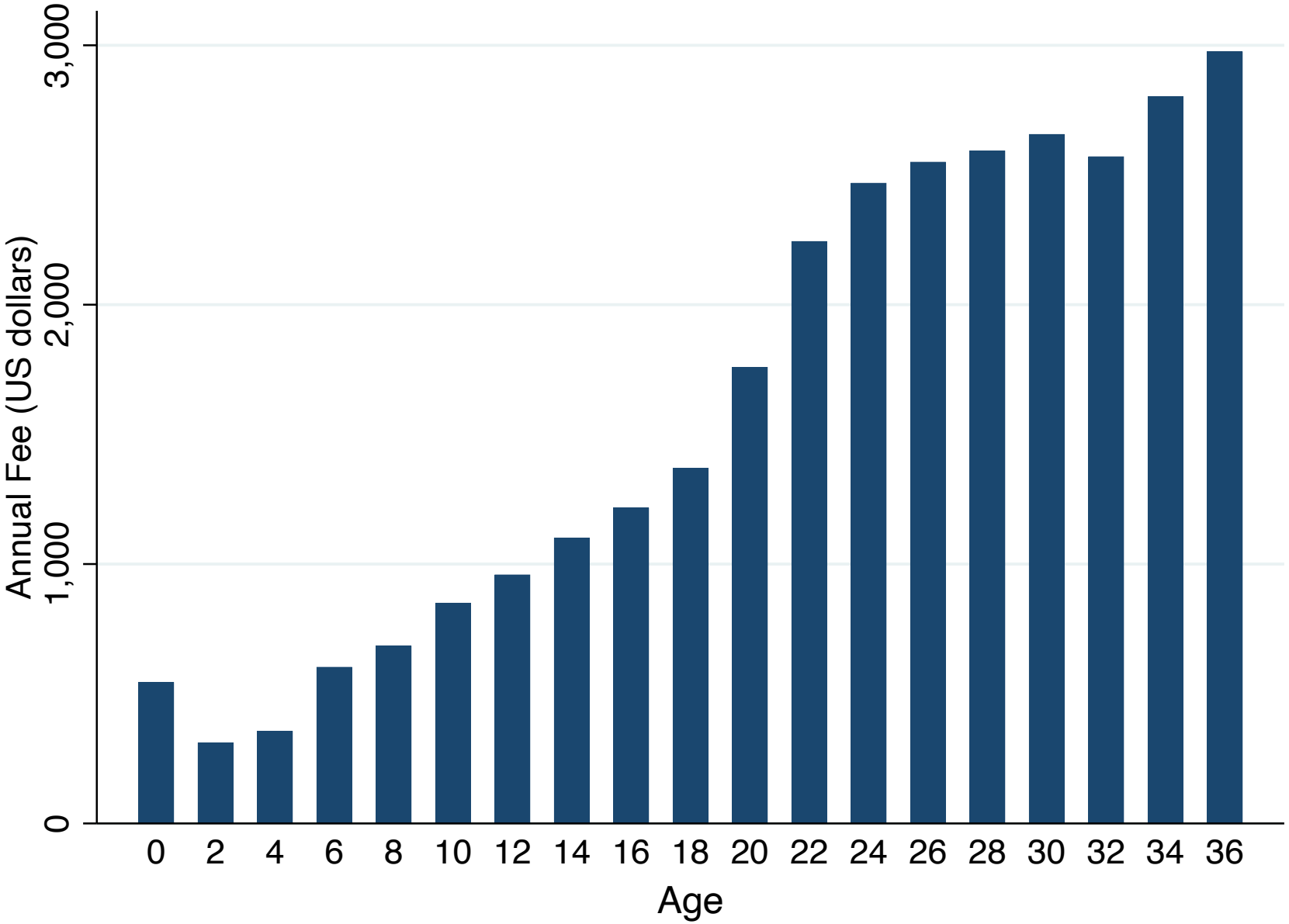

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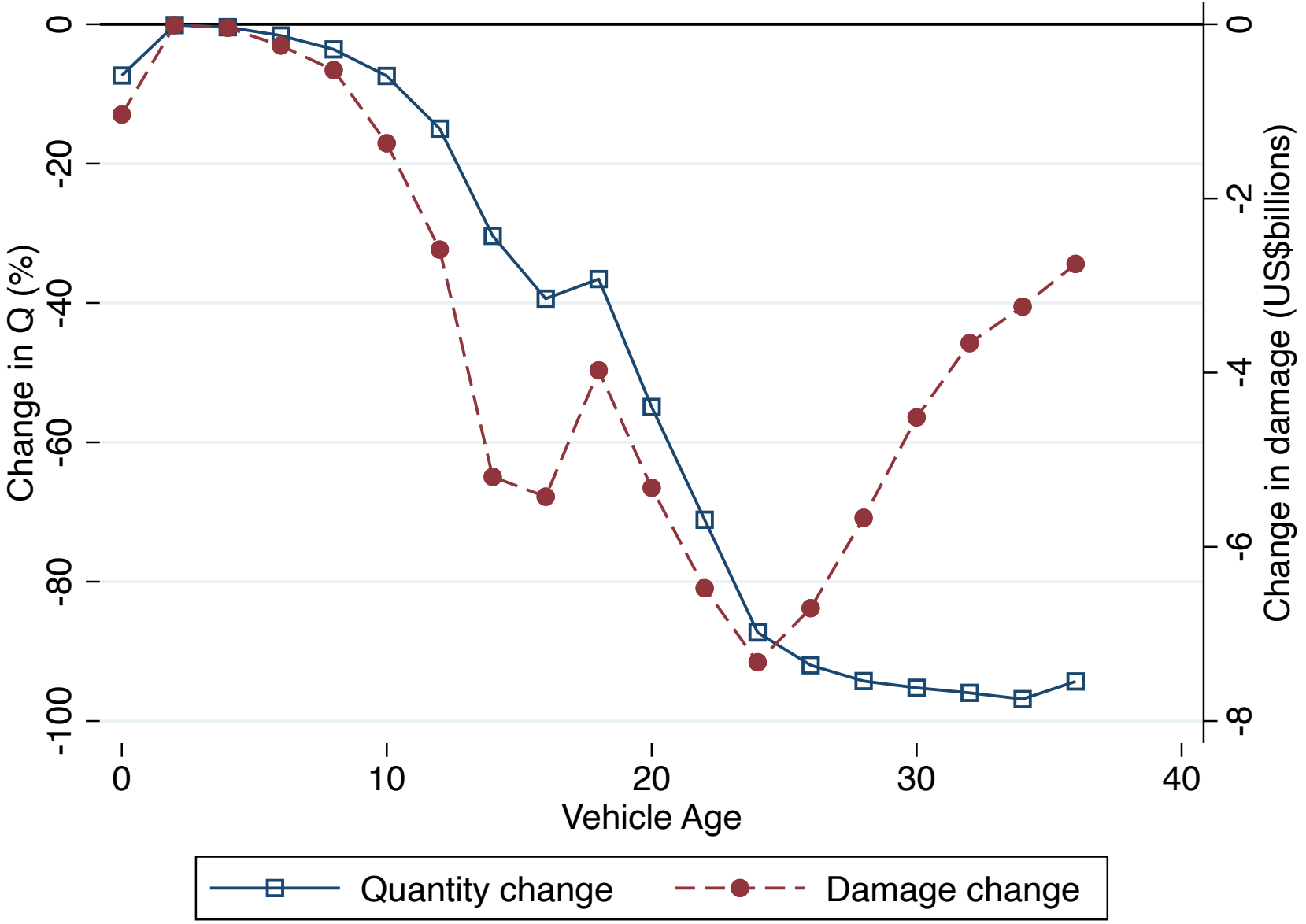

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Conclusions

- **Surprising findings**
  - Pollution/mile has fallen 99%
  - Clean Air Act exhaust standards extremely effective
  - Air pollution increases with vehicle age, not CO_2
  - Most emissions are from old vehicles
  - Registration fees are higher on cleaner vehicles
  - Gruenspecht Effect important in general, nonparametric setting
  - Big welfare gains, distributional consequences from reforming standards, fees
- **Broader comments**
  - Gasoline $\rightarrow$ electric
  - Equity: dirtier cars in low-income communities, communities of color
  - How generalize to China/India/Mexico/etc.?