Lecture 07

Multiple Market Failures and Second-Best Policies

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AEM 4510

Roadmap

1. What happens when we have another distortion like market power?
2. How do second-best policies like output taxes or intensity standards work?

Market power and pollution

Market power

Lets consider two extreme cases to understand whether and how market power matters

1. Perfect competition
2. Monopoly

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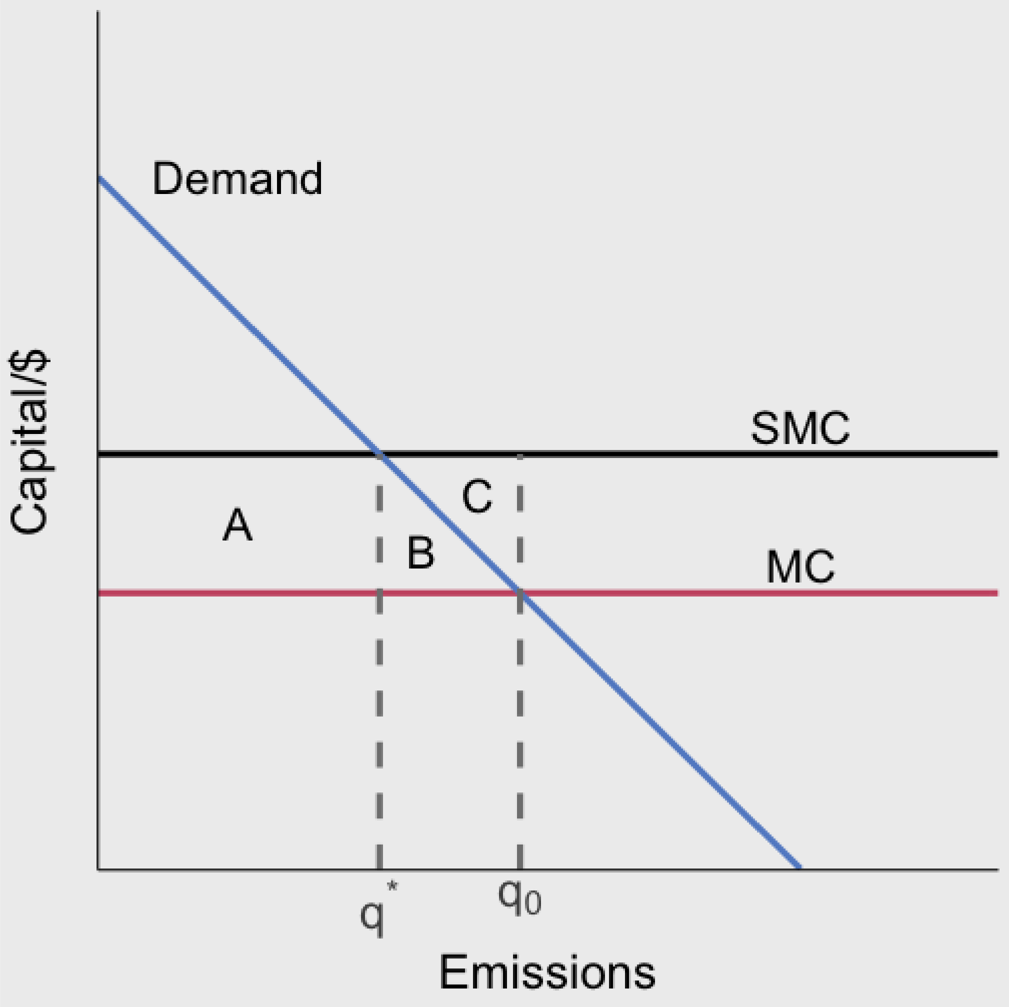
2. Monopoly

In both cases we assume that:

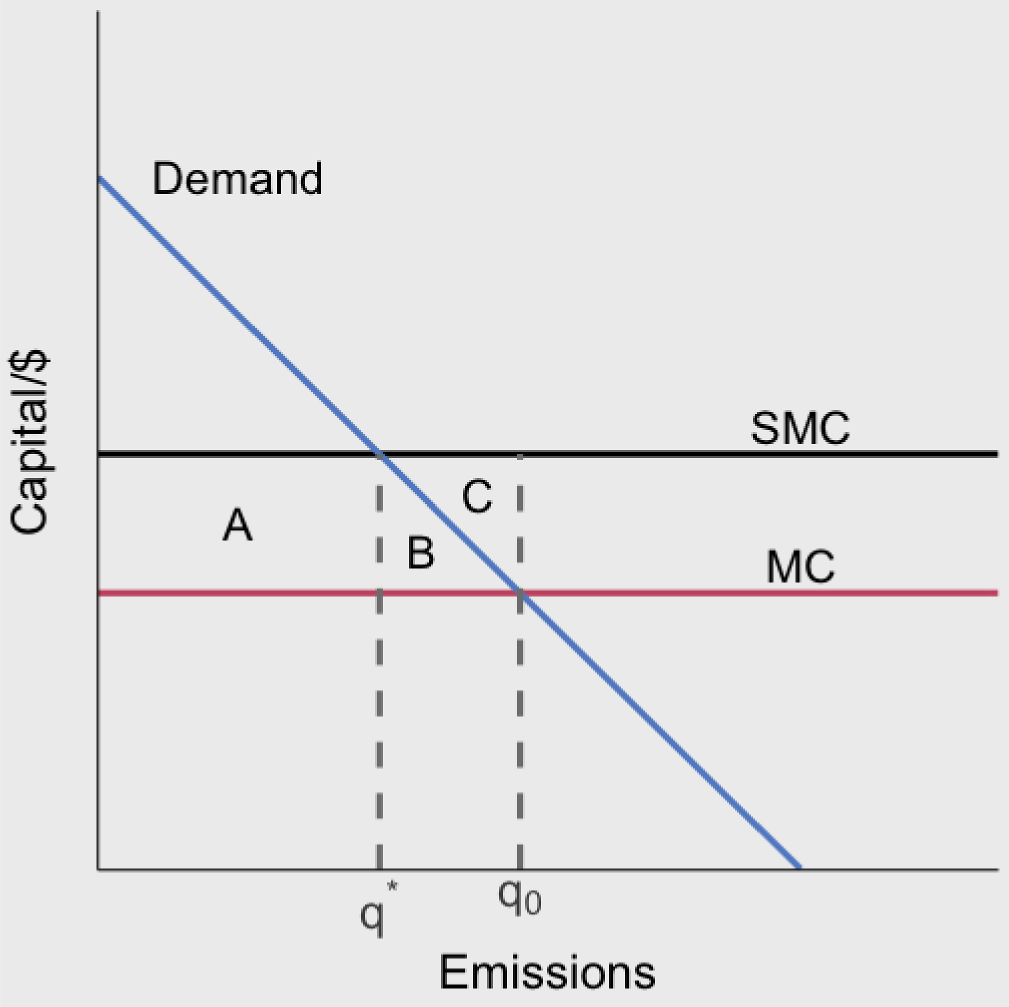
1. Marginal costs of production are constant MC
2. The marginal damage from a unit of output is constant giving us constant social marginal costs $SMC = MC + MD$

Perfect competition



The effect of moving from $q_0 \rightarrow q^*$ using a tax equal to marginal damage (SMC - MC):

Perfect competition



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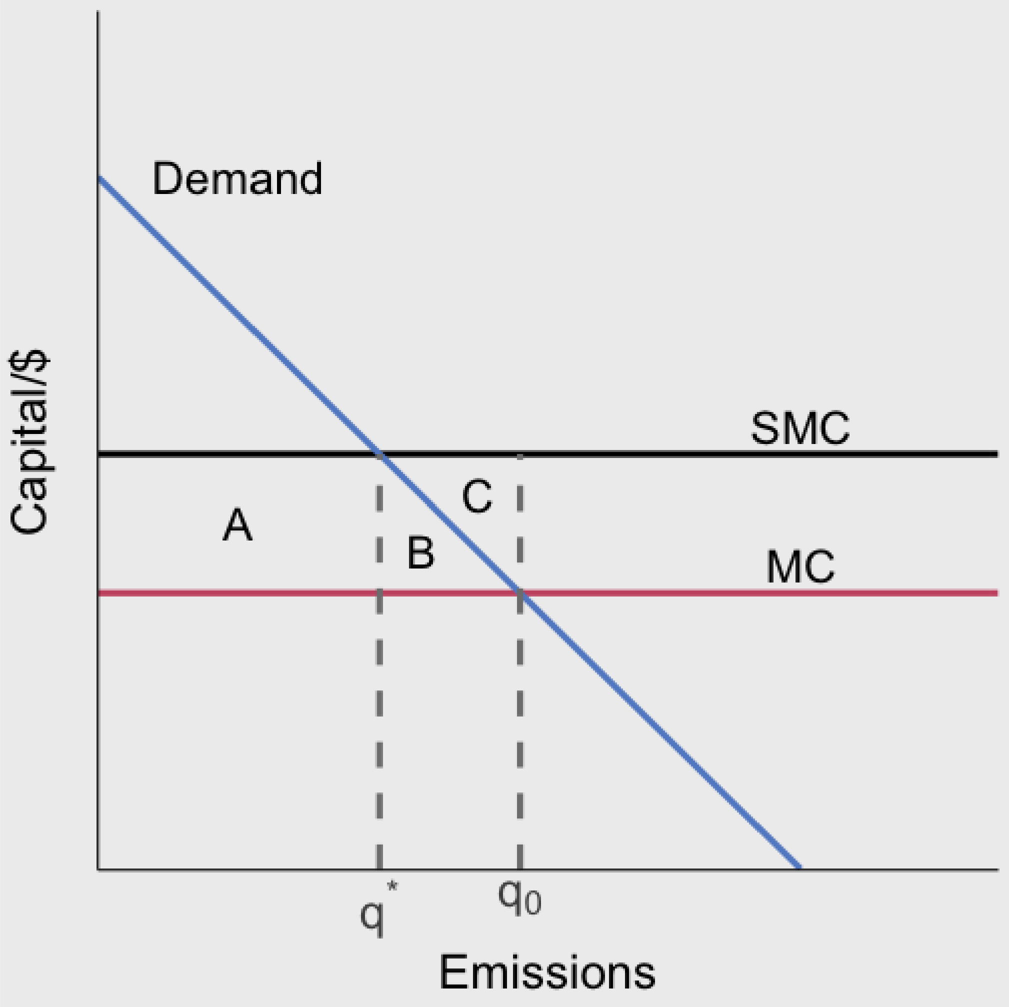

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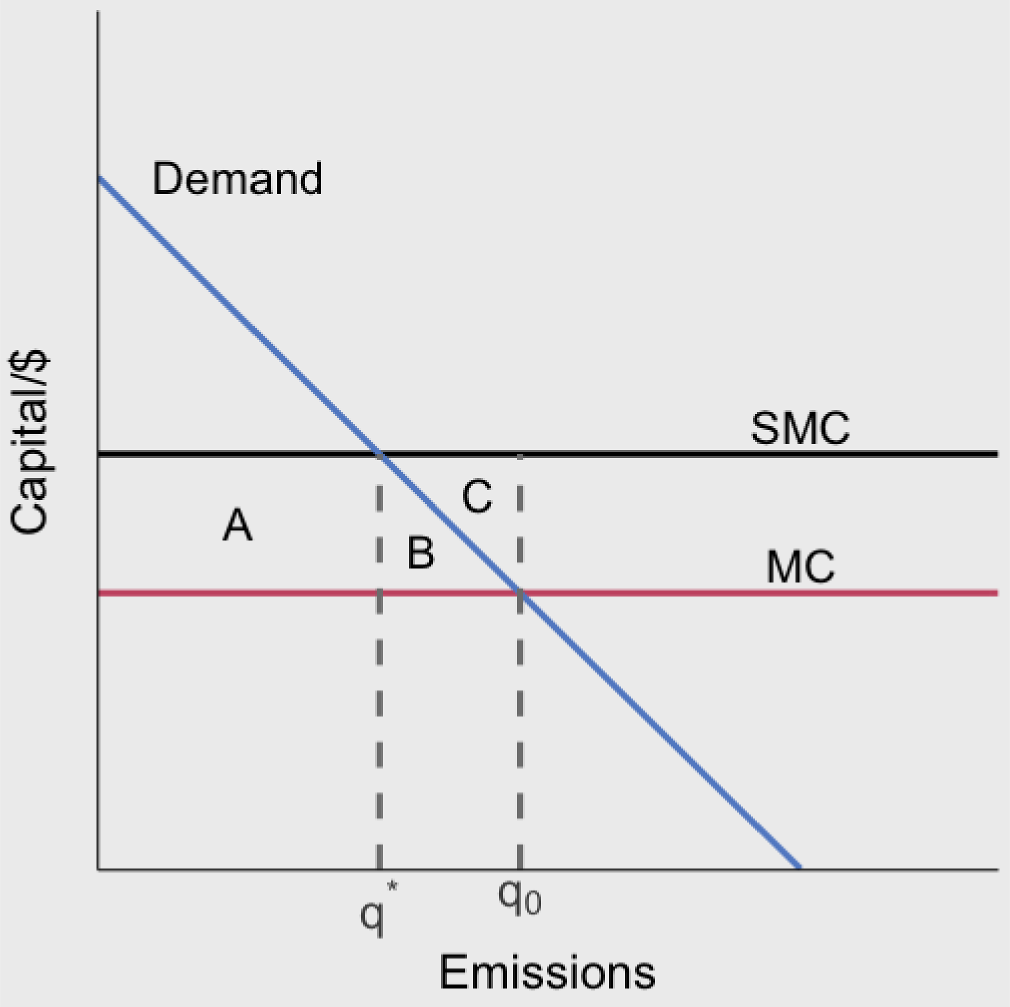

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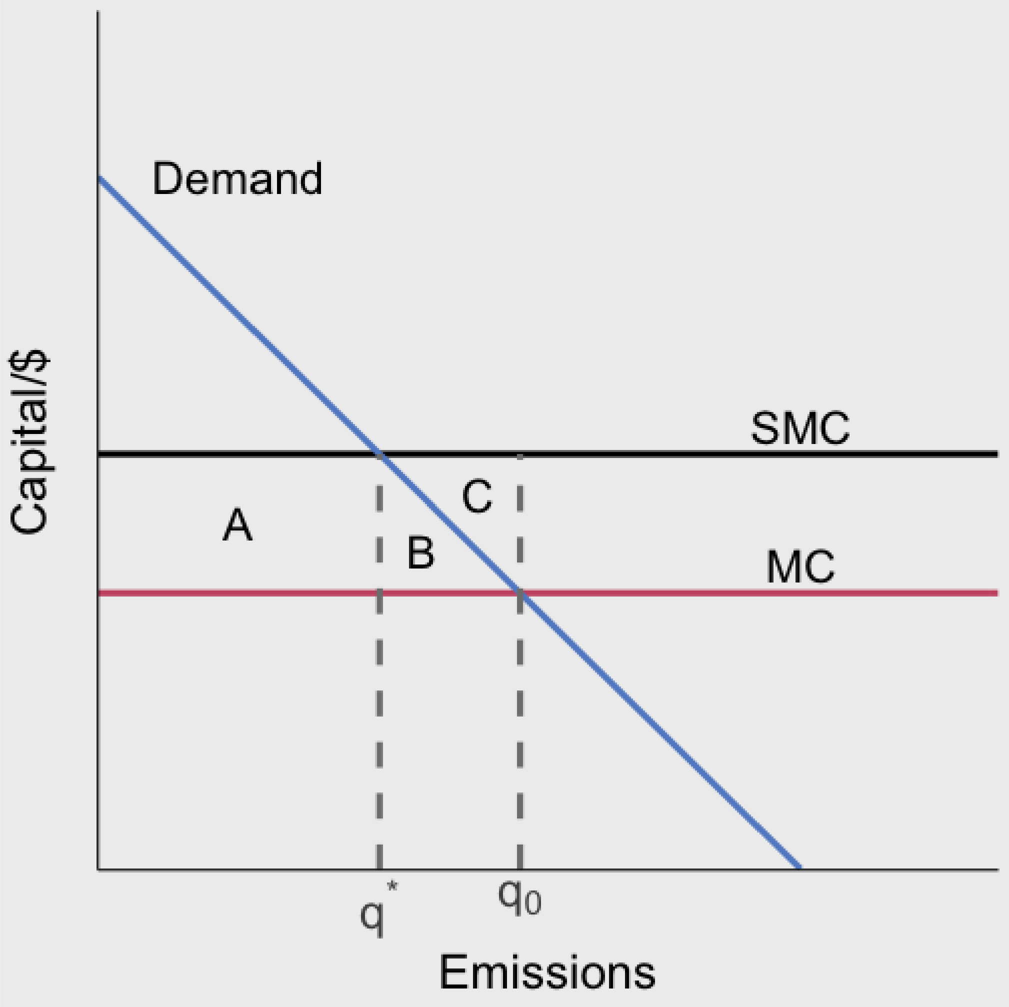

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Avoided damages: B+C

Tax revenue: A

Net gain: -(A+B) + (B+C) + A = C

Monopoly

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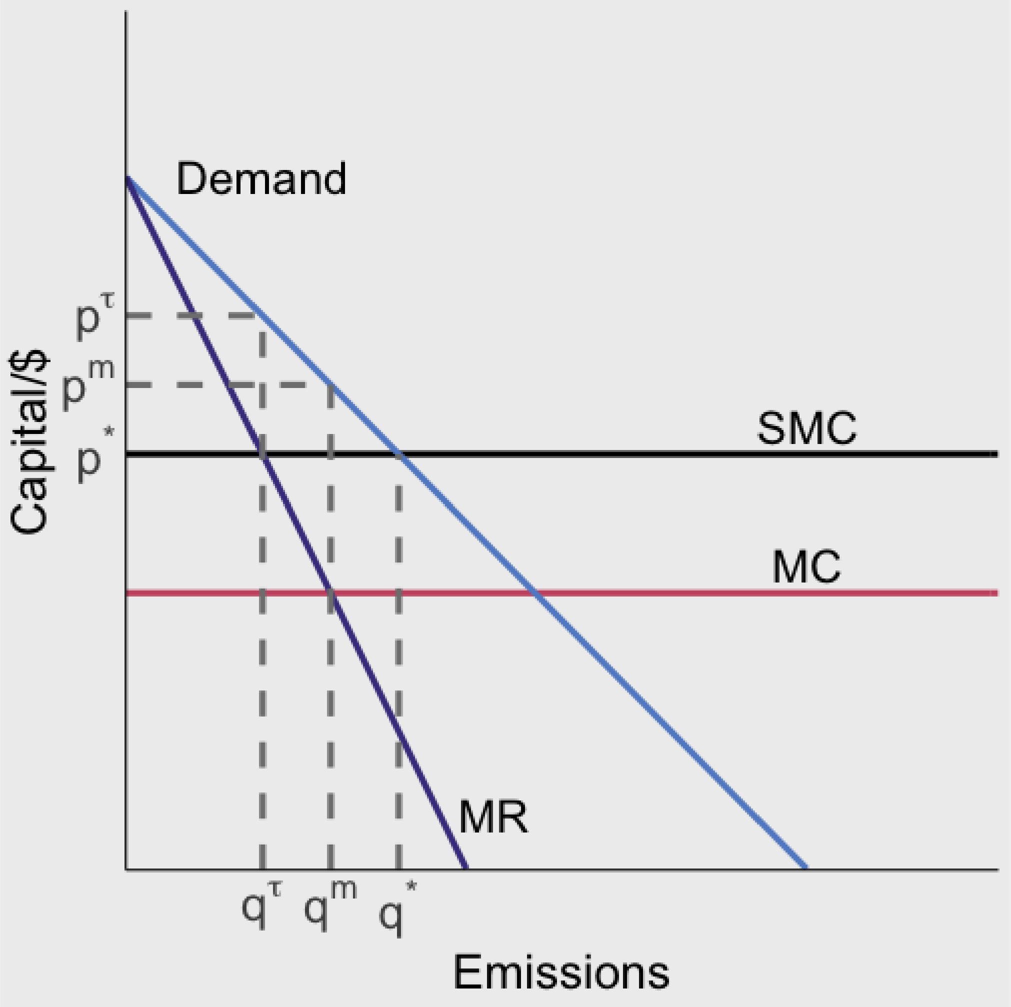
Why?

The monopolist accounts for how additional output lowers the market price on inframarginal units

Monopoly

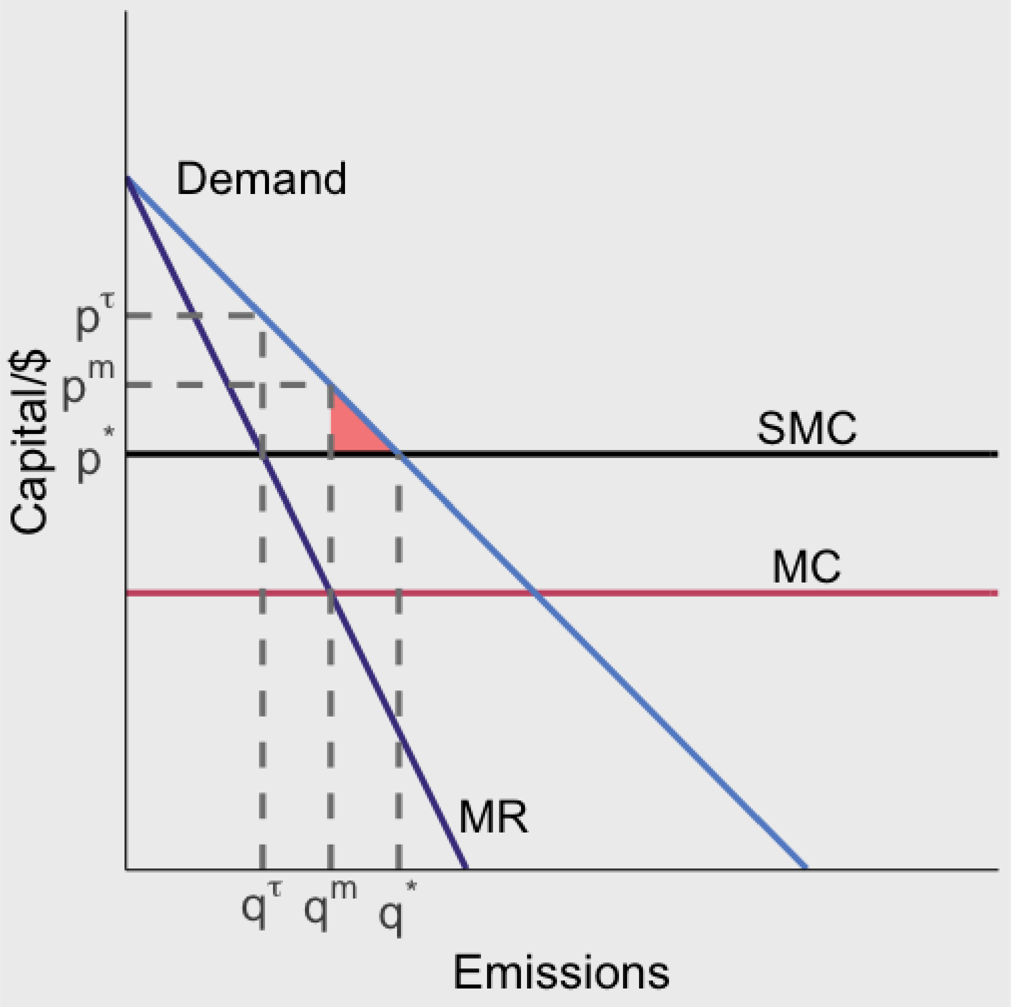


The socially efficient allocation is where social marginal cost is equal to the social marginal benefit

This is where SMC crosses the demand curve: (q^*, p^*)

What is the welfare outcome under the unregulated monopolist outcome?

Monopoly

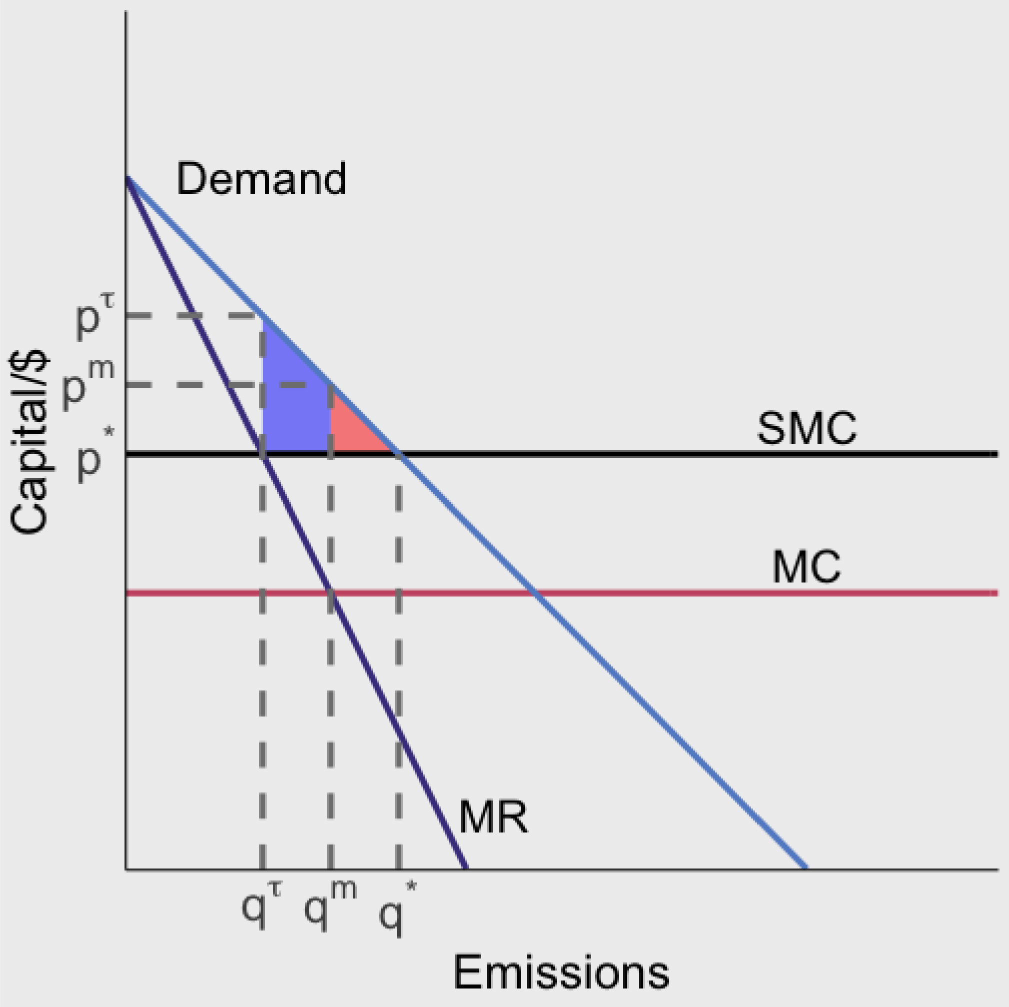


In the absence of regulation, the monopolist maximizes profit where MR = MC: (q^m, p^m)

This results in deadweight loss equal to the **red** area

Now what happens if we set a Pigouvian tax equal to marginal damage?

Monopoly

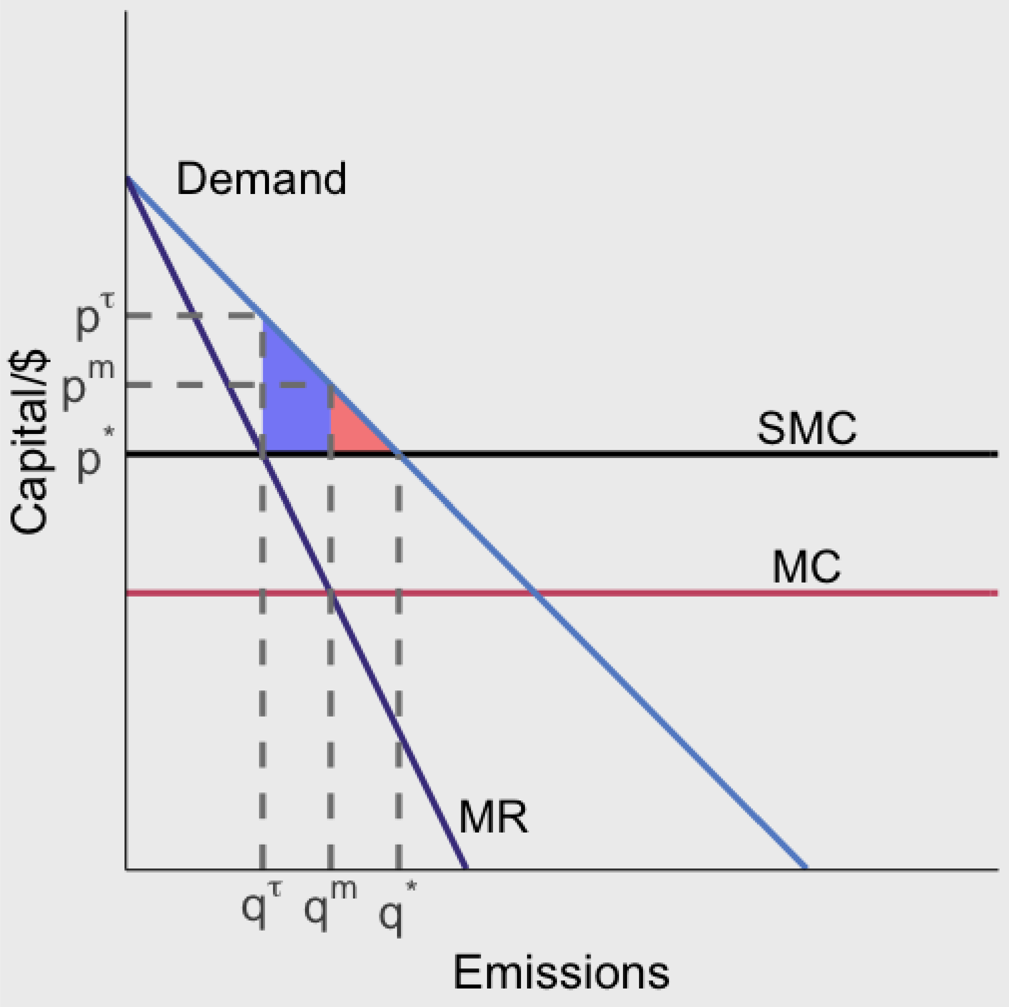


The Pigouvian tax restricts output even more, adding deadweight loss equal to the **blue** area on top of the deadweight loss in the **red** area

The tax actually made us worse off by the blue area!

Why?

Monopoly



We now have two distortions:

1. Market power
2. Pollution externality

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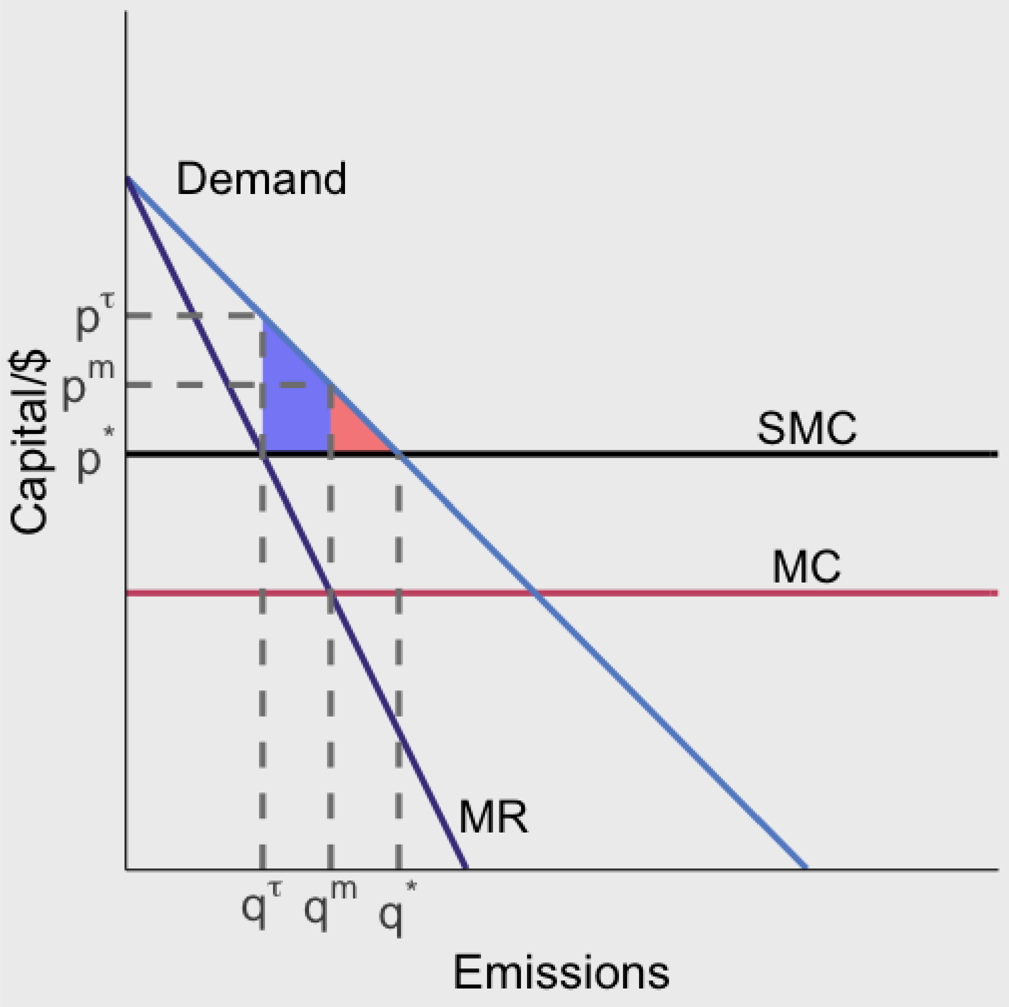

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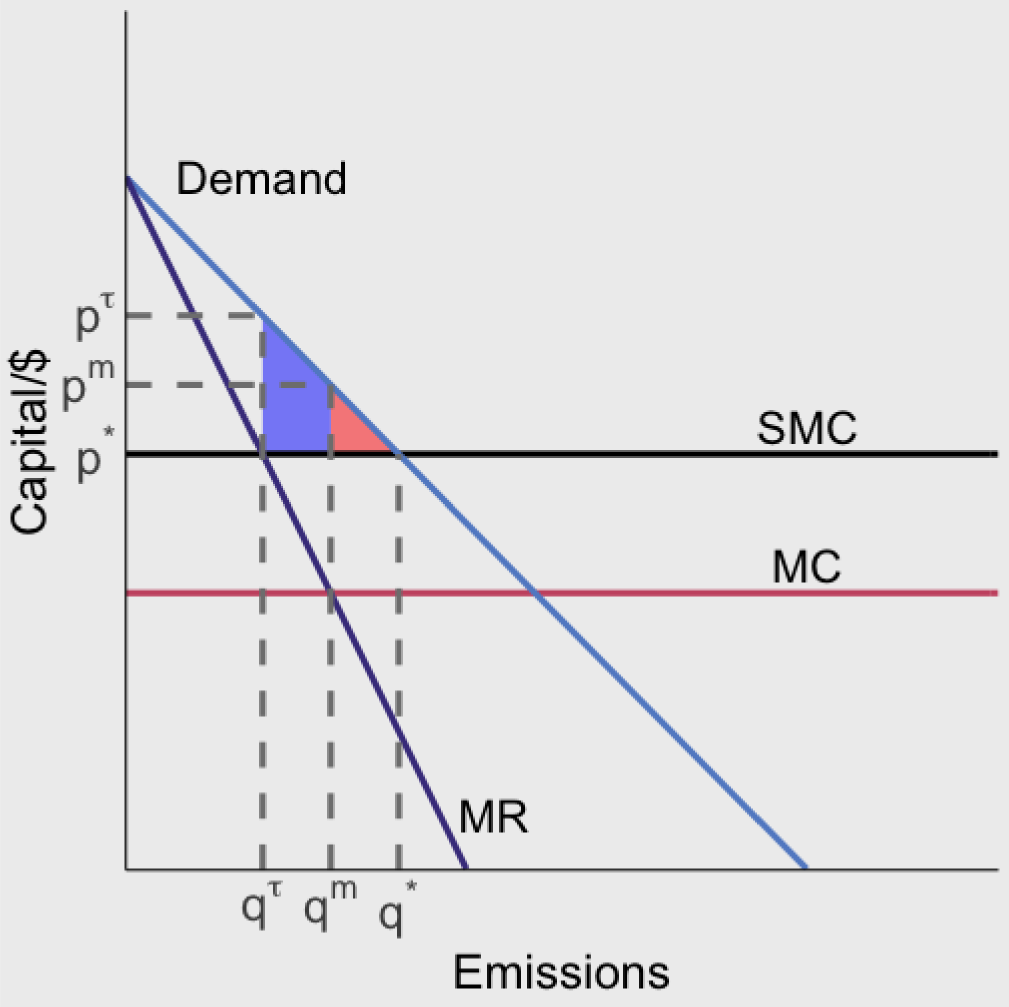

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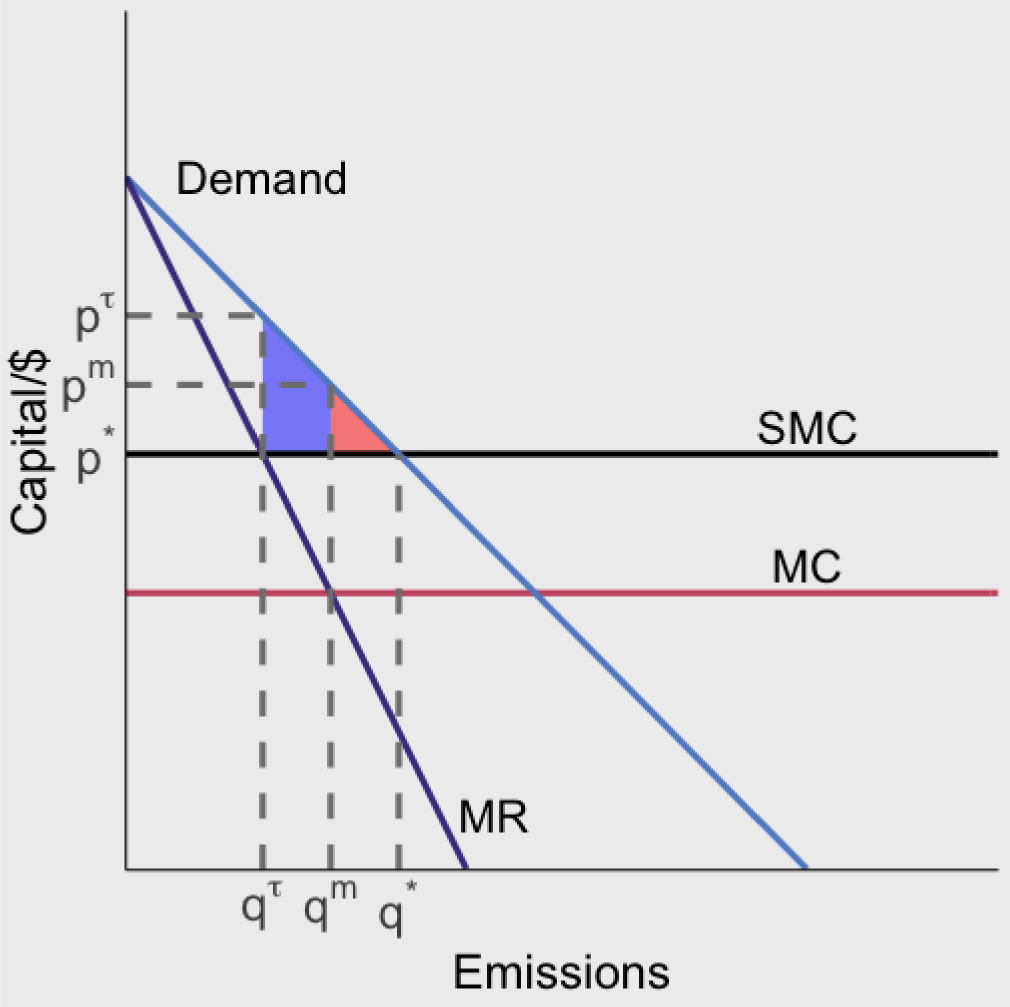
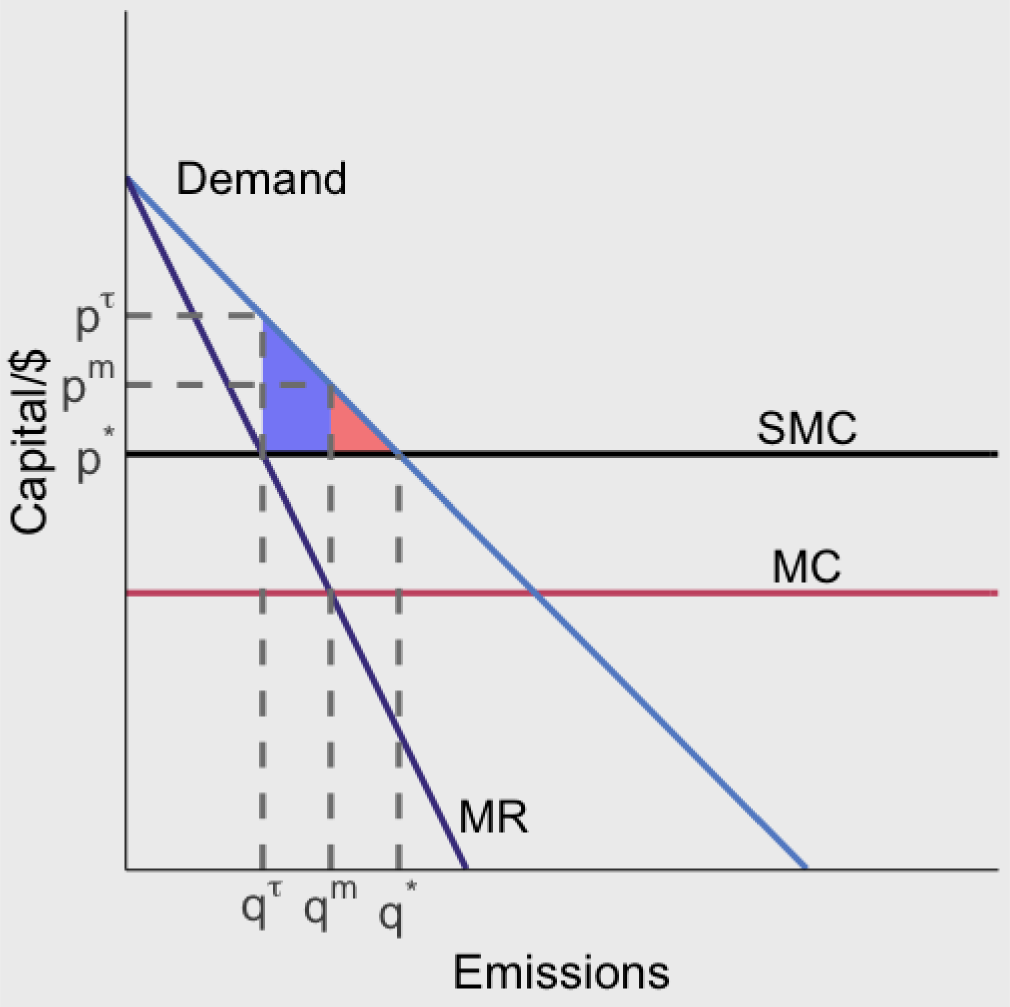


They have opposing forces on quantities, so the market failures offset each other (partially)

Monopoly



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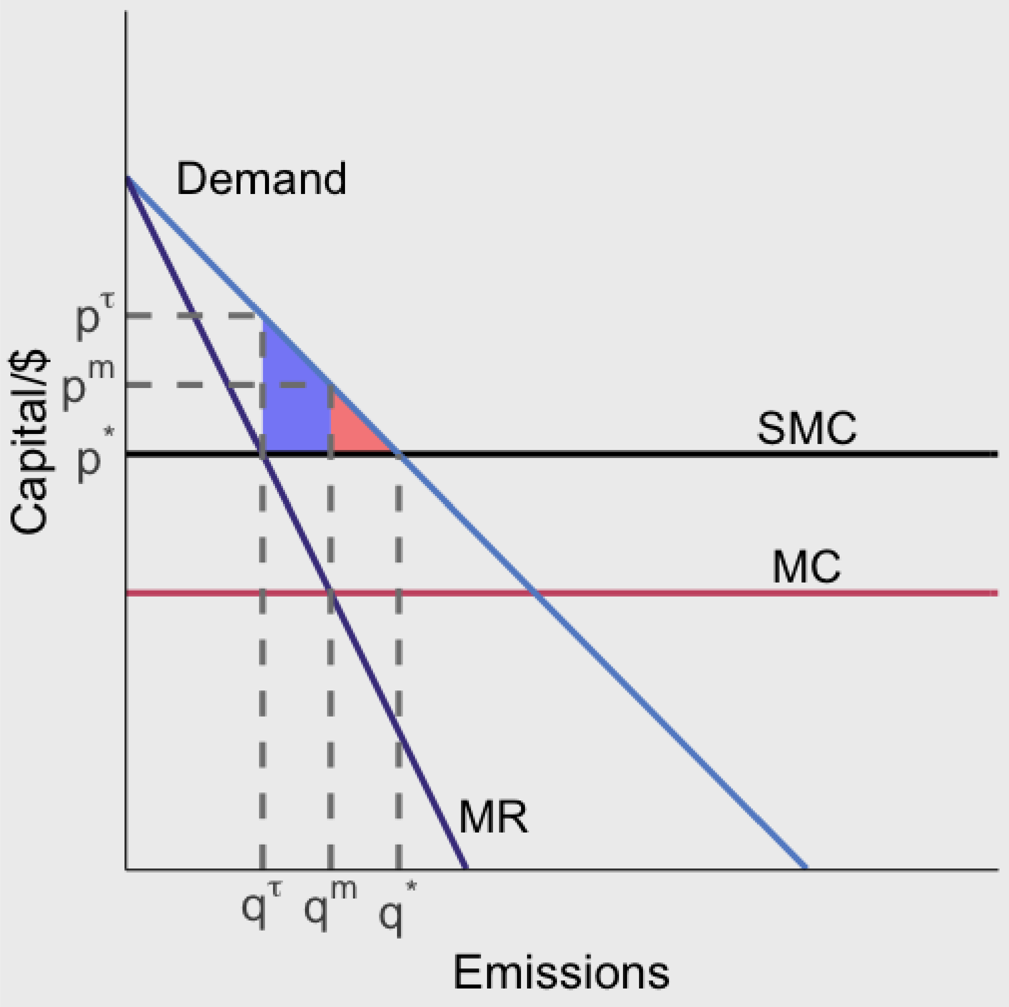
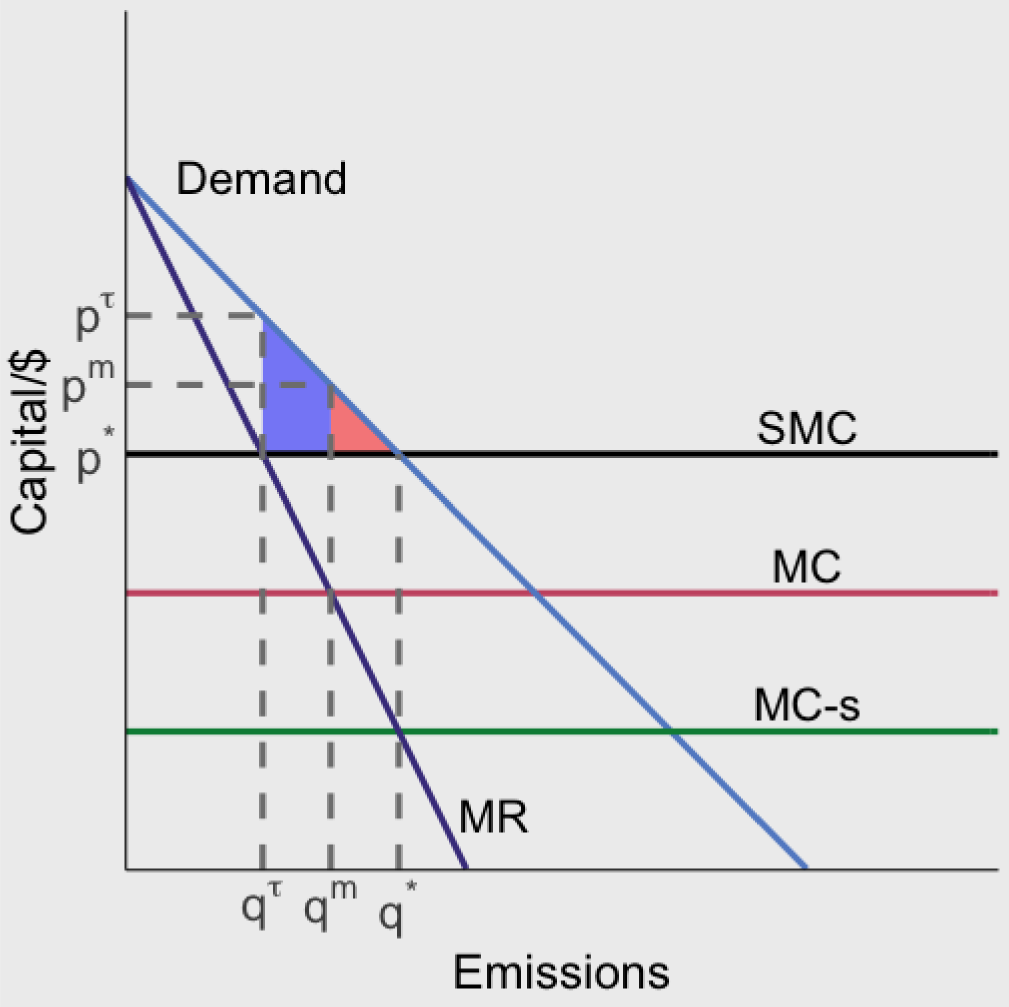
This means that if we fully correct the pollution externality, we no longer get the off-setting benefit and have the full welfare cost of market power

Monopoly



What is the actual optimal thing to do here?

Monopoly



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subsidize output at rate s so $MC - s$ crosses MR at q^*

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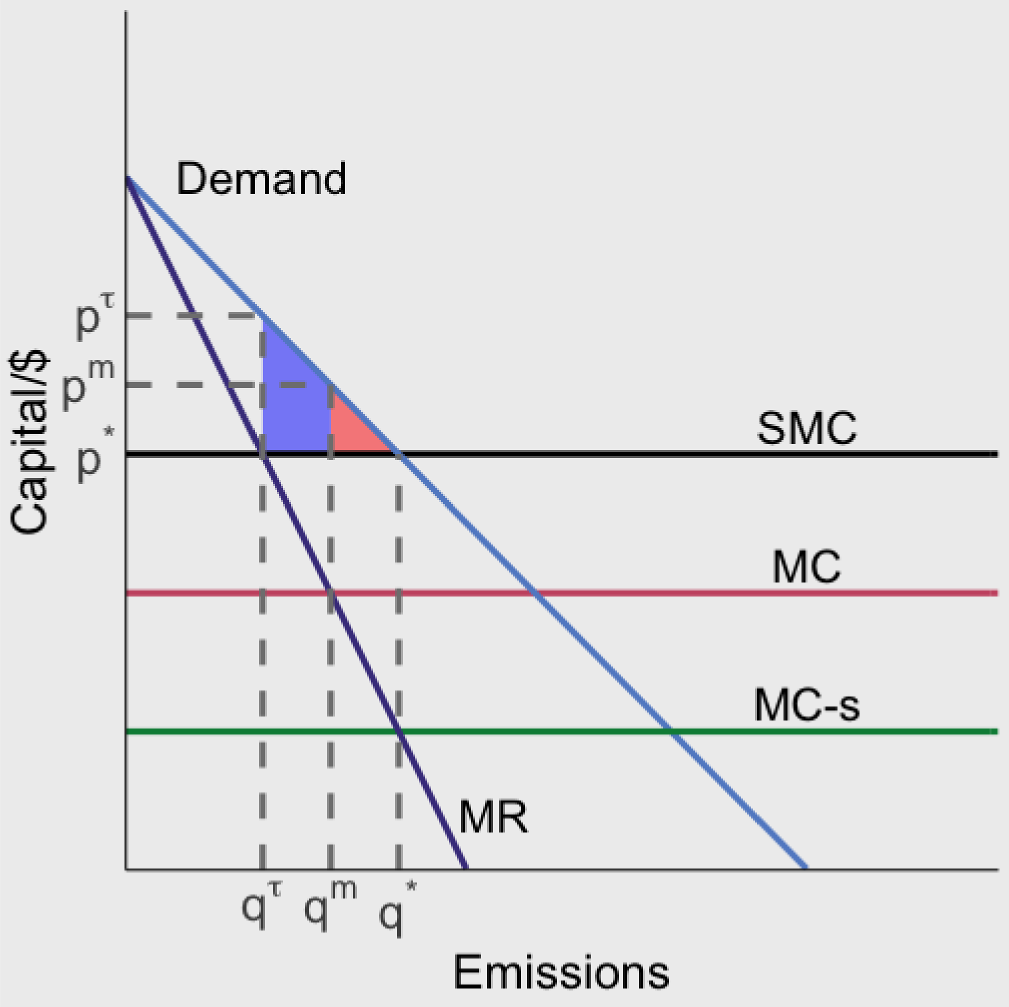

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In this example, the market power externality dominates the pollution externality: we need to increase output

Monopoly

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You can always draw this example in a different way where you should tax output

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In this example we actually wanted to do the **opposite** of what you likely thought

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You just need marginal damages to be sufficiently large relative to the market power effect on quantity

Monopoly: more generally

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If we generalize this so that the emission and output decisions are separate, we still have the two opposing market failures[1]

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What changes is we can no longer fix them both with just a pollution tax/subsidy

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Monopoly: more generally

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Monopoly: more generally

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What does that mean here?

We need:

1. Pollution tax
2. Output subsidy

The tax incentivizes abatement, the subsidy incentivizes production

Output taxes

Sometimes emission taxes and abatement subsidies are difficult to administer because monitoring is hard

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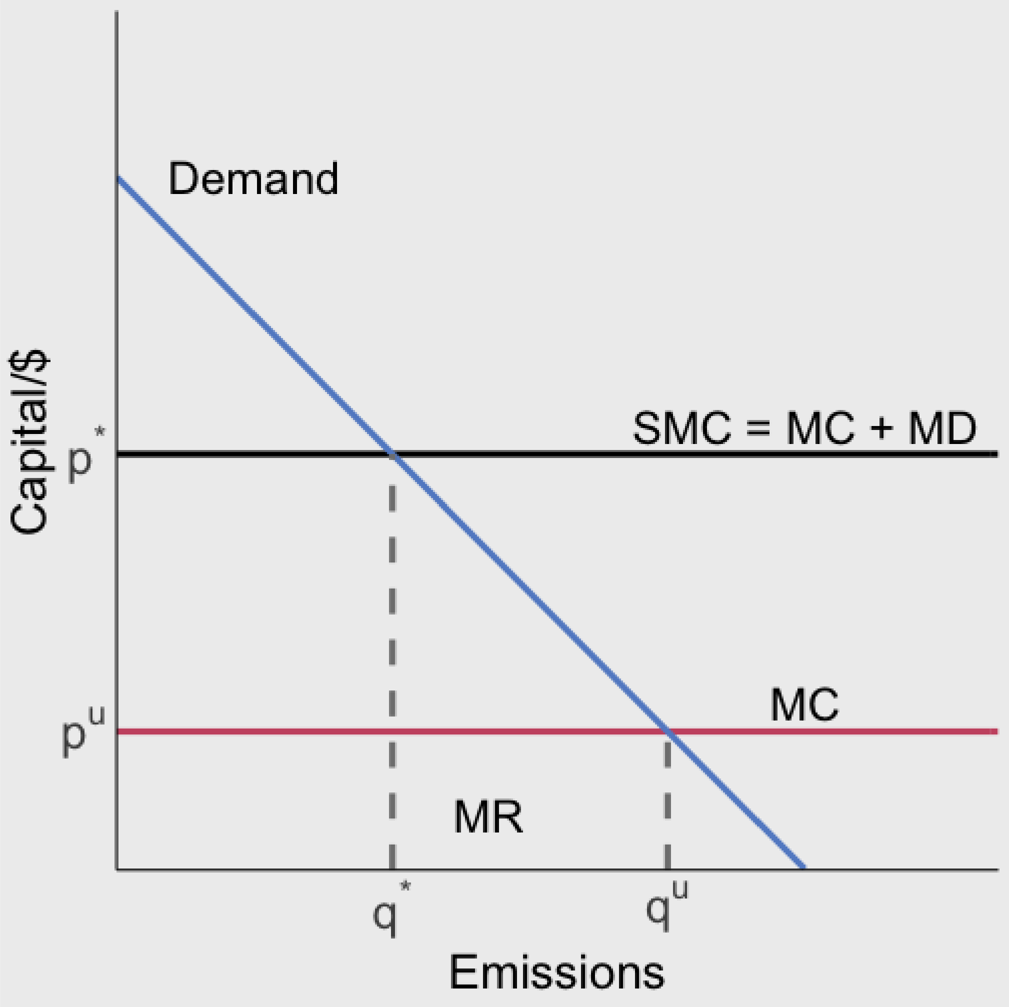
Will this be efficient?

If so, what assumptions do we need about the production process?

Output taxes



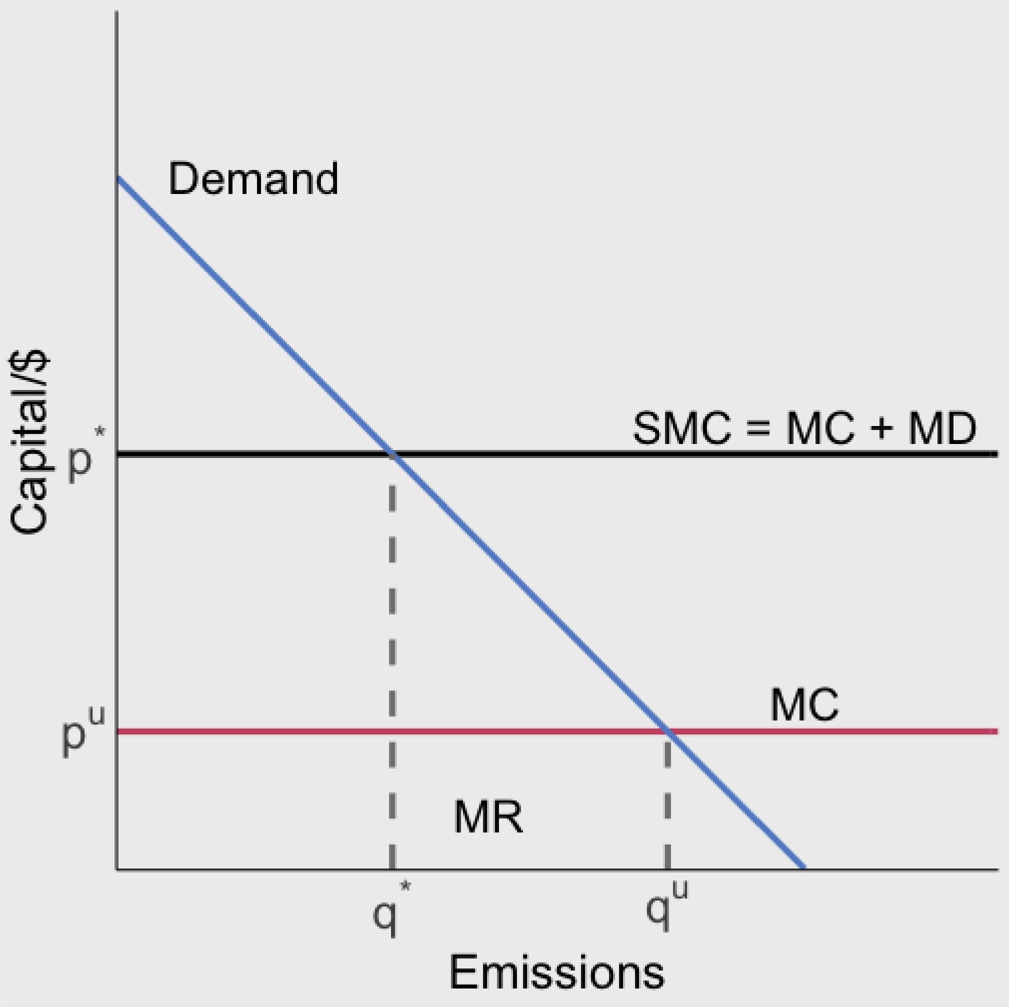
Assume emissions are proportional to output

And MD is constant

The firm chooses to produce/emit at q^u in the unregulated equilibrium

If we tax output equal to MD we can achieve the socially optimal allocation q^*

Output taxes



An output tax can be efficient, if we assume that emissions are proportional to output

Now let's break the tight link between output and emissions by writing down a slightly more complicated model where the firm chooses emissions and output separately

Output taxes, part two

Here's our model:

- Cobb-Douglas production using labor and emissions as inputs: $L^\alpha E^{1-\alpha}$
- The firm pays wages w, rental rate r to emissions (capital)
- The firm receives a price p per unit of output
- Emissions cause marginal damage d

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What does an output tax τ_o do versus a regular emission tax τ_e?

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The regulator's problem is:

$$\max_{L,E} p\, L^{\alpha} E^{1-\alpha} - wL - rE - dE$$

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The for a social optimum we want to equate the MR (left hand side) with the SMC (right hand side) for both inputs

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The output tax penalizes the use of clean labor despite it not causing any externalities at a marginal rate of: $\tau_o L^{\alpha-1} E^{1-\alpha}$, this is **not efficient**

Output taxes, part two

How does this compare to a pure emission tax?

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The firm's problem when facing an emission tax is:

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A tax of $\tau_e = d$ can achieve the efficient allocation!

Output taxes takeaways

If emissions are perfectly determined by output, we can use output taxes to achieve the efficient outcome

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If emissions can be chosen separately from outcome by the firm, this is no longer true

In this case an output tax incorrectly taxes our clean inputs

Intensity standards

One of the most commonly used regulations for environmental problems is the **intensity standard**

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Intensity of ethanol in the fuel supply

Intensity standards: RPS

What is a Renewables Portfolio Standard (RPS)?

aka Renewable Energy/Electricity Standard (RES)

Renewables Portfolio Standard

A requirement on retail electric suppliers…
To supply a minimum percentage or amount of their retail load…
With eligible sources of renewable energy

Typically	Backed with penalties of some form
Often	Accompanied by a tradable renewable energy certificate (REC) program to facilitate compliance
Never	Designed the same in any two states

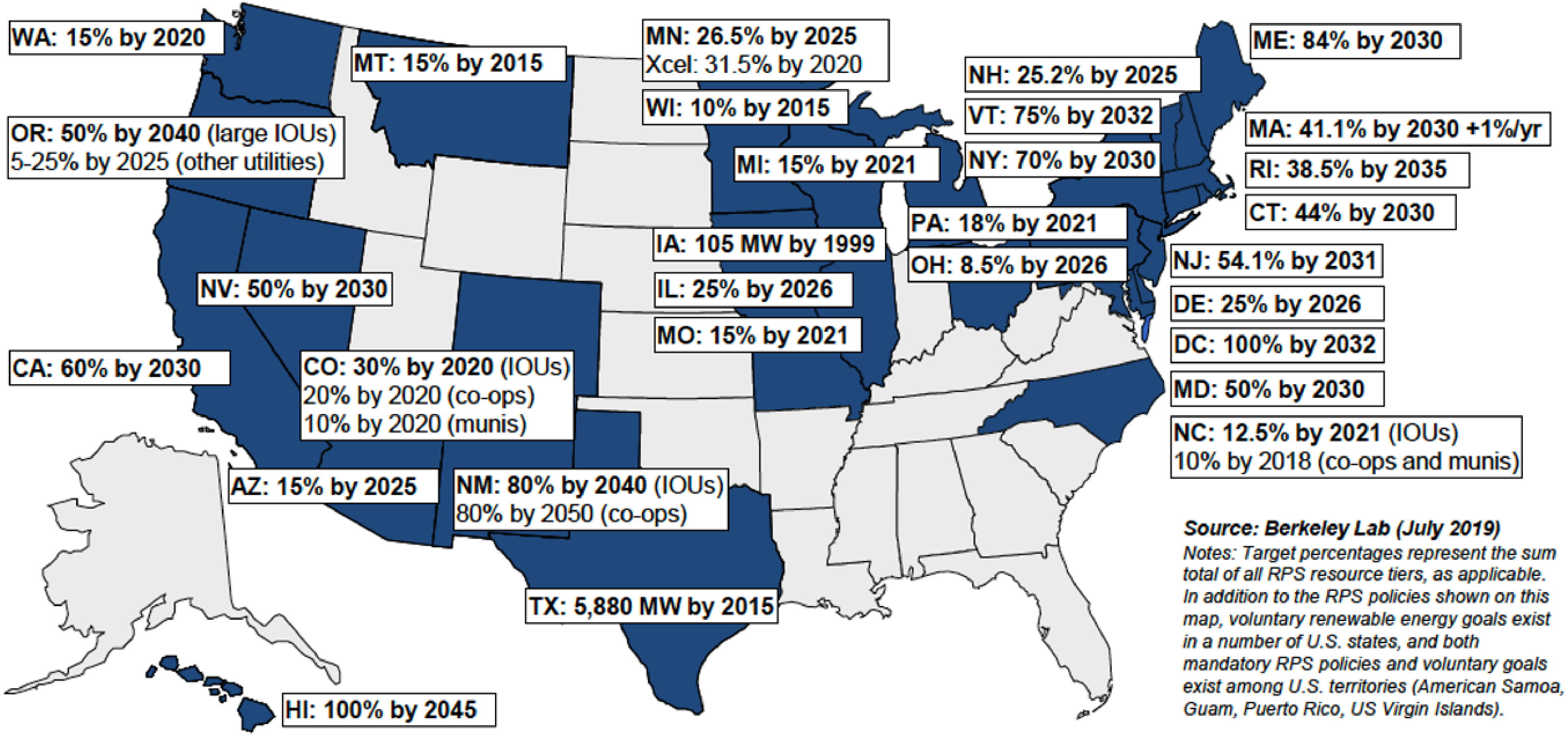
This report covers U.S. state RPS policies. It does not cover:

- Voluntary renewable electricity goals
- Broader clean energy requirements without a renewables-specific component (briefly discussed in a side-bar)
- RPS policies outside of the United States or in U.S. territories

Intensity standards: RPS

RPS Policies Exist in 29 States and DC

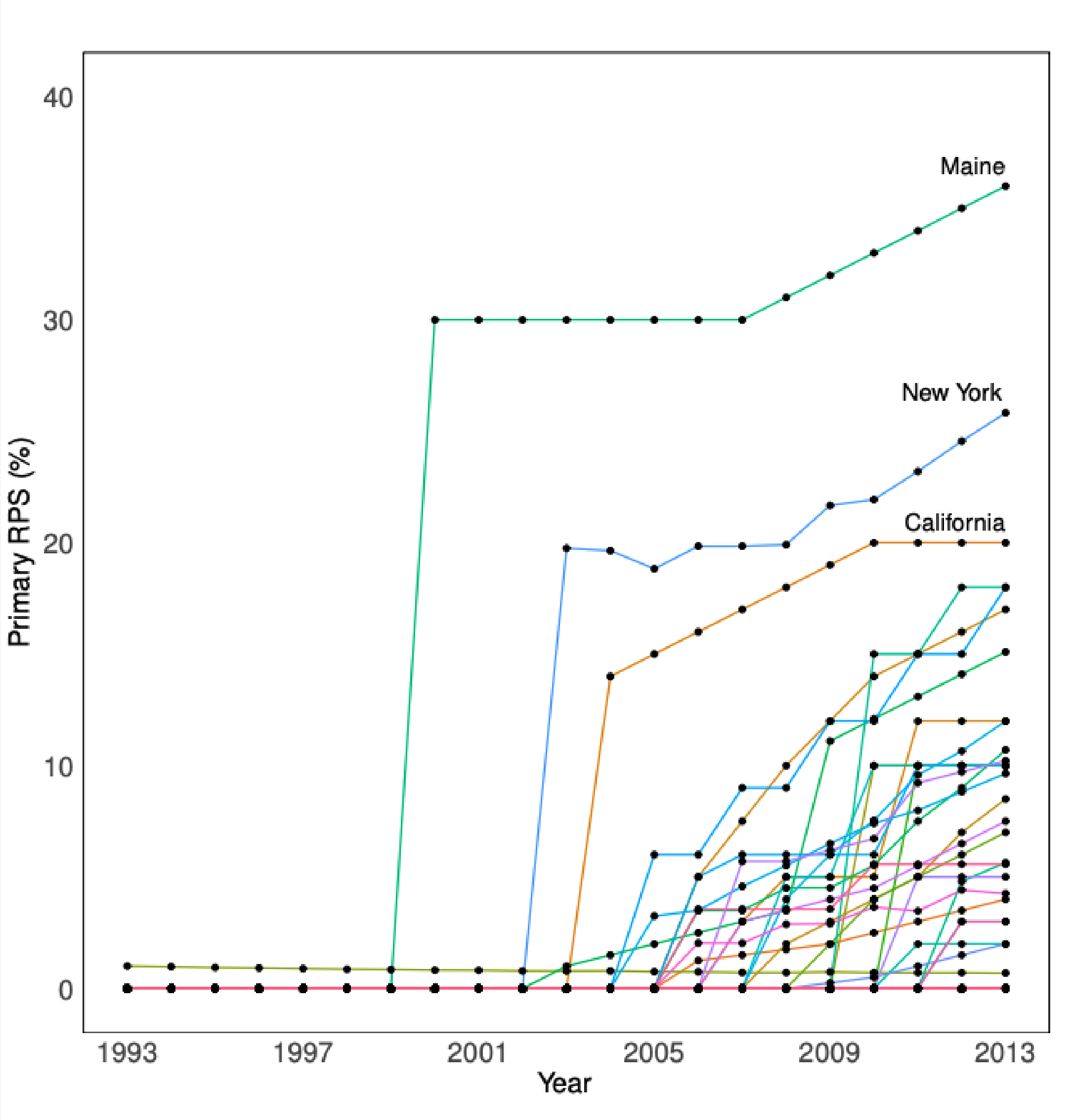
Apply to 56% of Total U.S. Retail Electricity Sales



Source: Berkeley Lab (July 2019)

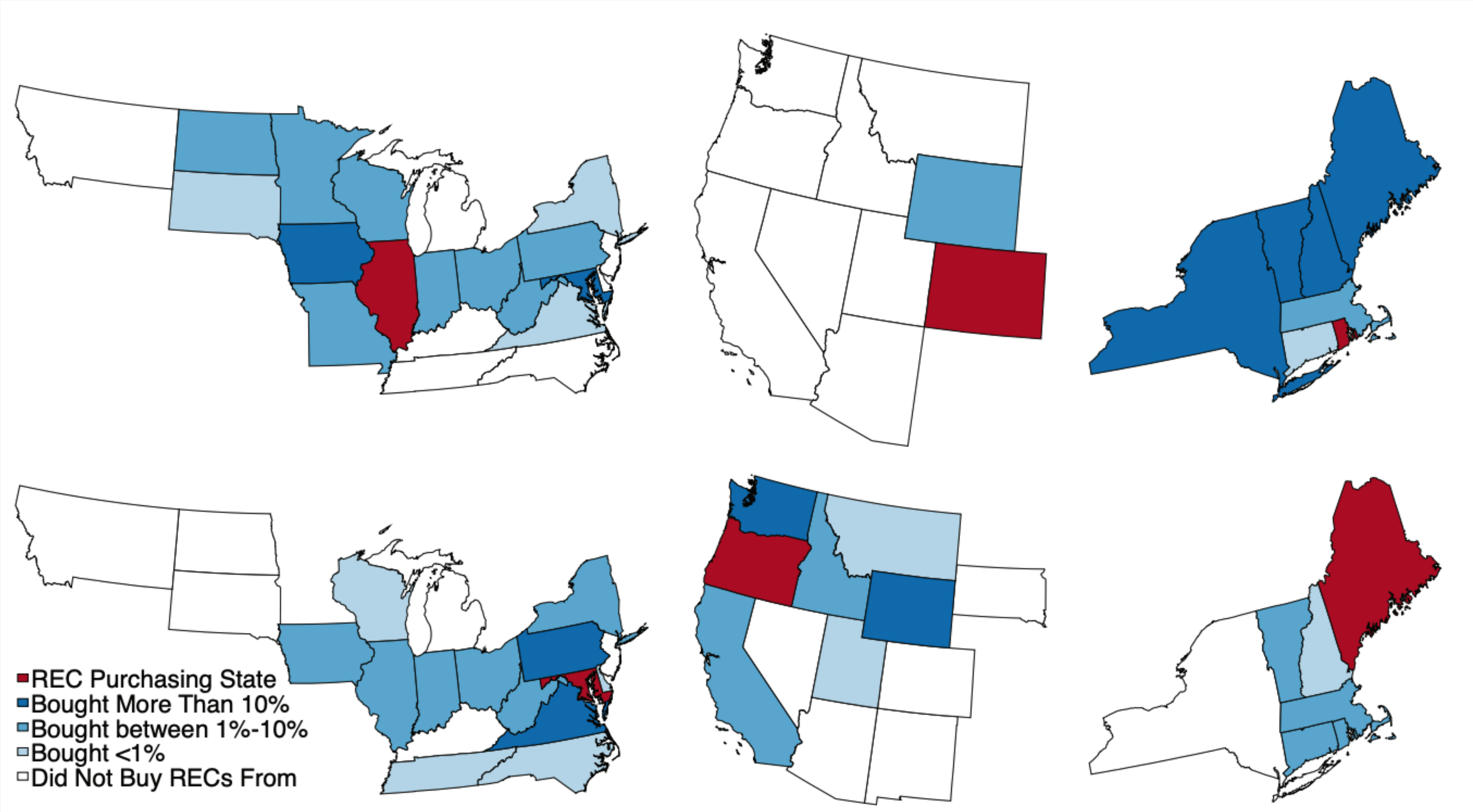
Notes: Target percentages represent the sum total of all RPS resource tiers, as applicable. In addition to the RPS policies shown on this map, voluntary renewable energy goals exist in a number of U.S. states, and both mandatory RPS policies and voluntary goals exist among U.S. territories (American Samoa, Guam, Puerto Rico, US Virgin Islands).

Intensity standards: RPS



Intensity standards: RPS

RPSs combine intensity standards and tradable credit markets (Holt, 2014)



Intensity standards: gas flaring

Flaring of natural gas at oil wells in North Dakota is regulated with an intensity standard

North Dakota Industrial Commission Order 24665 Policy/Guidance Version 041718

Policy Goals:

1) reduce the flared volume of gas
2) reduce the number of wells flaring
3) reduce the duration of flaring from wells

Intensity standards: gas flaring

Mandates a minimum fraction of gas captured (max fraction of gas flared)

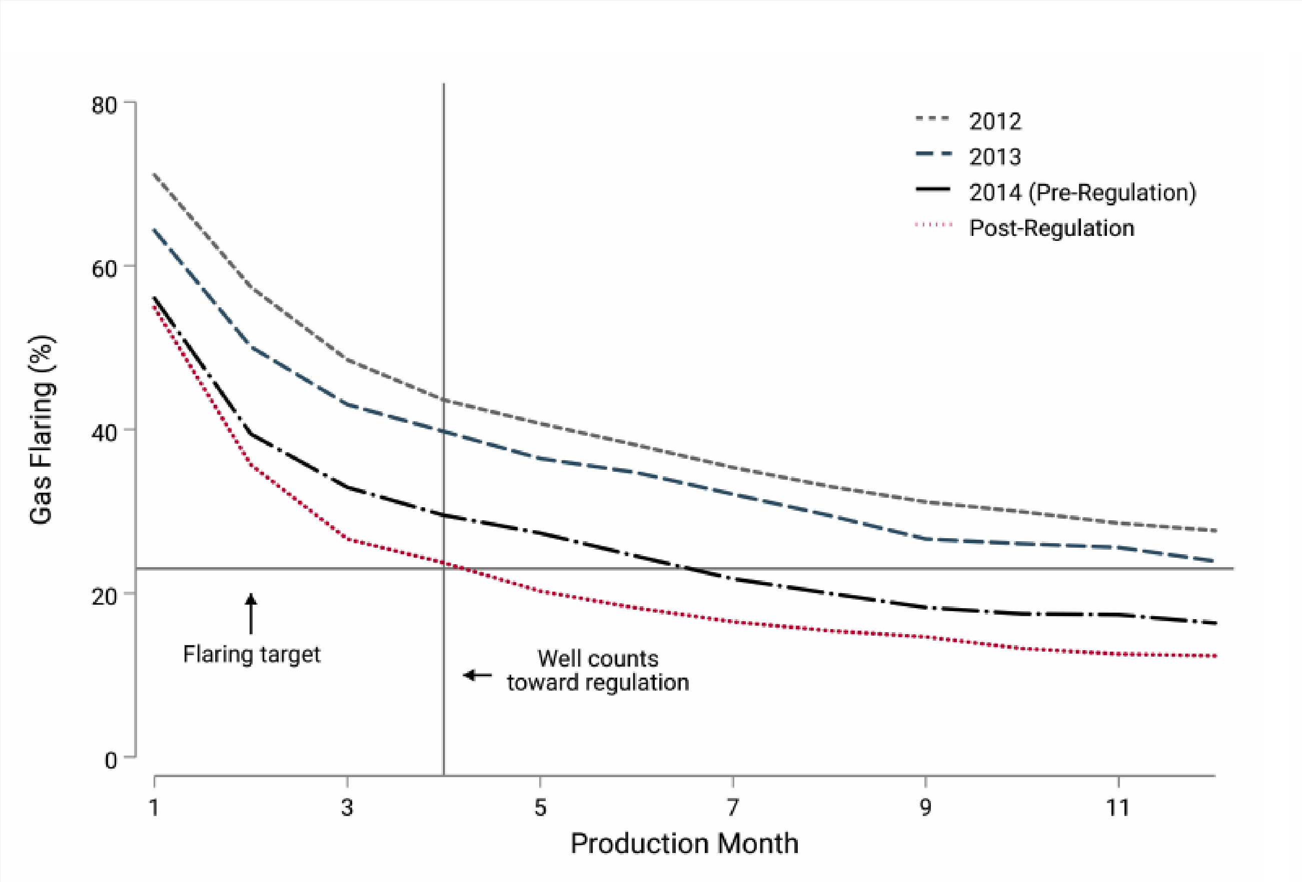
The Commission establishes the following gas capture goals:

74% October 1, 2014 through December 31, 2014
77% January 1, 2015 through March 31, 2016
80% April 1, 2016 through October 31, 2016
85% November 1, 2016 through October 31, 2018
88% November 1, 2018 through October 31, 2020
91% beginning November 1, 2020

The gas capture percentage is calculated by summing monthly gas sold plus monthly gas used on lease plus monthly gas processed in a Commission approved beneficial manner, divided by the total monthly volume of associated gas produced.

Intensity standards: gas flaring

The regulation pushed flaring rates down



Intensity standards

Consider a case where we have a good with two types:

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The social benefit of consuming the goods is
given by a social utility function $U(Q_H, Q_L)$

Intensity standards: social planner

That's our set up!

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The social planner's problem is:

$$\max_{Q_H, Q_L} U(Q_H, Q_L) - C_H(Q_H) - C_L(Q_L) - \tau(\beta_H Q_H + \beta_L Q_L)$$

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Maximize the social utility of the good, minus the private and external costs

The first-order conditions tell us how social welfare is maximized:

$$\frac{\partial U(Q_H, Q_L)}{\partial Q_i} = \frac{\partial C_i(Q_i)}{\partial Q_i} + \tau\beta_i \;\; i = L, H$$

Intensity standards: social planner

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What is this condition saying?

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Now what if we try to address the pollution externality with an intensity standard: a cap on the emissions per unit of output?

Intensity standards: social planner

An emission standard might look something like this:

$$\frac{\beta_H Q_H + \beta_L Q_L}{Q_H + Q_L} = \sigma$$

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For the standard to make any sense it must be: $\beta_L \leq \sigma \leq \beta_H$, otherwise it doesn't do anything $\sigma > \beta_H$ or its unattainable $\sigma < \beta_L$

Intensity standards: firm

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The firm's problem is:

$$\max_{Q_H, Q_L} \pi(Q_H, Q_L) = p_H Q_H + p_L Q_L - C_H(Q_H) - C_L(Q_L)$$

$$\text{subject to: } \frac{\beta_H Q_H + \beta_L Q_L}{Q_H + Q_L} = \sigma$$

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Notice that we can solve the intensity standard constraint for Q_H:

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$$\max_{Q_L} p_H \frac{\sigma - \beta_L}{\beta_H - \sigma} Q_L + p_L Q_L - C_H\left(\frac{\sigma - \beta_L}{\beta_H - \sigma} Q_L\right) - C_L(Q_L)$$

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Next, the first-order condition for a maximum

Intensity standards: firm

The first-order condition is:

$$p_H \frac{\sigma - \beta_L}{\beta_H - \sigma} + p_L = \frac{\sigma - \beta_L}{\beta_H - \sigma} MC_H + MC_L$$

which is equivalent to:

$$\frac{p_L - MC_L}{\beta_L - \sigma} = \frac{p_H - MC_H}{\beta_H - \sigma}$$

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To get to the final part of the intuition let:

$$\lambda \equiv (p_i - MC_i)/(\beta_i - \sigma)$$

Intensity standards: firm

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This lets us write the Q_L FOC as:

$$p_L = MC_L(Q_L) + \lambda(\beta_L - \sigma)$$

and it turns out if we instead framed the problem instead of Q_H we'd get the same FOC:

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What are these FOCs telling us about the firm's problem:

$$p_i = MC_i(Q_i) + \lambda(\beta_i - \sigma) \;\; i = L, H$$

Intensity standards: firm

The firm equates marginal revenue p_i and total marginal cost for each type i

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Is the intensity standard efficient?

Intensity standards: efficiency

Social welfare is maximized when:

$$\frac{\partial U(Q_H, Q_L)}{\partial Q_i} = \frac{\partial C_i(Q_i)}{\partial Q_i} + \tau\beta_i \;\; i = L, H$$

Intensity standards: efficiency

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The firm maximizes profit under the intensity standard at:

$$p_i = MC_i(Q_i) + \lambda(\beta_i - \sigma) \;\; i = L, H$$

$\frac{\partial U(Q_H,Q_L)}{\partial Q_i} = p_i$ from household utility maximization[1]

[1] Prices reflect the marginal value of consumption.

Intensity standards: efficiency

Social efficiency:

$$\frac{\partial U(Q_H, Q_L)}{\partial Q_i} = \frac{\partial C_i(Q_i)}{\partial Q_i} + \tau\beta_i \;\; i = L, H$$

Firm choice:

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These conditions show us that an intensity standard is not efficient

Why?

Intensity standards: efficiency

At a social optimum, we want to **tax** both L and H goods because they are both polluting

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The intensity standard cannot reach the efficient allocation because it is subsidizing a good that produces a negative externality[1]

[1] Technically it can in the specific case when the L type good does not emit any pollution, $\beta_L = 0$, but in general this won't be true.

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The intensity standard cannot reach the efficient allocation because it is subsidizing a good that produces a negative externality[1]

We call policies that can't achieve the social optimum second-best

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Intensity standards: graphical

Now lets look at intensity standards graphically

A few things you'll need to know:

1. Iso-profit curves: ovals that tell us the combinations of Q_H, Q_L that achieve the same profit
2. Iso-welfare curves: ovals that tell us the combinations of Q_H, Q_L that achieve the same social welfare

Intensity standards: graphical

These are like indifference curves for consumers, but are ovals instead of convex curves

Why ovals?

Intensity standards: graphical

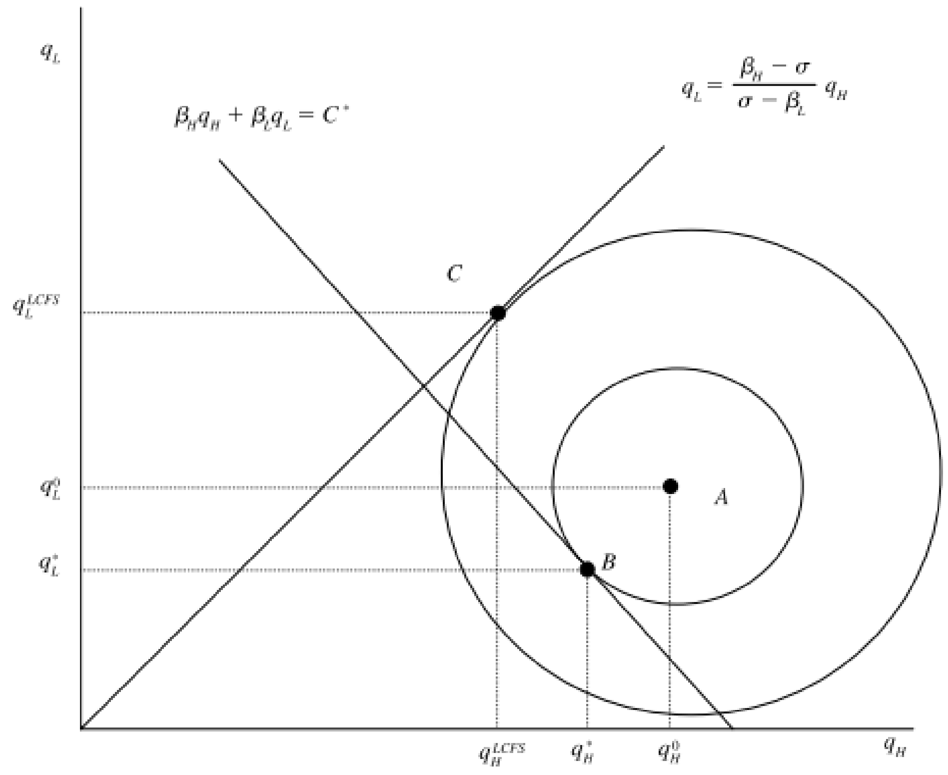
These are like indifference curves for consumers, but are ovals instead of convex curves

Why ovals?

Producing too much can decrease profit and/or welfare so eventually profit starts falling

With consumption, more is always better so increasing consumption always moves onto higher ICs

Intensity standards: what happens?



GURE 1. ISO-PRIVATE-SURPLUS CURVES WITH LCFS CONSTRAINT AND EFFICIENT CARBON TRADING CONSTRAINT

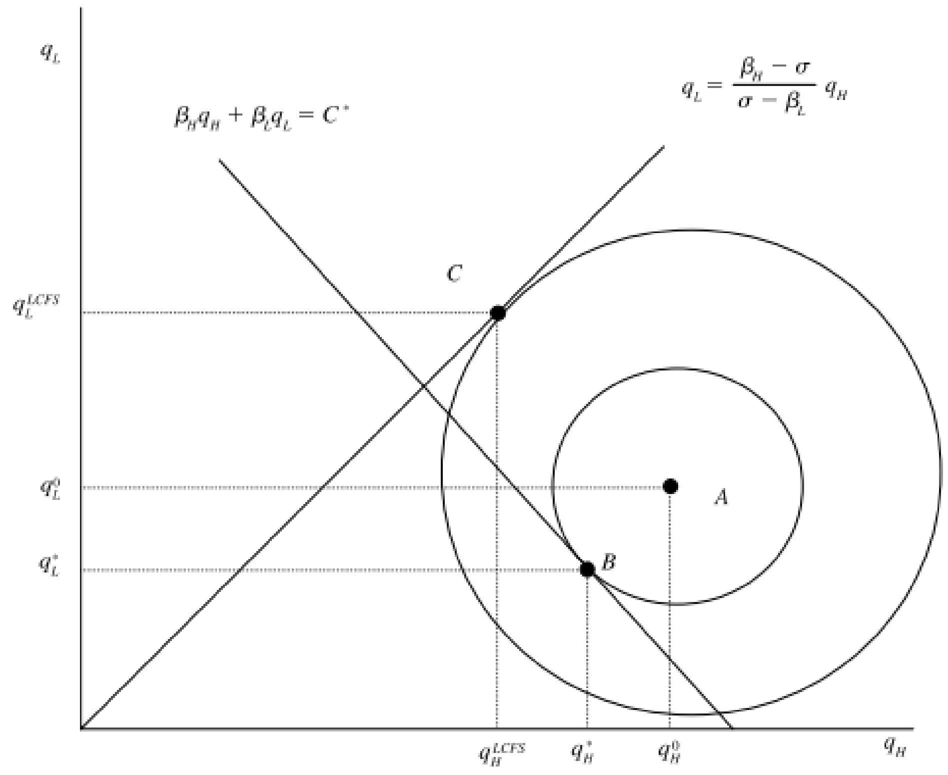
The circles are iso-private welfare (iso-profit) curves

A is where profit is maximized for the firm

The line $Q_L = \frac{\beta_H - \sigma}{\sigma - \beta_L} Q_H$ tells us which combos of Q_L, Q_H satisfy the intensity standard

Holland, Hughes, and Knittel (2010)

Intensity standards: what happens?



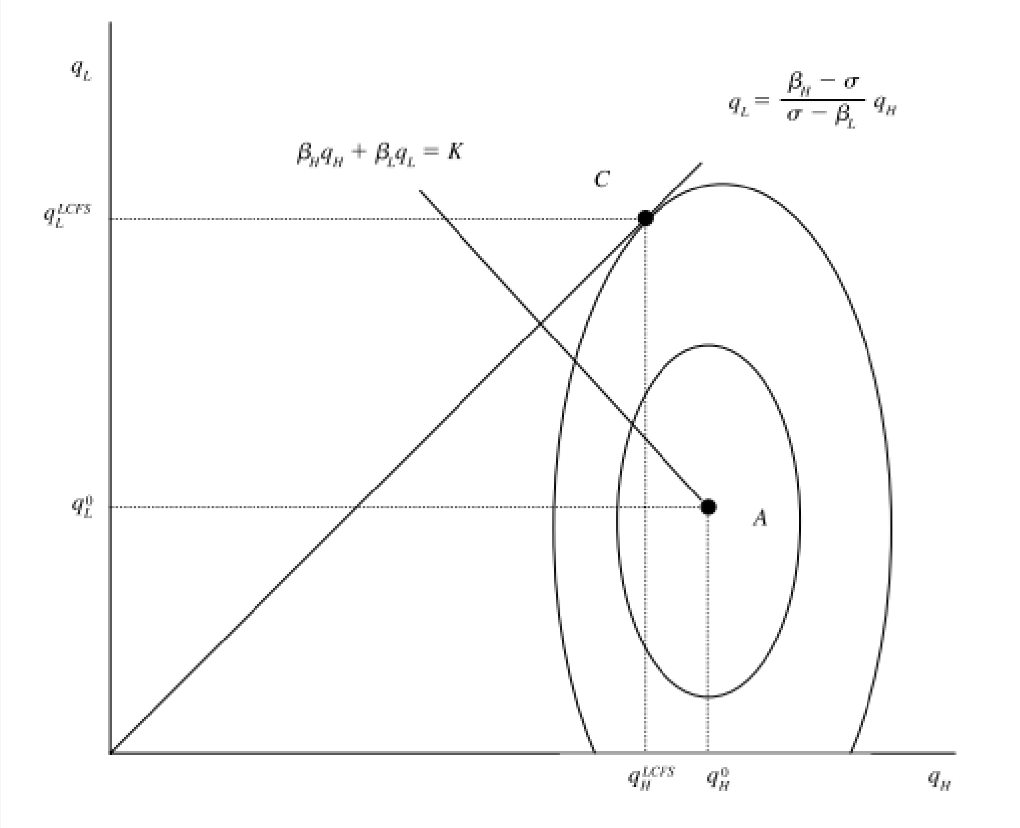
GURE 1. ISO-PRIVATE-SURPLUS CURVES WITH LCFS CONSTRAINT AND EFFICIENT CARBON TRADING CONSTRAINT

The intensity standard forces the firm to produce on the line

The highest iso-profit curve it can achieve is at point C

This is more Q_L and less Q_H than is optimal, consistent with the subsidy/tax combination implicit in the policy

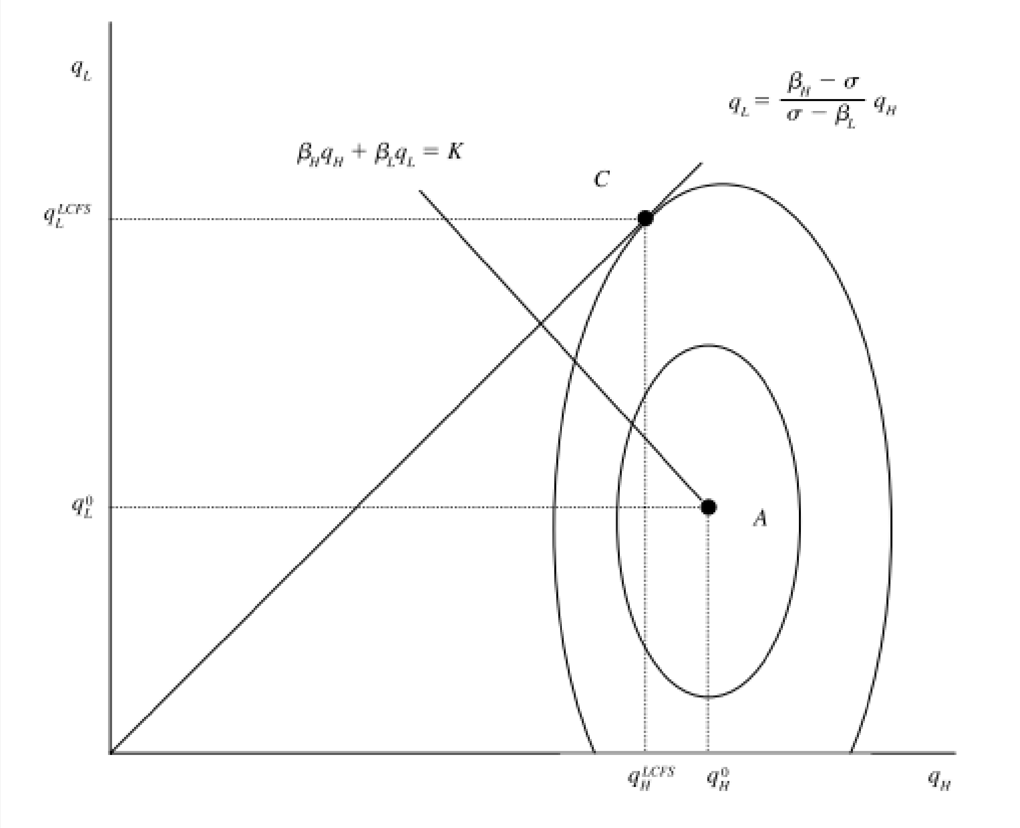
Intensity standards: perverse incentives



Intensity standards can actually backfire and increase emissions

How?

Intensity standards: perverse incentives

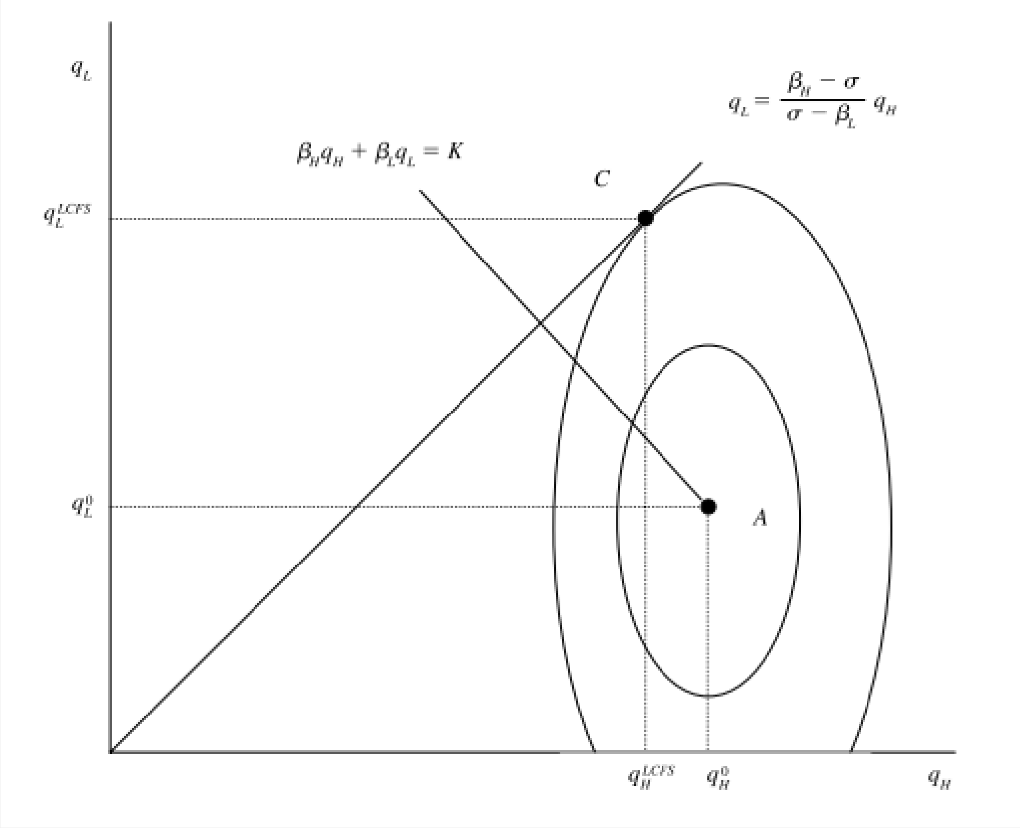


$\beta_H Q_H + \beta_L Q_L = K$ is the line showing all combinations of Q_L, Q_H that generate K units of emissions

K crosses through point A which is the unregulated profit-maximizing choice by the firm

Anything to the top right of the line is **more emissions**

Intensity standards: perverse incentives



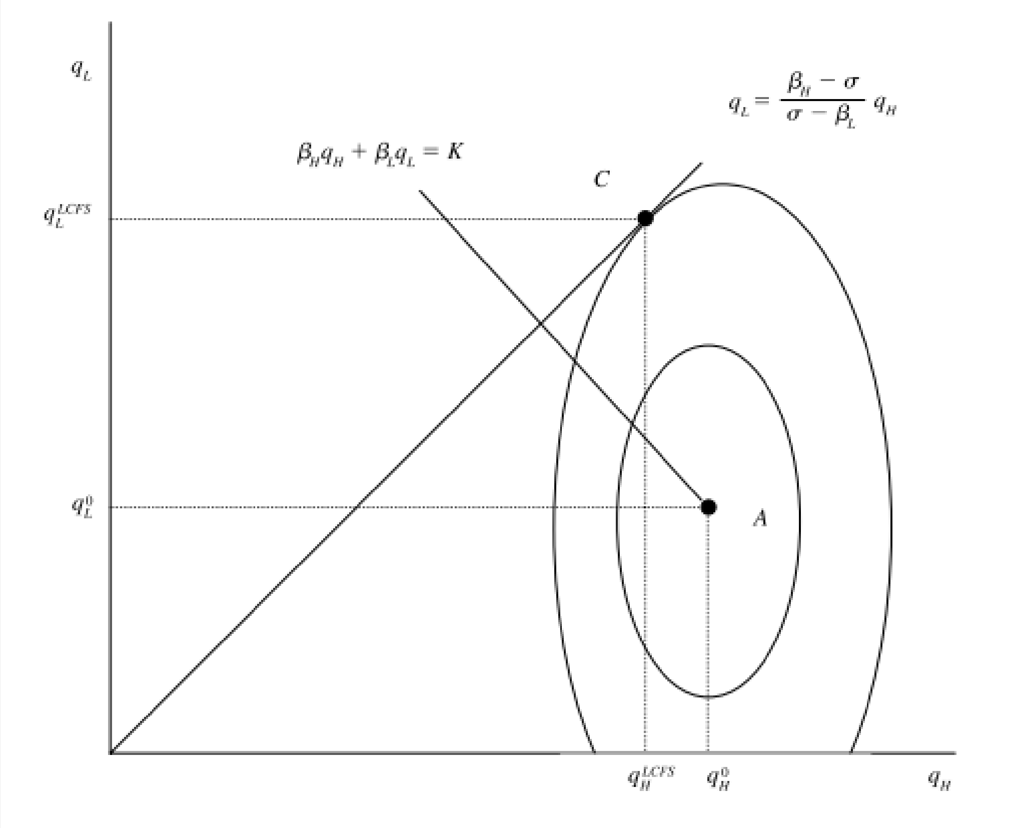
The regulation induces the firm to move to point C

This is slightly less Q_H, but a lot more Q_L

The increase in emissions from Q_L is more than the decrease from the lowering of Q_H

Overall emissions went up!

Intensity standards: perverse incentives



This perverse outcome was possible because production of the L type was very elastic while the H type was inelastic

Intensity standards: second-best

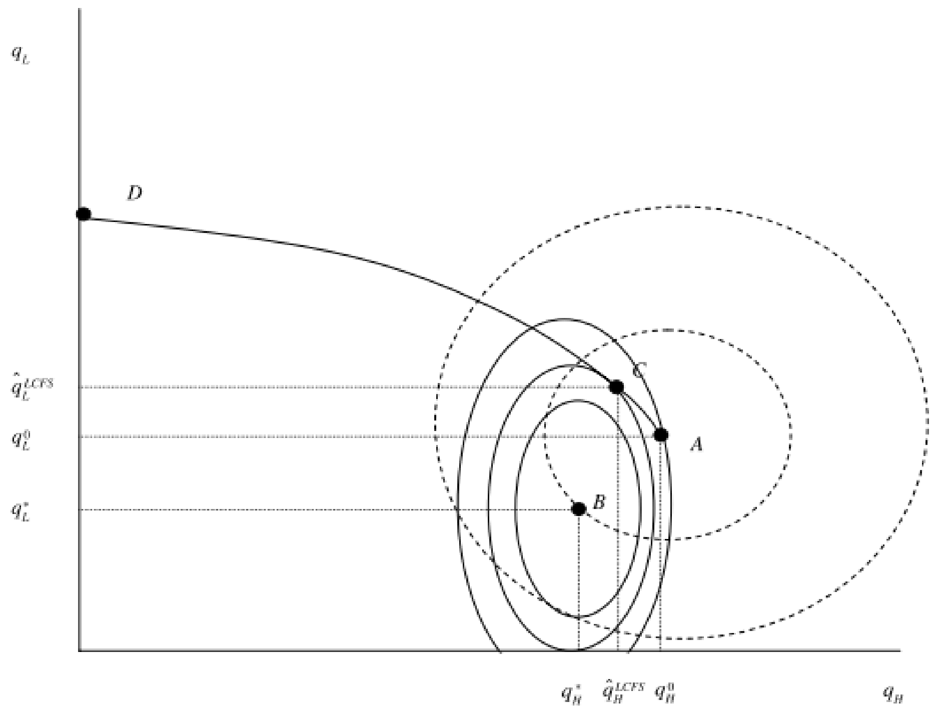


Figure 3. Illustration of the Best LCFS at C with Locus of LCFS Equilibria, Iso-Private-Surplus Curves, and Iso-Welfare Curves

What is the best intensity standard?

The dashed ovals are the iso-profit curves

The solid ovals are the iso-welfare curves

Welfare is maximized at point B

Profit is maximized at point A

Intensity standards: second-best

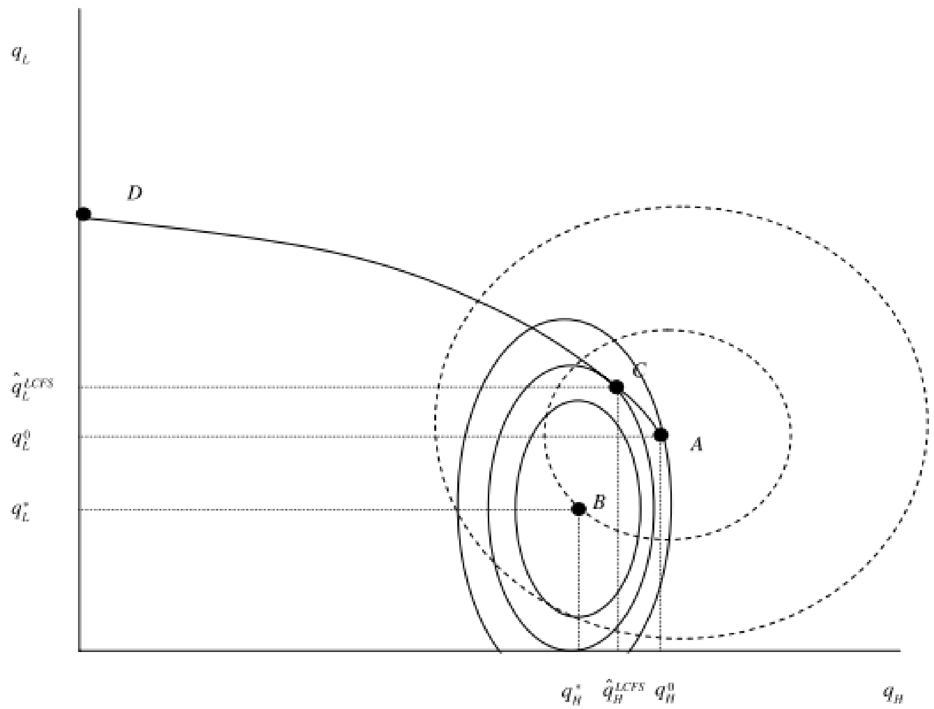


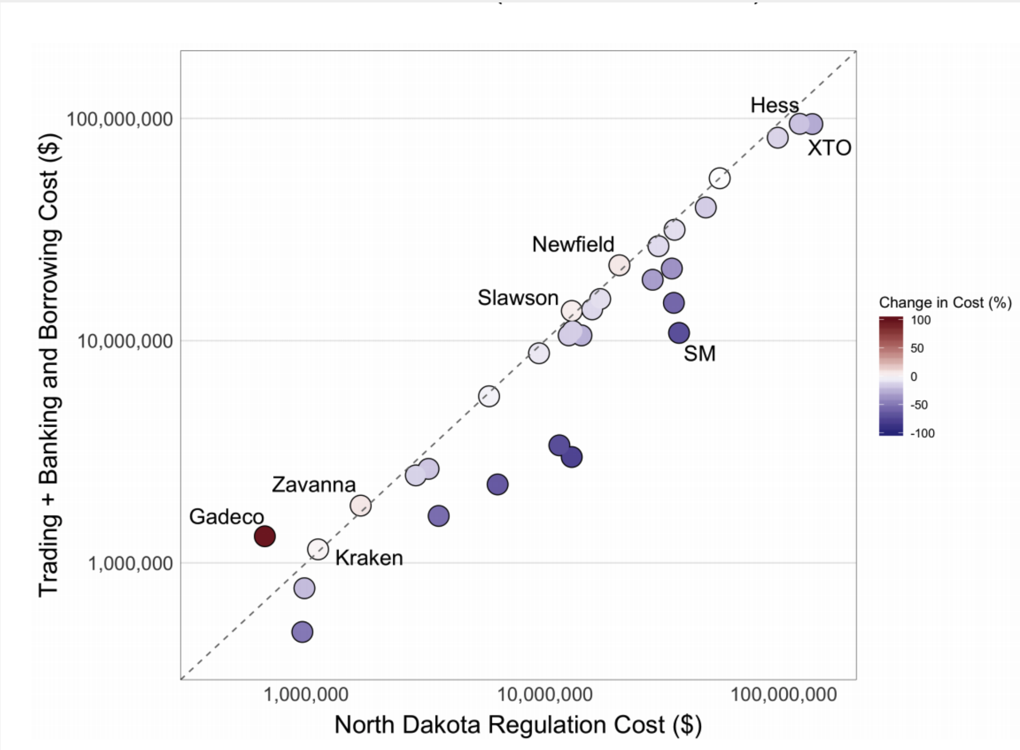
FIGURE 3. ILLUSTRATION OF THE BEST LCFS AT *C* WITH LOCUS OF LCFS EQUILIBRIA, ISO-PRIVATE-SURPLUS CURVES, AND ISO-WELFARE CURVES

The solid line shows the firm's choices of Q_L, Q_H as we increase the intensity standard σ

Increasing σ pivots the intensity standard counter-clockwise:
$Q_L = \frac{\beta_H - \sigma}{\sigma - \beta_L} Q_H$

The optimal intensity standard is the one that lets us get on the highest iso-welfare curve, which is at point C

Intensity standards: gas flaring



Moving from a flaring intensity standard to tradable permits or a tax generates massive welfare gains!

A tax that captures the same quantity of gas would have >40% lower cost than the actual intensity standard