Lecture 18: Regulating Cars

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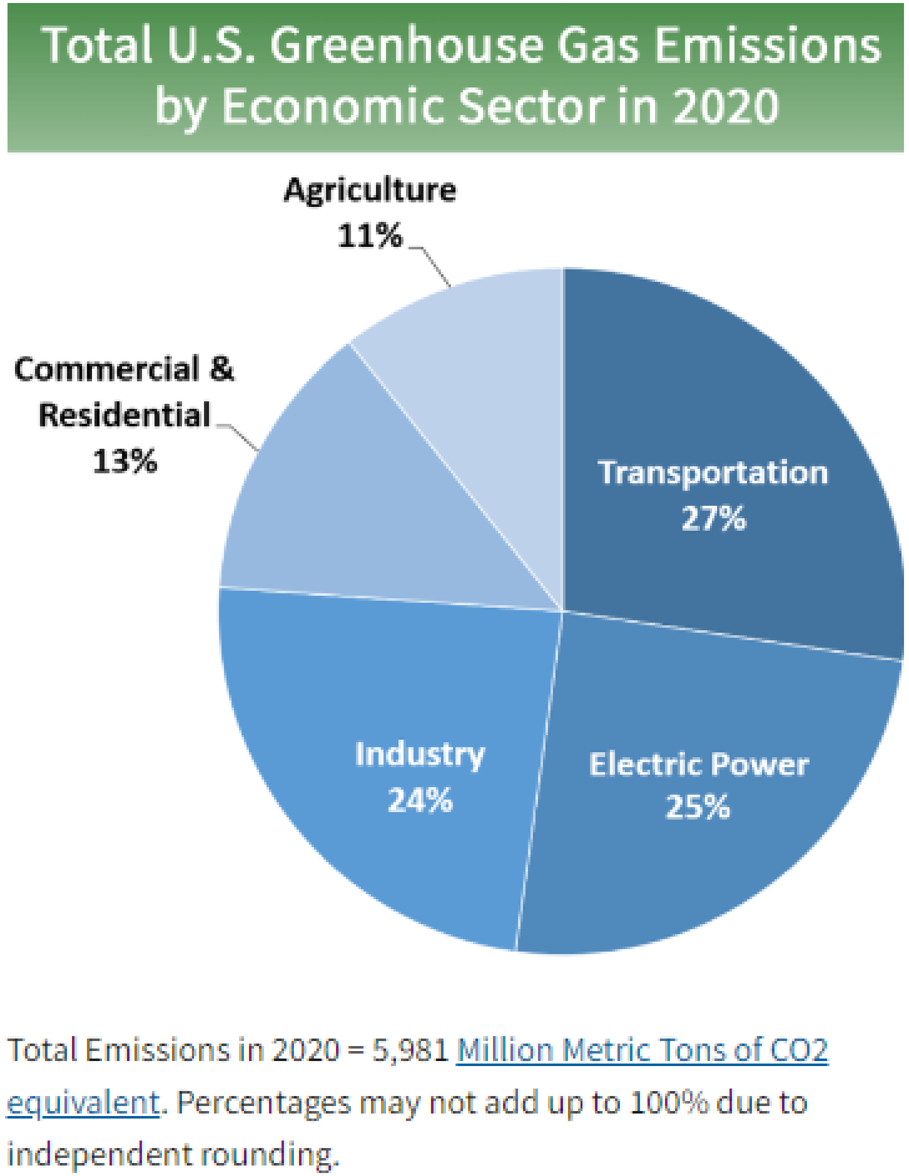
Environmental Economics
Econ 475

Why Regulate Cars?

Many externalities:

- GHG emissions
- Other air pollutants (e.g., CO, PM, NOx)
- Traffic congestion costs
- Accidents and fatalities



Source: EPA (2021).

Some Policy Options

Some options for reducing these externalities:

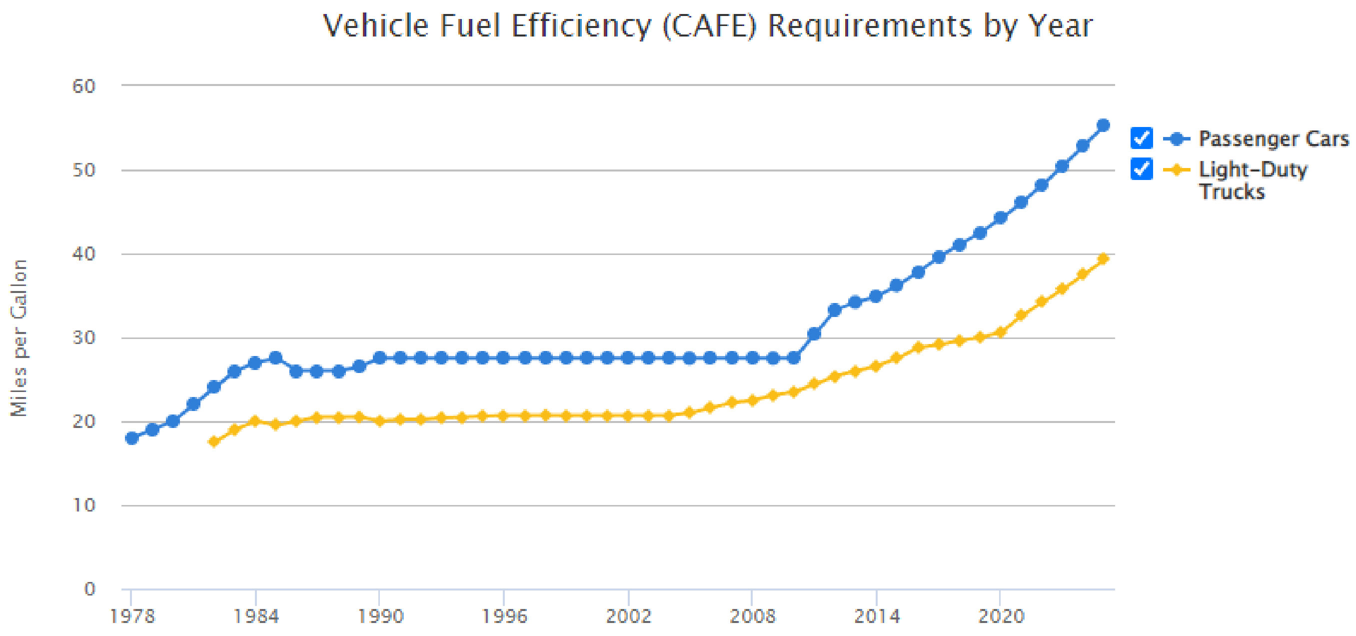
- **Fuel Tax:** a tax on each unit of fuel purchased.
- **Fuel Economy Standard:** A car must meet a certain miles per gallon standard.
- **Attribute-based Fuel Economy Standard:** Different types of cars must meet different miles per gallon standards.
- **Emissions Standards:** Specific required reductions of tailpipe emissions for all car models.
- Others: car property tax, tax on car attributes (engine size, age, weight), car type requirements, new/old car registration fee, etc.

The Corporate Average Fuel Economy Standard

For each manufacturer, the average mpg of all cars sold must be below the CAFE Standard:

$$CAFE = \frac{1}{N}\sum_i n_i mpg_i$$

- i is a model of car sold, n_i is the total sold of that model, N is the total cars sold of a given type for one manufacturer.
- \$55 charge per car for each mpg under the standard originally, now \$290.



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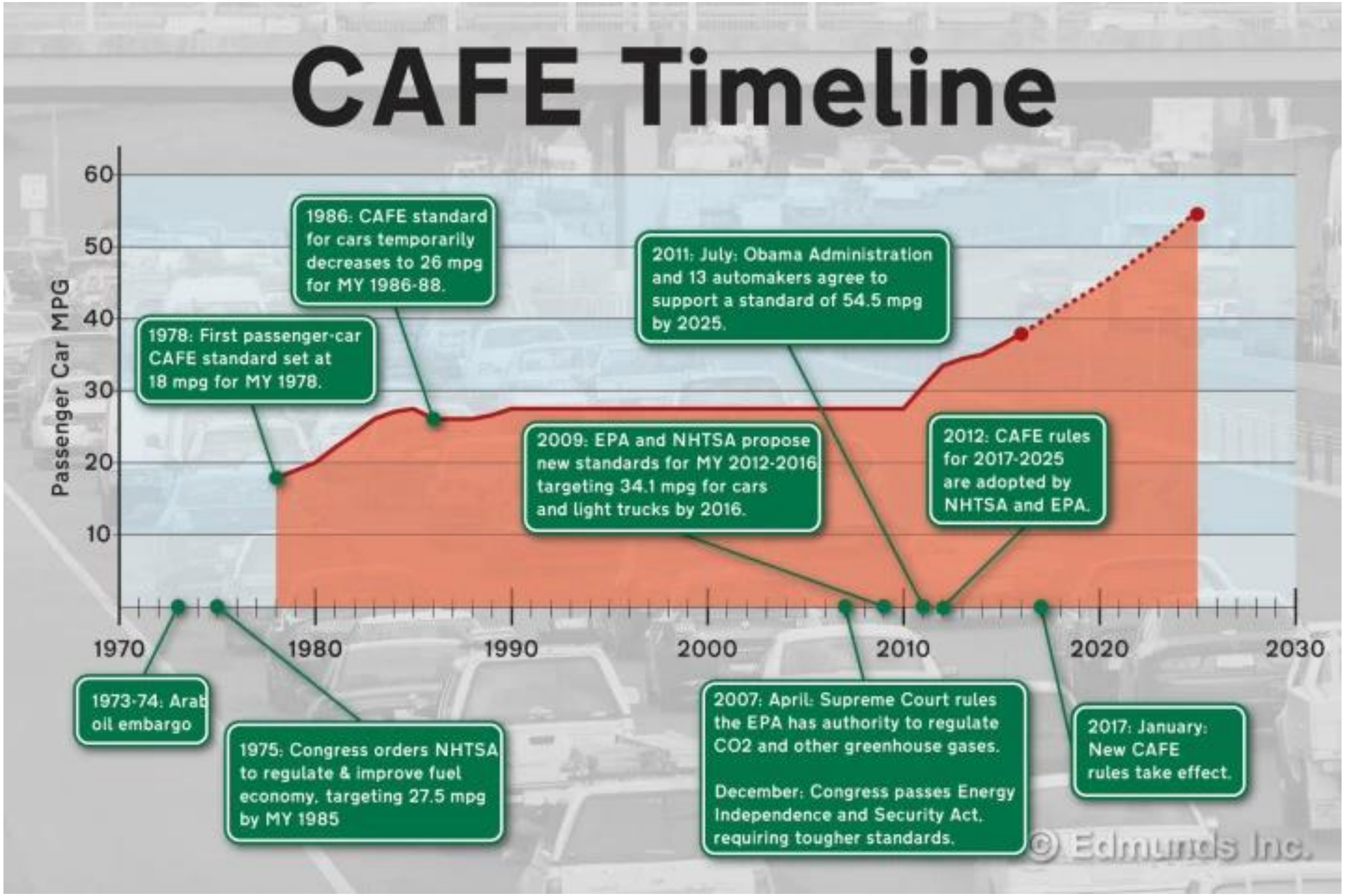
CAFE Timeline
Passenger Car MPG
60
50
40
30
20
10
1970
1980
1990
2000
2010
2020
2030
1986: CAFE standard for cars temporarily decreases to 26 mpg for MY 1986-88.
1978: First passenger-car CAFE standard set at 18 mpg for MY 1978.
2011: July: Obama Administration and 13 automakers agree to support a standard of 54.5 mpg by 2025.
2009: EPA and NHTSA propose new standards for MY 2012-2016 targeting 34.1 mpg for cars and light trucks by 2016.
2012: CAFE rules for 2017-2025 are adopted by NHTSA and EPA.
1973-74: Arab oil embargo
1975: Congress orders NHTSA to regulate & improve fuel economy, targeting 27.5 mpg by MY 1985
2007: April: Supreme Court rules the EPA has authority to regulate CO2 and other greenhouse gases.
December: Congress passes Energy Independence and Security Act, requiring tougher standards.
2017: January: New CAFE rules take effect.
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CAFE Standard in Practice

Some effects of the attribute-based CAFE Standard:

- Trucks have lower standards than traditional passenger vehicles
  - Increased the share of trucks on the road
  - Decreased size of cars
- More trucks + smaller cars → more hazardous accidents, especially for smaller cars.
- Also, unexpected engineering incentives.

Car or truck?

The PT cruiser was engineered to meet design classifications of a light truck to lower Chrysler's light truck AFE.

More on CAFE in Practice

Also, the **Gruenspecht effect**:

- AFE standards decrease relative sale prices of new high fuel economy cars vs. new low fuel economy cars (Bento et al., 2020).
  - New high fuel economy cars are relatively cheaper in relation to used ones, hence scrapped sooner
  - New low-fuel economy cars are relatively more expensive in relation to used ones, hence scrapped later

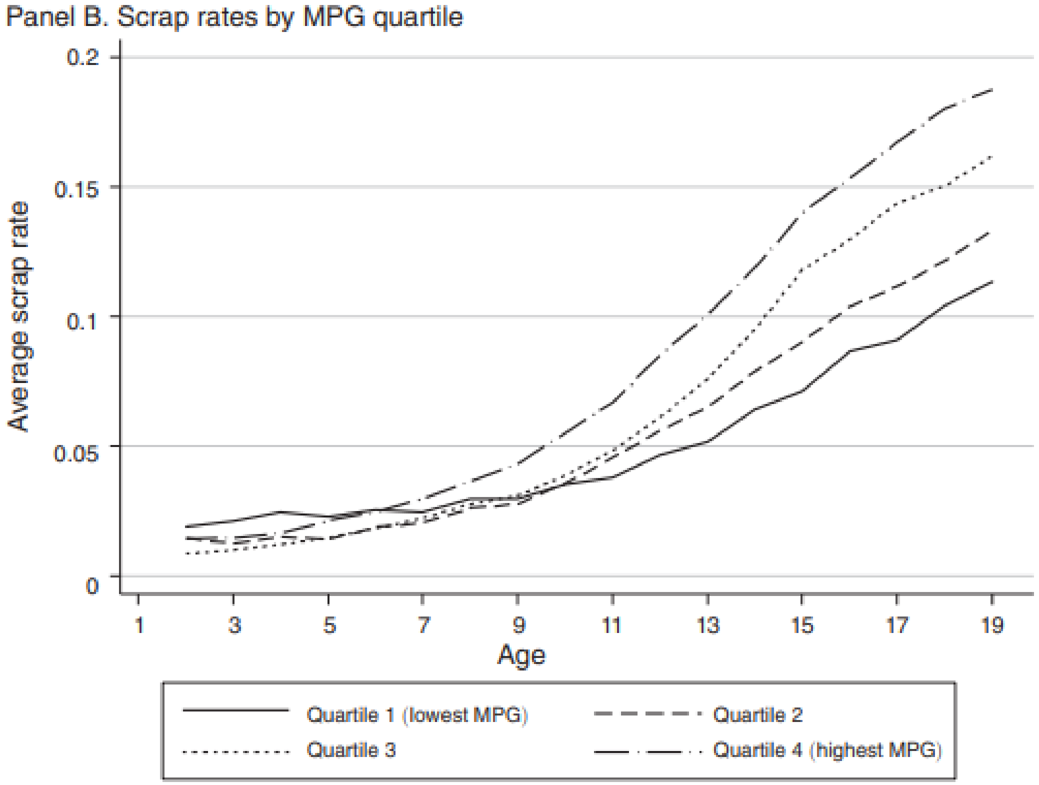


Figure 1. Scrap Rates by Vehicle Age and Make or MPG Quartile

Source: Jacobsen and Benthem (2015).

Even More on CAFE in Practice

A CAFE standard does not directly impact the activity that leads to many externalities associated with driving cars:

- No incentive to reduce driving. Actually, incentive to ***increase*** driving (the **Rebound Effect**).
  - More congestion, air pollution, and traffic fatalities.
- Carmakers may meet AFE targets with engine changes that can increase emissions of air pollutants other than carbon dioxide.
  - Shift to gasoline direct injection (GDI) engines increases emissions of particulate matter (Neyestani, 2020).

Why CAFE?

Q: Given these potentially unintended consequences, why implement attribute-based fuel economy standards?

One answer: The primary motivation for AFE standards was energy independence.

Another answer: Consumers systematically mis-judge the vehicle-specific lifetime cost of fuel when purchasing a vehicle because they have **MPG illusion**.

MPG Illusion

Suppose you drive 10,000 miles per year (about average). Which improvement in fuel economy is best?

a) From 10 to 11 mpg
b) From 17 to 20 mpg
c) From 35 to 50 mpg

http://www.mpgillusion.com/p/what-is-mpg-illusion.html

MPG Illusion

$$gpm = \frac{1}{mpg}$$

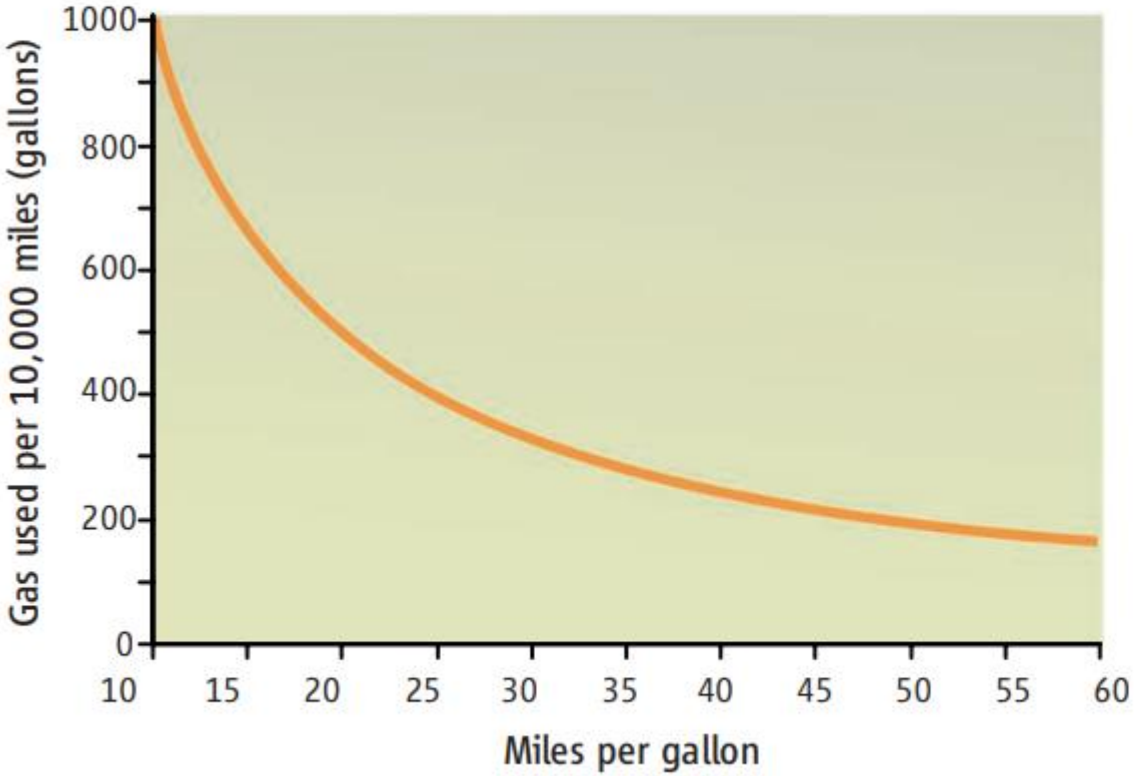
Miles per gallon is a useful metric for:

- How far you can go with one gallon
- Range of your tank

What is most useful in making a fuel economy consumer decision?

- How much gas you'll use given your driving habits, or **gallons per mile**.
- Related, how much you'll spend on gas.

The latter is also more useful for considering the GHG implications. One gallon is 20 pounds of CO2.



http://www.mpgillusion.com/p/what-is-mpg-illusion.html

MPG Illusion

Table displays MPG improvements that yield equal decreases in gas consumption

- Gas savings are not a linear function of MPG.
- Gallons per mile is a more intuitive way of thinking about fuel economy

Miles Per Gallon	Gallons Per 100 Miles	Gallons Per 10,000 Miles
10.0	10	1000
11.0	9	900
12.5	8	800
14.0	7	700
16.5	6	600
20.0	5	500
25.0	4	400
33.0	3	300
50.0	2	200

http://www.mpgillusion.com/p/what-is-mpg-illusion.html

Larrick & Soll, 2008

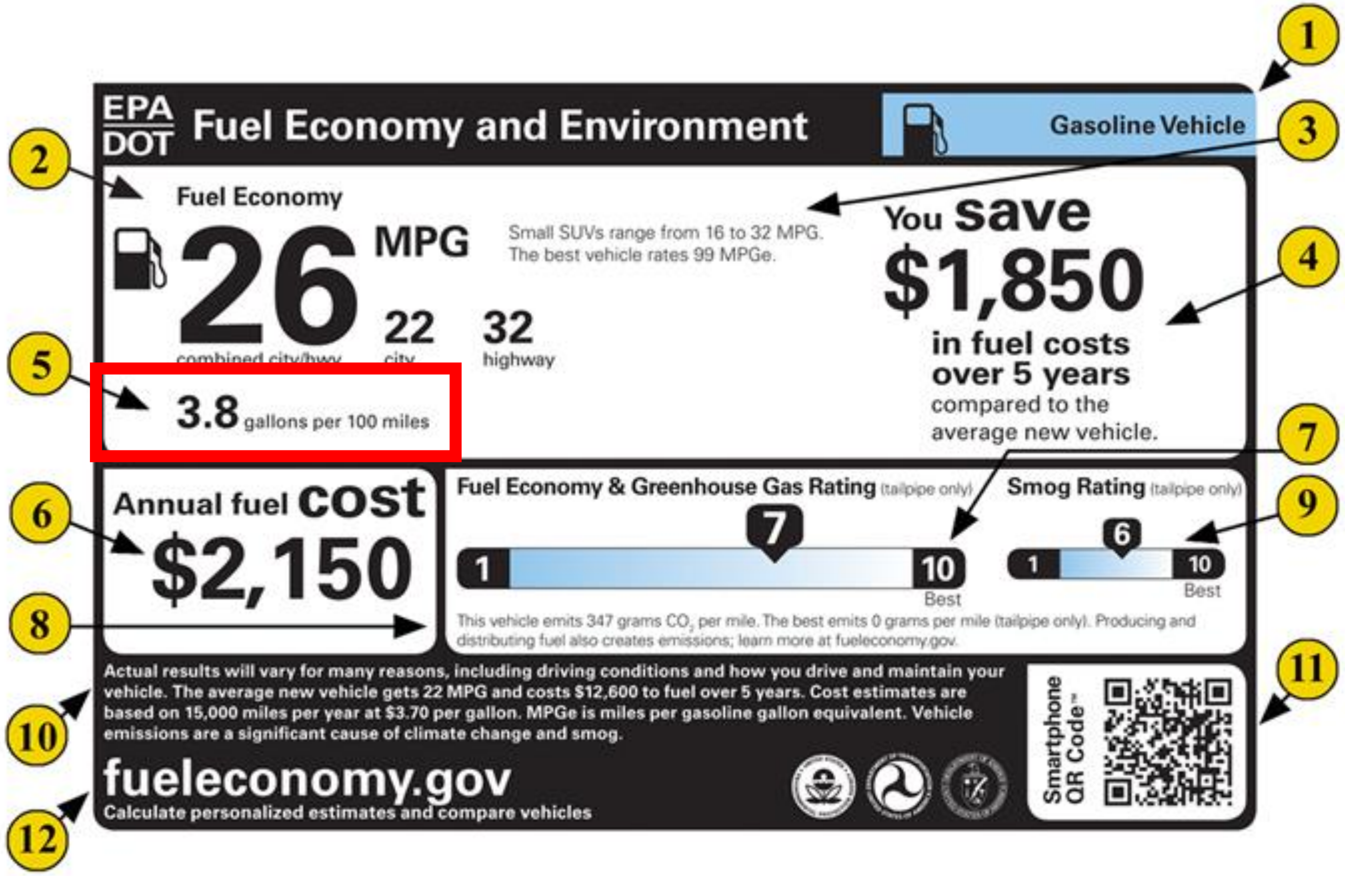
- Consumers do systematically mis-judge fuel economy savings.
- Can be improved dramatically by re-framing in terms of GPM and providing this information to consumers.

Perceived and actual benefits of improving gas mileage

Change in vehicle pairs* (old vehicle to new vehicle)	Perceived rank in gas savings (mean)	Actual rank in gas savings	Actual reduction in gas consumption per 10,000 miles
34 MPG to 50 MPG	1.18	3	94.1
18 MPG to 28 MPG	1.95	1	198.4
42 MPG to 48 MPG	3.29	5	29.8
16 MPG to 20 MPG	3.73	2	125.0
22 MPG to 24 MPG	4.86	4	37.9

*Vehicle pairs are listed in order from largest linear change (34 to 50) to smallest linear change (22 to 24). Participants did not see the actual rank in gas savings or the actual reduction in gas consumption when they gave their answers.

Solving MPG Illusion

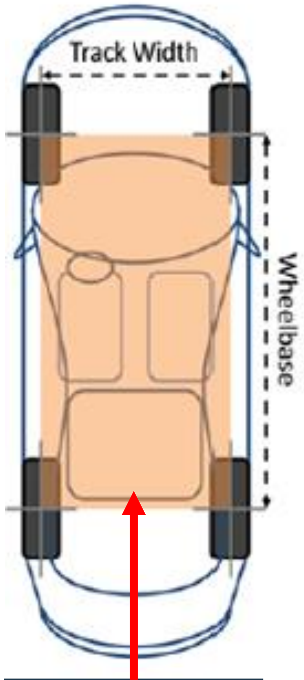


http://www.mpgillusion.com/p/what-is-mpg-illusion.html

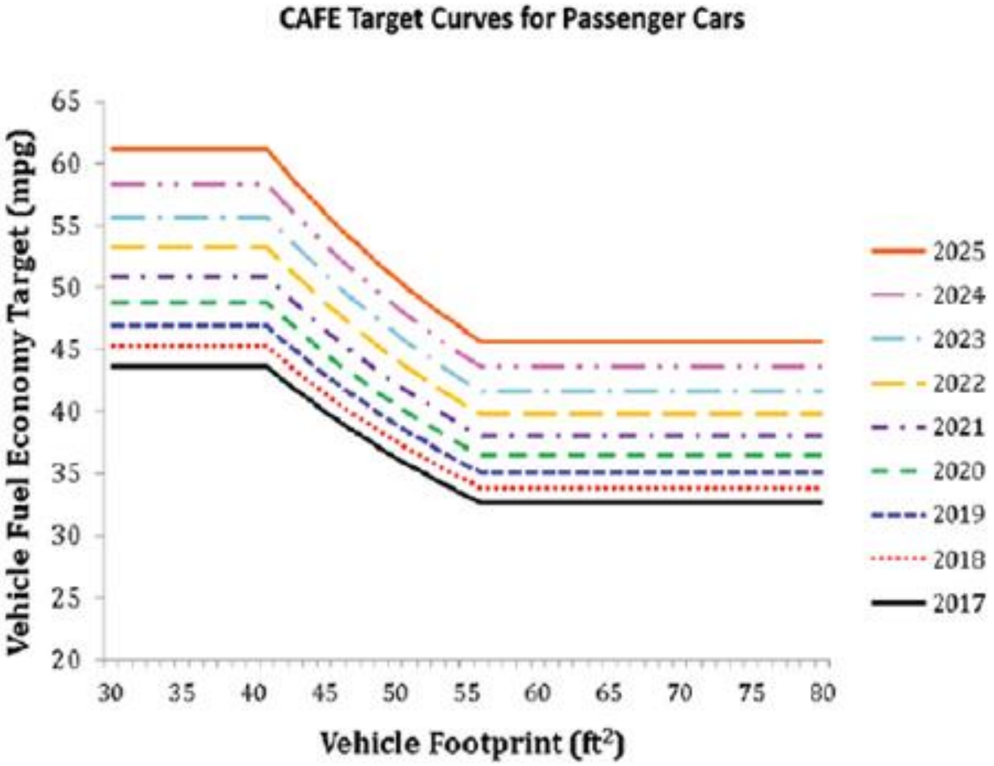
CAFE after 2011

The CAFE standards were modified after 2011.

- Allowed trading of MPG allowances across firms.
- New fuel standard depending on **footprint** of the vehicle.
- Continuous increases in AFE standard by footprint over time.



Footprint (sq feet)



Source.

CAFE after 2011: Increased Vehicle Size

One motivation for footprint-based standards was to improve safety. Carmakers no longer had a strong incentive to decrease car size to achieve AFE standards.

Actual effect:

- Cars became larger within type (Jean, 2015).
- Compact trucks and station wagons far less common (link).

Aggregate effect on accident fatality risk?

Image source.

CAFE after 2011: A Tariff?

US-made cars were on average larger and had lower MPG than imported cars.

- Imported cars had an easier time meeting a uniform AFE of 33.3 mpg.
- Difference in MPG of -0.5 is roughly $28 disadvantage per car for US carmakers.
- For big three US auto-makers (GM, Ford, Chrysler), difference of -4.4 is a $242 disadvantage per car.

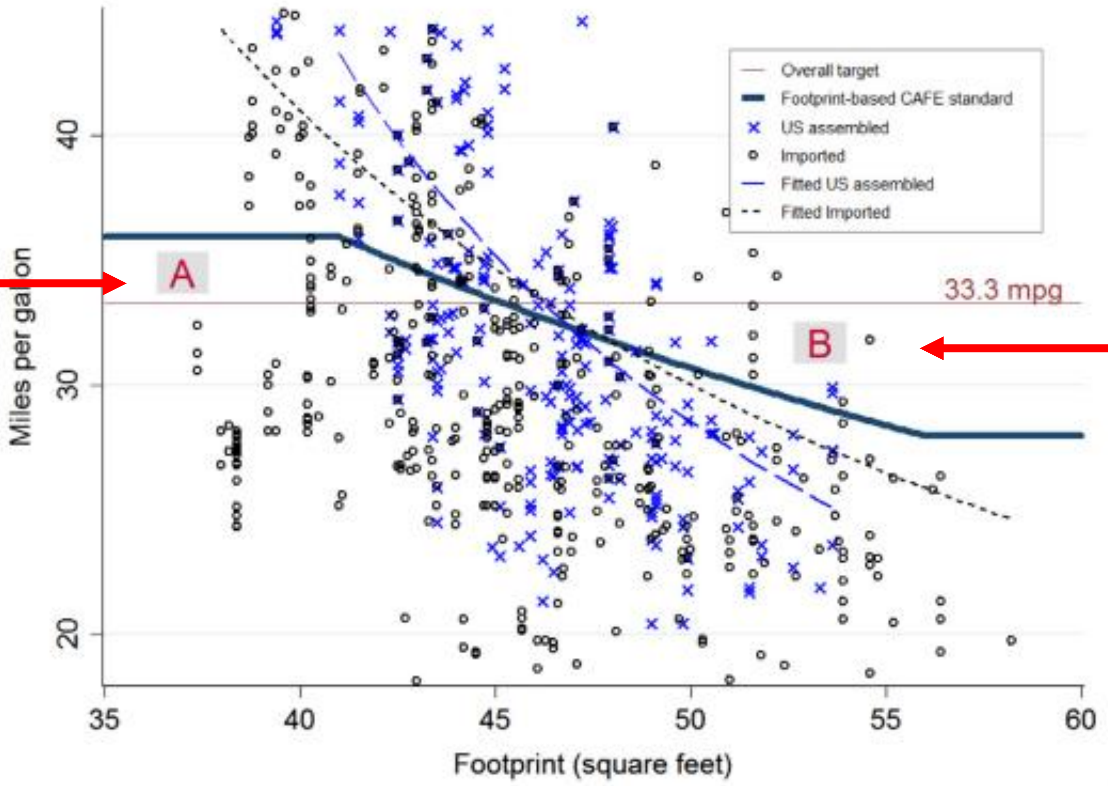
Table 1
Difference in average mpg and footprint, US and non-US cars and light trucks.

	2012		2015	
	MPG (1)	**Footprint** (2)	**MPG** (3)	**Footprint** (4)
Cars				
US-assembled	33.2	46.0	36.0	46.3
Imported	33.6	44.6	36.5	45.0
Difference	**−0.5**	**1.5**	**−0.5**	**1.4**
Big 3	30.4	46.8	32.6	47.0
Non-Big 3	34.8	45.1	37.9	45.5
Difference	**−4.4**	**1.7**	**−5.3**	**1.5**

Source: Levinson (2017)

CAFE after 2011: A Tariff?

Fail a new footprint based AFE, but pass a uniform AFE.



Note: Cars only. A similar graph for light trucks available from the author.

Pass a new footprint based AFE, but fail a uniform AFE.

Source: [Levinson (2017)]

CAFE after 2011: A Tariff?

Switch to footprint-based standards meant US-made cars were on average 0.62 above the new AFE, while imported cars were -0.68 below it.

- With fine of $55 per mpg difference, this is a $72 advantage per car.
- With trading of allotments, this meant US carmakers could also sell their new footprint advantage to foreign carmakers.

Table 2
Difference in average mpg per vehicle between the overall target and footprint-based CAFE standard.

Model Year	2012	2013	2014	2015
US-assembled	0.62	0.65	0.56	0.70
Imported	−0.68	−0.62	−0.44	−0.75
Difference	**1.30**	**1.27**	**1.00**	**1.45**
Big 3	1.00	0.93	0.85	1.06
Non-Big 3	−0.20	−0.07	−0.05	−0.15
Difference	**1.20**	**1.00**	**0.90**	**1.21**

Source: See Table 1. Includes both cars and light trucks.

Source: Levinson (2017)

CAFE after 2011: A Tariff?

TABLE 2. Real Civil Penalties 1978–2014 (1 = US$100,000 measured in 2007 dollars).

Manufacturers	Imported fleet	Domestic fleet
BMW	3,101.2	0.0
Mercedes Benz	3,025.4	0.0
Daimler–Chrysler[a]	1,165.9	0.0
Volvo	901.2	0.0
Jaguar	684.7	0.0
Porsche	661.0	0.0
Daimler	203.4	0.0
Fiat	187.4	0.0
Sterling	69.7	0.0
Ferrari Maserati	53.5	0.0
Peugeot	46.3	0.0
Maserati	40.2	0.0
Ferrari	27.8	0.0
Small Luxury Manufacturers[b]	2.5	5.2
Chrysler[a]	0.9	0.0
Ford	0.0	0.0
General Motors	0.0	0.0
Fleet share of total fines	**99.95%**	**0.05%**

Source: Levinson (2017)

CAFE: Overall Costs and Benefits

Still, large net benefits of new CAFE standards.

What about alternative policy designs?

TABLE 3. Costs and benefits of 2012-16 CAFE standards, 3% discount rate ($2007 millions).

	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	Sum 2012–2016
Private costs and benefits (costs shown as negative benefit)						
Technology	−5,902	−7,890	−10,512	−12,539	−14,903	−51,748
Lifetime fuel expenditures	9,264	20,178	29,082	37,700	46,824	143,048
Consumer surplus from additional driving	696	1,504	2,151	2,754	3,387	10,492
Refueling time value	707	1,383	1,939	2,464	2,950	9,443
Net private benefits	4,765	15,175	22,660	30,379	38,258	111,235
Social costs and benefit (costs shown as negative benefit)						
Congestion	−447	−902	−1,282	−1,634	−2,000	−6,265
Accidents	−217	−430	−614	−778	−950	−2,989
Noise	−9	−17	−25	−32	−39	−122
GHG reductions	921	2,025	2,940	3,840	4,804	14,530
Petroleum market externalities	546	1,153	1,630	2,079	2,543	7,951
Conventional air pollutants	475	947	1,310	1,646	1,991	6,369
Net social benefits	1,269	2,776	3,959	5,121	6,349	19,474
Net total benefits	6,033	17,950	26,619	35,501	44,606	130,709
Addendum: Net benefits at 7%	3,587	12,792	19,230	25,998	32,888	94,495

Source: *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, 14, Table 12.

Source: [Levinson (2017)]

Fullerton and West (2000)

Research Question: What combination of taxes or subsidies on cars maximizes consumer welfare?

Methods:

1) Consumer utility model parameterized with real data from 1261 individuals/cars.
2) Simulate alternative combinations of taxes.
   - No tax
   - Ideal Pigouvian tax on externalities
   - Combination of gas, engine size, and vehicle age taxes.
3) Calculate welfare improvements.

Fullerton and West (2000)

Consumer utility model:

Consumer maximizes utility:

$$U_i = \left[\alpha_i^{\frac{1}{\sigma}} m_i^{\frac{\sigma-1}{\sigma}} + \beta_i^{\frac{1}{\sigma}} s_i^{\frac{\sigma-1}{\sigma}} + \gamma_i^{\frac{1}{\sigma}} v_i^{\frac{\sigma-1}{\sigma}} + (1-\alpha_i-\beta_i-\gamma_i)^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} - \mu E$$

Subject to budget constraint:

$$y_i = \left(\frac{(p_g+t_g)}{MPG(s_i,v_i)} \right) m_i - (p_s+t_s)s_i - (p_v+t_v)v_i - (1+t_x)x_i - t_E EPM(s_i,v_i) m_i$$

Fullerton and West (2000)

Consumer utility model:

Consumer maximizes utility:

VMT (m)

Engine size (s)

Car vintage (v)

Other goods

External damages

$$U_i = \left[\alpha_i^{\frac{1}{\sigma}} m_i^{\frac{\sigma-1}{\sigma}} + \beta_i^{\frac{1}{\sigma}} s_i^{\frac{\sigma-1}{\sigma}} + \gamma_i^{\frac{1}{\sigma}} v_i^{\frac{\sigma-1}{\sigma}} + (1-\alpha_i-\beta_i-\gamma_i)^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} - \mu E$$

Subject to budget constraint:

$$y_i = \left(\frac{(p_g + t_g)}{MPG(s_i, v_i)} \right) m_i - (p_s + t_s) s_i - (p_v + t_v) v_i - (1 + t_x) x_i - t_E EPM(s_i, v_i) m_i$$

Fullerton and West (2000)

Aside: External damages **E** are a function of miles traveled and emissions per mile (EPM), where EPM is in turn a function of car size and newness:

$$E = \sum_i m_i EPM(s_i, v_i)$$

Based on their consumer and car data, larger cars have higher emissions, newer cars have lower emissions.

Fullerton and West (2000)

Consumer utility model:

Consumer maximizes utility:

$$U_i = \left[\alpha_i^{\frac{1}{\sigma}} m_i^{\frac{\sigma-1}{\sigma}} + \beta_i^{\frac{1}{\sigma}} s_i^{\frac{\sigma-1}{\sigma}} + \gamma_i^{\frac{1}{\sigma}} v_i^{\frac{\sigma-1}{\sigma}} + (1-\alpha_i-\beta_i-\gamma_i)^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} - \mu E$$

Subject to budget constraint:

Gas tax

Size tax

Vintage tax

Ideal emissions tax

Income

$$y_i = \left(\frac{(p_g + t_g)}{MPG(s_i, v_i)} \right) m_i - (p_s + t_s) s_i - (p_v + t_v) v_i - (1 + t_x) x_i - t_E EPM(s_i, v_i) m_i$$

Fullerton and West (2000)

Parameterize the model using 1261 consumer and vehicle data points:

- Gasoline and car expenditures from 1994 Consumer Expenditure Survey
- California Air Resource Board surveillance program data on air emissions per car, VMT

Table 2: Parameter and Variable Descriptions and Means (n=1261, σ=1)

Parameters	Description	Mean
Y	Total quarterly expenditure (from CEX data)	5011.37
α_i	Miles parameter (derived from equation 8a)	.03
β_i	Cubic inches of displacement parameter (from 8b)	.07
γ_i	Newness parameter (from 8c)	.04
$(1-\alpha_i-\beta_i-\gamma_i)$	Composite commodity parameter	.86
MED	Marginal environmental damages ($/gram)	.0076
p_g	Price of gas after removing pre-existing taxes ($/gallon)	.72
p_s	Price per cubic inch of displacement per quarter ($/CID)	1.23
p_v	Price of newness per quarter ($/unit)	1.00
p_x	Price per unit composite commodity ($/unit)	1.00
Variables		
m_i	Miles per quarter	3685.8
s_i	Cubic inches of displacement	166.45
v_i	Newness (depreciation per quarter)	181.39
x_i	Composite commodity (all other goods)	4455.5
g_i	Gallons of gasoline per quarter	169.63
$MPG(s_i,v_i)$	Miles per gallon	21.74
$EPM(s_i,v_i)$	Emissions per mile (in grams)	2.04

Fullerton and West (2000)

Results:

1) 71% of the welfare gains from the first-best Pigouvian can be achieved with a three-part tax.

Table 3: Simulation Results (n=1261, $\sigma = 1$)

Scenario	t_E	t_g	t_s	t_v	Welfare	% Gain from Zero-Tax	% of Pigovian Tax Gain
Pigovian Tax	.0076	0	0	0	6286201.7	.2511	100.00
Three-part	0	.267	-.007	-.107	6281712.3	.1795	71.49
Two-part #1	0	.268	0	-.107	6281706.3	.1794	71.45
Two-part #2	0	.291	-.004	0	6280270.1	.1565	62.33
Gas tax	0	.291	0	0	6280267.7	.1565	62.31
Two-part #3	0	0	-.023	-.148	6273598.2	.0501	19.96
New subsidy	0	0	0	-.148	6273543.3	.0493	19.61
Size subsidy	0	0	-.020	0	6270501.3	.0007	.29
Zero taxes	0	0	0	0	6270455.4	0	0

Fullerton and West (2000)

Results:

2) 62% of the welfare gains from the first-best can be achieved with just a fuel tax.

Table 3: Simulation Results (n=1261, $\sigma = 1$)

Scenario	t_E	t_g	t_s	t_v	Welfare	% Gain from Zero-Tax	% of Pigovian Tax Gain
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New subsidy	0	0	0	-.148	6273543.3	.0493	19.61
Size subsidy	0	0	-.020	0	6270501.3	.0007	.29
Zero taxes	0	0	0	0	6270455.4	0	0

Fullerton and West (2000)

Results:

3) What's going on with taxes on size and vintage?

Adding car size or increasing vintage affects fuel efficiency, meaning these individuals already pay more for extra size through gas tax. Optimal tax rebates part of that.

Table 3: Simulation Results (n=1261, $\sigma = 1$)

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Anderson and Sallee (2016)

To summarize the literature and provide a few key take-aways.

1) No regulatory alternative achieves the economic efficiency of a fuel tax.
2) Biases in consumer choice are not strong enough to overturn the finding that a fuel tax is more efficient than a fuel economy standard.
3) Attribute-based standards are obtuse instruments for addressing behavioral biases because they preserve existing tradeoffs between fuel economy and other car attributes.

Latest in Average Fuel Economy Standards

Two newer revisions to the rules:

- 2020 Safer Affordable Fuel-Efficient (SAFE) Vehicles Act
- 2022 proposed new CAFE is set at higher AFE levels over time.

Each are the same as 2011 CAFE in policy design. EPA and DOT coordinate on similar fuel economy and carbon dioxide standards that increase over time.

New CAFE Footprint-based Standards

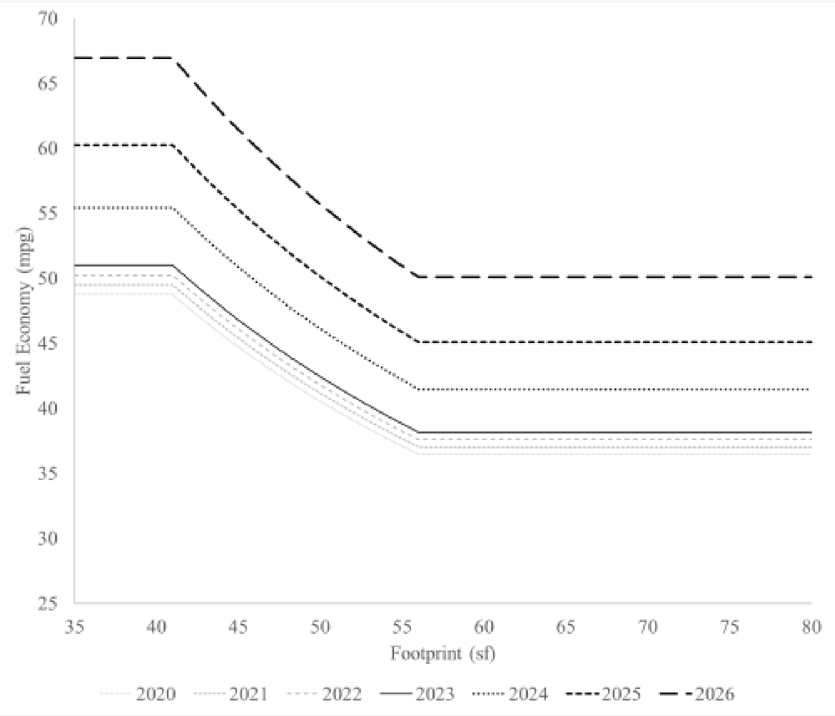


Figure II-1 – Final Passenger Car Standards, Target Curves

Part 2: Vehicle Air Pollution Standards

Regulatory Instruments in CAA

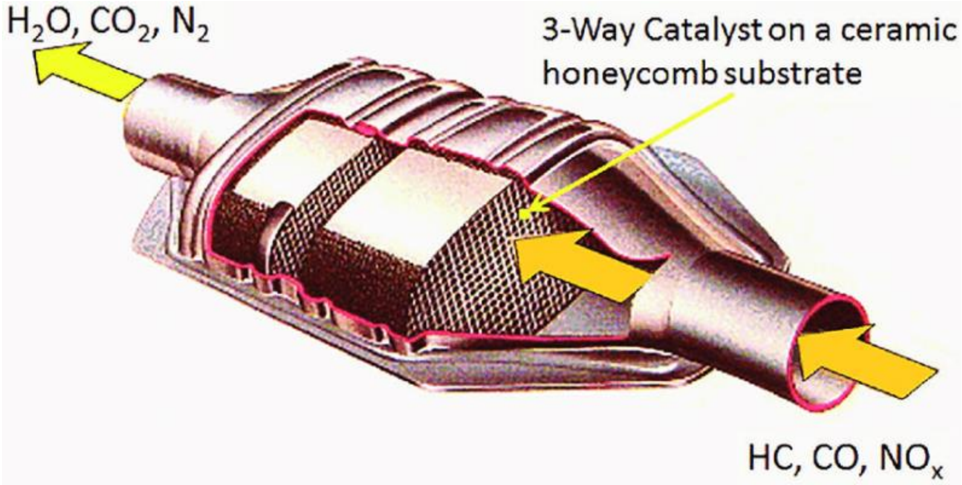
The Clean Air Act allows regulation of mobile sources of pollution. Three general types of regulatory instrument have been used:

- Technology-based emissions standards for new vehicles
  - Examples: catalytic converters
- Emissions standards for new vehicles
- Fuel content regulations
  - Examples: leaded gasoline, VOCs, renewable fuel standards

Earliest Emissions Standards

1972 standards for carbon monoxide and NOx in mobile sources essentially required installation of catalytic converters:

- Catalytic converters were not economically viable in the 1960s, but rapidly became so after standards.
- Composed of precious metals that serve as catalysts in neutralizing air pollutants without altering the metal itself.
  - Rhodium abates NOx.
  - Palladium abates CO.
  - Platinum abates both.



Source.

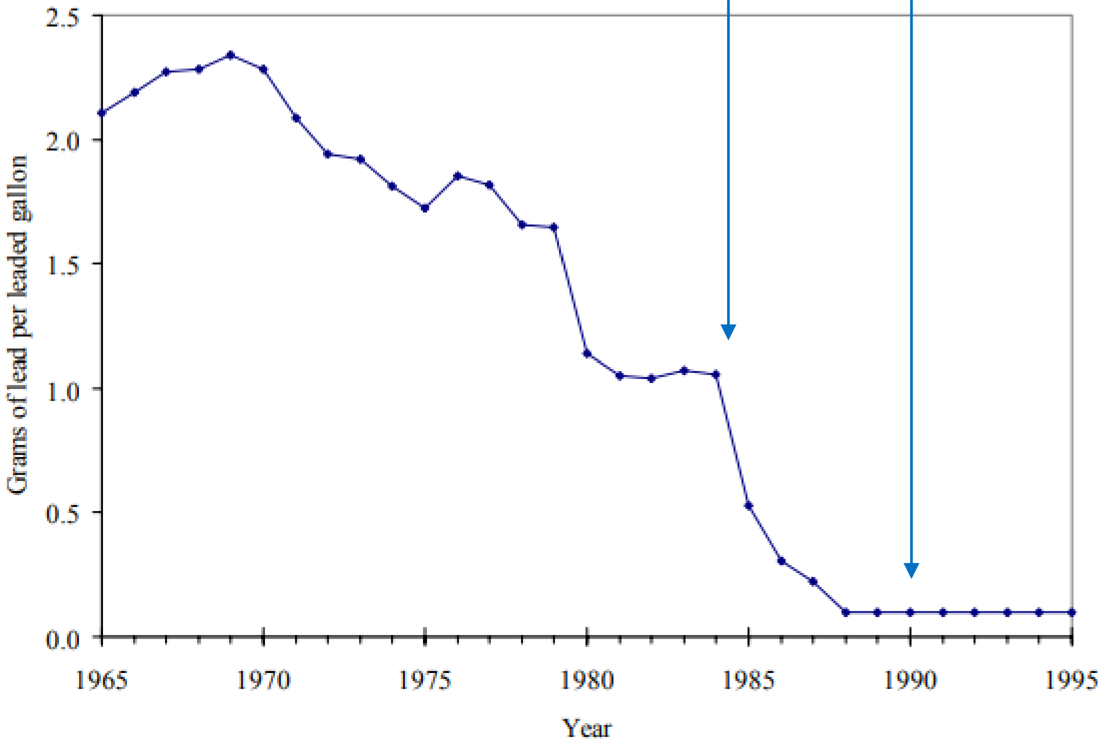
Lead Fuel Content Regulations

Leaded gas fully banned in cars

Market-based phasedown

Lead coats the metals in a CC, decreasing its efficacy over time.

- In 1975, new vehicles required to use unleaded gasoline (fuel content regulation)
  - ➢ Smaller refineries couldn't abate lead from their fuel at competitive costs.
- Market-based lead phasedown allowed firms to reduce lead by under the legal limit and sell the difference as credits to other refiners or bank them for later.
- Lead phase-down (1982-1987) took place faster than expected and generated 20% savings compared to uniform limit.



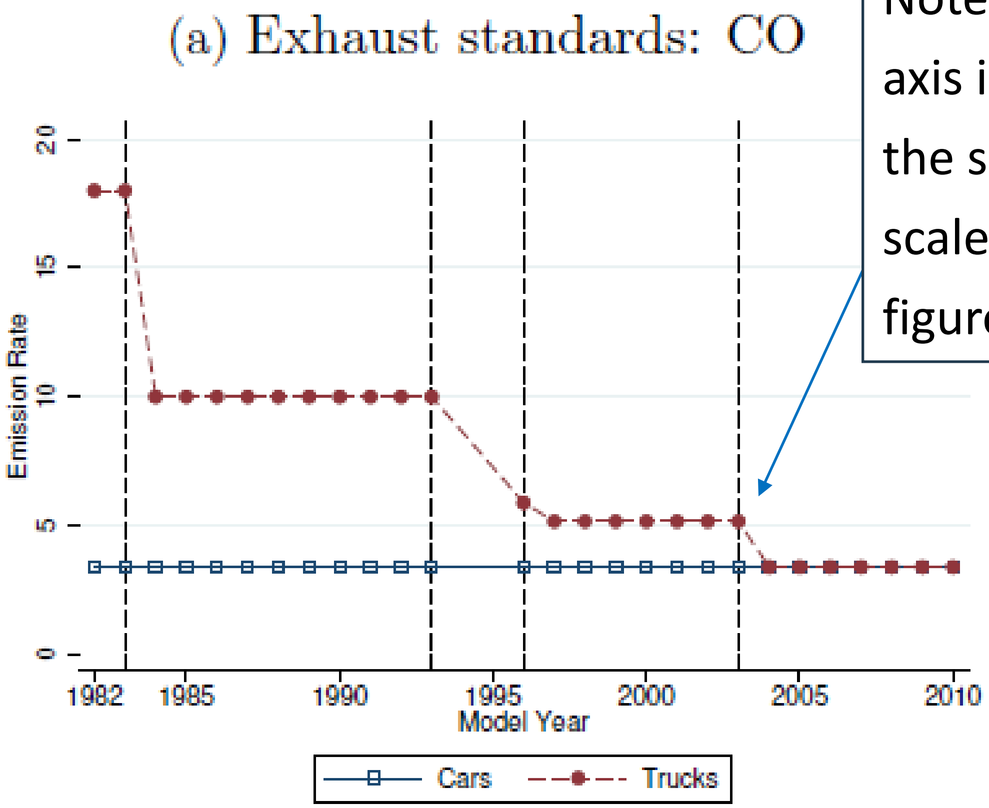
Source: [Newell and Rogers, 2003]

Evolution of Exhaust Standards

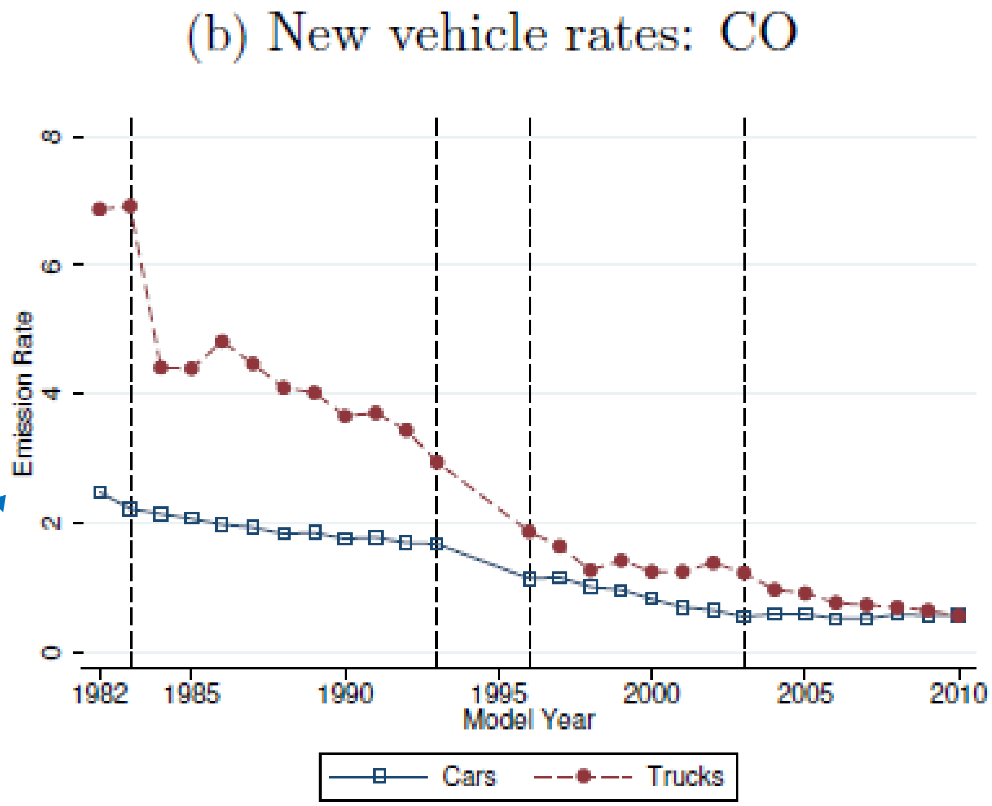
Car exhaust standards for specific criteria air pollutants have dramatically lowered these emissions over time.

- Few incentives to reduce tailpipe emissions for manufacturers, and consumers are generally not aware of pollution composition of emissions.
- Increasing standards over time explains ~99% of the reductions in tailpipe emissions for criteria pollutants (Jacobsen, Sallee, Shapiro, and Benthem, 2022).
- Roughly 16 percent of all vehicles sold (80 million), had recalls for failing emissions standards from 1975-2008.

Evolution of Exhaust Standards: CO

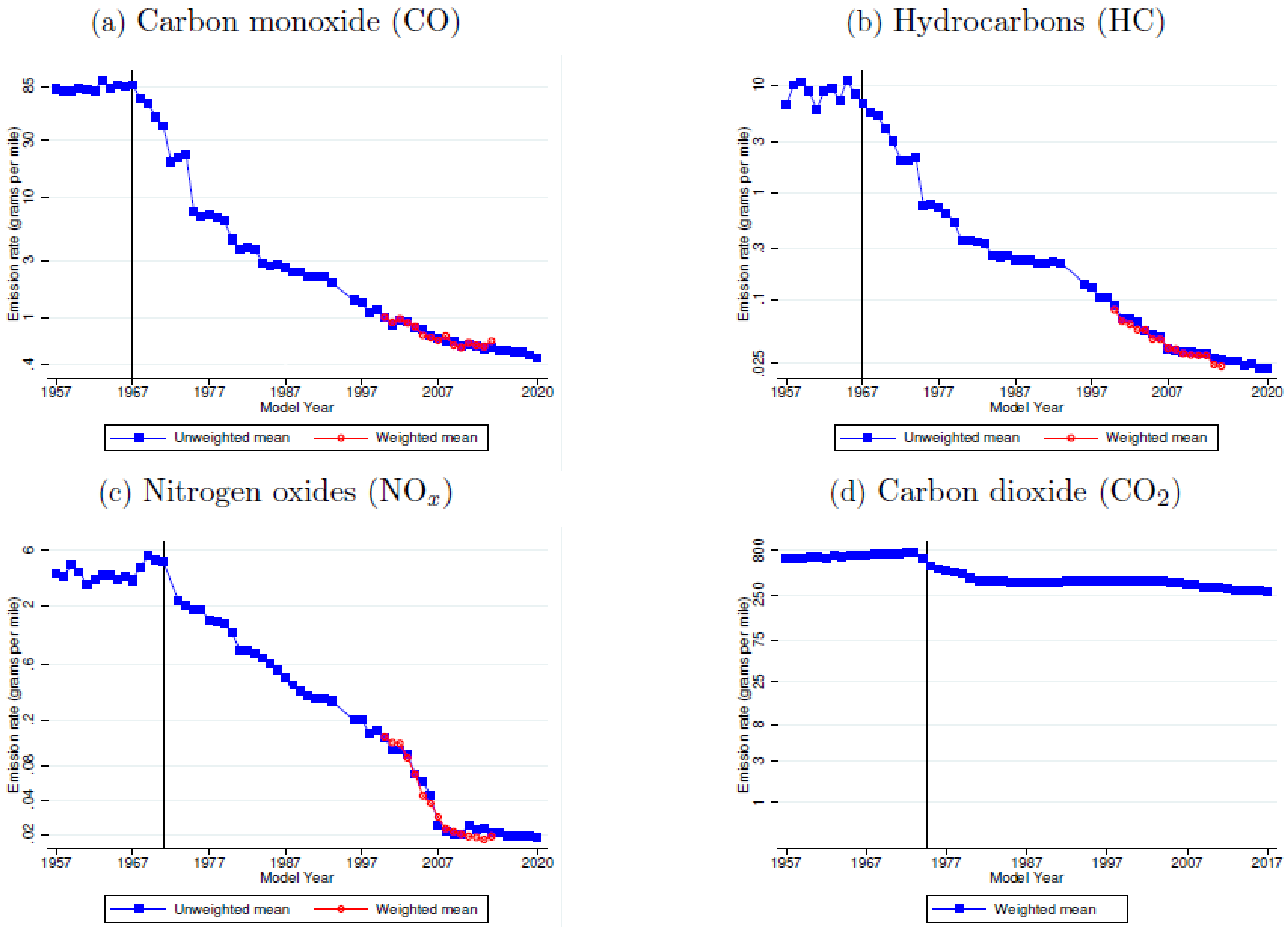


Note the y axis is not the same scale across figures



Source: [Jacobsen, Sallee, Shapiro, and Benthem (2022)](#).

Evolution of Car Emission Rates of New Vehicles



Source: [Jacobsen, Sallee, Shapiro, and Benthem (2022)](#).

Pitfalls of Tailpipe Emissions Standards

Two concerns over time:

- New car standards increase prices of new cars relative to older cars.
  - **Gruenspecht effect**: dirty cars are kept for longer, hence more air pollution.
- Cheating on emissions tests: Automakers have incentives to engage in various types of cheating behaviors.
  - Volkswagen "defeat devices": Sold 600,000 cars in US from 2006-2015.
    - Each released equivalent air pollution of 150 gasoline cars.
    - Estimated 40,000 additional low birthweight newborns caused by the cheating cars (Alexander and Schwandt, 2022)

Next class

- Don’t forget to **submit your third case study** by Monday’s class!
- On Monday we will start by going over your case study and then play a review game for the Midterm.