Does behavior undermine climate policy?

ECON-4210

Economics of Climate Change

Class 23

Prof. Casey Wichman

Georgia Institute of Technology

Today's class

1. Questions?
2. Attendance
3. Housekeeping
    1. Unit 4 overview
    2. Ghost Emissions rounds 9 and 10
4. Energy efficiency and the rebound effect
5. For next class…

Unit 4: Behavior, uncertainty, and cooperation

- Today: *Does behavior undermine climate policy? Rebound effects (class 23)*
- *What don't we know? Uncertainty, fat tails, and insurance (class 24)*
- *Can we fix climate change with this weird trick? Geoengineering (class 25)*
  - Guest lecture: Tony Harding, Georgia Tech, School of Public Policy
- *Can we address climate change on our own? International cooperation (class 26)*
- *Is changing our own behavior the solution?* (class 27)

- **Problem set 4 due:** Sunday, 12/6, 11:59 PM.
- **Exam 4:** Wednesday, 12/16, 2:40–5:30 PM (classes 23–27).

Ghost Emissions rounds 9 and 10

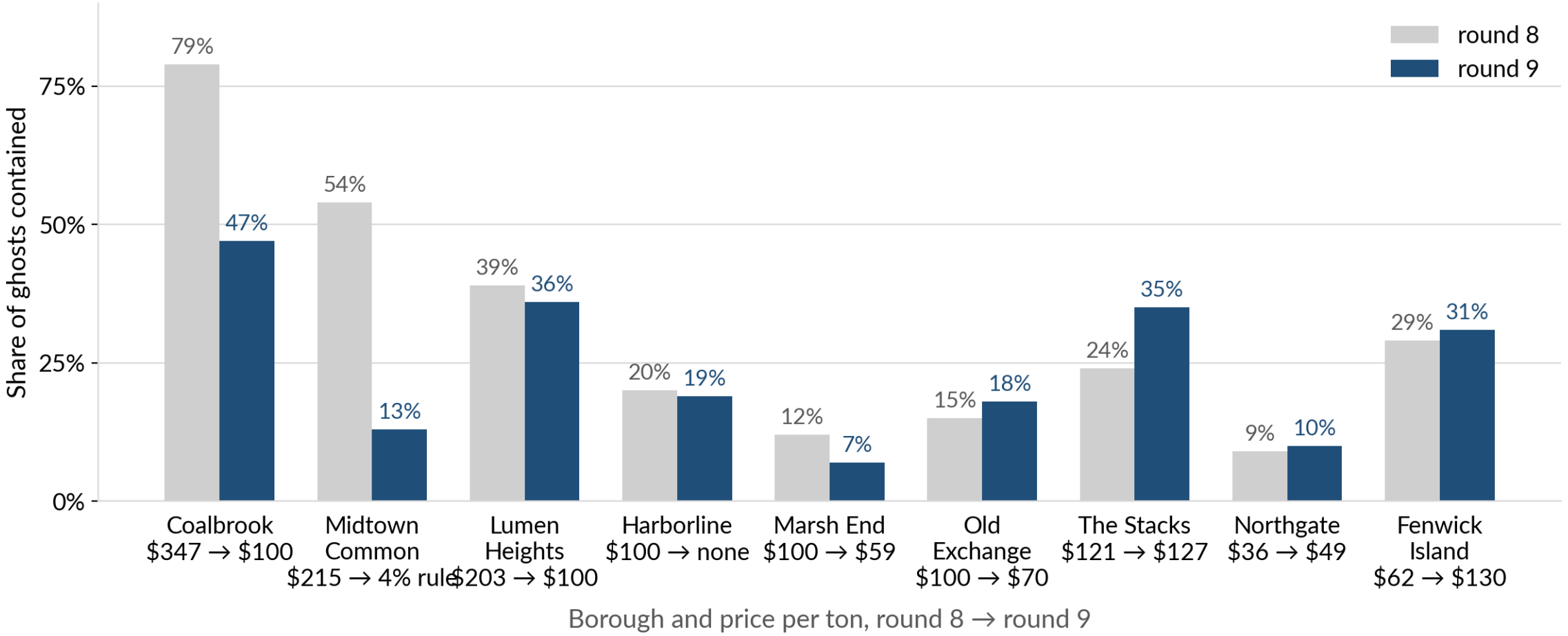
- Round 9 (better traps): spending on trap R&D lowers containment costs in every later round.
- Round 10 (live with it, or fix it?): spend on defense (i.e., adaptation) or on containment.
  - Defense protects your own borough immediately.
  - Containment protects every borough but plays out over time.

What did each borough do in round 9?

Borough	Price on ghosts this round	How did the mayor spend the budget?	Price set for round 10
Coalbrook	$100 tax	Three-quarters R&D, rest defense	$50 tax
Fenwick Island	$90 tax + $40 subsidy	A little of each, half in reserve	Cap of 34 tons
Harborline	None	All of it on slime defense	$40 tax
Lumen Heights	$100 tax	All held in reserve	$20 tax
Marsh End	$50 tax + $9 subsidy	Some defense and R&D, most in reserve	$110 tax
Midtown Common	4% containment rule	Mayor did not submit (repeat last week)	4% rule again
Northgate	$20 tax + $29 subsidy	Defense and subsidy, half in reserve	$150 tax
Old Exchange	$70 subsidy (cap not binding)	Mayor did not submit (repeat last week)	Same cap
The Stacks	$120 tax + $7 subsidy	R&D and defense, half in reserve	$40 tax

Budget spending takes effect this round. The price set this week binds in round 10.

Containment, round 8 to round 9



Where the price fell, containment fell. City total: 496 → 544 ghosts, the most since round 6.

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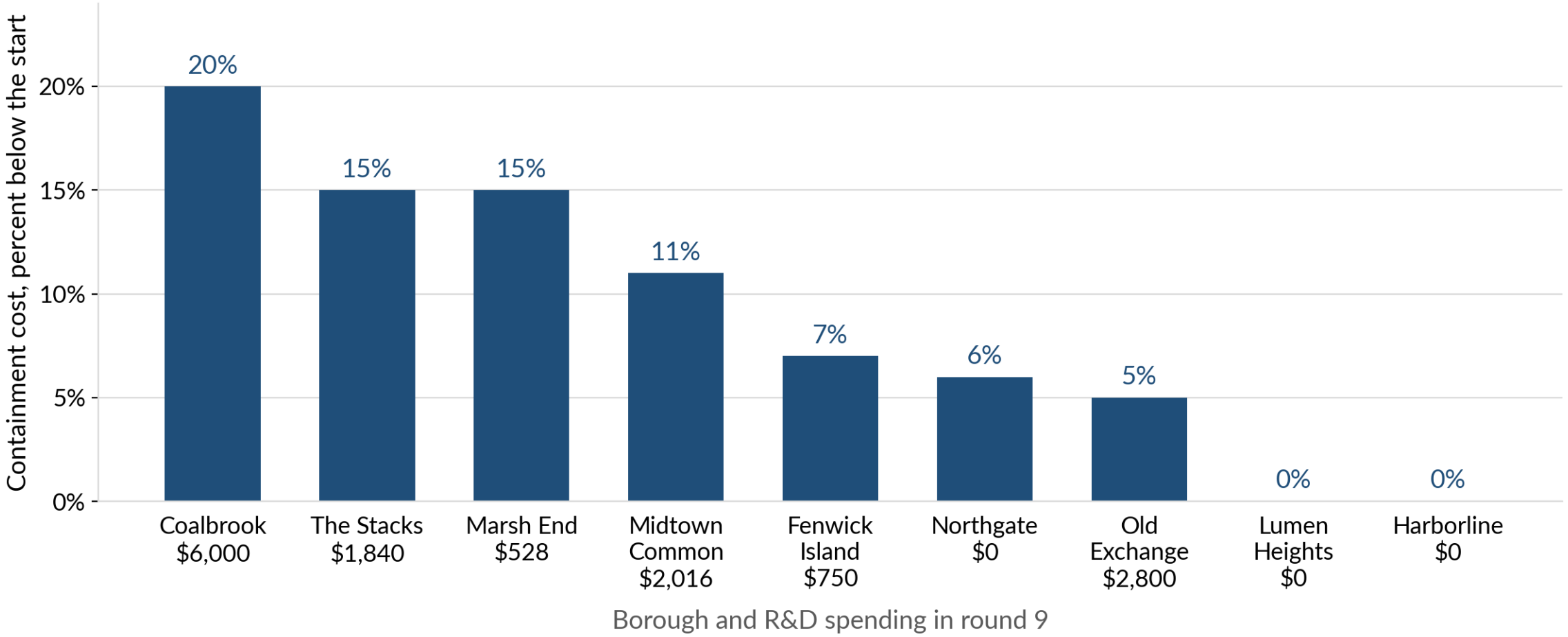
Containment cost reductions via R&D so far



A full budget allocated to R&D reduces every business's containment cost by 12% permanently. The reduction shows up next round.

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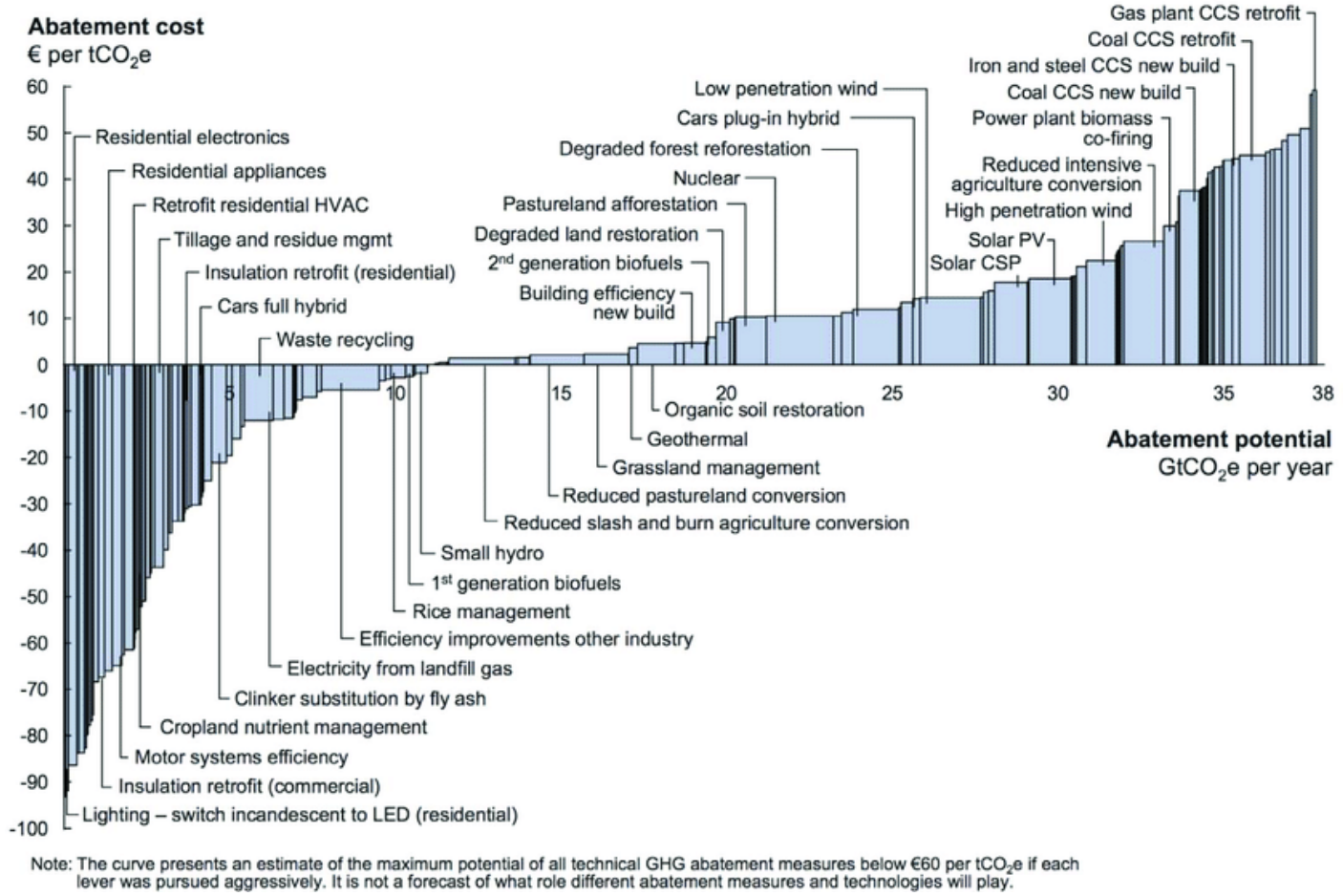
Energy efficiency

- "Fifth fuel" (after coal, petroleum, nuclear, and renewables)
  - Energy efficiency is "the largest, the most evenly geographically distributed, and least expensive energy resource." -UN
- May accelerate transition to green energy economy
  - National efficiency program may reduce GHGs by 1.1 gigaton/year –McKinsey
  - Switching from incandescent to CFL or LED lights has a *negative* MAC (i.e., it is a "win-win" – saves money and reduces CO2)

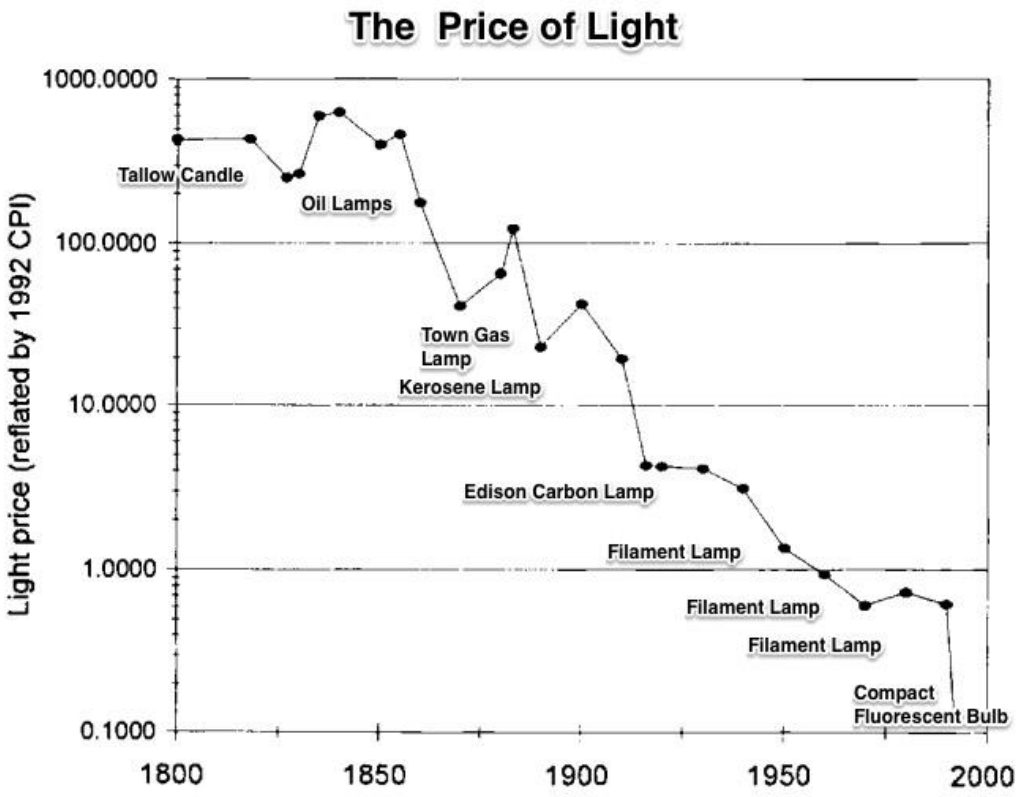


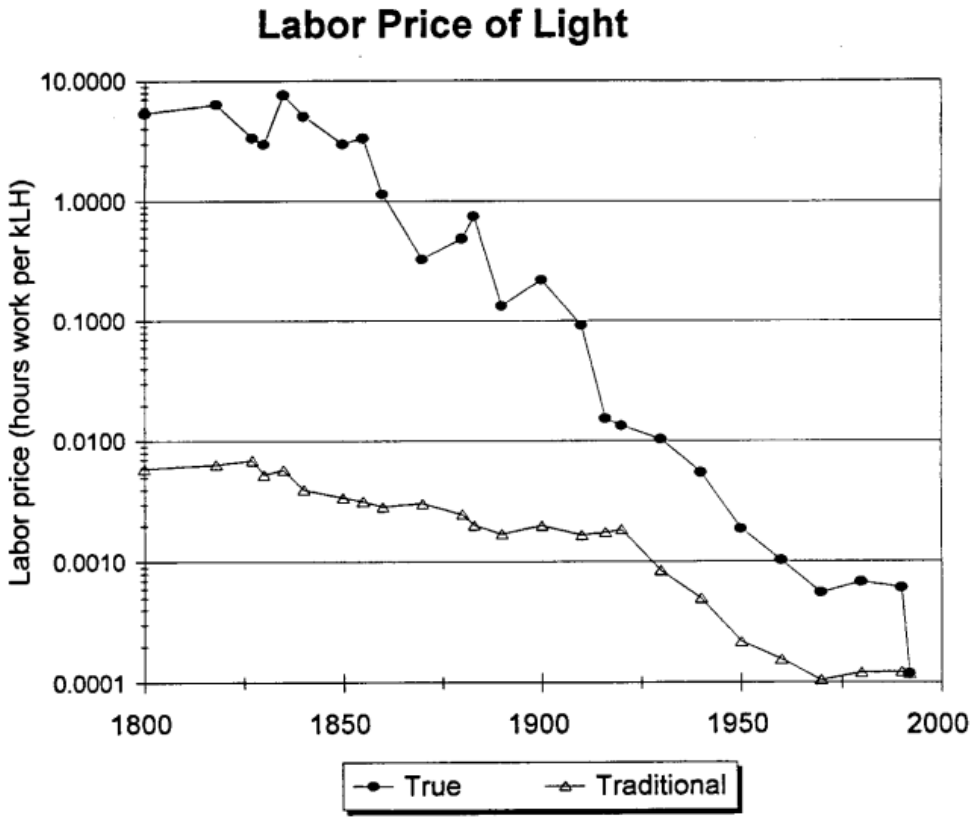
Recall: McKinsey CO2 abatement cost curve.

McKinsey & Company (2009). Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement cost curve.
Granade, H.C., et al. (2009). Unlocking energy efficiency in the U.S. economy. McKinsey & Company.

The price of light

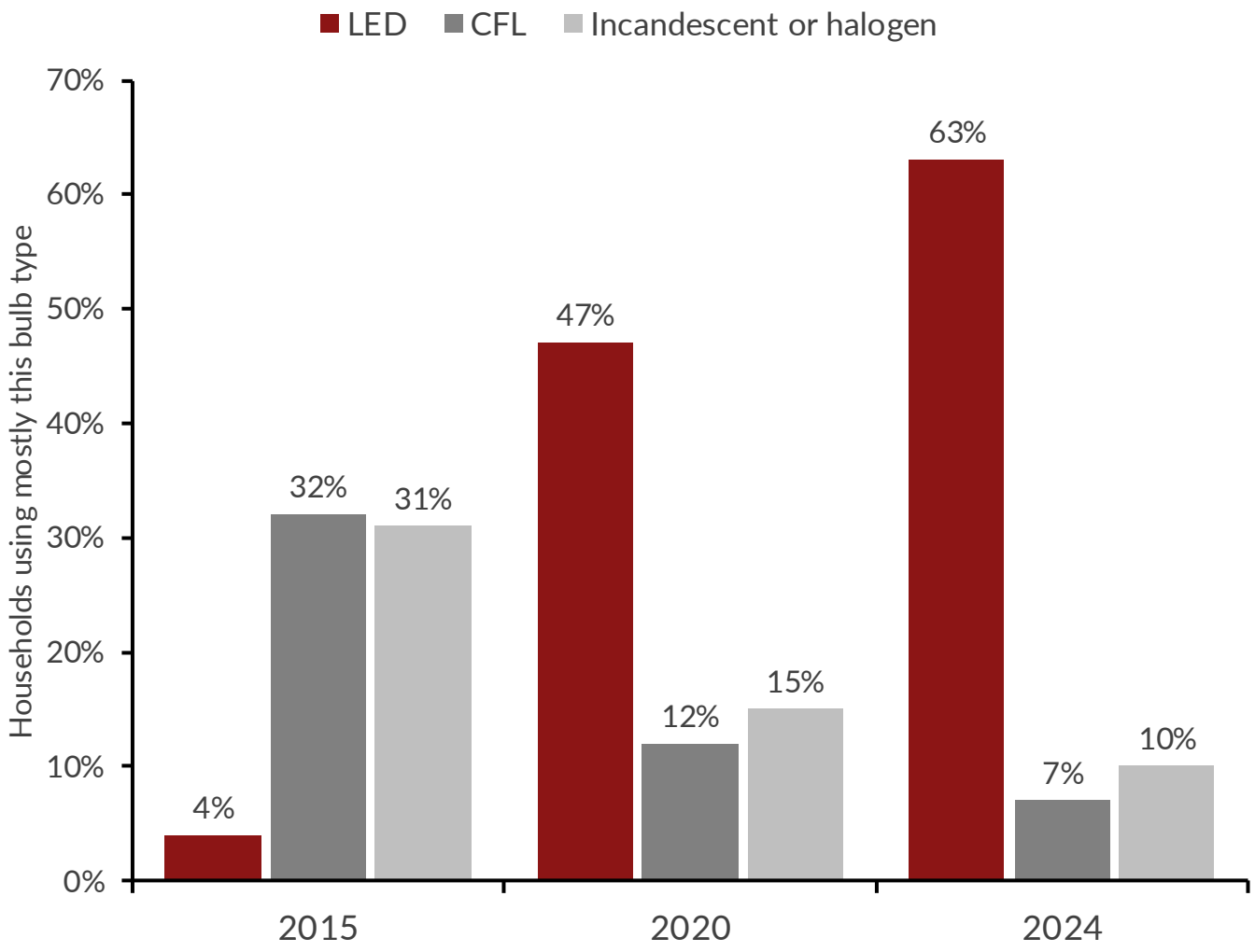
- In the 1990s, Nordhaus collected data on the cost of light (in cents per 1000 lumen hours)
- In 1800, a tallow candle cost between 100 and 1000 cents per 1000 lumen hours.
- In 2000, a CFL light bulb provided the same service at ~0.10 cents





Nordhaus, W.D. (1996). Do real-output and real-wage measures capture reality? The history of lighting suggests not. In T.F. Bresnahan and R.J. Gordon (eds.), The Economics of New Goods. University of Chicago Press. Cowles Foundation Discussion Paper 1078

LEDs in U.S. homes

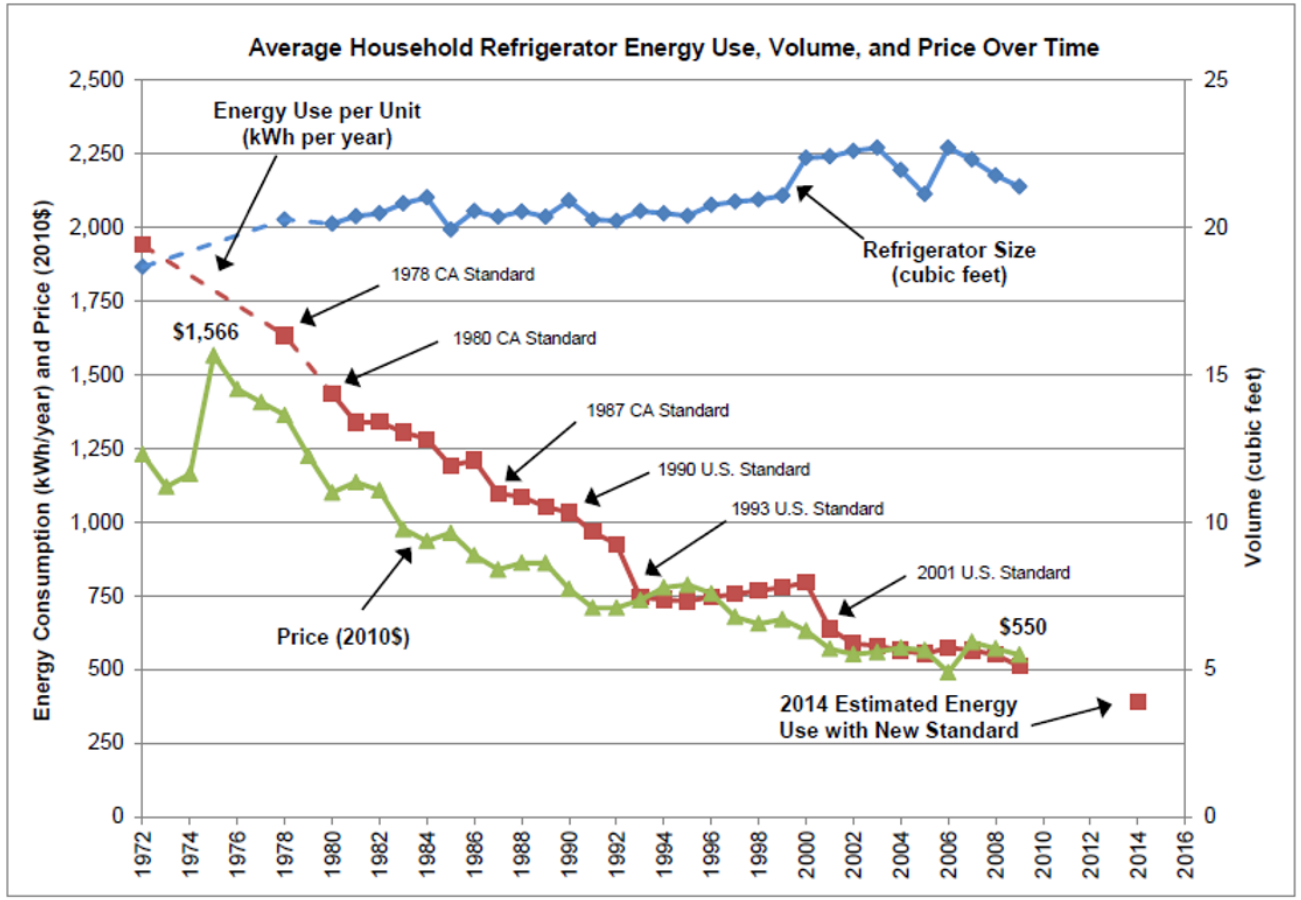


- Share of households that use mostly LED bulbs: 4% in 2015, 47% in 2020, 63% in 2024.
- Electricity for lighting per household decreased 41% from 2015 to 2020 (1,105 kWh to 654 kWh).
  - Lighting bills decreased from $147 to $91 per year.

U.S. Energy Information Administration, Residential Energy Consumption Survey (2015, 2020, 2024). eia.gov/todayinenergy/detail.php?id=67368; eia.gov/pressroom/releases/press535.php

Appliances have gotten cheaper, better, & more efficient

ASAP | APPLIANCE STANDARDS AWARENESS PROJECT



Sources: Association of Home Appliance Manufacturers (AHAM) for energy consumption and volume; U.S. Census Bureau for price

Notes: a. Data includes standard-size and compact refrigerators.
b. Energy consumption and volume reflect the DOE test procedure published in 2010.
c. Volume is adjusted volume, which is equal to the fresh food volume + 1.76 * freezer volume.
d. Prices represent the manufacturer selling price (e.g. excluding retailer markups) and reflect products manufactured in the U.S.

- Refrigerators cost 65% less than what they did in the 1970s.
- Refrigerators have also gotten a lot larger (but much more efficient) than a 1970s refrigerator.

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The "energy-efficiency gap"

- **Energy Efficiency Gap (aka Energy Paradox):**
  - The difference between the *cost-effective* level of energy efficiency (based on NPV) and the actual level adopted by consumers and firms.

- Many cost-effective energy technologies (e.g., efficient vehicles, appliances) diffuse slowly.
- Even when the net present value of energy savings is positive, adoption rates remain low.

- Two perspectives:
  - *Engineering:* There's a gap between actual and optimal energy use.
  - *Economics:* We ask whether market failures (e.g., imperfect information, credit constraints, myopia) explain the gap.

Do consumers value fuel efficiency?

What is #1 most-purchased vehicle in the US?

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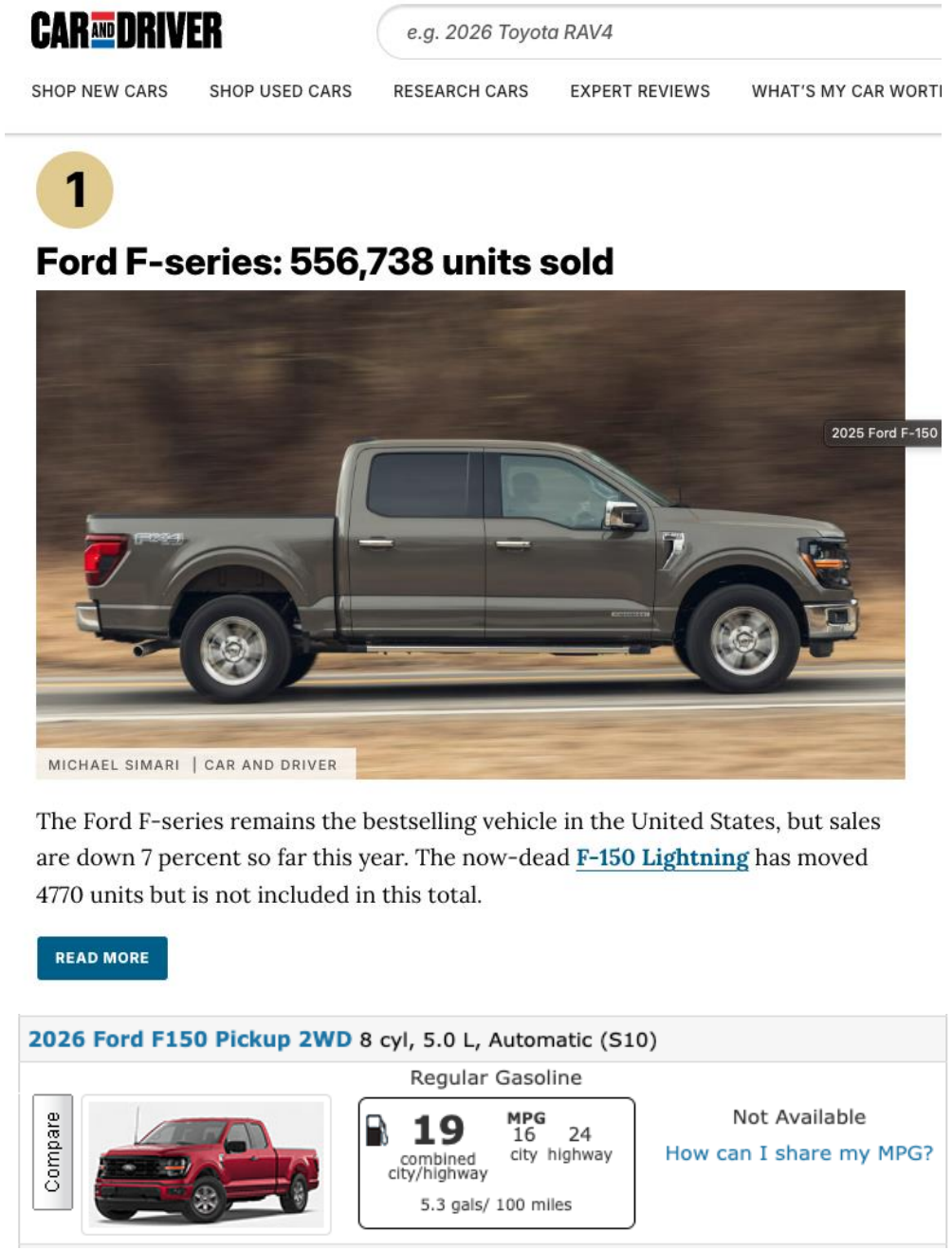
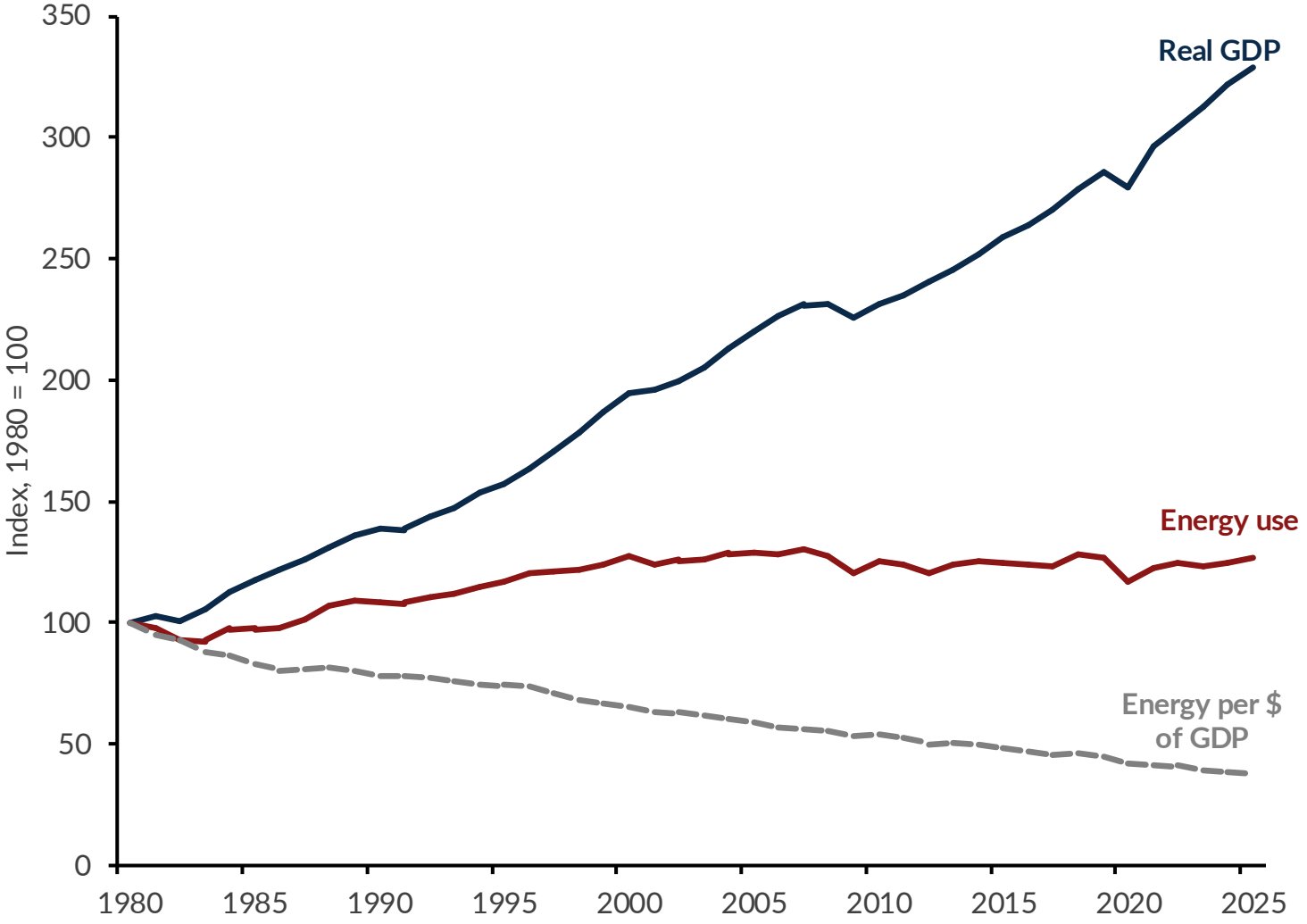


Sales figures: Car and Driver (2025)

Efficiency vs. totals in energy use



- Since 1980, real GDP has more than tripled. Energy use increased 27%.
- Energy use per dollar of GDP decreased 61%.
  - Part of this decrease is efficiency. Part is a shift from manufacturing to services.
- Energy use per person decreased 16%.
- Efficiency increased a lot. Did we use the savings to consume more?

U.S. Energy Information Administration (2026). Monthly Energy Review, October 2026, Table 1.7. eia.gov/totalenergy/data/monthly

Behavioral effects

- If energy efficiency increases, will you use less energy?
  - **Example 1: Suppose I buy a more energy efficient air conditioner (the durable good).**
    - As a result, the price of air conditioning (the energy service) is lower, and I use more air conditioning
  - **Example 2: Buy a more energy efficient washing machine.**
    - The price of doing a load of laundry falls, and I do more loads of laundry.
  - **Example 3: Put solar panels on your roof.**
    - The cost of consuming electricity (and guilt associated with energy use) goes down, and you use more electricity.
- Economical use of fuel may result in an increase in consumption, not a decrease.

Jevons' paradox

"Whatever, therefore, conduces to increase the efficiency of coal, and to diminish the cost of its use, directly tends to augment the value of the steam-engine, and to enlarge the field of its operations."

THE

COAL QUESTION;

AN INQUIRY

CONCERNING THE PROGRESS OF THE NATION,

AND THE

PROBABLE EXHAUSTION OF OUR COAL-MINES.

W. STANLEY JEVONS, M.A.

FELLOW OF UNIVERSITY COLLEGE, LONDON;

CORRESPONDING MEMBER OF THE STATISTICAL SOCIETY OF PARIS;

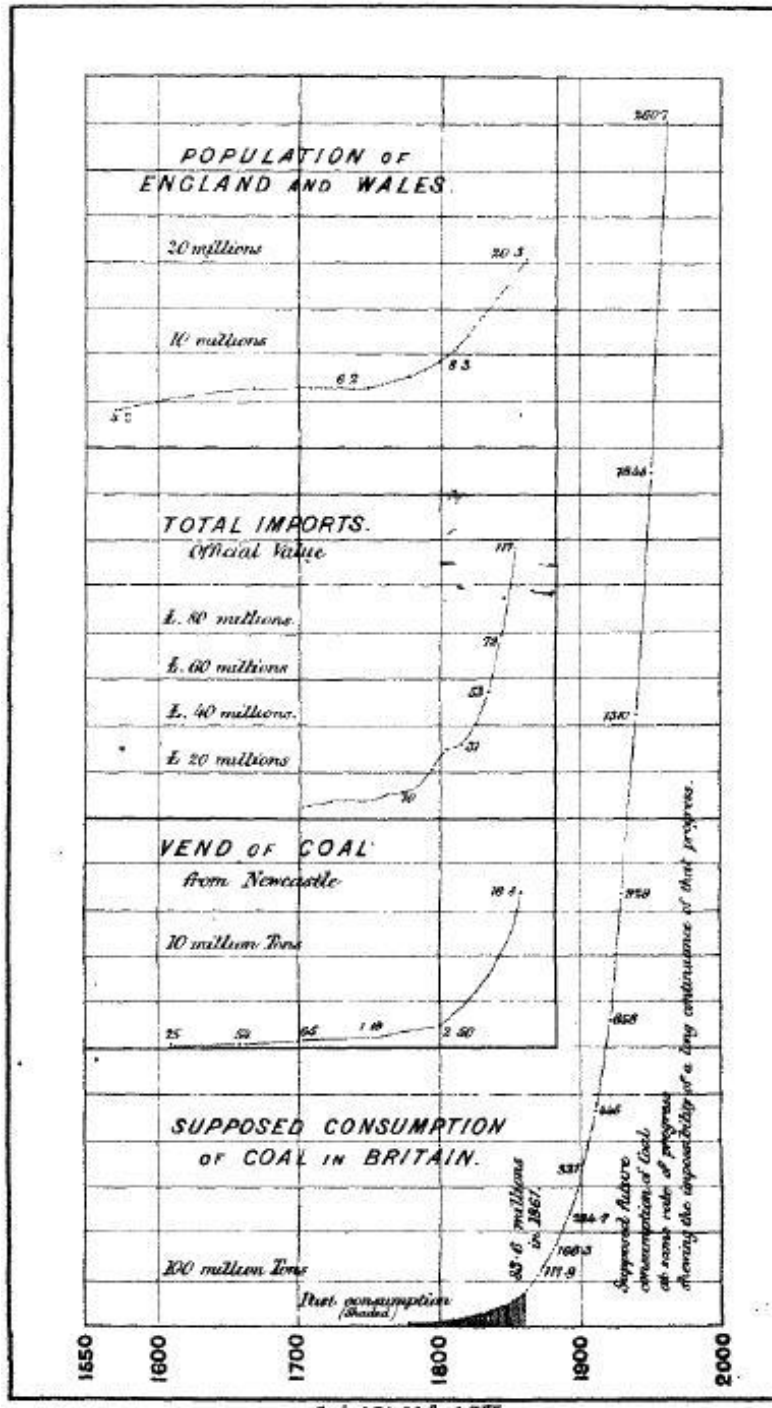
CORRESPONDING PROFESSOR OF POLITICAL ECONOMY IN OWENS COLLEGE, MANCHESTER.

SECOND EDITION, REVISED.

London:

MACMILLAN AND CO.

1866.



Jevons, W.S. (1865). The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal-Mines. London: Macmillan.

Rebound effect:

An increase in consumption of an energy service due to an increase in the energy efficiency of the associated durable good

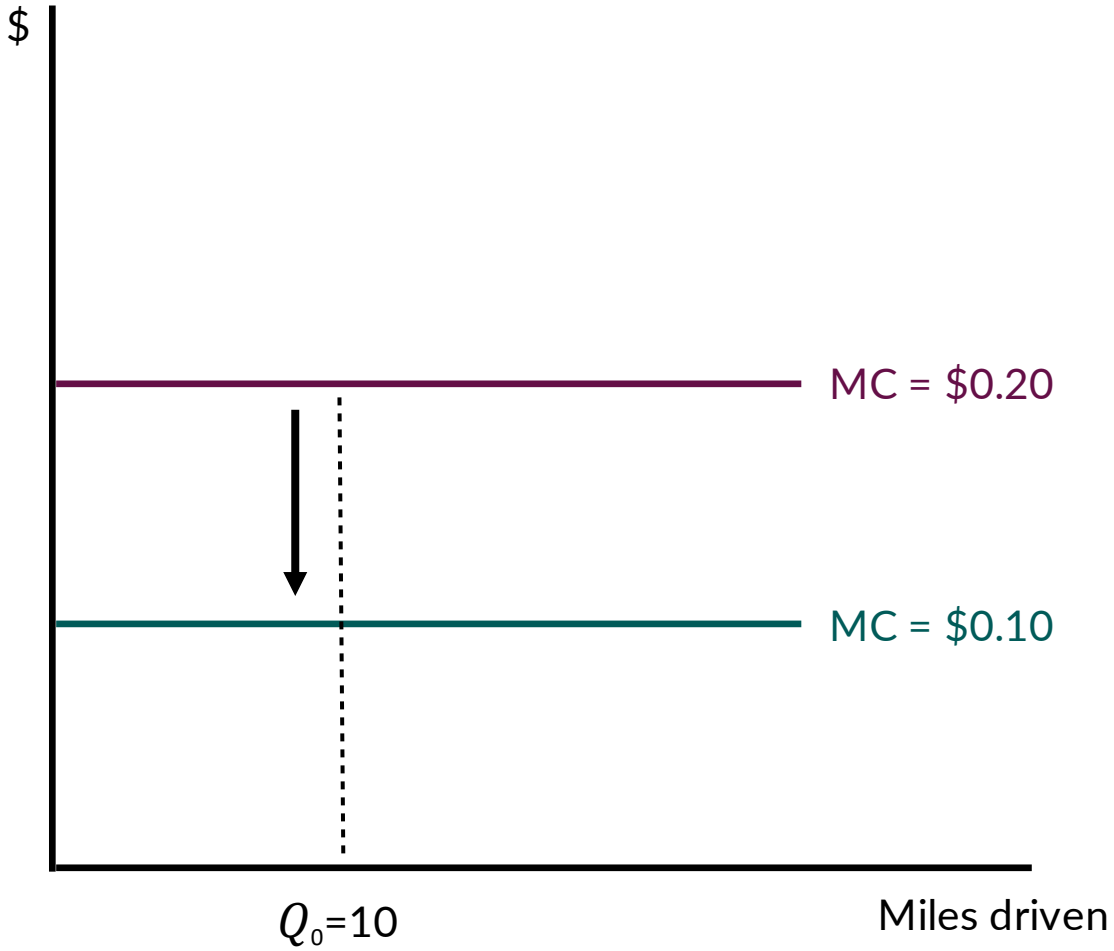
A fuel efficiency rebound example…

- Assume gas consumption is the only cost of a vehicle-mile traveled (VMT)
- Total cost = miles × (gallons/mile) × ($/gallon)
- Marginal cost = (gallons/mile) × ($/gallon)
  - Gallons/mile (gpm) measures energy use (e.g., 116,000 BTUs per gallon)

- Assume price of gas = $4/gallon
- If **Car A gets 20mpg** → gpm = 1/20 = 0.05 → MC = 0.05 × $4 = $0.20
- If **Car B gets 40mpg** → gpm = 1/40 = 0.025 → MC = 0.025 × $4 = $0.10

  - Assuming no change in total miles driven, the more fuel-efficient car cuts energy usage in half.
  - But, energy use is ***cheaper*** for Car B, so Car B will consume more miles.

A fuel efficiency rebound example…



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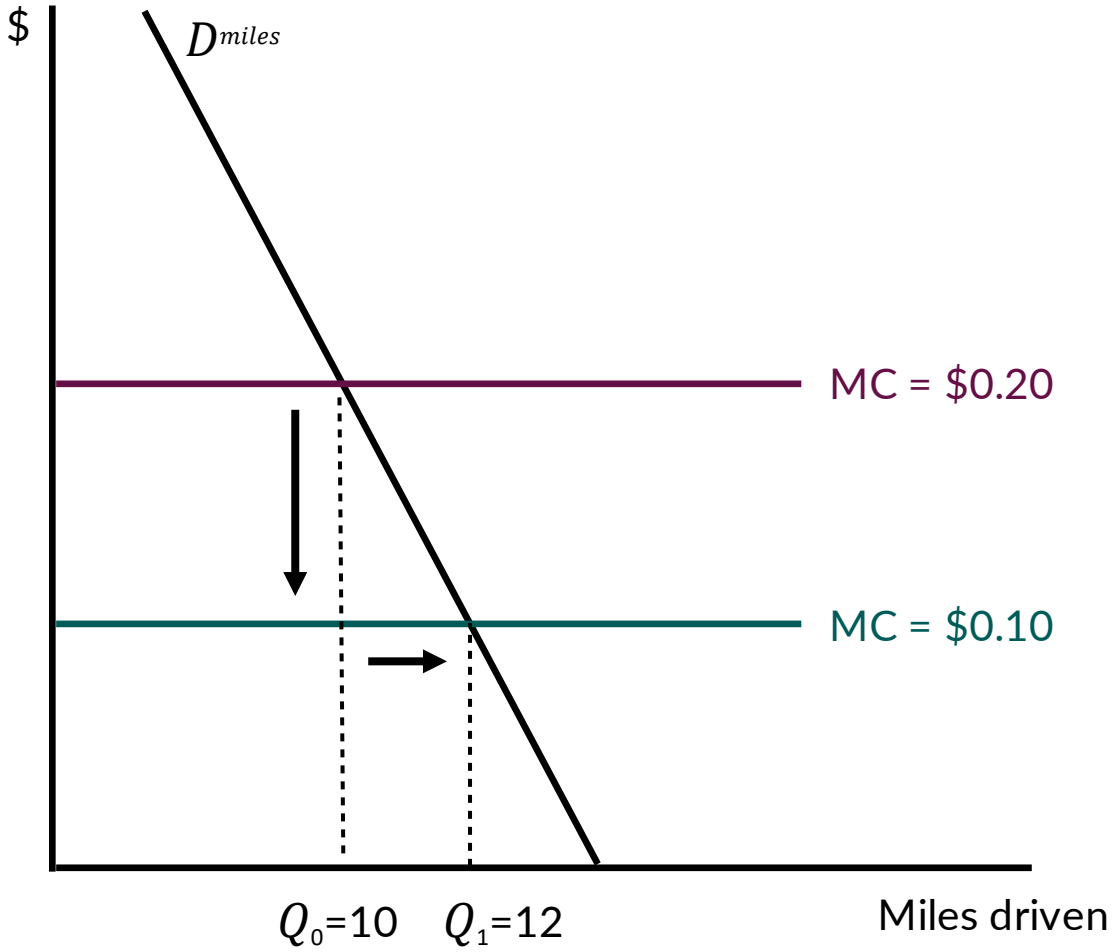
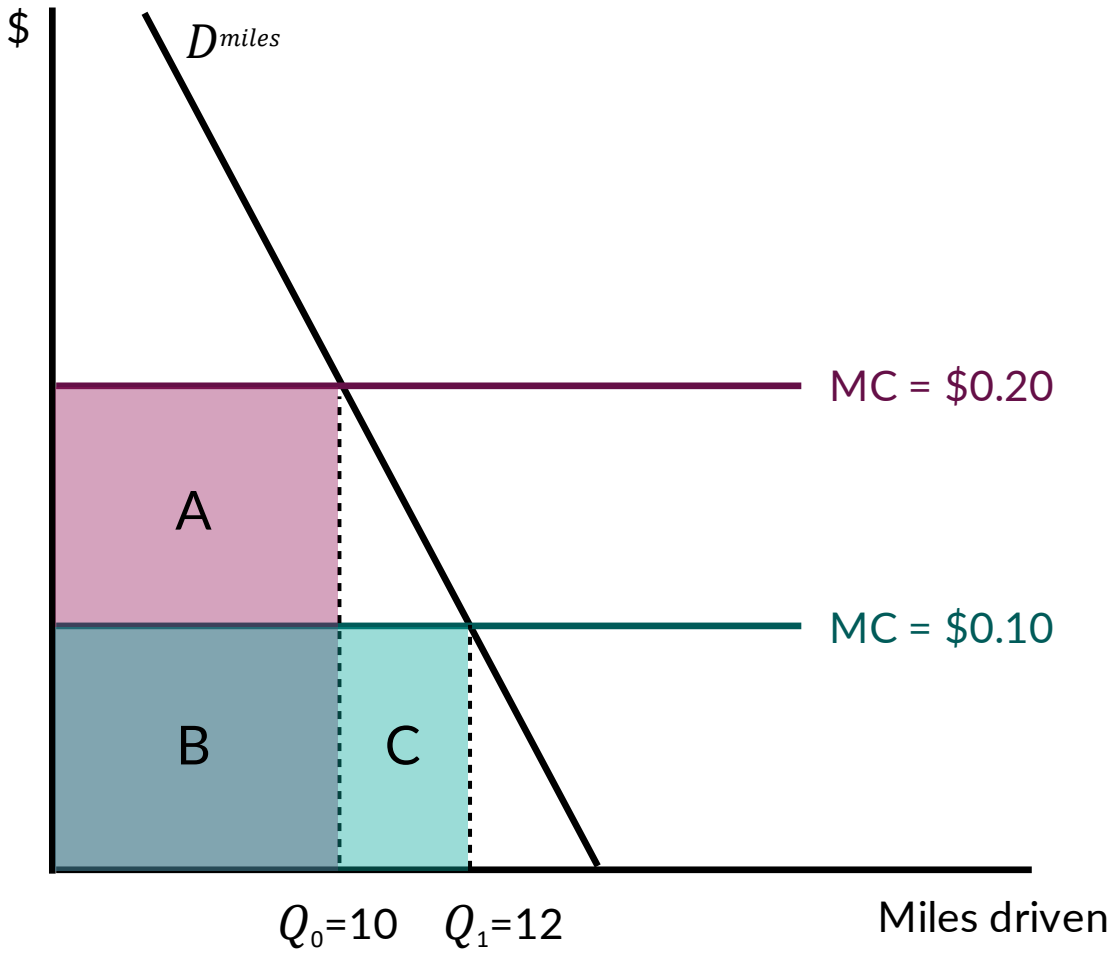
A fuel efficiency rebound example…



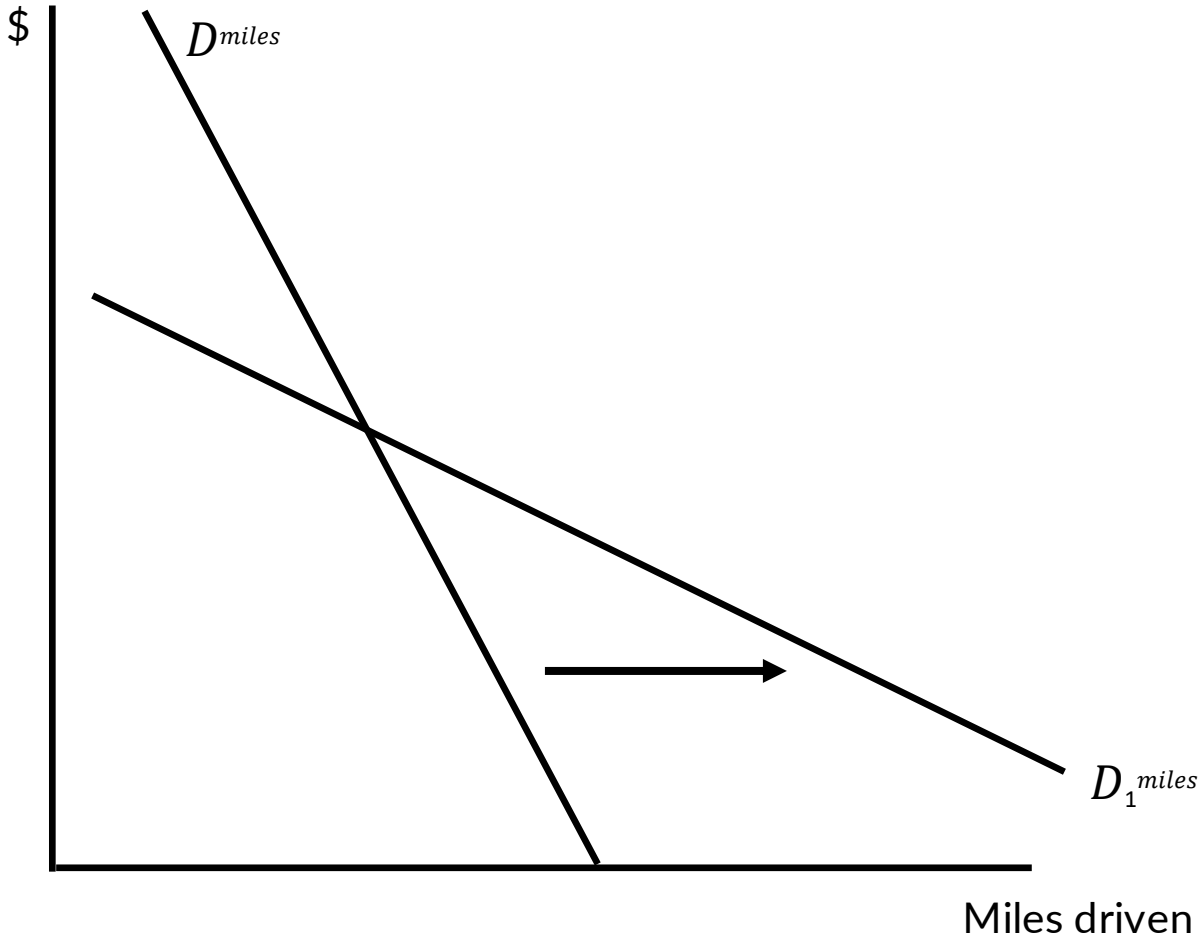
- Rebound effect stimulates a behavioral response (driving is cheaper!), so reduction in energy use is smaller than it otherwise would be.
- Increase in fuel efficiency leads to increase in quantity of miles demanded ($Q_0 \rightarrow Q_1$)

A fuel efficiency rebound example…



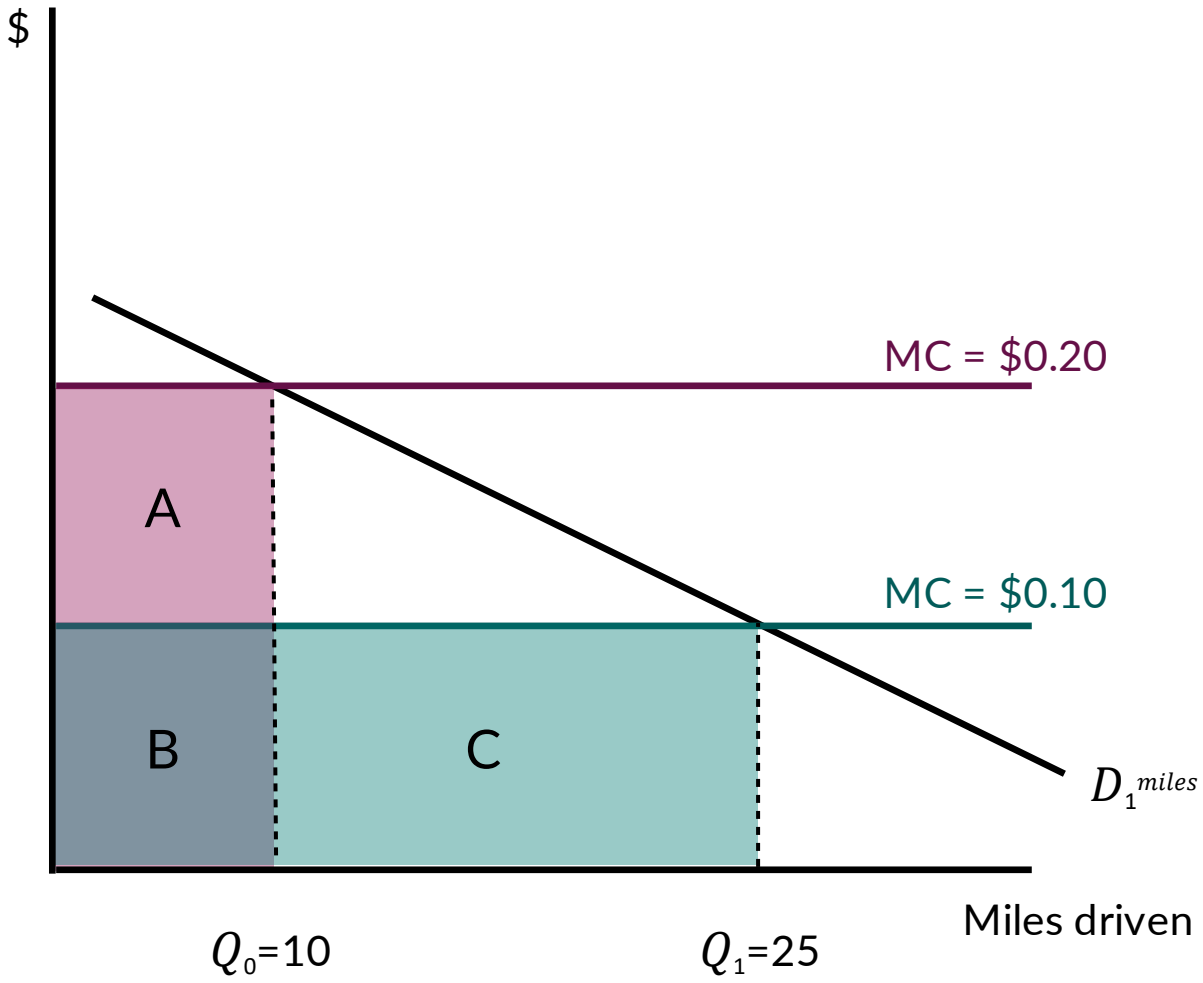
- Rebound effect stimulates a behavioral response (driving is cheaper!), so reduction in energy use is smaller than it otherwise would be.
- Increase in fuel efficiency leads to increase in quantity of miles demanded ($Q_0 \rightarrow Q_1$)
- Since gasoline price is the same for both fuel efficiencies, then ratio of total costs is an expression of the ratio of fuel use.
  - Ratio of TC: (B+C) / (A+B) = 0.6 / 1
  - TC is 60% of original use (not 50%)
- Or… in gallons (= miles × gpm)
  - $\Longrightarrow$ (12*0.025) / (10*0.05) = 0.3/0.5 = 0.6
  - $\Longrightarrow$ fuel use is 60% of original use

A fuel efficiency rebound example…



- What do you think would happen if the demand curve for miles was much more elastic?

A fuel efficiency rebound example…



- In this example, miles driven increase by more than 100% (10 → 25) after the change in fuel efficiency.
- Total cost of driving *increases*
  - (B+C) / (A+B) = (25 × $0.10) / (10 × $0.20) = 125%
- Jevons' paradox: rebound effect is so large that energy use *increases* after an increase in energy efficiency.
  - This is called **backfire** (i.e., rebound > 1)

Jevons' paradox continued

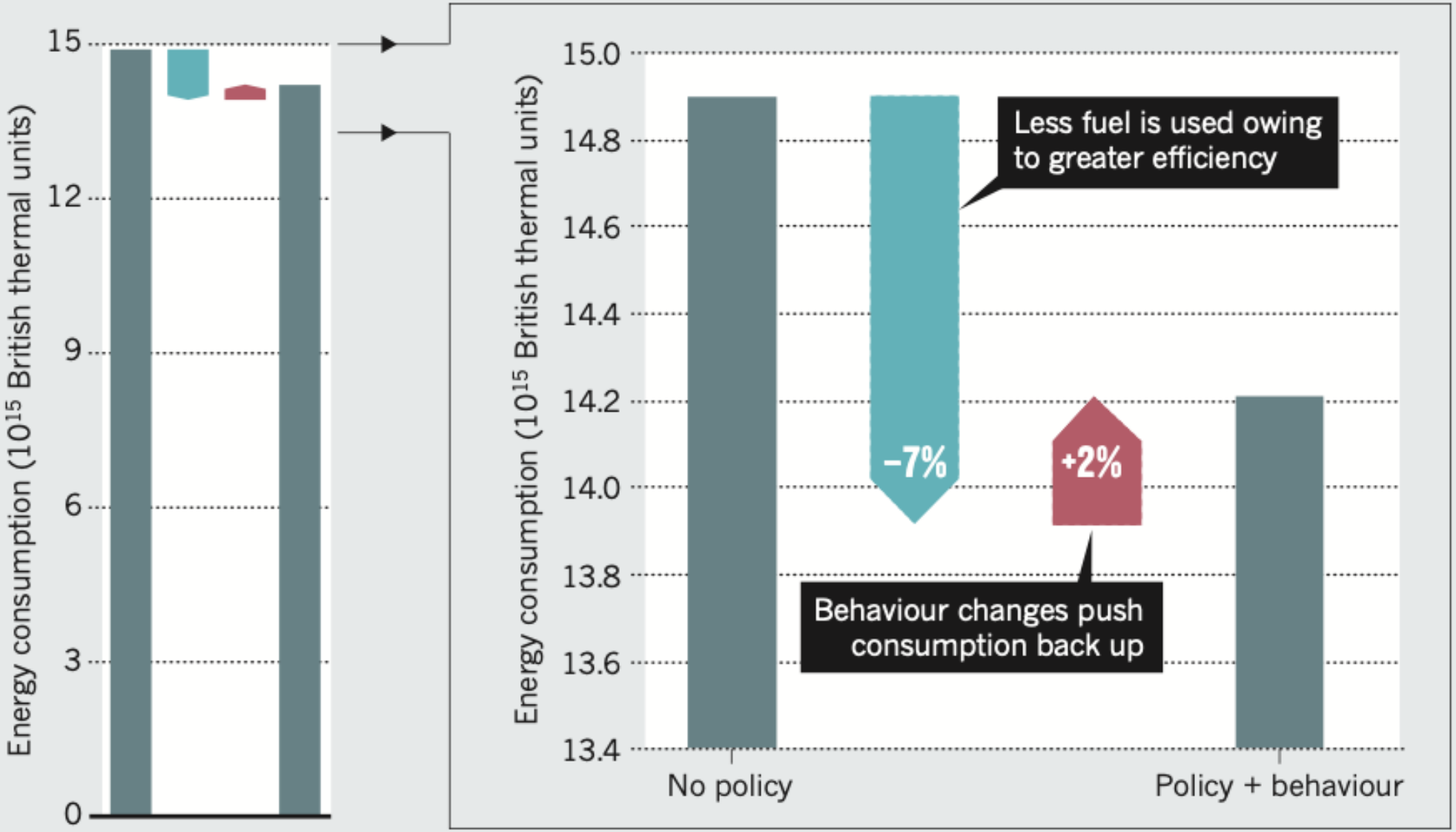
- But there is another aspect to the paradox…
- **Direct rebound effect:** Increased energy efficiency lowers the cost of a vehicle mile, and hence increases the consumption of vehicle miles.
- **Indirect rebound effect:** If rebound effect is not so large as to generate the Jevons' paradox directly, then income for consumption of other goods increases, implying an increase in energy consumption
  - This is a "general equilibrium" effect.
  - May generate an overall increase in energy consumption (depends on the energy intensity of producing the other goods)

Jevons' paradox continued

- Should we expect to see Jevons' paradox in real life?
- Should we expect to see any rebound?
- Should rebound be bigger/smaller in the short run vs. long run?

BOUNCE BACK

US policy to double fuel economy standards by 2025 would reduce projected energy consumption by almost 7% in the absence of behaviour changes. A conservative estimate of rebound effects from driving more and purchasing additional goods limits energy reductions to around 5%.



Gillingham, K., M.J. Kotchen, D.S. Rapson, and G. Wagner (2013). The rebound effect is overplayed. Nature 493: 475–476. doi.org/10.1038/493475a

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“Macro” rebound

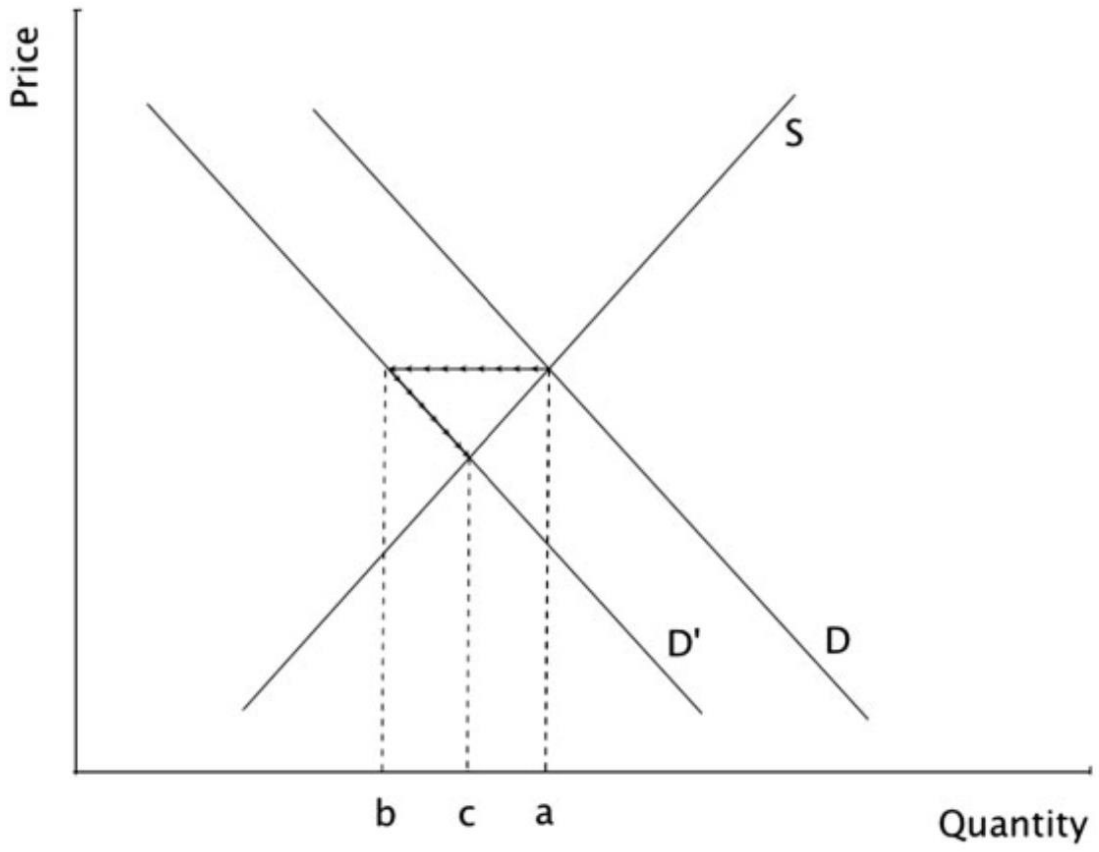

Figure 1 Macroeconomic price effect

Notes: This graph depicts the macroeconomic price effect associated with an energy efficiency policy that shifts demand inwards from D to D′. The shift in demand reduces the quantity of energy demanded from a to b; however, the equilibrium outcome yields a smaller energy reduction due to the price effect, which moves quantity from b to c.

- Efficiency improvements in US cars (e.g., from fuel economy standards) reduce demand for oil (D→D’)
- Reduced demand drives down the global price of oil.
- Cheaper global gas prices cause increases in quantity of fuel used in other countries.
- Backfire is impossible here.

Figure 1 from Gillingham, Rapson, and Wagner (2016). Review of Environmental Economics and Policy 10(1): 68–88. doi.org/10.1093/reep/rev017

Takeaways on rebound and climate change

- Energy efficiency can help reduce fossil fuel usage.
- But, people might not take up energy efficiency measures at the “optimal” rate.

- Rebound effects also mitigate potential gains from energy efficiency.
  - An X% increase in energy efficiency leads to a <X% decrease in fuel use
  - Rebound effects are real.
  - Estimates range from 5–30% (Gillingham et al., 2013).
  - Not big enough to cancel energy efficiency programs, but big enough to take into account for policy decisions.

- Rebound effects might dampen benefits of efficiency standards, but are not a problem for Pigouvian taxes!

Gillingham, K., M.J. Kotchen, D.S. Rapson, and G. Wagner (2013). The rebound effect is overplayed. Nature 493: 475–476. doi.org/10.1038/493475a

Next class…

- Next class:
  - Monday, 11/23: What don't we know? Uncertainty, fat tails, and insurance.
- No class
  - Wednesday, November 25 (Thanksgiving break)
- Problem set 4 due Sunday, December 6.
  - www.caseyjwichman.com/econ4210#week14