The permits game: debrief

ECON-4210

Economics of Climate Change

Class 19

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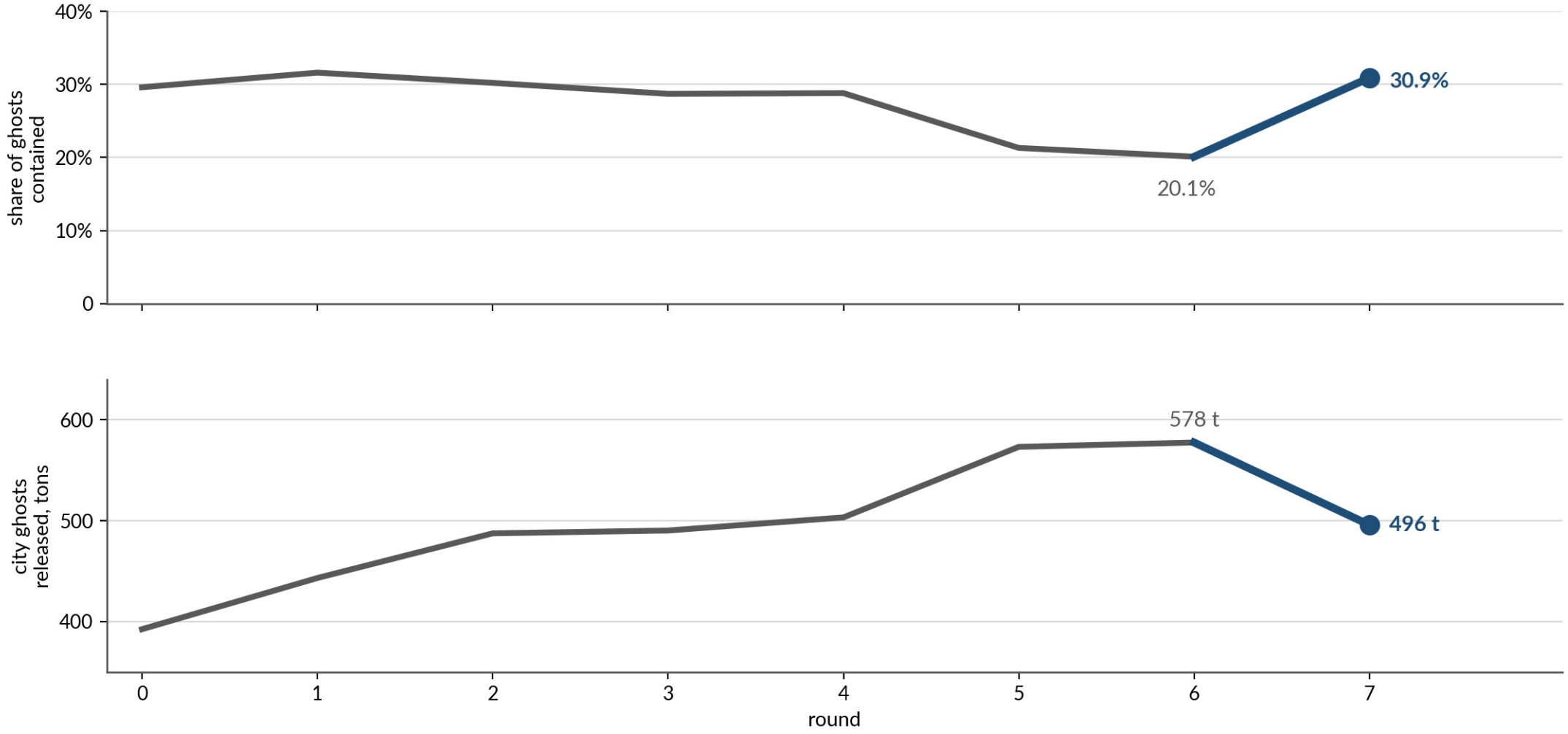
Georgia Institute of Technology

Today's class

1. Questions?
2. Attendance
3. Housekeeping
    1. Problem set 3 due Friday, November 13
    2. Exam 3 on Monday, November 16
4. Ghost emissions
5. Debrief: the permits game
6. For next class…

Ghost Emissions Rd 7: first round with policy



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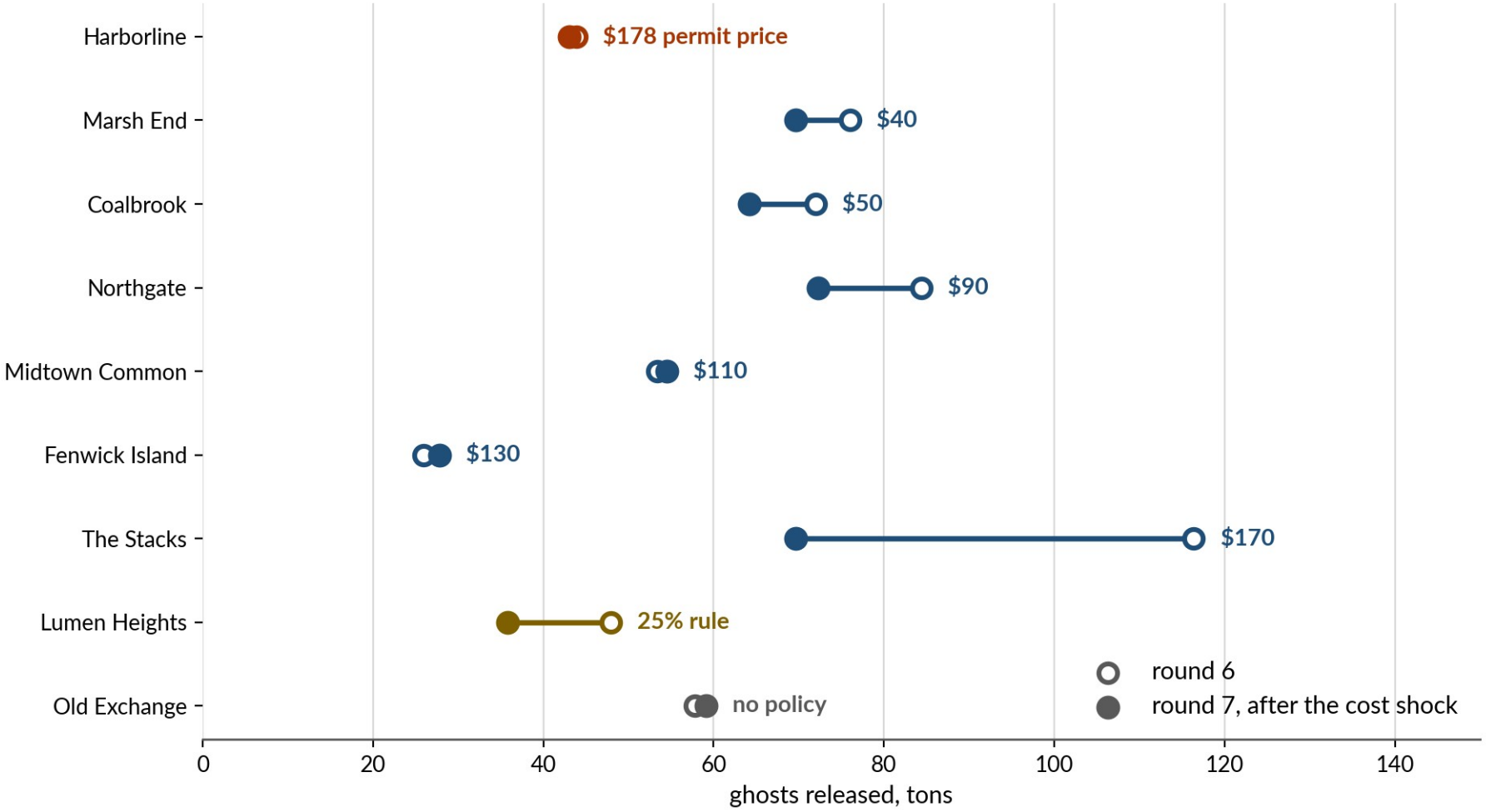
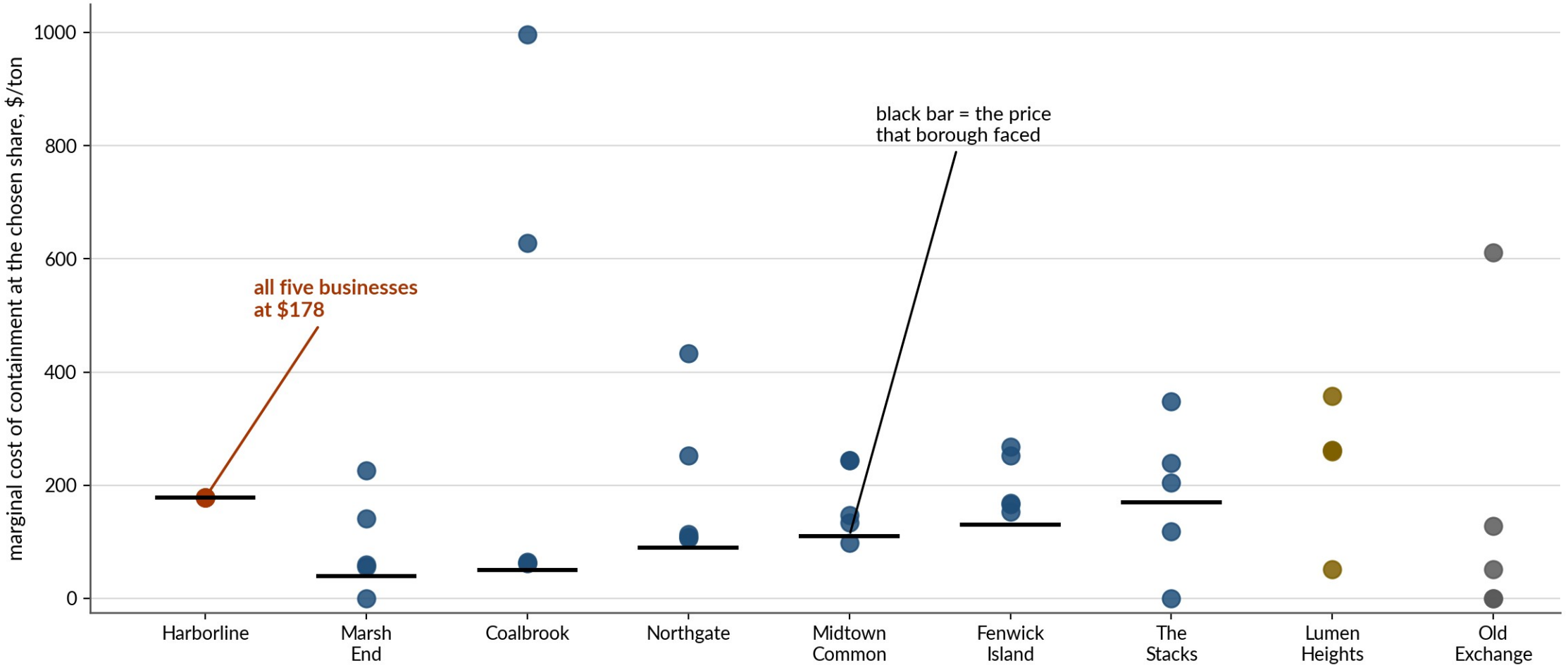
Prices vs. quantities, with 45 students



Cap led to equalized MACs. Taxes did not.



The game

- Eight firms. Each emits 20 tons without regulation, so 160 tons in total.
- Abating a firm's q-th ton costs s × q.
  - Four cost types: s = $4, $6, $12, or $30. Two firms of each type.
  - Each firm knew its own costs.
- The government knew the marginal benefit of abatement: MB = 92 − A/2
  - A is the total tons abated by all eight firms.
- Three rounds:
  - (1) survey,
  - (2) uniform standard and carbon tax,
  - (3) cap-and-trade.

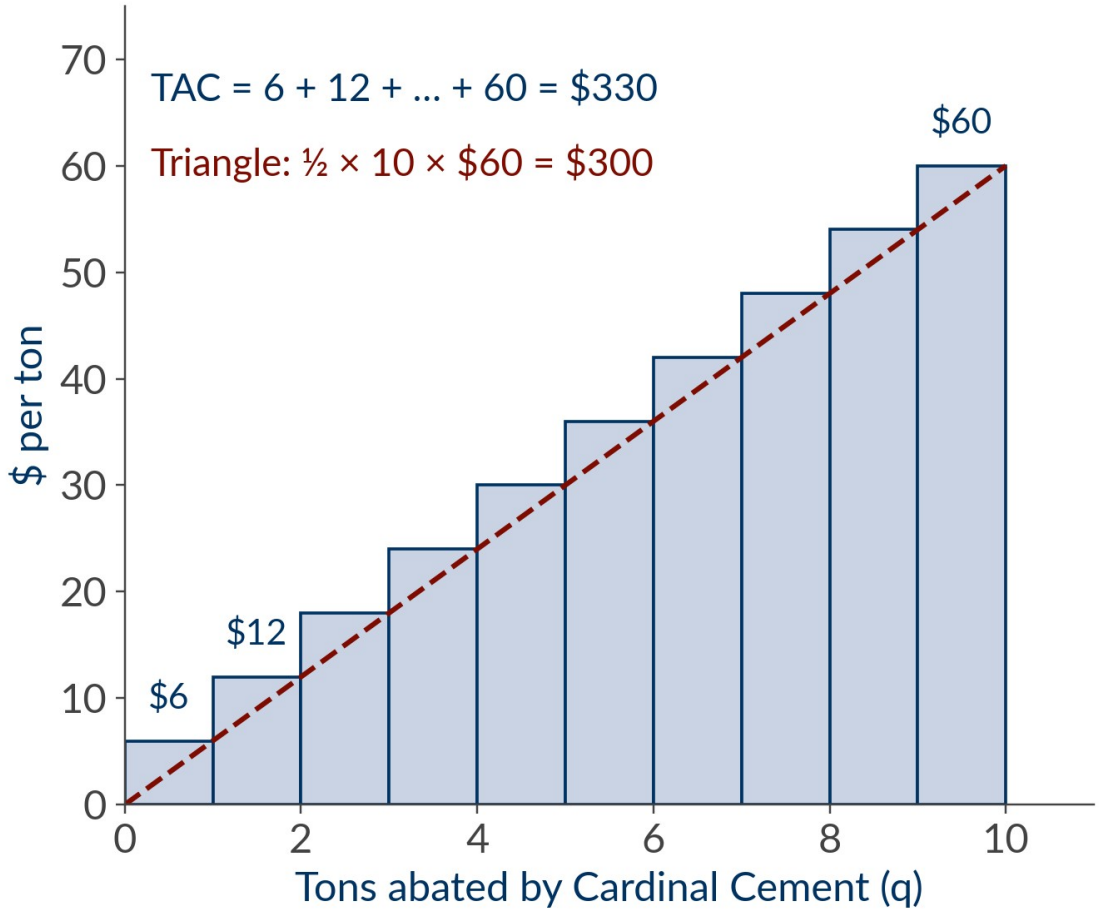
Which firms had high/low costs?

Firms	MAC of the q-th ton	5th ton	10th ton	15th ton
Atlas Steel (A), Foxglove Fertilizer (F)	4 × q	$20	$40	$60
Cardinal Cement (C), Harbor Shipping (H)	6 × q	$30	$60	$90
Bluebird Brewing (B), Granite Glass (G)	12 × q	$60	$120	$180
Dogwood Dairy (D), Eagle Energy (E)	30 × q	$150	$300	$450

Atlas's 15th ton costs $60, the same as Dogwood's 2nd ton.

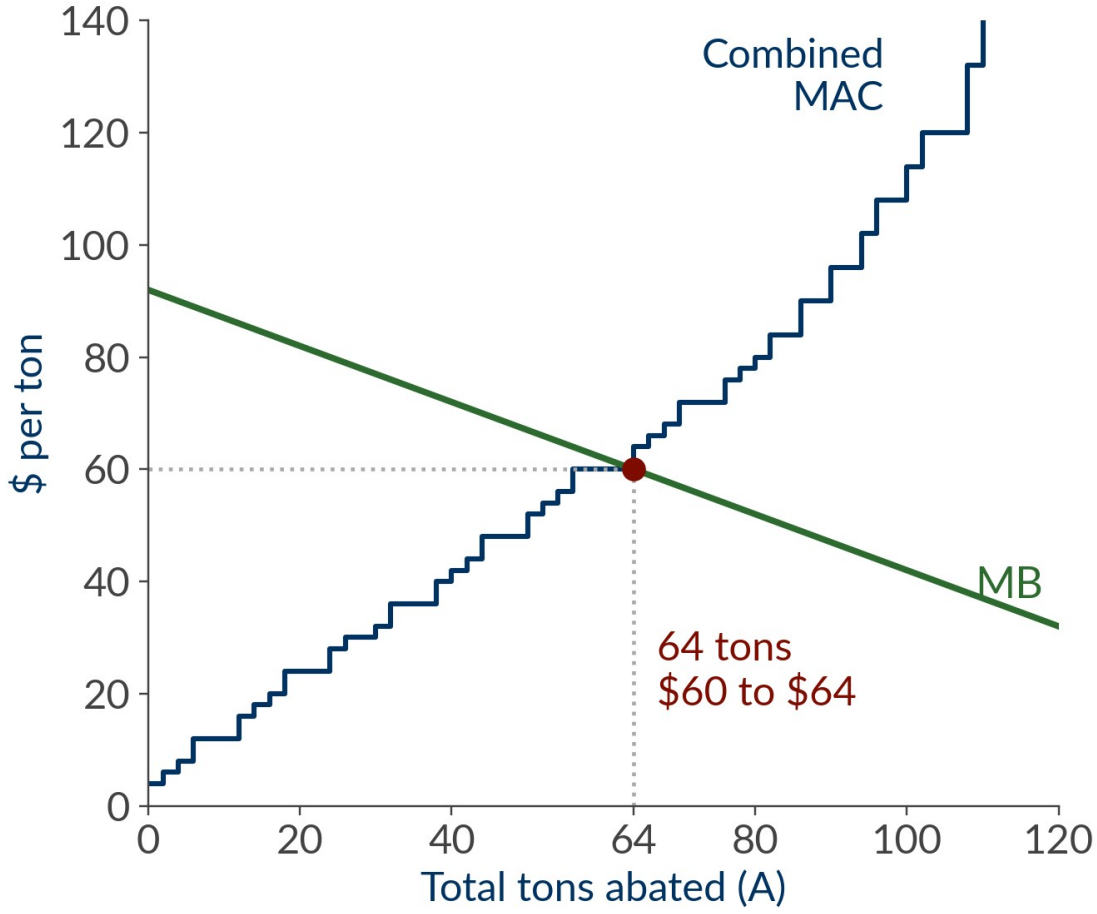
Total abatement cost

- Cardinal Cement (s = $6) abates 10 tons. Each ton costs $6 more than the last:
  - TAC = $6 + $12 + $18 + $24 + $30 + $36 + $42 + $48 + $54 + $60 = $330
- Note: because tons are discrete, we can't use our typical triangle formula here.



What should have happened?

- Line up every ton from cheapest to most expensive. This is the combined MAC.
- Abate a ton of GHGs if it costs less than its MB.
- **Efficient abatement: 64 tons.**
  - The 64th ton costs $60.
  - The 65th costs $64.
  - Any price from $60 to $64 gets us there.
- Total abatement cost: $2,160
- Net benefits: $2,688



Round 1 Survey

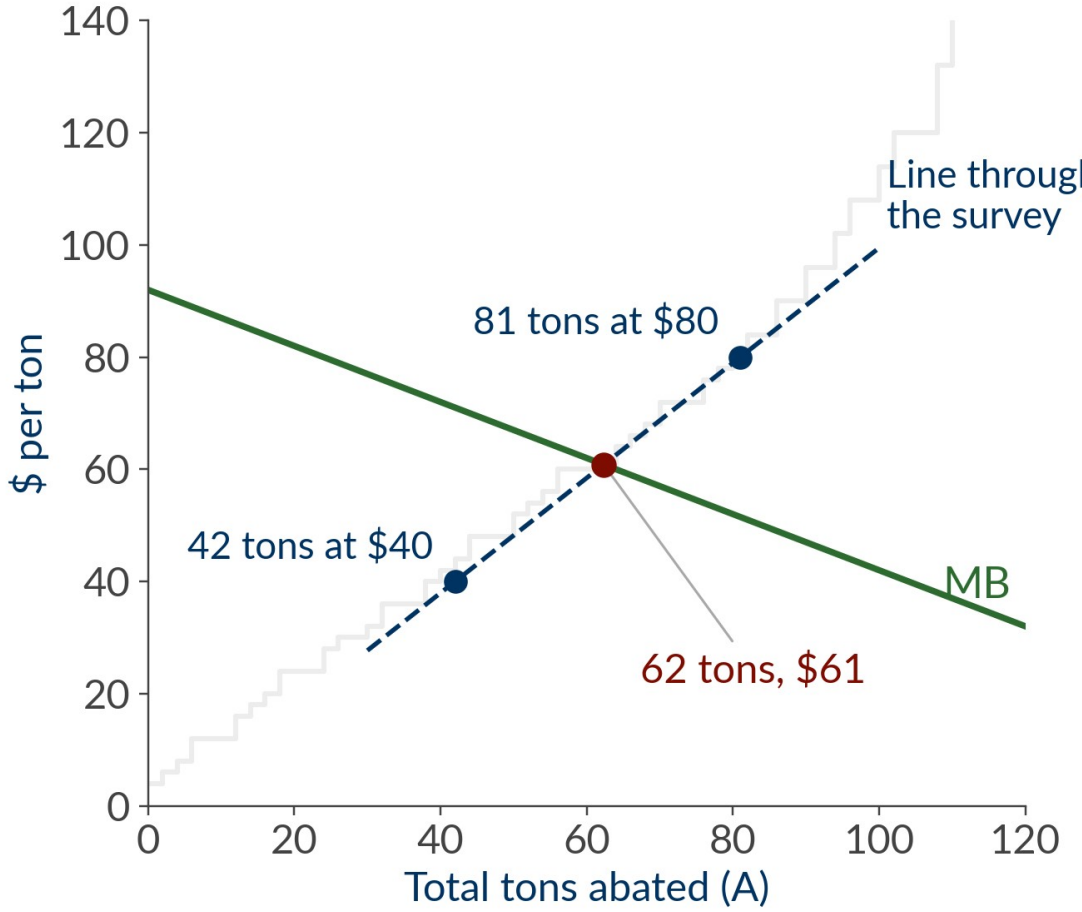
How many tons each firm would abate at the government's survey prices ($0, $40, $80)

Firm	Reported at $40	True at $40	Reported at $80	True at $80
Atlas Steel (A), s = $4	10	10	20	20
Bluebird Brewing (B), s = $12	3	3	6	6
Cardinal Cement (C), s = $6	6	6	13	13
Dogwood Dairy (D), s = $30	0	1	1	2
Eagle Energy (E), s = $30	1	1	2	2
Foxglove Fertilizer (F), s = $4	13	10	20	20
Granite Glass (G), s = $12	3	3	6	6
Harbor Shipping (H), s = $6	6	6	13	13
Total	**42**	**40**	**81**	**82**

- Six of eight firms told the truth.
- Dogwood reported fewer tons (i.e., higher costs).
- Foxglove reported more tons at $40.
- The errors more/less cancel, so the government had very good information on MAC!

Round 1: what did the government do with the survey results?

- Draw a line through the reported totals at $40 and $80.
- The line crosses MB at 62.3 tons and $60.84.
- **The government chose a standard of 64 tons (8 per firm) and a tax of $61.**
- Truthful reports give 62.0 tons and $60.98.
- With more/less accurate reporting, the government was able to guess the aggregate MAC curve accurately.



The costs of a uniform standard

64 tons in total, so 8 tons per firm. TAC adds up the cost of each of the 8 tons.

Cost type	Firms	MAC of 8th ton	TAC per firm	TAC, both firms
s = $4	A, F	$32	$144	$288
s = $6	C, H	$48	$216	$432
s = $12	B, G	$96	$432	$864
s = $30	D, E	$240	$1,080	$2,160
Total				**$3,744**

Atlas: $4 + $8 + … + $32 = $144. Eagle: $30 + $60 + … + $240 = $1,080.

The standard costs $3,744.

Every firm abates the same amount. The 8th ton costs $32 at Atlas and $240 at Eagle.

The costs of a $61 carbon tax

Each firm abates every ton that costs less than $61. Values are per firm.

Cost type	Tons abated	MAC of last ton	TAC	Tax paid	Total cost
s = $4	15	$60	$480	5 × $61 = $305	$785
s = $6	10	$60	$330	10 × $61 = $610	$940
s = $12	5	$60	$180	15 × $61 = $915	$1,095
s = $30	2	$60	$90	18 × $61 = $1,098	$1,188
Total (8 firms)	**64**		**$2,160**	**$5,856**	**$8,016**

Same 64 tons for $2,160 in abatement costs. The government collects $5,856.

All eight firms reported exactly these tons in Round 2.

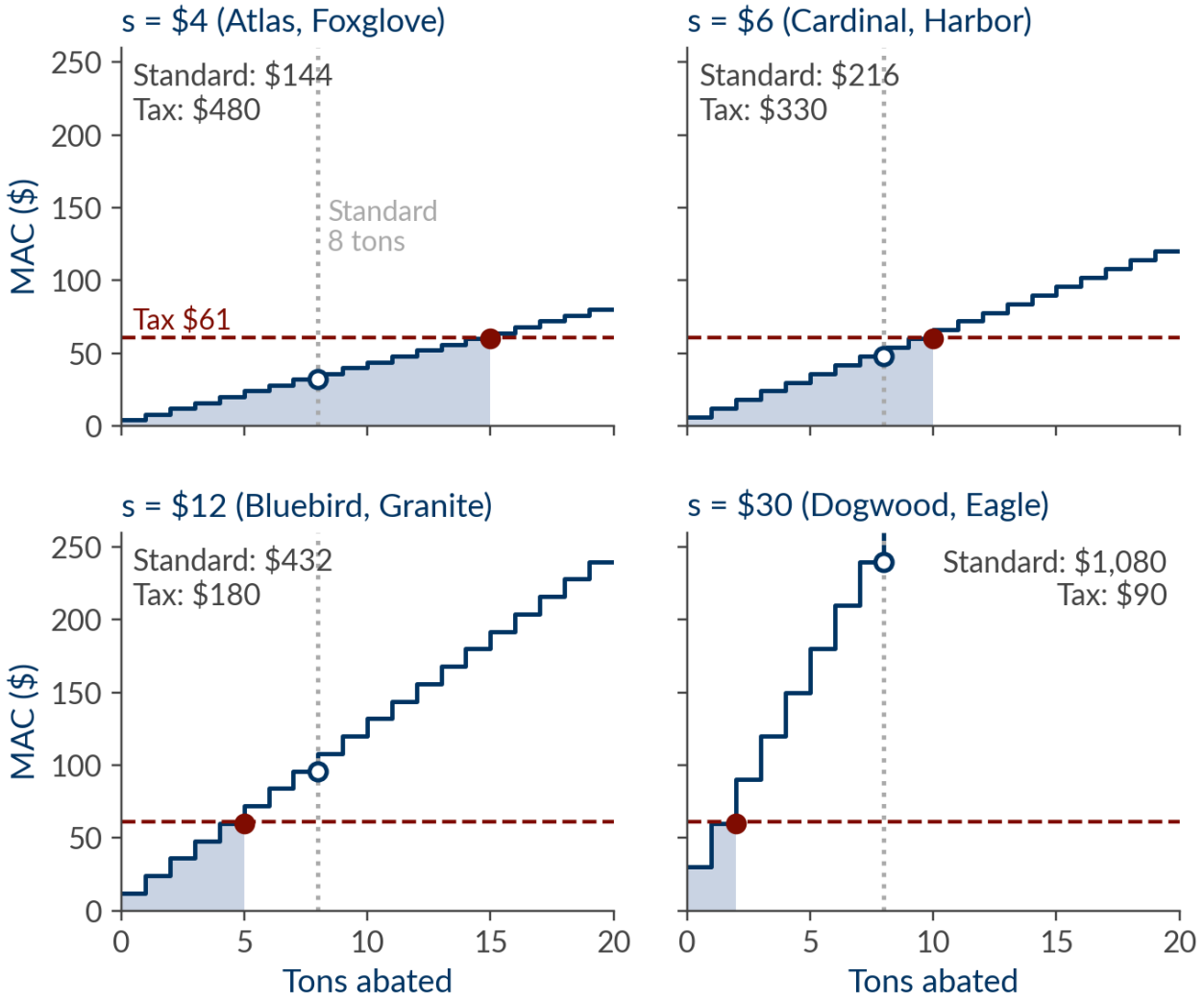
Why is the tax cheaper?

- **64 tons of abatement.**
- **TAC under Standard: $3,744.**
- **TAC under Tax: $2,160.**

- Standard (open circles): every firm abates 8 tons. The 8th ton costs $32 at Atlas and $240 at Eagle.

- Tax (red dots): every firm abates until its next ton costs more than $61.
  - Low-cost firms abate more.
  - High-cost firms abate less.
  - Moving one ton from Eagle to Atlas saves $240 – $36 = $204.

- Equal MACs across firms = least-cost abatement. The government needed the right price, not anyone's costs.



What about the tax revenue?

Values per firm. The government splits the $5,856 equally: $732 per firm.

Cost type	Standard: TAC	Tax: TAC	Tax paid	Firm pays under the tax	Equal rebate	Net cost with rebate
s = $4	$144	$480	$305	$785	−$732	$53
s = $6	$216	$330	$610	$940	−$732	$208
s = $12	$432	$180	$915	$1,095	−$732	$363
s = $30	$1,080	$90	$1,098	$1,188	−$732	$456
Total (8 firms)	**$3,744**	**$2,160**	**$5,856**	**$8,016**	**−$5,856**	**$2,160**

The $5,856 is not a cost to society. It moves from firms to the government.

Firms pay $8,016 under the tax and $3,744 under the standard. That is why firms lobby for standards and free permits.

With an equal rebate of the tax revenue, every firm pays less than under the standard.

- This is the same as giving each firm 12 free permits at $61.

Where should the money go?

Round 3, first try: nothing to trade

Cap: 96 permits (160 tons total − 64 tons abated). One permit for every ton emitted.

Firm	Permits from the government	Emissions under the $61 tax
Atlas Steel (A)	5	5
Bluebird Brewing (B)	15	15
Cardinal Cement (C)	10	10
Dogwood Dairy (D)	18	18
Eagle Energy (E)	18	18
Foxglove Fertilizer (F)	5	5
Granite Glass (G)	15	15
Harbor Shipping (H)	10	10
Total	**96**	**96**

The government gave every firm *exactly* its emissions under the tax. Every MAC was already about $61.

The tax reports revealed the efficient allocation because firms mostly told the truth.

Real regulators never get this information.

Round 3, second try: 12 permits to each firm

Same 96-permit cap, split equally.

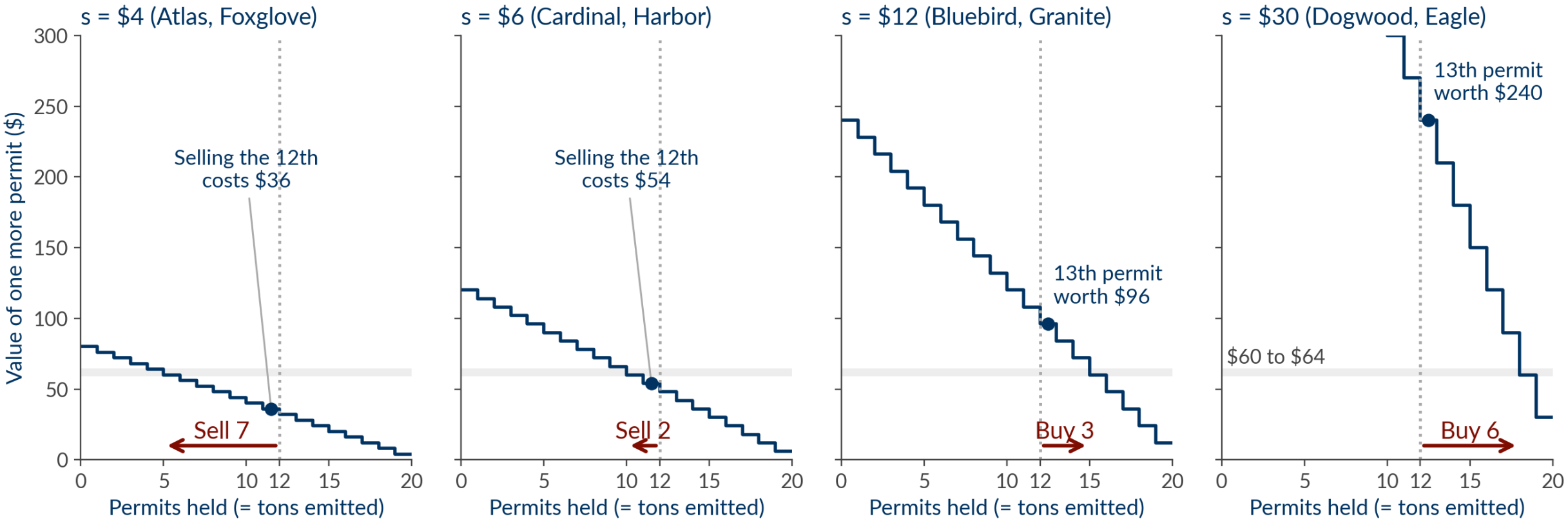
Cost type	Firms	Permits	MAC of 8th ton	Efficient emissions	Buy or sell?
s = $4	A, F	12	$32	5	Sell 7 each
s = $6	C, H	12	$48	10	Sell 2 each
s = $12	B, G	12	$96	15	Buy 3 each
s = $30	D, E	12	$240	18	Buy 6 each

Firms with an 8th ton above $64 should buy.

Firms with an 8th ton below $60 should sell.

18 permits should change hands, at a price from $60 to $64.

Who should buy/sell?



Sellers give up a permit if the price beats the cost of abating one more ton.

Buyers pay up to the cost of the ton they skip.

At any price from ~$60-64, the s=$4 and s=$6 firms offer 18 permits and the s=$12 and s=$30 firms want 18.

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What did happen?

Our trade log.

Buyer	Seller	Permits	Price per permit
Dogwood Dairy (D)	Atlas Steel (A)	7	$60
Granite Glass (G)	Cardinal Cement (C)	1	$90
Granite Glass (G)	Foxglove Fertilizer (F)	2	$70
Bluebird Brewing (B)	Foxglove Fertilizer (F)	3	$70
Total		**13**	

Four trades in about four minutes. 13 permits changed hands at $60 to $90.

Eagle Energy and Harbor Shipping never traded.

Where did we end up?

64 tons abated, as the cap requires.

Firm	Permits after trading	Tons abated	MAC of last ton	TAC	Efficient TAC
Atlas Steel (A)	5	15	$60	$480	$480
Bluebird Brewing (B)	15	5	$60	$180	$180
Cardinal Cement (C)	11	9	$54	$270	$330
Dogwood Dairy (D)	19	1	$30	$30	$90
Eagle Energy (E)	12	8	$240	$1,080	$90
Foxglove Fertilizer (F)	7	13	$52	$364	$480
Granite Glass (G)	15	5	$60	$180	$180
Harbor Shipping (H)	12	8	$48	$216	$330
Total	**96**	**64**		**$2,800**	**$2,160**

Our market: $2,800. Standard: $3,744. Efficient: $2,160.

We captured $944 of the $1,584 in possible savings (60%).

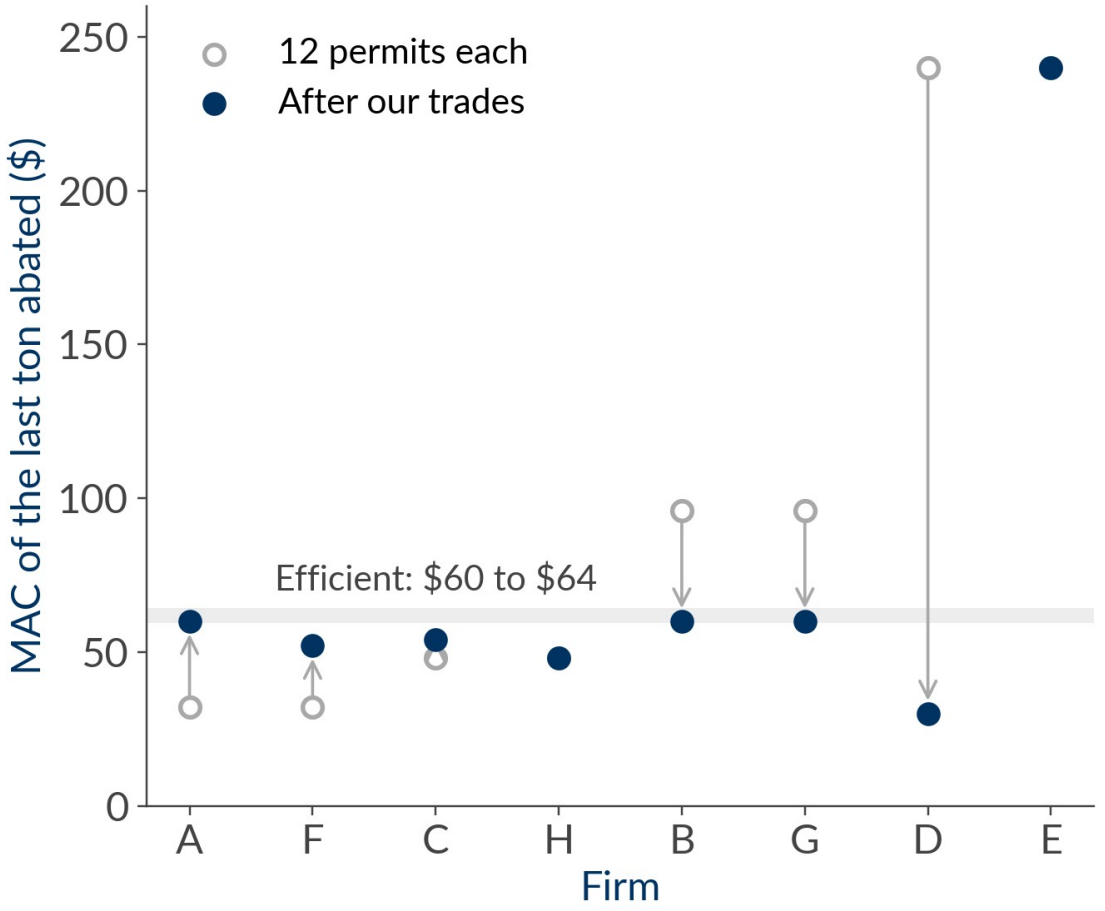
Who should still trade?

- With 12 permits each, MACs ranged from $32 to $240.
- After trading, six firms had MACs from $48 to $60.

- **Eagle Energy never traded. Its 8th ton cost $240.**
  - Buying 6 permits at $62 would have saved Eagle $618.

- Dogwood bought 7 permits, one more than it needed. Its last ton cost $30.

- Thin markets and short clocks leave money on the table.



Who gained from trading?

Net cost = abatement cost + payments for permits bought − payments for permits sold.

Firm	Cost with 12 permits, no trading	Abatement cost after trading	Permits bought (+) or sold (−)	Net cost	Gain
Atlas Steel (A): s=$4	$144	$480	−$420	$60	$84
Bluebird Brewing (B): s=$12	$432	$180	+$210	$390	$42
Cardinal Cement (C): s=$6	$216	$270	−$90	$180	$36
Dogwood Dairy (D): s=$30	$1,080	$30	+$420	$450	$630
Eagle Energy (E): s=$30	$1,080	$1,080	$0	$1,080	$0
Foxglove Fertilizer (F): s=$4	$144	$364	−$350	$14	$130
Granite Glass (G): s=$12	$432	$180	+$230	$410	$22
Harbor Shipping (H): s=$6	$216	$216	$0	$216	$0
Total	**$3,744**	**$2,800**	**$0**	**$2,800**	**$944**

Every firm that traded came out ahead. The price splits the gain between buyer and seller.

Granite paid $90 for one of Cardinal's permits. Granite skipped a $96 ton (gain $6). Cardinal abated a $54 ton (gain $36).

The allocation of permits only changes who wins/loses

Net cost per firm when firms trade to the efficient outcome.

Cost type	Net cost: government's first allocation	Net cost: 12 each, then trade at $62
s = $4 (A, F)	$480	$46
s = $6 (C, H)	$330	$206
s = $12 (B, G)	$180	$366
s = $30 (D, E)	$90	$462
Total (8 firms)	**$2,160**	**$2,160**

Both allocations end at 64 tons and $2,160 in abatement costs.

The allocation only decides who pays (gets paid) for permits.

An auction is a different type of allocation.

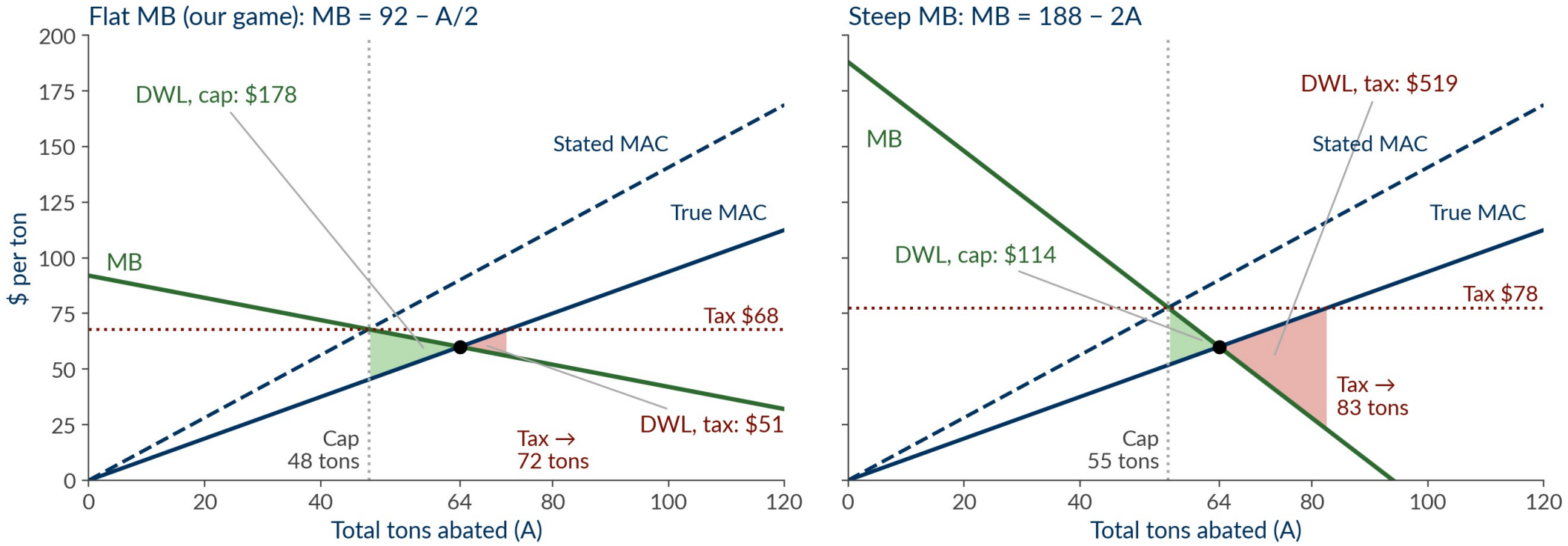
- It would send 96 × $62 = $5,952 to the government instead.

Should firms tell the truth?

- In Round 1, firms didn't know how the government would use the survey.
- If a survey sets a standard or a tax, a firm gains by overstating its costs (i.e., reporting fewer tons at each price).
  - The government then sets a weaker policy.
  - Dogwood reported 0 tons at $40 and 1 ton at $80. The truth was 1 and 2.
- Here, the errors by Dogwood and Foxglove nearly cancelled. If every firm overstates its costs, the errors add up.
- Kwerel (1977) pairs permits with a subsidy for unused permits so that firms gain nothing by misreporting.

Prices vs. quantities with our firms

Suppose firms report costs 50% higher than they really are (the dashed line).
The government sets a cap or a tax where the stated MAC crosses MB.



Cap: firms abate exactly 48 tons, so the government's mistake is more consequential.

Tax: firms abate until their true MAC equals the tax, which undoes part of the mistake

Flat MB (our game): the tax loses less. Steep MB: the cap loses less.

One year of emissions has a small effect on the stock of CO_2, so the MB of abatement is flatter (for climate change)

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Key takeaways

- A uniform standard generated 64 tons of abatement for $3,744.
- A tax generated the same 64 tons of abatement for $2,160 (+ tax payments)

- Every firm abates until its last ton costs the price.

- Cap-and-trade gets the same result if firms actually trade.
  - Our trading got close (but left some money on the table).

- Who gets the permits decides who pays, not how much we abate.

- IRL, regulators don't know firms' costs. When MB is flat, a tax is the "less costly" option.

Practice problem 1

A $24 carbon tax vs. a uniform standard

- Same eight firms. The government sets a tax of $24 per ton.
  - (a) How many tons does each type of firm abate? What is total abatement?
  - (b) What is total abatement cost? How much tax revenue does the government collect?
  - (c) A uniform standard set at the same level of total abatement, split equally across the eight firms. What does it cost?
  - (d) Is a $24 tax efficient? Compare it to MB.

Practice problem 1

$24 tax. MAC = s × q. TAC = the sum of the cost of each ton abated.

Cost type	Tons under the tax	TAC under the tax	Tons under the standard	TAC under the standard
s = $4				
s = $6				
s = $12				
s = $30				
Total (8 firms)				

Practice problem 2

Who gets the permits?

- Same 96-permit cap. The government gives 6 permits to each s=$4 and s=$6 firm and 18 permits to each s=$12 and s=$30 firm.
  - (a) Before trading, how many tons does each type abate? What is its MAC for the last ton? What is total abatement cost?
  - (b) Who buys permits, who sells, and how many?
  - (c) Permits trade at $62. What is each type's net cost after trading?
  - (d) Compare total abatement cost after trading with the 12-each allocation. Why?

Practice problem 2

Net cost = TAC + $62 × permits bought − $62 × permits sold.

Cost type	Permits	Tons abated before trading	MAC of last ton	Bought (+) or sold (−)	Net cost after trading
s = $4	6				
s = $6	6				
s = $12	18				
s = $30	18				
Total (8 firms)	**96**				

Practice problem 3

Give every permit to one firm

- Same 96-permit cap. The government gives all 96 permits to Eagle Energy (s = $30). The other seven firms get none.
  - (a) Before trading, how many tons does each firm abate? What is total abatement cost?
  - (b) Permits trade at $62. How many permits does each firm buy or sell?
  - (c) What is total abatement cost after trading? Compare it with the 12-each allocation.
  - (d) What is each firm's net cost after trading? Who comes out ahead?

Practice problem 3

Values per firm. Net cost = TAC + $62 × permits bought − $62 × permits sold.

Firm	Permits	Tons abated before trading	Bought (+) or sold (−)	Tons abated after trading	Net cost after trading
s = $4 (A, F)	0				
s = $6 (C, H)	0				
s = $12 (B, G)	0				
Dogwood (s = $30)	0				
Eagle (s = $30)	96				
Total (8 firms)	**96**				

Next class…

- Problem set 3 due Friday, November 13.
- Next class: Who pays for a carbon tax?
- Read Pizer and Sexton (2021), “The distributional impacts of energy taxes.”

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