# Performance Standards and the Rebound Effect

# Or, Why CAFE Sucks

Lecture 4

ARE 264

January 27, 2022

# Preparing for lecture 5

- Leaks assignment due
- Read Tarduno

# Lecture 3 Recap

1. What criteria might determine which instrument is best?
   - Goulder and Parry suggest: Efficiency, Cost effectiveness, Equity/distribution, Robustness to uncertainty, Political feasibility, Political flexibility or robustness, Administrative costs, Enforcement
2. More on Prices vs. Quantities, Pizer and Prest discussion
   - Weitzman's model suggests that the relative slopes of supply and demand determine whether a price or quantity instrument is more efficient when there is uncertainty about costs
3. Discussion: the Coase Theorem

> Coase has become code for: government doesn't need to solve all the pr

# Outline

1. What is the rebound effect?
   - Most often we mean: raising energy efficiency lowers cost of energy services and raises quantity demanded, which erodes conservation gains
   - Borenstein delineates several versions of rebound
2. Why are performance standards not cost effective?
   - Create rebound
   - Fail to correct market size
   - Used durable market interactions
3. What are attribute-based standards?
   - Performance standards that target one characteristic, but create a sliding scale based on some secondary attribute

# The rebound effect


- The **Jevons paradox** states that an improvement in energy efficiency leads to an increase in the consumption of energy

# The rebound effect

- Raising energy efficiency decreases the cost of energy services
- This induces additional usage

- Example: cost of driving a mile is $c_m = \frac{P_g}{mpg} \Rightarrow \frac{\partial c_m}{\partial mpg} = \frac{-P_g}{mpg^2}$

- This is called **rebound effect**
- Generally: need to recognize that energy savings eroded by additional utilization
- This is most basic insight, but Borenstein article shows there are many varieties of rebound effect, and much nuance to keep track of

- Today we are covering the rebound effect and performance standards

- We often say that performance standards for **energy efficiency** are not cost effective "because of the rebound effect"
- But this is imprecise: we mean that a Pigouvian tax on energy consumption would induce mitigation by both encouraging greater energy efficiency and by reducing utilization rate (intensive margin)

- Performance standard fails to get reductions from intensive margin
- Under rebound, it may in fact cause increases in intensive margin

# Corporate Average Fuel Economy (CAFE) Standards

- CAFE mandates a fleet average fuel economy for all vehicles in US
- This is inefficient because it fails to reduce mileage (conditional on mpg) and fails to motivate savings among used cars
- Austin and Dinan (JEEM 2005): CAFE 65% more expensive than gasoline tax for same mitigation

- Rebound exacerbates mileage related externalities (accidents, congestion)–co-benefits matter a lot in calculations (Parry and Small, AER, Harrington, Parry and Walls JEL)

# Mexican "Cash for Coolers" Program

- Mexico offered rebates for households upgrading old appliances to new ones that met current standards
- Subsidies for **air conditioners** and **refrigerators** ranged from \$30 to \$170
- Household had to have relatively low energy consumption (to target low income)
- Old appliance must be at least 10 years old
- Old appliance must be "scrapped"

# Mexican "Cash for Coolers" Program

- World Bank and McKinsey estimates, based on engineering analysis:
  - Refrigerators will save 481 kWh/year
  - Air conditioners will save 1,200 kWh/year
- Davis, Fuchs and Gertler (2013) evaluate program
  - Refrigerators save 134 kWh/year
  - Air conditioners save -92 kWh/year
- Paper uses electricity consumption data on 25 million Mexican households
- *Ex ante* estimates assumed no behavioral response

# More details on rebound, Borenstein (2015)

- Borenstein (2015) provides microeconomic model of **quantitative** rebound effect
- Decomposes total change in energy from upgrade in efficiency of product:
  1. static efficiency effect: efficiency gain lowers consumption
  2. indirect rebound: you buy other goods (which require energy!) with your extra income
  3. direct rebound (income): you buy more energy services with extra income
  4. direct rebound (substitution): you buy more energy services because they are cheaper
  5. cross effects: price effect causes reduction in other goods
- This is "energy accounting", not welfare analysis. In particular, increasing consumption because of lower prices is a welfare gain

# More details on rebound, Borenstein (2015)

- Also: **macroeconomic price effect**—e.g., shifting in demand for oil causes drop in price, which raises consumption
- Non-marginal cost pricing affects interpretation; changes nature of income effect
- Energy efficiency paradox has implications for whether there are income effects

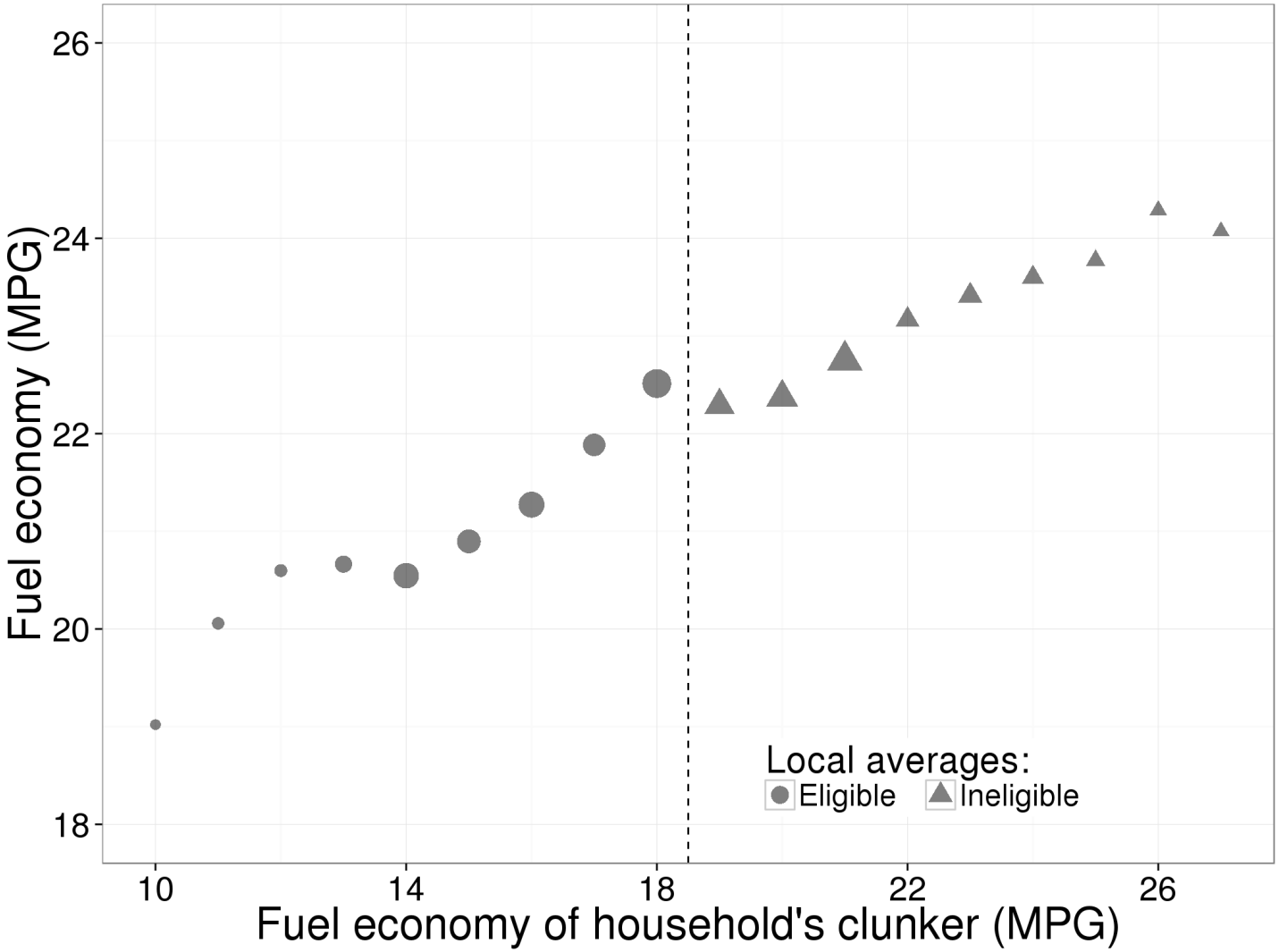
- Generally: not likely to get rebound large enough to raise energy consumption (Jevons paradox)
- But, rebound substantial; and exercise does not consider macroeconomic price effect
- Remember: this is **energy accounting**, not welfare analysis

# Other characteristics

- Rebound effect literature largely ignores other product characteristics

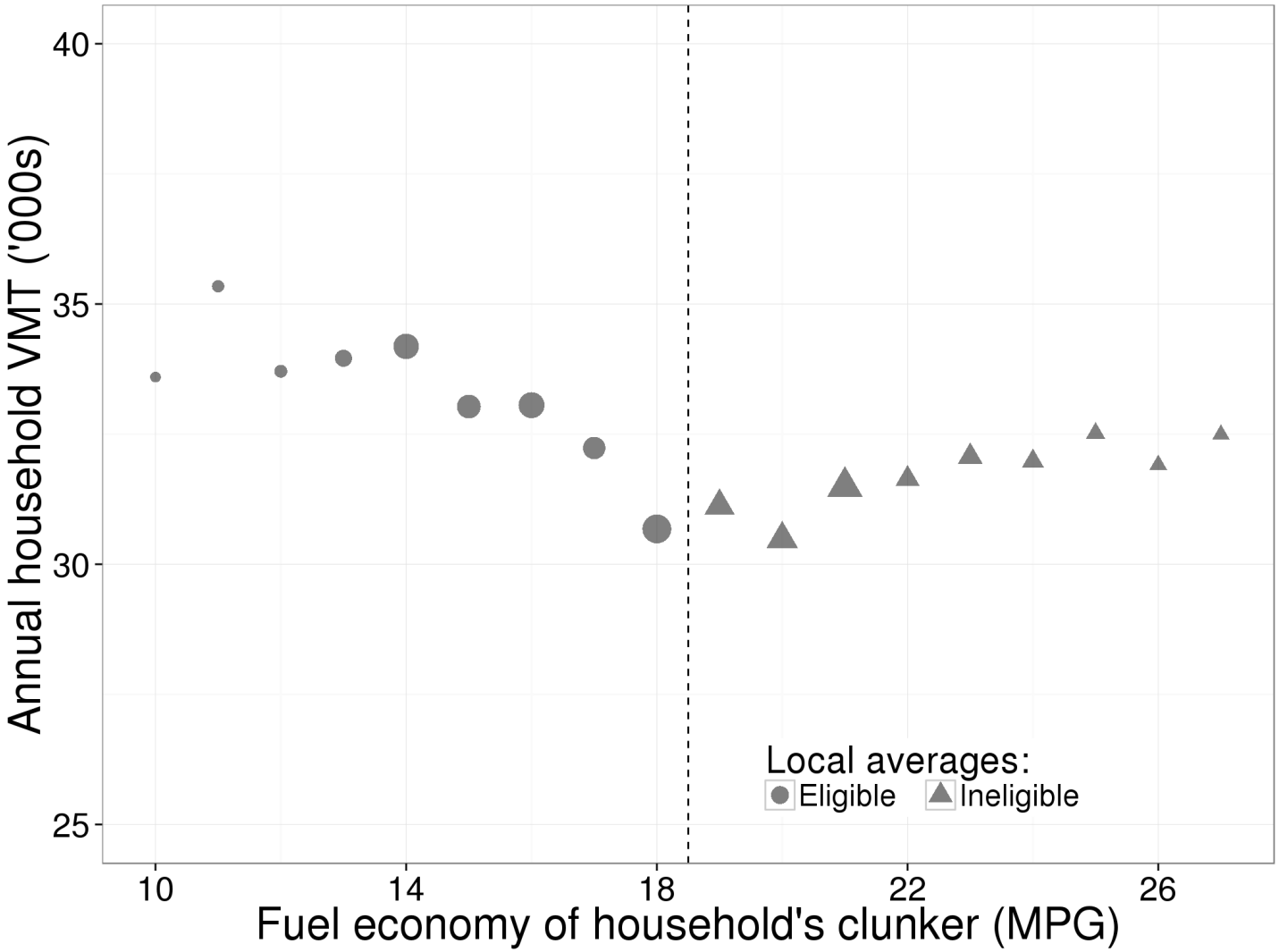
- West, Hoekstra, Meer and Puller (2015) study Cash for Clunkers
- Now published Journal of Public Economics, 2017
- Perform RD based on clunker eligibility
- Policy induced some consumers to buy more efficient car
- Do you think they drove more?

(a) Fuel efficiency (miles per gallon)




West, Hoekstra, Meer and Puller (2015)

(a) Annual total household vehicle miles traveled (VMT)




West, Hoekstra, Meer and Puller (2015)

# Other characteristics

- Rebound effect literature largely ignores other product characteristics
- If other attributes raise (lower) benefit of adaptation, this affects utilization margin
- Relates to technology—if technology makes products more useful and more efficient, then technology changes will amplify rebound effect (original Jevons example of steam engines)
- West et al. is an interesting exception
- Anderson and Sallee, 2016 "Designing Policies to Make Cars Greener" ARRE
  - If you estimate rebound effect from fuel price variation, you keep all other attributes fixed
  - If regulation causes product downgrading to meet standard, this offsets rebound effect
  - If regulation forces technology, get amplified version

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- Holland, Hughes and Knittel (2009) AEJ: Policy models the Low-Carbon Fuel Standard
- This is just an example of a performance standard, and our interest in the paper is more general
- It requires that the carbon content of fuels be, on average, below a certain threshold
- This is just how fuel-economy standards work, as another example

- Two highly-substitutable fuels $H$ and $L$, where $H$ is high-carbon (dirty)
- Simple model: perfectly competitive supply
- Convex, separable costs $C_H(q_H)$ and $C_L(q_L)$
- Common utility function $U(q_h, q_L)$
- Constant per unit emissions factors $\beta_H > \sigma > \beta_L$, where $\sigma$ is the policy
- With constant marginal damage $\tau$ (externality)

# The planner's problem

$$\max_{q_H, q_L} \quad U(q_H, q_L) - C_H(q_H) - C_L(q_L) - \tau(\beta_H q_H + \beta_L q_L)$$

$$\text{FOC: } \frac{\partial U}{\partial q_i} = MC_i(q_i) + \tau\beta_i$$

where $i$ is $H$ or $L$

- Social optimum just sets marginal social cost equal to marginal benefit
- A Pigouvian tax on each fuel source is just $\tau\beta_i$ and this is first best
- Note that the first-best taxes would shift demand from $H$ towards $L$, and it would make both goods more expensive, thereby lowering total quantity $q_H + q_L$

# A performance standard

- A performance standard requires average emissions to be below threshold $\sigma$:

$$\frac{\beta_H q_H + \beta_L q_L}{q_H + q_L} \leq \sigma$$

Multiply through: $\beta_H q_H + \beta_L q_L \leq \sigma(q_H + q_L)$

- To see the effects of a performance standard, solve the market actor problem with this as a constraint.
- This matches planner's problem, except for an undesirable term

$$\begin{aligned}\max_{q_H, q_L} & U(q_H, q_L) - C_H(q_H) - C_L(q_L) + \lambda[\sigma(q_H + q_L) - \beta_H q_H - \beta_L q_L] \\ = & U(q_H, q_L) - C_H(q_H) - C_L(q_L) + \underbrace{\lambda\sigma(q_H + q_L)}_{\text{oops!}} - \lambda(\beta_H q_H + \beta_L q_L)\end{aligned}$$

- When policy is set so that $\lambda = \tau$, we get exactly the right tax on $q_H$ and $q_L$ from the final term $(\lambda(\beta_H q_H + \beta_L q_L))$

- But we also get an unintended **subsidy** to total output: $\lambda\sigma(q_H + q_L)$

- Can model this as a tax on each good, plus an output subsidy; or as taxes on each good equal to $\lambda(\beta_i - \sigma)$

- In short, the performance standard can correctly induce substitution between $H$ and $L$ by getting their relative prices right, but it gets the "market size" wrong

- Point here is (a) pointing out problem with performance standards and (b) pointing out that this policy can be modeled exactly as a set of taxes

- Goulder, Hafstead and Williams use that equivalence to model performance standards as taxes and show how getting market size wrong interactions with pre-existing distortions to complicate efficiency analysis

# Size matters

Prius

Hummer

- CAFE requires firms to meet a sales-weighted average fuel economy $\Rightarrow$ must sell at least X% Prii

$$\frac{\beta_h q_h + \beta_p q_p}{q_h + q_p} \leq \sigma$$

- What does a Pigouvian tax on gasoline (or emissions) do to price of each vehicle?
- What does CAFE do to the price of each vehicle?

# Market size effect

Price effect of alternative policies

| | Efficient product | Inefficient product |
|---|---|---|
| Pigouvian tax | + | ++ |
| Performance standard | - | + |

- Firm maximizes profits subject to constraint $\frac{\beta_h q_h + \beta_p q_p}{q_h + q_p} \leq \sigma$
- Shadow price $\lambda$
- FOC for product $i$: $p_i = mc_i + \lambda(\beta_i - \sigma)$
- Standard subsidizes any product that pollutes less than standard

# Market size effect

- Kwoka (1985) models monopolist facing CAFE constraint:
  - Car market may get bigger
  - Gasoline consumption could rise
- Issue common to any performance standard
- This is the same problem we discussed related to Holland, Hughes and Knittel (2009) on California's Low-Carbon Fuel Standard

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# Used product markets

- Most energy efficiency policies exclusively target the new vehicle market
  - Minimum efficiency standards for appliances, building codes, power plant regulation ("new source review" and grandfathering), vehicle emissions policies, etc.

- This fails to create incentives on the intensive margin for existing products (e.g., Austin and Dinan 2005)
- It also fails to create incentives to scrap existing products optimally (e.g., Li, Timmins and von Haefen 2009)

- It also allows leakage through price effects in the used car market

# The Gruenspecht effect

Old, inefficient car

Old, efficient car

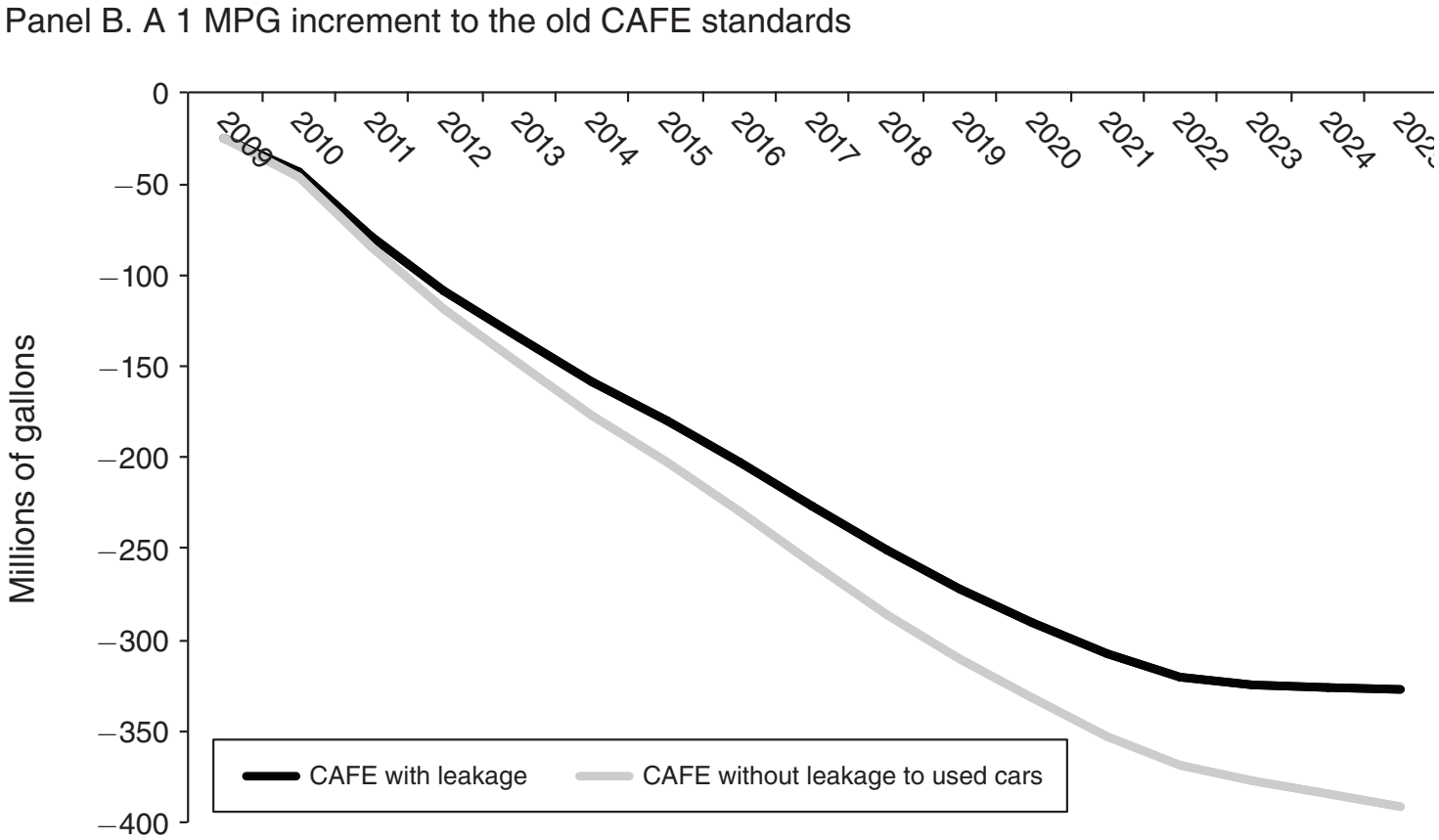
- Vehicles are scrapped when their value (price) below threshold
- What does a Pigouvian tax on gasoline (or emissions) do to price of each vehicle?
- What does CAFE do to the price of each vehicle?

# The Gruenspecht effect

Prius

Hummer

- CAFE-style regulation makes new trucks more expensive than new cars
- Assuming old trucks are better substitute for new trucks, this raises price of old trucks
- This reduces scrap rate, causes old inefficient vehicles to be driven longer
- Alternate example: incandescent lightbulbs




Jacobsen and van Benthem (2015)

- Jacobsen and van Benthem (2015) estimate scrap elasticity and simulate role of Gruenspecht effect
- Leakage as big as rebound effect

# Jacobsen and van Benthem

- What are the strengths and weaknesses of this paper?
- Do you find the empirical evidence compelling?
- Why did it publish in a top five?
- Do you think the basic insights are relevant to other contexts, or is this just about cars?

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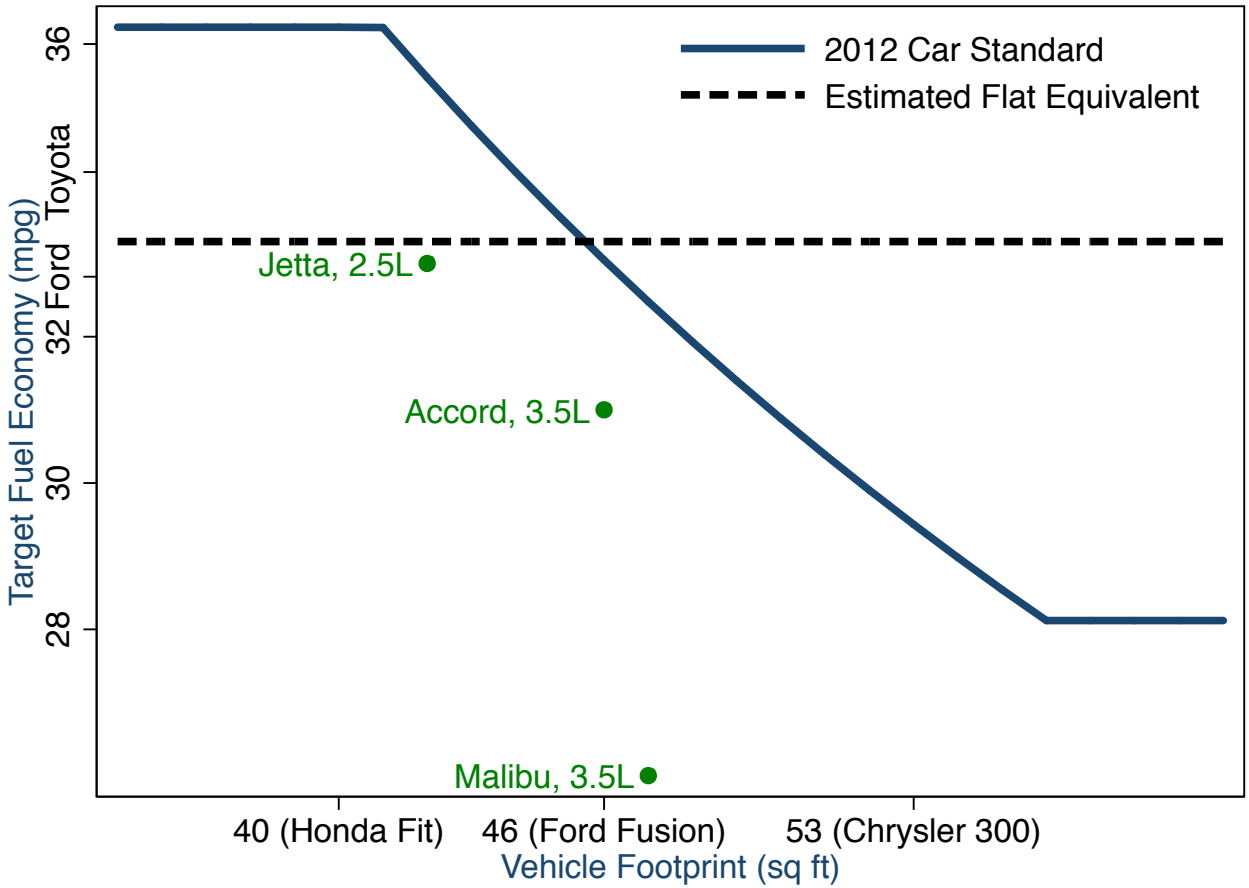
# Ito and Sallee

**What is an "attribute-based regulation"?**

- An ABR is a regulation that targets some characteristic of a product or firm, but which takes some secondary attribute into consideration when determining compliance

# Fuel Economy Standards in the U.S. since 2012




MPG standard (regulation) depends on footprint (attribute)

- **Potential cost:** secondary attribute may be distorted in response to the regulation; cars may get larger

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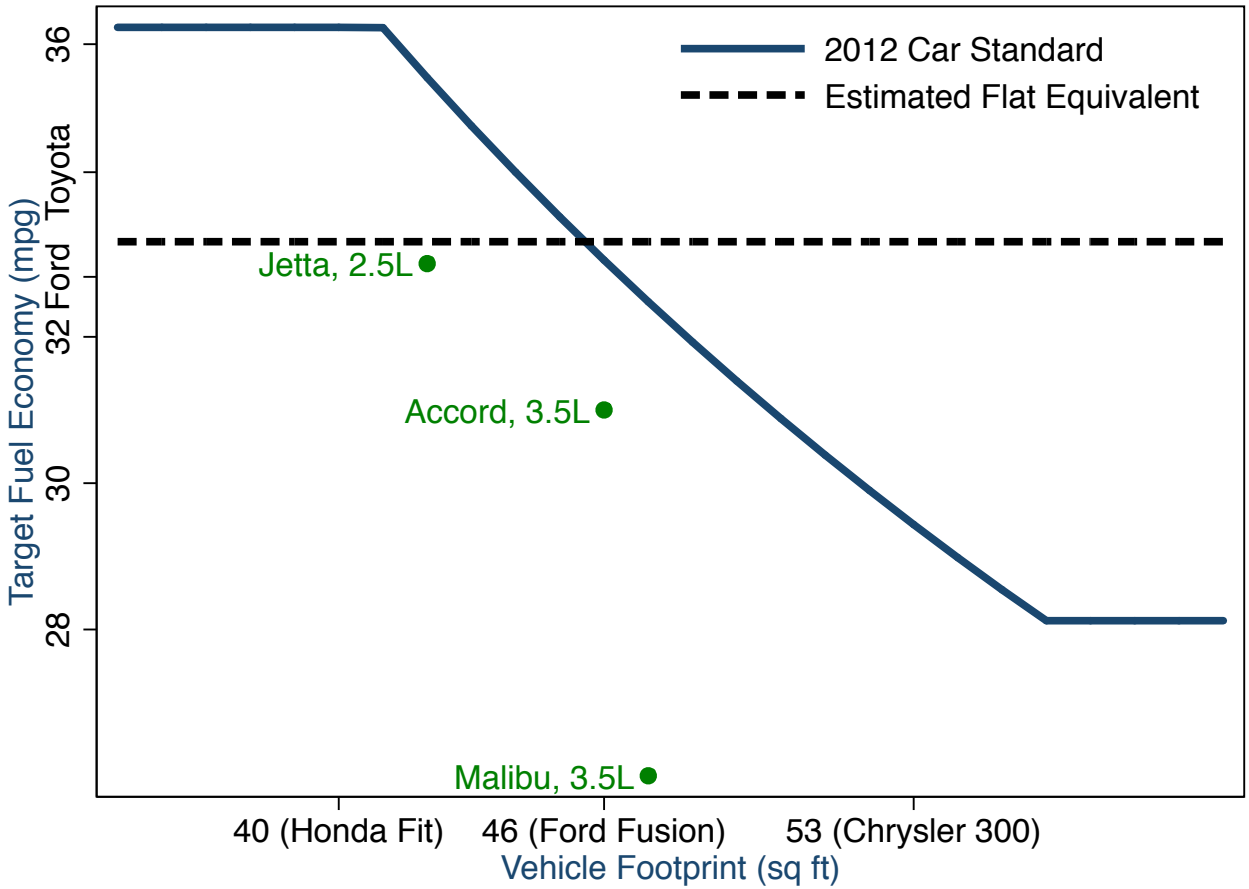
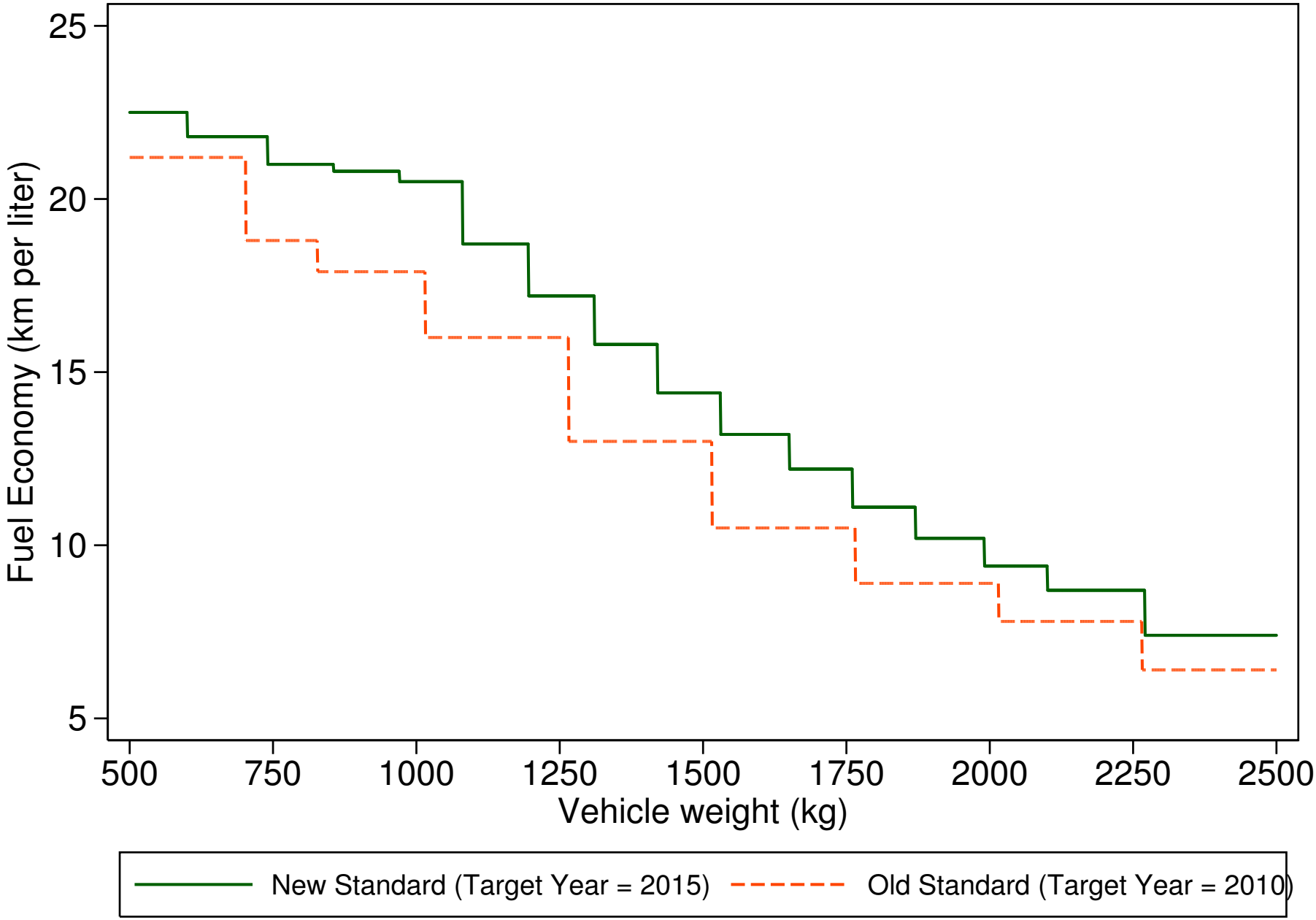


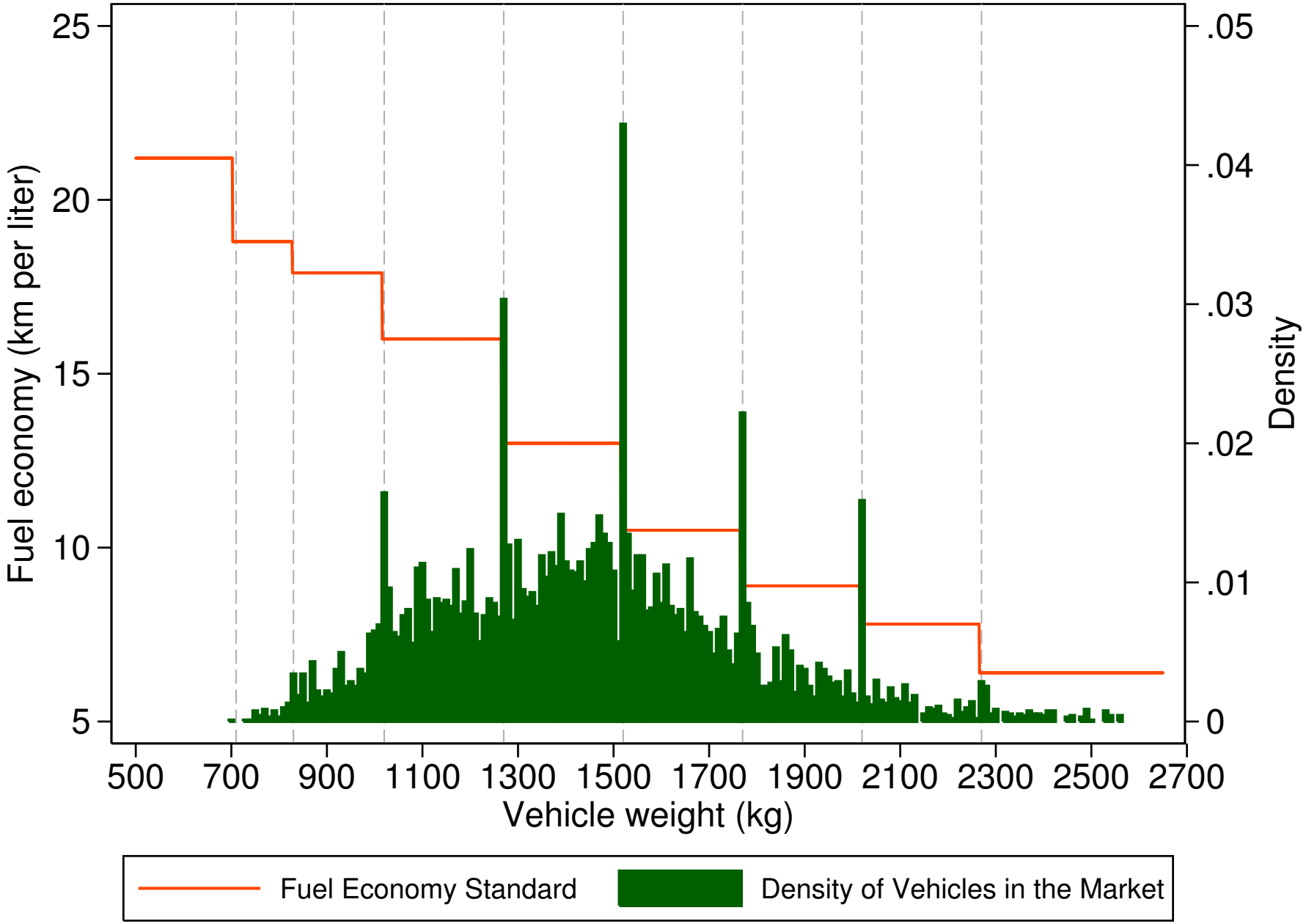

MPG standard (regulation) depends on footprint (attribute)

- **Efficiency benefit?** equalize marginal cost of compliance
- **Other possible benefits:** incidence, "fairness", safety, technology, targeting/tagging, imperfect competition

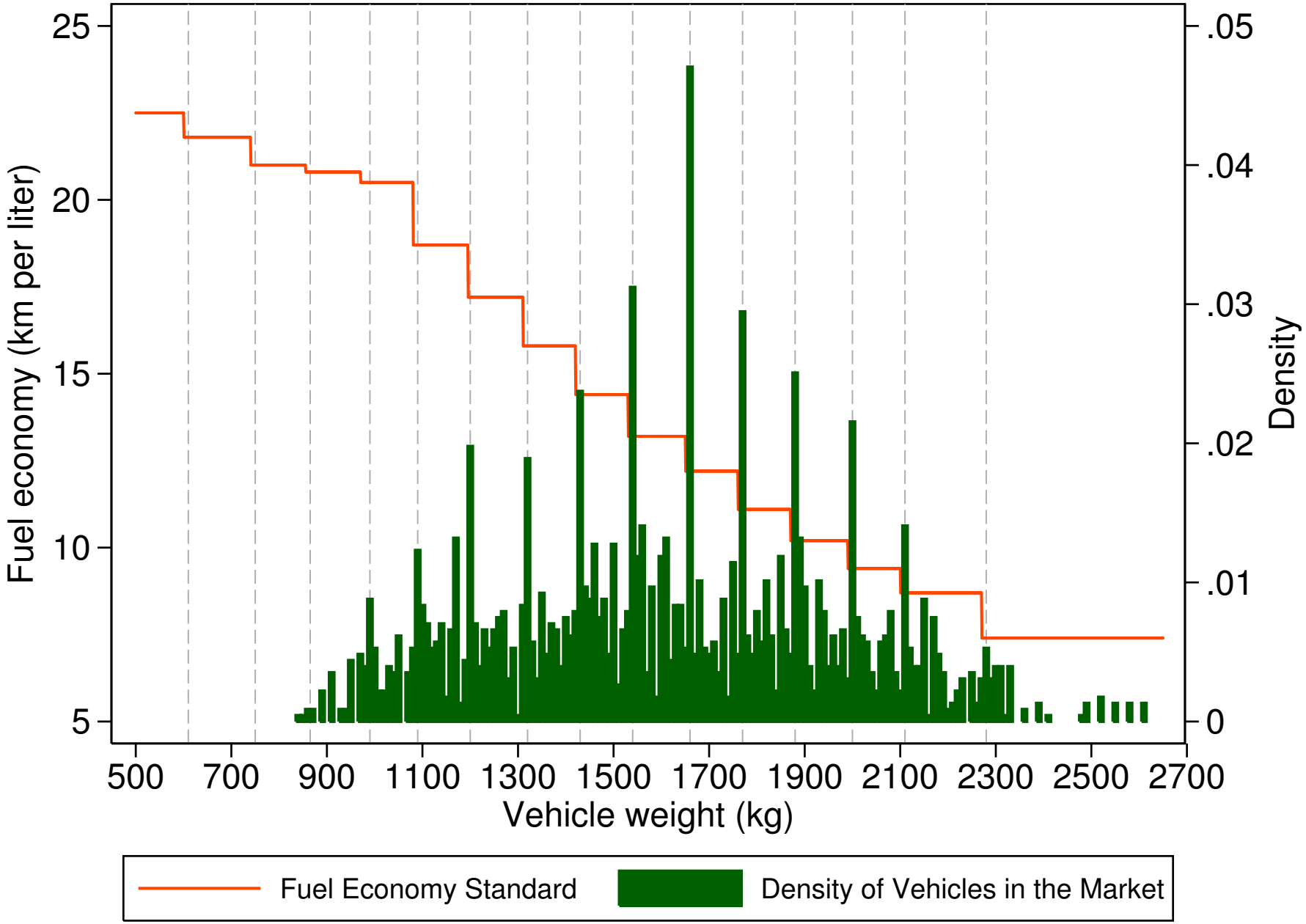
- "Notched" Fuel Economy Standard Schedule in Japan



- Use "bunching" to estimate firm's responses to policy



- Use a policy change to test if bunching moved accordingly



# Sketch of the theory to get intuition (details in paper)

- Suppose fuel economy **e** creates (positive) externality $\phi$
- Non-attribute-based Pigouvian subsidy for fuel economy **e** is:

$$\text{Subsidy } = S(e) = s \cdot e$$

- Attribute-based subsidy for fuel economy **e** and weight **a** is:

$$S(a, e) = s \cdot (e - \sigma(a)), \text{ where } \sigma'(a) < 0$$

- Essentially, ABR creates an implicit extra subsidy for weight **a**

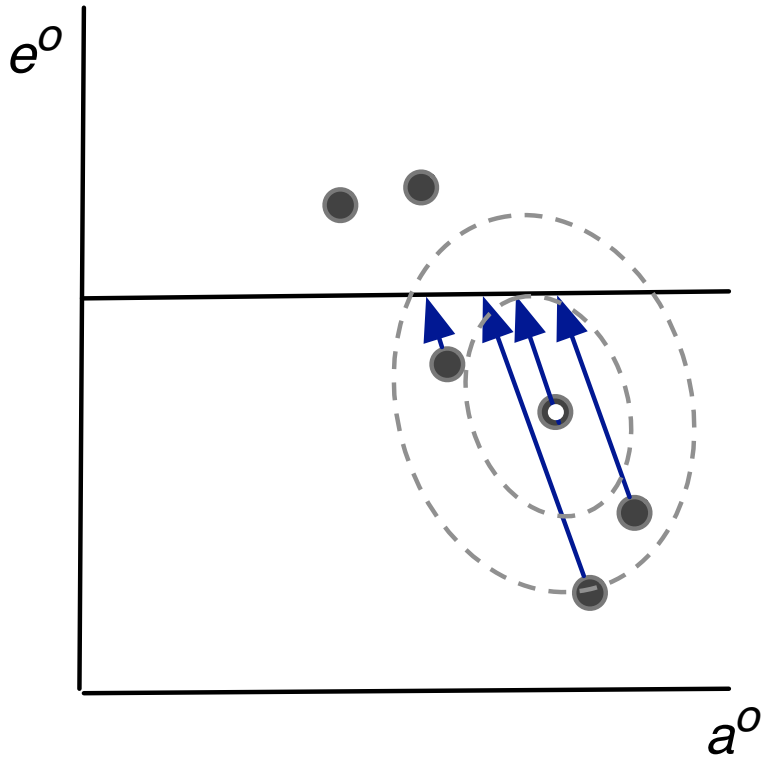
# ABR creates two incentives

- ABR creates two subsidy incentives for **a** and **e**:

$$\frac{\partial S(a,e)}{\partial e} = s$$
$$\frac{\partial S(a,e)}{\partial a} = -\sigma'(a) \cdot s$$

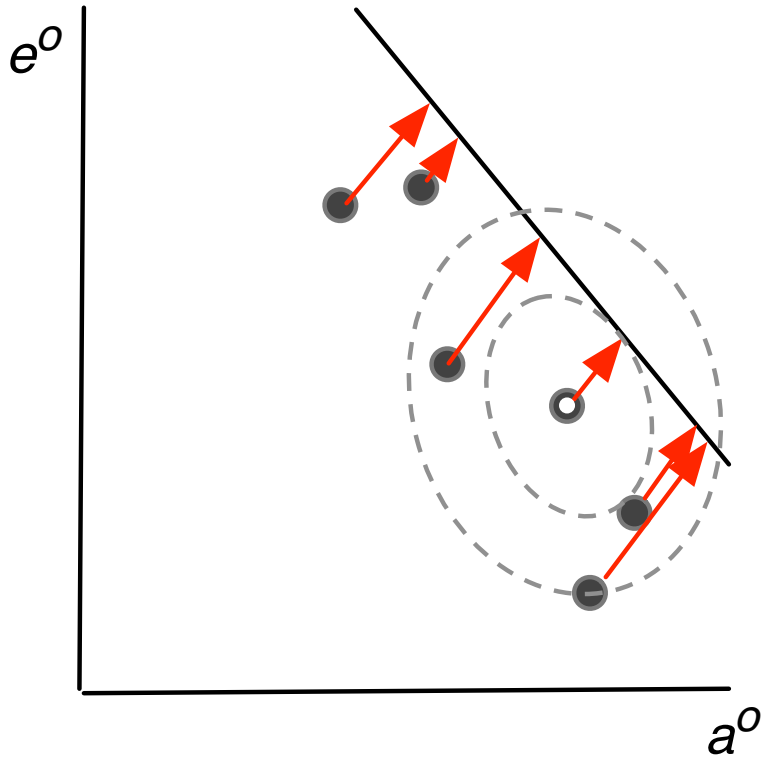
- 1st incentive is sufficient to correct externality (by $s$ = Pigou)
- 2nd incentive creates unnecessary distortions in **a**

# Illustration of ABR, quadratic costs




- This is how firms comply under flat standard

# Illustration of ABR, quadratic costs

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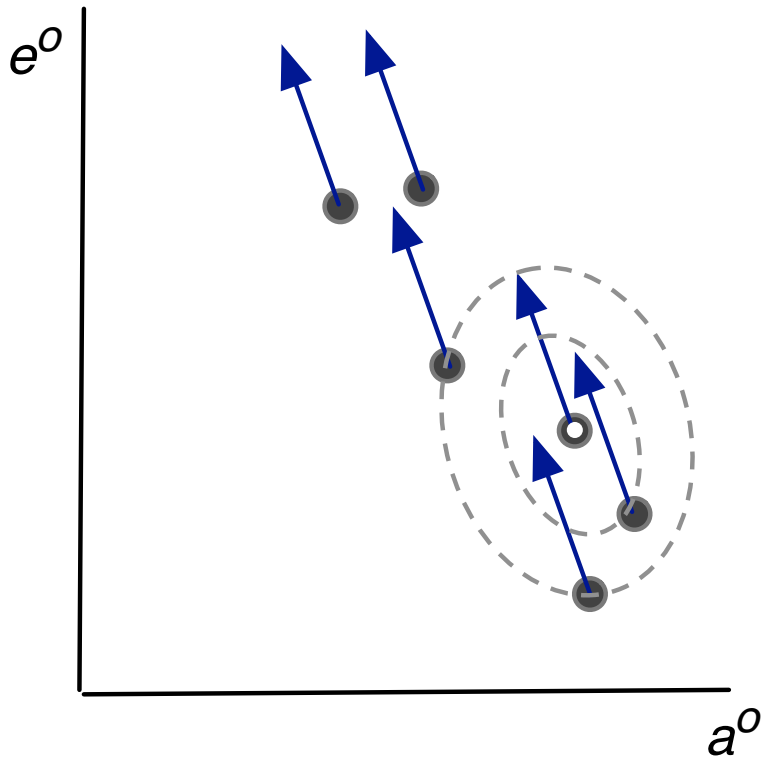
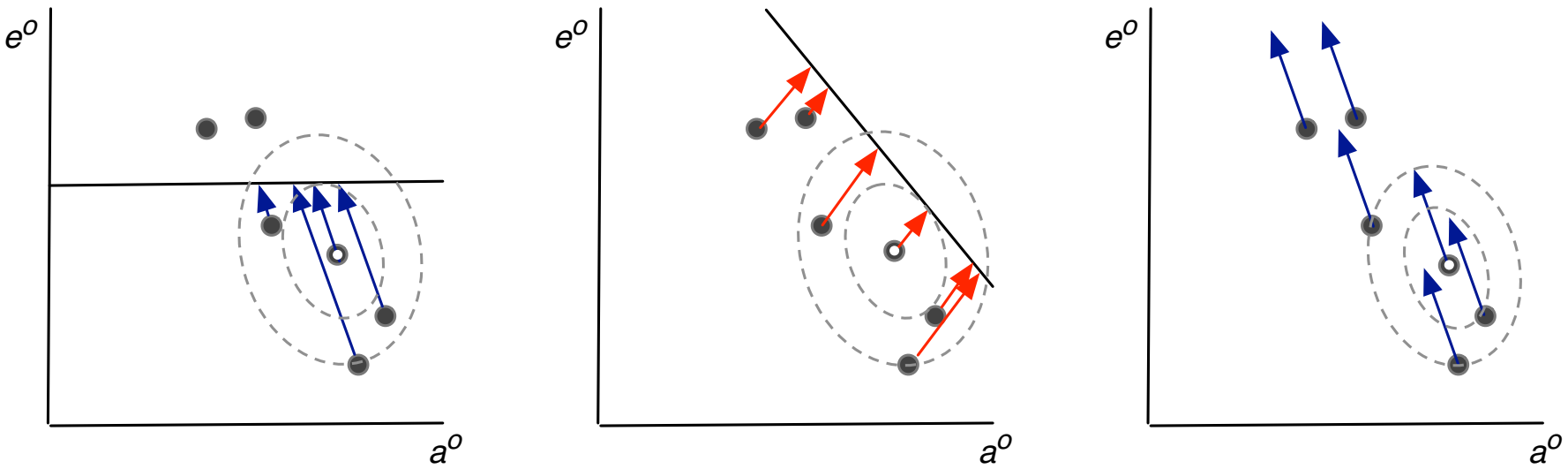



- This is how firms comply under flat standard with trading, so all MC equalized




- ABR trades-off the (partial) equalization of marginal compliance costs against distortion of changing "angle"
- SB policy (with no trading) does not equalize MC as much as possible; it attenuates to mitigate distortion in angle

# What benefits can possibly justify ABR?

- Equalizing marginal costs (but trading is better)
- Incidence: you want to transfer wealth among market segments
- Safety (we disagree)
- Technology forcing: spillovers
- Creates a more stable shadow price (i.e., you really want a tax instead of a performance standard)

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